DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT—INDEPENDENT AGENCIES APPROPRIATIONS FOR 1981

HEARINGS

BEFORE A

SUBCOMMITTEE OF THE

COMMITTEE ON APPROPRIATIONS

HOUSE OF REPRESENTATIVES

NINETY-SIXTH CONGRESS

SECOND SESSION

SUBCOMMITTEE ON HUD—INDEPENDENT AGENCIES

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PART 5

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DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT—INDEPENDENT AGENCIES APPROPRIATIONS FOR FISCAL YEAR 1981

TUESDAY, MARCH 11, 1980.

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

WITNESSES

DR. FRANK PRESS, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY
BENJAMIN HUBERMAN, ASSOCIATE DIRECTOR, NATIONAL SECURITY, INTERNATIONAL AND SPACE AFFAIRS
DR. GILBERT S. OMENN, ASSOCIATE DIRECTOR, HUMAN RESOURCES AND SOCIAL AND ECONOMIC SERVICES
PHILIP M. SMITH, ASSOCIATE DIRECTOR, NATURAL RESOURCES AND COMMERCIAL SERVICES
WILLIAM J. MONTGOMERY, EXECUTIVE OFFICER

	1979 actual	1980 estimate	1981 request	Difference
Appropriation	$2,496,000	[1] $2,712,000	$2,948,000	+$236,000
Positions	24	24	24	

[1] Includes supplemental request of $87,000 for increased pay costs.

Mr. BOLAND. The Committee will come to order.

We are delighted to have with us today Dr. Frank Press, Director of the Office of Science and Technology Policy, accompanied by Mr. Benjamin Huberman, Dr. Gilbert S. Omenn, Mr. Philip M. Smith, and Mr. William J. Montgomery. You have all been here before.

I read your statement last night and for the life of me I cannot understand how you can do all that work, or this office can do it with only 24 people. How do you do it?

Dr. PRESS. Those 24 people are superb professionals and highly devoted to the office. I appreciate the compliment.

Mr. BOLAND. You have a fine statement. It covers an awful lot of ground and is extremely well done. It takes a little while to get through the 19 pages. It clearly indicates the importance of this Office with respect to other agencies of the Government that you advise. And it certainly highlights the importance of this Office for the President, himself, in reaching some very important decisions in the fields you cover. You do cover an awful lot of them.

I take it that a great number of the conclusions that are reached in the statement and the amount of work done in these areas, must

be done by consultants. You couldn't possibly do it alone. This highlights the importance of the consultant program. We will be getting into that with the justifications.

GENERAL STATEMENT

We are delighted to have you and your staff here today. Perhaps you can highlight some areas of your statement which are more important than others. It would take some time to read it all. We will place your full statement in the record at this point.

[The statement follows:]

TESTIMONY BY DR. FRANK PRESS
DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY
BEFORE THE
SUBCOMMITTEE ON HUD - INDEPENDENT AGENCIES
COMMITTEE ON APPROPRIATIONS
HOUSE OF REPRESENTATIVES
MARCH 11, 1980

Mr. Chairman and Members of the Committee: The past year has been an active one for the Office of Science and Technology Policy. I am pleased to appear before you today to discuss the current status of the overall Fiscal 1981 budget request for research and development, some of the activities of the Office of Science and Technology Policy over the past year, and OSTP's budget request for Fiscal Year 1981.

I have with me today my three Associate Directors, Benjamin Huberman, Gilbert Omenn, and Philip Smith, and the OSTP Executive Officer, William Montgomery. They will join me in responding to your questions.

I.

The Budget for R&D

The budgets of the Carter Administration have reflected a strong commitment to research and development. Steady progress has been made in strengthening research and development in the Department of Defense, and in several other mission agencies, such as the Department of Agriculture and the Environmental Protection Agency. In the Department of Energy, there have been significant advances in the efforts to achieve a balanced support for all of the longer-term and mid-term supply technologies, including basic research underlying these technologies. The biomedical and health research programs of the National Institutes of Health and the activities of the National Science Foundation have also received continued, significant support. This year, physical sciences and engineering in particular have been the focus of our attention because we believe that these disciplines have had comparatively less growth -- in constant dollars -- than other disciplines of basic research over the last two decades. The Administration has also focused on the relationship of research and development to industrial innovation; and our program requests for Fiscal Year 1981 reflect several initiatives that we believe important to the longer-term health of the economy. An interest in research and development, and an understanding of their importance to the Nation are shared by all the leaders of the Administration. It is important to understand these points, because R&D activities, like all others, are under review now in the current reassessment of the Fiscal Year 1981 budget.

As the recent data on the Consumer Product Index, wholesale price indices, and the rates of commercial loans have revealed, our economy is increasingly vulnerable to the malignancy of inflation. Dramatic action

is required by the Government to demonstrate to our people and to the financial markets that the Government views this inflation as serious and that we are willing to take drastic action to control it. As a result, the Administration has undertaken an intense review of the budget to determine how to bring it into balance. This review has focused on the non-defense, so-called controllable portions of the budget, of which R&D in the civilian agencies constitute a significant fraction; on the various accounts represented in the trust funds and receipts, and on the indexed or so-called uncontrollable portions of tne budget. I cannot tell you how this review will turn out -- it is still in progress -- but I would mislead you if I did not indicate that the President's requests for R&D are likely to look different once this review is completed.

I can assure you that this search for budget reduction has been an exceptionally painful exercise. I believe in the value of the R&D programs the President has proposed. We all believe in the need to establish new relationships between industry, universities, and Government in R&D. We all believe in the importance of laying the foundation for the future through investment in basic research. And the President, the OMB, and the cabinet have endorsed these positions in the FY 1981 budget request. But just as in combating a serious disease, we must occasionally make sacrifices for the sake of the general health, so too we must now cut back the budget where we can.

The consequences will be serious and distressing to the scientific and technological community, among many others. Nonetheless, in the long run, we will all benefit by bringing inflation under control. Certainly, scientists and engineers, as much as anyone else, have suffered directly the harm from inflation as costs escalate and savings erode. Moreover, they may receive indirect benefits from the restoration of a stable economic climate in which people are more willing to invest in the future -- a future that inevitably must rest on scientific and technological advance. Thus, the upcoming budget cuts will be in our long-run best interest.

II.

OSTP Activities in 1980

The science and technology policy work of OSTP over the past year has dealt with a wide range of issues. Many of these have been associated with difficult decisions that have been made by the President. Others have approached problems that must be addressed over the next decade, where ground work now will better prepare the President, the Executive Branch, and the Congress for the policy determinations that will be required. To give the Subcommittee a feeling for the work of the Office over the last year, I would like today to describe a number of our activities. I have selected examples in the areas of international affairs; national security and defense R&D; space policy; energy; health and agriculture; regulatory policy; and, productivity and innovation. I believe they illustrate well the diversity of technological and scientific policy issues faced by the President and his advisers. Further, several key initiatives of the Administration have resulted from these activities.

I will also discuss the Intergovernmental, Science, Engineering and Technology Advisory Panel activities and the work of the Federal Coordinating Council for Science, Engineering and Technology.

International Scientific and Technological Cooperation

The President's Message to the Congress on Science and Technology spelled out four themes that have shaped U.S. policy in international scientific and technological cooperation. The President indicated that:

-- We have pursued new international initiatives to advance our own research and development objectives;

-- We have attempted to develop and strengthen scientific exchanges to bridge political, ideological and cultural divisions between this country and other countries;

-- We have formulated programs and institutional relationships to help developing countries use science and technology beneficially;

-- We have cooperated with other nations to manage technologies with global impact.

In 1979, the Administration actively pursued bilateral and multilateral iternational programs in science and technology in accord with these themes.

In January 1979, the President and Chinese Vice Premier Deng Xiaoping signed an agreement for science and technology cooperation. Since that time, our two countries have signed 13 protocols for bilateral cooperation in a broad array of areas including space, student and scholar exchanges, agriculture, public health, environmental protection, hydropower development, and earth sciences research. In January of this year we reviewed, in China, the rapid and remarkable progress that has been made in the implementation of each of these protocols during the first year of normalized relations. At that time we also signed an agreement for cooperation between our two prestigious national academies of science.

The S&T Agreement provides for facilitation of contacts between the U.S. private sector and the Chinese to support their modernization efforts in energy and other sectors. It is clear that R&D cooperation naturally leads to enhanced commercial relationships. Our cooperative efforts are of great importance to building a strong China, which is obviously in our interest.

The U.S. and the Soviet Union work together under a framework of 11 separate agreements for cooperation in scientific and technical fields. The most senior of these agreements is the S&T Agreement for which I am the U.S. Co-Chairman. Others are in fields such as energy, space, environmental protection, public health, oceans -- to name a few.

Our cooperation with the Soviet Union has changed dramatically,

however, as a result of that country's invasion and continued occupation of Afghanistan. The Administration has taken steps to demonstrate that such actions will have an adverse effect on all forms of cooperation, including scientific exchanges. The President has made the deliberate decision to focus our restrictive measures against specific activities, not against the framework of our bilateral agreements themselves. Each activity planned under the 11 bilateral agreements is currently being reviewed to determine its appropriateness. Only those substantive exchanges which are of overriding scientific interest to the U.S. or which involve humanitarian concerns, such as health or the environment, will be continued under the present circumstances.

It is ironic that this change in policy takes place at a time when many U.S. participants in U.S.-USSR cooperative science programs were beginning to feel that programs of true mutual benefit were at last underway. Our decision to keep the framework of cooperation intact reflects this sense of U.S. gain from the programs. At a future time when conditions change, we may want to resume some or all of our cooperative programs with the Soviet Union.

A major step in further expanding the already extensive scientific cooperation between the U.S. and Japan was taken in May 1979 with the signing of a bilateral agreement for cooperation in energy R&D projects, such as coal liquefaction, nuclear fusion, and geothermal and solar energy. President Carter has proposed to the Japanese a complementary program of joint R&D in various non-energy areas of global importance such as space, environmental protection, health, agriculture and resource conservation. We have had two preparatory meetings with the Japanese to discuss this proposal, one in Tokyo last September, and one here in Washington this February. We have reached agreement on a number of specific R&D projects pending budgetary approval on both sides.

In both the energy and non-energy areas, our joint projects are based on the concept of mutual interest and benefit. Manpower, physical resources and financing of these large-scale projects will be shared. The scale of these programs represents a new concept in international S&T cooperation. This is a very important, positive aspect of our sometimes-troubled relationship with the Japanese.

Impressive progress has been made in our science and technology relationship with Mexico. During the President's February 1979 meeting with President Lopez Portillo, our two countries signed a memorandum of understanding to inaugurate cooperation in a number of areas including arid lands agriculture and energy R&D.

In October 1979, I led a delegation of senior government scientists and science officials to a number of countries in South America and the Caribbean, including Venezuela, Brazil and Peru. We also met with representatives of the Andean Pact and Caribbean regional organizations. As a result of consultations with leaders in these areas, numerous joint S&T activities are underway and many additional ones are planned.

There is increasing recognition that a wide range of major issues cannot be treated by the action of individual nations. Such issues

include the world environment, oceans and fisheries affairs, population, energy, space, food and natural resources, and economic development. It is the general policy of the U.S. to support the activities of international organizations which are addressing global problem areas collectively.

While we are often forced to attend to immediate crises, it is essential that we nurture our long-term relations with other countries. Scientific and technological cooperation is a very important aspect of overall relationships with other countries. Furthermore, we must sustain our international efforts to deal with global problems needing scientific attention. Our international science and technology activities, in addition to supporting this country's foreign policy objectives, provide a variety of distinct benefits. At the same time, these activities increase the world's stores of scientific knowledge, affect worldwide welfare and prosperity, promote our international commercial relationships, and add a valuable dimension to our development assistance programs.

As I reported to you last year, we work very closely with the Departments and agencies of the Government in designing, implementing and reviewing our international S&T programs. We continue to work especially closely with Assistant Secretary of State Pickering and depend greatly on his support.

The Institute for Scientific and Technological Cooperation (ISTC)

As the Subcommittee will recall from my earlier appearances, one of the Administration's principal initiatives to foster scientific and technological cooperation with developing countries is the proposal to create an Institute for Scientific and Technological Cooperation. The ISTC was authorized by Congress in 1979 to serve as a mechanism to facilitate the application of science and technology to the most important problems of developing countries. The primary functions of the ISTC are three-fold: to strengthen the capacity of the people of developing countries to solve their development problems through scientific and technological innovation, to foster sustained research efforts on critical development problems affecting large numbers of poor people in developing countries, and to facilitate scientific and technological exchange with these countries.

At this point the status of tne ISTC is still unresolved. Since the enactment of the Foreign Assistance Bill authorizing the establishment of ISTC, the inauguration of the Institute's program has awaited final action by the Congress on the Foreign Assistance Appropriations Act for FY 1980. We have just learned that final House and Senate consideration of the Conference Committee's report on this bill has been further postponed, and that FY 1980 programs will operate under authorities of a continuing resolution. Because ISTC was not in existence in FY 1979, no appropriations for ISTC are authorized under the continuing resolution for FY 1980. In light of this, the Administration is now reviewing options with respect to the funding and location of tne Institute in FY 1980 and FY 1981. However, I want to stress the Administration's

commitment to proceed with some arrangement which will enable us to preserve this important initiative.

National Security and Defense R&D

Over the past year my office and I have continued to participate in the review of scientific and technical issues that relate to our Nation's national security. The forums for this participation include my participation in various mechanisms of the National Security Council and work that is done cooperatively with, and often at the request of, the Department of Defense.

I have been the Chairman of three NSC policy review committee (PRC) groups; formulating the policy options for the China science and technology agreement, reviewing our space policy, and of reviewing our telecommunications policy. At the request of the President, on a number of occasions I have also assembled special committees of prestigious scientists and engineers outside government to provide him with independent advice on key national security issues. These have included M-X and cruise missile weapons development, the nuclear weapons test program, the South Atlantic explosion, and arms control issues, such as verification procedures for the comprehensive test ban treaty which is currently under negotiation.

U.S. Government support for research and technology, especially in the advanced technology base and basic research with the Department of Defense, declined in the 1960's and the early 1970's. This Administration has sharply reversed this trend. As a result, the cumulative growth -- from Fiscal Years 1978 to 1981 -- in the technology base will be over 50 percent, which will include an increase in basic research of nearly 65 percent.

The Department of Defense is also continuing its initiative to rebuild its relationship with universities in order to employ the research and development resources of the academic community. Defense support of university research will have increased more than 40 percent between Fiscal Years 1978 and 1981.

Early in the Administration, the Secretary of Defense asked me to conduct an outside review of basic research in the Department of Defense. As I mentioned last year, this review was well received by the Department and led to strong and continuing support by the Department for increases in basic research. DOD also undertook several other actions in agreement with the report's recommendations. For example, a new management initiative assigned to the Deputy Under Secretary for Research and Advanced Technology the responsibility for oversight and management over the entirety of the DOD basic research program. The Secretary of Defense has issued a policy statement clarifying the Department's view of the role of basic research. DOD is also using some of its real growth in basic research to provide funding to new performers, especially researchers from universities.

Space Policy

President Carter has expended considerable effort in developing a coherent space policy. The President's directive in May 1978 reaffirmed broad U.S. policy principles that have been overarching objectives through five previous Administrations. The President established and directed the Policy Review Committee (Space), which I chair, to assess the needs of the nation's civil space program. The Carter Administration's space policy is designed to carry us successfully into the next era in space. We have for the first time the opportunity for choices with regard to direction and pace: First, our space policy will reflect a balanced strategy of space applications, space science and exploration and technology development. Second, our space policy will become more evolutionary, rather than centering around a single engineering feat. Our space policy is sound, progressive and fiscally responsible -- very appropriate for this pre-Shuttle period.

In the last year the Policy Review Committee has focused on space applications, especially the evolving policy for remote sensing. The President named Commerce's National Oceanic and Atmospheric Administration (NOAA) the operational manager for all civilian space remote sensing programs; Defense will continue to manage space activities related to national security needs. Initially, our civil operational land remote sensing program will be based on the experience derived from LANDSAT. In addition, to investigate the value of satellite data for monitoring agricultural crop conditions, the President initiated a six-year research program in worldwide agricultural production forecasting. The success of this program already exceeds all expectations.

Because of the budget review, I cannot tell you precisely what mixture of continuing and new programs the President will recommend. The President is committed to maintaining the Shuttle development schedule to meet the nation's scientific, commercial and national security requirements. We continue to believe the first launch of the Space Shuttle in 1980 will herald a significant era for the utilization of space for human needs. The Shuttle will provide a cost effective way to launch and retrieve satellites and conduct repairs in space. It, therefore, may be desirable to continue the development while deferring certain other missions for a year or two.

Energy

My staff and I participate in the energy budget review and other activities of the Executive Office where our capability in the area of energy research and technology makes our participation appropriate. Today I will highlight several of these activities.

As you are aware, the accident at Three Mile Island revealed substantial shortcomings on the part of Government and the utilities in assuring the safety of nuclear power. The President thus established a Commission to investigate the accident and its cause. This Commission,

which was chaired by John Kemeny, the President of Dartmouth University, reported to the President in the fall, making some 44 recommendations for change. These recommendations included proposed modification of the structure and procedures of the NRC, improved training of operating personnel, and greatly strengthened emergency planning and response, among others. The President has adopted virtually all these recommendations although in some cases he has taken a somewhat different approach than the Commission recommended. A reorganization plan will be submitted to the Congress shortly that should serve to assist in the development of a unified and more reliable nuclear safety regulatory program.

OSTP has been closely involved in this issue from its outset. At the time of the accident, I was in constant touch with the evolving situation at Three Mile Island. My staff and I helped to establish the Kemeny Commission. Finally, Dr. John Deutch, the Under Secretary of Energy, and I chaired the internal group that developed a response on benalf of the Administration. We have been actively involved in the task of assuring the safety of nuclear power, and expect this task to continue.

For over two years, OSTP has participated in the President's Interagency Review Group on Nuclear Waste Management (IRG). The particular roles played by OSTP were to chair the technical working group that examined alternative technical strategies for the disposal of high-level radioactive wastes and spent fuel, and, in the later phases of the review, to coordinate much of the preparation of the IRG report, the recommendations to the President, and the subsequent announcements. This activity reached its implementation phase on February 12 of this year when the President sent to the Congress a plan for a comprehensive national radioactive waste management program. The program outlines the technical strategy that will be followed in working toward the construction of one or more mined, geologic waste repositories, the procedures that will be followed for State and local government and public participation, provisions for interim storage of spent fuel from nuclear reactors, plans for low-level waste disposal and remedial clean-up action at such sites and also of uranium mill tailings, and regulatory actions necessary to implement the program. Except for participation in the periodic monitoring of the progress of the Departments and agencies by the Executive Office, the OSTP's role in this activity will now draw to a close.

One of the most serious energy/environmental problems that may confront our nation in the next century derives from the buildup of carbon dioxide in the atmosphere. Through the burning of fossil fuels and tnrough deforestation, mankind returns carbon dioxide to the atmosphere. Plausible projections of future carbon dioxide concentrations suggest a doubling by the middle of the next century. Since carbon dioxide is a powerful absorber of thermal radiation in a region of the spectrum in which the atmosphere is otherwise quite transparent, small changes in the concentration of this trace constituent could have major effects on the heat balance of the earth. The consequence might be substantial changes in climate and large impacts on human society.

This is a problem about which greater knowledge and sophistication are needed. OSTP has therefore sponsored two studies by the Climate Research Board of the National Academy of Sciences to look into the question. The first study examined the status of the climate modelling in order to determine the climatic consequences of a doubling of carbon dioxide, and the level of uncertainty in our knowledge. Although much greater sophistication is necessary to provide detailed results in which we can have confidence, the study showed that there was reasonable agreement among different approaches that a doubling of carbon dioxide would result in major climatic shifts. A second study, which is currently underway, is attempting to structure the way in which we might examine and address the social and economic impacts that could result from increased carbon dioxide concentrations.

Occasionally OSTP is asked to evaluate technologies or prospective sources related to the long-term energy supply. While these do not have immediacy in the context of current energy shortages and the supplies for the next two decades, their assessment is nonetheless useful in establishing the relative priority the proposals should receive in long-term energy research. I will cite one recent example. In July of 1979, Gordon McDonald, now of the Mitre Corporation, and four Nobel prize winners wrote me a letter suggesting that the nation mount a major new program to explore for and develop methane derived from nonbiological sources, i.e., "abiogenic methane," as a potentially major contribution to the nation's energy problems. The hypothesis that there is a substantial amount of abiogenic methane in the crust -- entrapped during the formation of the earth itself -- has been promoted over the last several years by Professor Tommy Gold of Cornell University. It is quite controversial within the geosciences community. If correct, it would imply that substantial methane resources might be available to the United States that are not now being considered in government or industry resource development programs. I therefore undertook an assessment of the concept. This involved seeking the views of 26 of the nation's top geoscientists and other figures of stature in the scientific community and the commissioning of a National Academy of Sciences review panel to address the issue. The NAS panel was under the leadership of Dr. Philip Abelson. Professor Gold and Dr. McDonald addressed the panel and following deliberations the panel submitted a report to me. The committee recommended that no major drilling effort be initiated in a search for abiogenic methane, but suggested a number of scientific investigations which might be undertaken to provide information relevant to abiogenic methane and other matters of scientific interest. The report's conclusions are consistent with the great majority of the responses to my survey, and I personally endorse it. I transmitted the Academy's report to the relevant Federal agencies, who will utilize it in making their research funding decisions.

Health and Agriculture

OSTP has played a central role in a broad array of health policy and health research activities. Basic and applied biomedical and behavioral research is an investment in the Nation's future, to deal with various diseases, prevent disease and disability, and promote good health. The NIH budget and budgets of other health research agencies have been analyzed

and supported, and several significant long-term policy directives are worthy of emphasis. The most important of these directives is the higher priority given to individual investigator-initiated research in the science base of NIH. We have worked with staff of HEW and OMB and consulted extensively with the Congress in generating a proposal for the stabilization of extramural grant support in a way that can avoid the ups and downs of recent years, with resulting undesirable effects on subsequent years' commitment base. We have followed up the OSTP-chaired interagency effort on human nutrition research with a FCCSET Joint Subcommittee on Nutrition Research, which has brought together long-separated agency efforts in a series of joint plans and documents. We have supported the establishment and early work during the past year of both the National Center for Health Care Technology (and its Council) and the President's Commission for the Study of Ethical Problems in Medicine and in Biomedical and Behavioral Research. We have stimulated attention to innovation incentives and to solid scientific review in regulatory activities of the Food and Drug Administration involving drugs, food additives, and medical devices. We have worked with various HEW agencies and private sector institutions to devise more rational means of introducing new medical technologies and of reimbursing for their appropriate utilization.

OSTP has devoted a great deal of effort to strengthening the agricultural research enterprise in this country. We have worked with the Department of Agriculture, with other offices in the Executive Office of the President, with the agricultural research community, and with appropriate Congressional staffs to develop a strong, consolidated agricultural research budget, to establish a balance among intramural, formula-funded, and competitive mechanisms for the conduct and support of agricultural research, to upgrade the review and evaluation procedures used to assure the quality and relevance of agricultural research, to strengthen leadership and management of Federal agricultural research programs, and to revitalize the partnerships which characterize agricultural research in this country -- among government, the academic research community, and industry. In addition, OSTP has spearheaded Administration efforts to strengthen Federal aquaculture programs by formalizing coordination among the several Federal agencies with interests, programs, and responsibilities in aquaculture, by developing a National Plan for future development of aquaculture in the U.S., and by working with Congress to develop aquaculture legislation which the President can approve.

Regulatory Policy

Over the last several years the OSTP and other Executive Office units and the White House staff have devoted considerable attention to regulation and regulatory policy. The activities have resulted in a number of initiatives, including major reform proposals for airline, rail, and trucking deregulation, the implementation of Executive Order 12044, which established the Regulatory Council and Calendar, and the review of specific regulations proposed by the regulatory agencies. OSTP is a member of the Regulatory Analysis Review Group (RARG). Where our particular expertise in the scientific and technical sphere is useful, we participate in reviewing regulatory analyses produced by regulatory agencies as part of the President's Regulatory Reform Program under Executive Order 12044. We have been involved in reviewing the light

duty truck fuel economy standards recently proposed by the National Highway Traffic Safety Administration, surface mining regulations proposed by the Department of the Interior's Office of Surface Mining, the generic carcinogen policy from the Occupational Safety and Health Administration, the airborne carcinogen policy from the Environmental Protection Agency, diesel particulates and NO_x standards from EPA, and package inserts for patients from the Food and Drug Administration.

My staff and I bring to these discussions a viewpoint of the scientific and technical complexity, and of the uncertainty in our knowledge. Many of the overall questions and issues were summarized in an address that I gave to a meeting of the American Association for the Advancement of Science in June 1979. I would like to include this address for the record as I believe these issues are areas that are of great interest to this Committee with its responsibilities for agencies such as the Environmental Protection Agency and the National Science Foundation. It seems to me that we must begin to move toward greater scientific rigor in our regulatory programs. However, it is a diffuse and difficult area in which to make progress. Some agencies, such as EPA, are relatively sophisticated in their approach to scientific data. Other agencies use different types and styles of systems for viewing scientific and technological data in their regulatory process. At this time I am working with the National Science Foundation to begin a review of agency practices in the area and I will likely be initiating one or more studies on this important topic.

OSTP has worked to ennance the use of science and scientific panels in the regulatory agencies. OSTP worked with EPA to strengthen the role of their Scientific Advisory Board and its subcommittees to provide objective and analytical review of the science information and the information needs for that agency. In addition, OSTP encouraged OSHA to incorporate outside expert scientific panels into their review process for identification, classification and regulation of occupational carcinogens.

To give the Sub-Committee a feeling for the various ways that we approach issues in this area, I would like to describe five specific activities: the national toxicology program; the interagency regulatory liaison group; the establishment of the Radiation Policy Council; diesel automotive activities, and hazardous waste management.

OSTP played a major role in the development of the National Toxicology Plan (NTP) and the organization of the agencies involved in the Plan's development. The National Toxicology Program was established in November 1978 to centralize and strengthen HEW's activities in toxicology research and testing and to provide the toxicological information needed by research and regulatory agencies. The four HEW agencies that comprise the NTP are the Food and Drug Administration, the National Cancer Institute, the National Institute of Environmental Health Sciences and the National Institute for Occupational Safety and Health. However, the NTP is much broader than HEW. The Occupational Safety and Health Administration, the Consumer Product Safety Commission and the Environmental Protection Agency are full and active members of the NTP Executive Committee.

Thus, the NTP brings together the regulatory agencies and the research agencies doing fundamental and applied biomedical research. The NTP has three specific goals: (1) to expand the toxicological profiles of the chemicals nominated, selected and being tested; (2) to increase the number and rate of chemicals under tests; and (3) to develop, coordinate and validate a series of test protocols more appropriate for regulatory needs.

The Interagency Regulatory Liaison Group (IRLG) was formed in 1977 and is composed of five agencies -- the Consumer Product Safety Commission, the Environmental Protection Agency, the Food and Drug Administration, the Occupational Health and Safety Health Administration, and the Food Safety and Quality Service in the Department of Agriculture. The IRLG has established eight work groups to develop consistent or compatible practices in areas of common interest to the five agencies: (1) compliance and enforcement, (2) education and communications, (3) information exchange, (4) regulatory development, (5) epidemiology, (6) research planning, (7) risk assessment, and (8) testing standards and guidelines. My staff participated in the latter four work groups. Our Office stimuated and assisted the IRLG to produce a paper entitled "Scientific Bases for Identifying Potential Carcinogens and Estimating Their Risks." This document describes the bases for making a qualitative evaluation of whether a particular substance is a carcinogenic hazard and how epidemiological studies, animal bioassays and other information are to be used in making that evaluation. In addition, OSTP has published a complementary document proposing a framework for Federal decision-making in the identification, characterization, and control of potential human carcinogens. A copy of that paper is submitted for the record. In the related topic of individual differences in susceptibility to environmental hazards, OSTP commissioned a study of the statutory, legislative, judicial, and regulatory history of the Clean Air Act and the Occupational Safety and Health Act; that report has been reviewed in detail by the relevant Federal agencies and by numerous outside experts and interest groups.

OSTP had the lead role for the Administration in establishing the Radiation Policy Council and assessing research programs on the health effects of ionizing radiation. After an elaborate interagency effort for more than one year, my staff reviewed the massive documents and the specific recommendations. Stuart Eizenstat and I jointly took the resulting recommendations to the President, and President Carter on October 23, 1979, announced a number of significant actions to deal with ionizing radiation. First of all, he announced the establishment of the Radiation Policy Council, chaired by Douglas Costle, the Administrator of the Environmental Protection Agency, and having top policy officials from interested regulatory, research, and operating departments and agencies. The Council will review jurisdictional issues, such as guidance authorities, coordinate a major effort to enhance radiation protection in medical, dental industrial, and energy settings; and provide for public input and public education. The Executive Order establishing the Radiation Policy Council was issued last month. Second, President Carter directed the Secretary of Health, Education, and Welfare to establish an Interagency Radiation Research Committee, which is chaired by the Director of the National Institutes of Health, Dr. Donald Fredrickson. This

Committee builds upon an already active interagency committee chaired by Fredrickson, which has assisted OSTP and OMB in reviews of the agency programs, provided timely reports on the feasibility of health-related investigations of the populations near Three Mile Island, and organized expert review of several major research proposals. Third, the President ordered a task force on Compensation to extend its work on the development of guidelines to assess radiogenic effects from its earlier assignment of the Nevada and Utah civilian populations exposed to fallout in the 1950's to more recent and current exposures of military and civilian workers. Finally, the President directed OSTP and OMB to review the question of appropriate agency source for funding of health effects research, especially the research funded by the Department of Energy, to assure that programs of high quality, relevance, and objectivity were supported. With the help of the interagency research committee and the cooperation of all agencies, my staff completed that analysis in time for the FY '81 budget decisions. The role of HEW agencies and other agencies has been strengthened, while the DOE programs were recommended strongly for continued support.

The future of the diesel engine in the nation's passenger car fleet is one of the most important questions of energy-related technology that the nation will be addressing over the coming several years. The nation's need for energy conservation as expressed through the Corporate Average Fuel Economy (CAFE) regulations and the demand by the public for more efficient cars has induced the worldwide motor industry, lead in the U.S. by General Motors, to develop plans for greatly increased production of diesel engines, as substitutes for gasoline-powered engines in the passenger car fleet to be sold in the U.S. over the decade of the 80's. These engines can provide 20 to 30 percent greater fuel economy for a given vehicle weight. They are more expensive than gasoline powered cars, but the most important trade-off that must be made is with their possible health impact. Preliminary research by the Environmental Protection Agency is suggestive of human carcinogenicity of some of the components exhaust stream of the diesel engine; further research is underway.

Several policy initiatives are underway to deal with this prospective problem. The most important, and most immediate, is the recent promulgation of particulate emission regulations by the Environmental Protection Agency. These regulations limit the total particulates that can be emitted by diesel powered passenger cars. Total particulates have a well known health impact of their own; they also transport on their surface the substances which may be carcinogenic. However, these regulations are based on Section 202 of the Clean Air Act as amended in 1977, which states that the best available technology for control of total particulates must be imposed on diesel-powered automotive vehicles. In the course of developing these regulations, OSTP worked with others in the White House who are interested in such matters, especially the Council of Economic Advisors and the Council of Wage and Price Stability, in supporting EPA's regulatory program.

To deal with the carcinogenicity problem, we and our White House and agency colleagues felt that a broader policy review was necessary. We therefore worked over the spring and summer of 1979 with Ruth Clusen

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of DOE, Joan Claybrook of DOT and David Hawkins of EPA to organize, commission and fund a major policy review by the National Academy of Sciences. The Academy formed a top notch committee under the chairmanship of Professor Henry Rowan, from the Stanford University Business School, to address the question. There are three panels under the committee, headed respectively by Professor Robert Sawyer, Chairman of the Technology Panel, Professor Hershel Griffin, Chairman of the Health Effects Panel, and Mr. Fred Hoffman, Chairman of the Analytical Panel. An interim report from the committee reviewing the current health effects research programs in EPA, DOE, General Motors and elsewhere for their comprehensiveness and scientific adequacy is expected in May. A final report is due in December, addressing the impacts and merits of alternative government policies for dealing prospectively with this issue in the face of the extremely uncertain health effects situation.

Hazardous, non-nuclear wastes are increasingly being recognized as serious threats to human health and to the environment. Federal, State, and local governments and the private sector are having to take actions and spend large sums to clean up existing waste sites and to plan for controlling wastes in the future. The Federal Government has proposed regulations for controlling hazardous wastes and has requested funds to support corrective actions at uncontrolled sites. But limitations in our knowledge of the health and environmental effects of wastes and limitations in available control technologies severely constrain our capabilities to manage hazardous wastes.

Because of the widespread interest in this subject at the State and and local level, in the Federal Government, and in the private sector, OSTP and Intergovernmental Science, Engineering and Technology Advisory Panel staff undertook a major review in 1979 of the scientific and technical aspects of hazardous wastes management. Their report, issued in October 1979, offers recommendations for research, technology development, and application of existing knowledge that should be given the highest priority during the next five years (FY 1980-1984) to achieve substantially more effective management of hazardous wastes. Improvements in handling existing waste disposal can occur rapidly if recommendations with near-term implications are implemented. Other recommendations in the report with longer-term implications call for improved procedures and data to define wastes and waste sites in terms of the degree of hazard they pose to human health and the environment; new and improved technologies for destroying future waste streams as well as mixtures of wastes already in "problem" sites; criteria for siting new facilities; and an environmental research center dedicated to hazardous waste problems.

In preparing this report, the staff reviewed Federal hazardous waste research activities; drew on the results of eight workshops that involved extensive participation by more than 100 scientists, engineers, and representatives of all levels of government; interviewed numerous State and local representatives and analyzed survey responses from 50 States and 81 cities and counties; commissioned five papers; and visited the laboratories which fund virtually all of EPA's hazardous waste research activities. A copy of that report is included in our submission.

Productivity and Innovation

A year ago, I reported on the innovation domestic policy review that was being undertaken by the Administration. As you know, this review resulted in a series of Presidential decisions that were announced last October in a Message to the Congress on Industrial Innovation. My staff and I were involved throughout the review, but particularly during its inception and in the final stages.

There are many places in the chain from invention to sale where we found modification of Federal policy to be appropriate and that there is no one place where the Federal Government can take action and ensure that industrial innovation will be increased. Therefore, we chose a range of initiatives in a variety of areas. We expect that the aggregate impact will be substantial.

I believe that the measures announced by the President represent an important first step in what must be a continuing effort directed toward maintaining the technological strength of the American economy. The Executive Branch and the Congress must give priority attention to these issues in the 1980's. In this regard, I have noted with interest the discussion of innovation being held from time to time by a number of members of the House. I look forward to working with this Subcommittee and others to foster the initiatives proposed by the President.

In addition to the activities that have been directly associated with the industrial innovation initiatives, I have also directed attention toward two research initiatives that have implications for productivity and also for the pattern of cooperation between the government and industry and within industrial sectors. One of these initiatives -- the Ocean Margin Drilling Program (OMD) -- has become well known to the Sub-committee as it has been discussed with the Subcommittee and its staff by the National Science Foundation officials on several occasions. To date, eight oil companies have agreed to participate with the government in the first phase of the OMD. This activity, which will go forward after the preliminary engineering work now being carried out by an NSF contractor is completed, will enable both the government and industry to determine more exactly the costs of the total program and the engineering involved in the new riser technology, ship conversion, and so on. Since the program announcements in January there have been further discussions with industry and with the scientific community. The program will generally proceed as has been outlined, except that we may elect to have the first phase of the work extend over a two-year instead of a one-year period. Industry engineers advise us that this may be a better schedule. It also may be a schedule better suited to the extremely tight budget resulting from the President's current review.

The second industry-government initiative that I have helped initiate is the Cooperative Automotive Research Program (CARP). In May 1979, the President and the leaders of the American automobile industry met at the White House to agree on a set of guiding principles

for a new mutually-supported program of basic research related to automotive technology. The Department of Transportation, the National Science Foundation and possibly other agencies, and the five domestic automobile manufacturers -- American Motors, Chrysler, Ford, General Motors, and Volkswagen of America -- will participate in the Cooperative Automotive Research Program.

The principal purpose of the Program is to increase the level of basic scientific research underpinning automotive technology. The premise is that a better basic understanding in key research areas will lead to improved automobiles -- more efficient, safer, less polluting, and less costly to operate -- beginning in the decade of the 1990's. The program is designed to harness the capability of many university laboratories where scientists and engineers can make significant contributions to advanced basic automotive research.

Both the government and the industry recognize that their current investments in these areas, in work related to automotive technology, are adequate. The Administration has proposed an investment of $800M over the 1980's. Industry has made a commitment to build up to an expenditure level of $50M a year by 1983, with the industry amount divided among the companies on the basis of their respective percentages of domestic automobile sales. While the industry commitment is for five years, it would presumably renew the agreement if the program is going successfully.

Research will be carried out at the Nation's universities, at private and Federal research laboratories, and in the industry's own research centers and will include these areas: combustion, thermal and fluid sciences; structural mechanics; electrochemistry; aerodynamics, materials science and processing; control systems; tribology, acoustics and vibration; surface science and catalysis; environmental science; biomedical science; and behavioral science.

The Program will operate as a confederation of relatively autonomous participants (automobile manufacturers or Federal agencies) each of whom will select and manage the research projects supported with its share of the total funding under the agreement, consistent with the mutually agreed-upon administrative and technical frameworks. The Program calls for wide and open dissemination of research results, subject to appropriate patent provisions. Publication of research results in technical journals, personnel exchange programs, and extramural funding of work will enable diffusion of the new knowledge to all those who can utilize it.

These cost-sharing industrial sector-government agreements represent a significant development in the Federal sponsorship of research. I believe that they warrant Congressional support. I foresee other opportunities, for example in the space applications programs, and my office will continue to work with the Federal research and development agencies to pursue appropropriate programs.

Intergovernmental Science and Technology

ISETAP, the Intergovernmental Science, Engineering and Technology Advisory Panel has been effective in identifying and resolving policy issues and priority problems in intergovernmental science and technology. Working closely with Governor James Hunt of North Carolina, who co-chairs the Panel with me, our 20 State and local government officials who serve on the Panel have carefully formulated recommendations concerning:

-- priority State and local government problems, and

-- policies to increase the use of science and technology by State and local governments.

The ISETAP problem identification process initially identified 600 significant problems of State and local governments. Through careful analysis and participation of the officials who identified the problems, priority has been set on 39 of them. The American Association for the Advancement of Science (AAAS) has recently concluded a series of workshops funded by NSF in which research, development and technical assistance activities were recommended, which could help solve major parts of these problems.

Our next step in the process is to work closely with OMB and the agencies to evaluate the workshop recommendations and to find opportunities for R&D activities aimed to help solve these major problems, which include road and bridge maintenance, transportation of hazardous materials, resource recovery from waste, groundwater and drinking water quality and the like. ISETAP's recommendations have in the past year been especially significant factors in EPA and HEW program emphasis on hazardous waste problems, U.S. Fire Administration emphasis on firefighter health and fire protection effectiveness research, and Administration on Aging emphasis on elderly housing R&D.

ISETAP has also helped to set up new consultation and communication channels for State/local governments with the National Bureau of Standards Computer Center, the National Technical Information Service, the Department of Labor, and the Department of Energy.

In summary, ISETAP is beginning to achieve its full potential in helping to shape federal policy, budgets and programs.

Interagency Coordination of Research and Development

The Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), which I chair, facilitates coordination among agencies with research and development responsibilities and programs. FCCSET is the highest level formal, government-wide coordinating mechanism for science and technology issues. It operates as a sub-Cabinet group under my chairmanship, with membership composed of the chief officials for R&D in the various agencies. The Council itself meets as needed to consider major policy matters of concern to all R&D agencies.

Finally, special problems are handled by ad hoc groups. As summarized in the attached report on FCCSET, which was just released, there are now 13 active committees, including joint subcommittees on aquaculture and on human nutrition research. The latter two topics are excellent examples of research and development areas in which the FCCSET umbrella and our own staff have brought together agency-specific activities that had been isolated and competitive for too long. My Executive Secretary for FCCSET is Dr. Denis Prager. All the rest of the staffing for these committees comes from the interested agencies.

III.

OSTP Budget Request

Turning to OSTP's FY 81 Budget Estimate, I have requested $2,948,000 for the conduct of the work of the Office.

We have a small core staff of only 24 full-time permanent employees whose capabilities can be augmented by consultants, temporary employees and detailees. We use this approach to our staffing so that we can be flexible in addressing a changing array of scientific and technological issues.

Another important element in our planning that enables us to advise the President and other organizations within the Executive Office of the President is our use of contractual support. For FY 81 we have included $670,000 for major study contracts. This will allow us to seek outside analyses in about 10-12 problem areas. This is consistent with our experience of the last three years when we have found it necessary to initiate studies. I would like to emphasize that many times we undertake these studies as part of our function of assisting other agencies witnin the EOP. It is, therefore, difficult to predict precisely on which issues we will initiate study activity. We expect that these studies will occur in each of the major OSTP program areas.

I have requested travel funds of $283,000. Some of this is for expenses related to the consultants and experts I have just mentioned as being a key part to our staffing strategy. The remainder is for staff travel. We find that as the work of the OSTP has developed there is an increasing need for our people to travel both domestically and abroad. I have previously mentioned some of the important work done with other countries and we expect this trend to continue.

The requested budget authority has been put together in a way that will permit the Office to respond to a wide range of developing important scientific and technological issues. It provides for the efficient use of a small staff but with flexibility to increase our capabilities as needed.

I urge the Committee's support of our FY 81 budget request and its adoption in the full amount.

Mr. Chairman, this concludes my testimony. I will be pleased to answer questions you have on the activities of the Office of Science and Technology Policy and the details of our budget request.

Dr. PRESS. Let me make a brief statement so we can have more time for questions and discussions rather than going through this in detail, since you and your colleagues have read it.

ADMINISTRATION'S R&D PHILOSOPHY

Let me begin with the Administration's philosophy for the research and development budget. We believe that science and technology is one of America's most important institutions. It underpins so many things that are important to us—the ability of American industry to innovate and become more productive, the health of our people, the prestige of this country among the countries of this world. That is reflected in the three budgets that have been submitted by President Carter to Congress. That philosophy is still intact despite the fact that we are undergoing a reassessment, as you know, of the fiscal year 1980 budget because our prime national concern is the problem of inflation. So, although there will be a reassessment of the fiscal year 1981 budget in every aspect, we will be reassessing the R&D portion but trying to maintain the commitment we have to strengthen American science and technology.

In the statement we have reviewed our Office's activities for the last year, not all of them, even though this is a long statement. We have highlighted a number of areas, such as our participation in certain national and international issues, energy, health, regulatory policy and the issue of productivity and innovation.

INTERNATIONAL ACTIVITIES OF THE OSTP

In the international area, I suppose we could divide the world in terms of relations through science and technology into our relations with our western allies and Japan; the USSR represents a separate set of problems; and China and the developing countries.

With respect to our western allies, we have been trying to engage the advanced industrial nations in joint ventures. Science and technology cooperative agreements with these nations are not as important as having them participate with us in some globally important projects that are very expensive. By pooling our human and physical resources we can proceed more rapidly to tackle some of these problems.

Here I have in mind certain kinds of energy production, for instance, fuel plants, demonstration plants, expensive fusion energy development as well as non-energy areas that could be important to all the advanced nations.

We have made significant progress. Our first joint venture in synthetic fuels will be between Germany, Japan and the United States.

I was in Japan last fall, the Japanese have returned here and we have just about reached agreement on an unbrella science and technology agreement which will emphasize participation in joint ventures of this kind. As a result, I think both countries will be ahead and the whole world will be ahead.

BILATERAL SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS WITH THE U.S.S.R.

With respect to the U.S.S.R., we now have had some 25 years of scientific and technological cooperative projects with the U.S.S.R.

In recent years we have been trying to push this cooperation in the direction of mutual benefits so there would not be a one-way flow of benefits from the United States to the Soviet Union. In the past two or three years we have seen progress in this direction.

The Soviets are sending younger scientists. They are sending Jewish scientists here and we are having access to some of their previously closed-off laboratories. However, the overriding recent issue with the Soviets has been the invasion of Afghanistan and the treatment of dissidents, especially Dr. Sakarov, Dr. Scharantsky and several other prominent scientists, as well as hundreds of unknown scientists who have been placed in jeopardy because of their strong desire to express themselves.

We are following a policy of restricting these cooperative arrangements with the Soviets pending an improved climate as to the removal of troops from Afghanistan.

Mr. TRAXLER. What if that does not occur? We understand the Soviets are garrisoning their troops in Afghanistan and are constructing barracks and other recreational facilities, so it is rather clear what their intentions are for the foreseeable future. I am talking about the next several years at least.

Is it your view we will put the scientific contacts with the Soviets into the deep freeze for an indeterminate period of time?

Dr. PRESS. We have to let them know that their incursion is just not acceptable. Cooperation is only one element in this. There is the embargo on farm products.

Mr. TRAXLER. My farmers ask the same question. They want to know how long we are going to maintain this embargo and under what circumstances it will be lifted. We are sending a message to the Soviets, which is nice, that we are displeased with their incursion into Afghanistan, and all indications are it will continue for some years.

I am talking to you as a science adviser counseling the President on the question of scientific exchange. How long do you think this should go on in view of the apparent fact that the Soviets are going to be permanently in Afghanistan? Do you think the present situation will continue indefinitely?

Dr. PRESS. As of now we plan to continue this policy I have described, pending changes in the environment. I don't think anyone can predict the future Soviet behavior but at this time our policy is to defer these things pending improvement.

If you are asking for an Administration response to a hypothetical question, what if the Russians don't move out, we have not prepared a position that goes indefinitely into the future. We will take it a year at a time.

FUNDING FOR U.S.-U.S.S.R. COOPERATIVE AGREEMENTS

Mr. TRAXLER. Wouldn't it be logical for this Committee to cut off all cooperative funding, at least in the 1981 budget? This would be a clear message to both America and Soviet Union.

Dr. PRESS. We would like to keep the framework that took us a large number of years to build so that, if the situation does improve, we can reengage the Soviets in these endeavors, especially since there has been such an improvement in recent years in their performance.

If we have a zeroing of the budget, as you prefer, for fiscal year 1981 that will take us through 1982 effectively. What you are saying is shall we cut this program off now for a period of some two years or so.

Mr. TRAXLER. We are only dealing with the 1981 budget. It is 12 months. It is October to September.

Dr. PRESS. With our actions I have described for the remainder of this year and the proposal, it would be an effective two-year cutoff. We would like the ability to be responsive to Soviet behavior.

Mr. BOLAND. In line with what Mr. Traxler is talking about, I don't think there is any question about the fact that cooperation among all nations of the world is necessary. We no longer can go it alone in the field of science and technology. It affects every corner of the globe itself.

But bearing in mind the actions of the Soviet Union with respect to Afghanistan, what would be the most effective cutoffs there. It is difficult, I know, to target some of them. With problems of environmental protection, public health, oceans—all of this is wrapped up in global efforts. I guess perhaps it would be unwise to cut-off conversations and meetings completely with the Soviet Union in those areas which are attached to global problems. But with respect to problems that target in on the Soviet Union, itself, what about those particular areas?

CONTACT WITH SOVIET SCIENTISTS

Dr. PRESS. In terms of the scientific and technological cooperation which is distinct from experts and of high technological products, I would ask you to give us the flexibility to make those choices.

I have contacted a great many American scientists who have been engaged in these programs for a number of years. They ask us to keep the framework viable. They don't want to cut off contacts with their Soviet counterparts. They feel it is extremely valuable in terms of applying pressure on the Soviet government to be responsible for their behavior to the dissidents.

They feel that even though Dr. Sakarov has been exiled much worse might have happened to him had it not been for the pressure we put on the Soviets.

For our government to take an action that would close all contacts for a significant period of time without the possibility of reopening them depending upon circumstances would be a step that I believe most American scientists would not be happy with.

So, for all practical purposes, our contacts with the Soviets have drawn to a halt, and the signal has been sent. What good this will

do remains to be seen, but I think what we have done across the board in agricultural products, high technology exports and the Olympics represents a very strong pressure being applied to the Soviet government by us.

Mr. BOLAND. Whether or not the message has been heard by the Soviets, that message now has been sent what—two months ago? And what has happened in that two-month period? What sort of reaction have you received from the Soviet scientific community, or have you had any reaction at all?

Dr. PRESS. It is difficult for me to talk in an open meeting like this because I have had some reaction, but I think it would cause problems among those Soviets who have sent word informally one way or the other about the effect of all of this.

Let me make a general statement. So far as the working community is concerned, they are extremely concerned about the cutting off of these contacts. It bothers them because, to be productive scientists, they need these kinds of international avenues of communications, sharing results and participating in international events like this and, of course, the United States, as a leading nation in the world of science and technolgy, plays a dominant role in these kinds of contacts.

Mr. TRAXLER. Dr. Press, we could insert language into the bill which would provide that when the President certifies that the Soviets have substantially withdrawn all of their personnel from Afghanistan, the funds could be made available.

It is not really a big problem in terms of not giving you flexibility.

If, indeed, we are troubled with this incursion into Afghanistan and we see they have crossed over the line and we consider them bad boys until they go home again, wouldn't that language reinforce the Administration's position and give you the flexibility you are concerned about because, upon their becoming a respectable part of the world, we could again resume scientific cooperation with them?

Dr. PRESS. Do you think this is not accomplishing the goal? There are no working groups going to the Soviet Union.

POLICIES OF OTHER COUNTRIES ON COOPERATIVE PROGRAMS

Mr. TRAXLER. Have other countries adopted such a tough attitude?

Dr. PRESS. Australia has taken a tough stand. Canada and the United Kingdom are about the same as we are. I am not sure of France and Germany. At a recent meeting in Hamburg, all of the countries took a very strong stand on the issue of human rights as evidenced by the problems of Sakarov and other Soviet dissidents.

Mr. COUGHLIN. This is certainly a field of substantial interest to the Subcommittee, both in terms of how real the steps we are taking are, and in terms of what effect they are having on the Soviets. Obviously, you have some feelings about that that you are reluctant to express in an open meeting. If we had a closed meeting at a later time, would you be willing to testify in that connection?

Dr. PRESS. Yes, but what I would tell you about would be the kinds of informal messages passed to western scientists by Soviet

counterparts at meetings expressing great concern about this breakdown in communications, and expressing sorrow. I hope in time the situation will improve.

Mr. COUGHLIN. You said there are no working groups and then you qualified that by saying in a visible capacity.

Dr. PRESS. Official working groups under the Science and Technological Agreements with the Soviets, they mostly have stopped functioning.

However, in certain areas where there is a very great advantage to us or where it is the humane thing to do, we might permit certain of these working groups to function.

For example, Parkinson's Disease and cancer research would be an important area.

Mr. COUGHLIN. What areas have we not deferred?

Dr. PRESS. I think we have deferred all of them.

Mr. HUBERMAN. Where we have not deferred is in low-level working groups and in areas of particular interest to us where essentially there is a unilateral advantage to us. Some of our equipment in MHD is being tested at a Moscow facility and we have continued testing our equipment there. That is of unilateral advantage to us.

CONTACT BETWEEN INDIVIDUAL SCIENTISTS

Dr. PRESS. As far as individual scientists going to the Soviet Union or individual Soviets coming here, we have not raised impediments to this kind of contact. Most scientists would want to continue on an individual basis.

It is the officially-sanctioned working groups based on those agreements which are in the budget that we have deferred. I would hasten to say a number of American scientists, as a matter of conscience, are refusing to participate in these programs.

Mr. COUGHLIN. Is there any effort by your Office in the non-governmentally sponsored areas?

Dr. PRESS. If you are talking about individual scientists writing to each other or visiting with each other, no, we have not interfered in that area. If you are talking about commercial companies, in that case we do have laws on the books and regulations that have to be followed by the individual companies. I believe most of them know about these things and are complying. They have to apply for licenses in certain types of technology.

In the area of high technology, most of these licenses are being denied right now.

We participate on the committee for these activities. Mr. Huberman chairs a committee on that activity. Would you like to describe that?

Mr. HUBERMAN. The particular activity related to the high technology transfers to the Soviet Union is not handled by my committee, but another NSC committee. I chair a committee dealing with longer-term issues, not specifically related to Afghanistan policy issues but related to enforcement.

EXPORT OF HIGH TECHNOLOGY PRODUCTS TO THE U.S.S.R.

Mr. COUGHLIN. I am trying to find out how effective our efforts to restrict the export of high technology products to the Soviet Union are and what effect they are having on the Soviets.

Are we still granting licenses?

Mr. HUBERMAN. We have denied a large number of licenses in accordance with the President's policy of clamping down on high technology licenses. We have clamped down on spare parts for existing facilities.

Mr. COUGHLIN. Clamped down or shut up?

Mr. HUBERMAN. I think clamped down is the proper phrase because, depending on the nature of the facility, if it were a hospital, for example, you might allow replacement. If it were some sort of factory, you might not.

Mr. COUGHLIN. There were reports that we were continuing to export fertilizer components, for example. Has that been shut off now?

Dr. PRESS. Yes, that has been cut off.

Mr. COUGHLIN. Totally?

Dr. PRESS. Yes.

Mr. COUGHLIN. What other areas other than hospitals are we still providing high technology?

Mr. HUBERMAN. I am not aware of the details. We can provide that information, if you like.

Dr. PRESS. Let me say the situation is dramatically different now. Essentially the door has been closed but as to the details as to what few items are permitted to go through, I think we would have to supply them separately to you.

Mr. COUGHLIN. Would you provide for the record, in the last month the list of licenses that were granted for export.

[The information follows:]

No validated licenses have been issued to the Soviet Union in the past month. On January 11, the Commerce Department issued a general order suspending all outstanding validated licenses to the Soviet Union, and announced the suspension of issuances of new licenses pending completion of a Presidentially directed review of export policy. No validated licenses for the Soviet Union have been issued since then and all such validated licenses issued earlier remain suspended as of today (March 12).

MEETINGS OF INTERNATIONAL SCIENTIFIC ASSOCIATIONS

Mr. TRAXLER. While we are on this subject, Dr. Press, most scientific disciplines have international associations they belong to. One that comes to mind is the International Association of Foundrymen. They schedule meetings around the world.

The Russians and eastern bloc countries are significant participants and they present papers and there is an exchange of ideas. These are private associations. Although usually the host countries participate in the funding in the international conference that is held in that country, it is not the position of the Administration that the Americans participating in these kinds of international conferences, or something similar—where the funding essentially comes from the private sector or perhaps some people go to these at the expense of the National Science Foundation grants—do not

attend? Are you suggesting we should not participate in those international conferences?

Dr. PRESS. I am talking about bilateral relations between the United States and the Soviet Union.

Mr. TRAXLER. There is a significant hole in the theory, then. If our people participate in the international conferences, I am somewhat at a loss to know what the difference between that is and bilateral association and exchange. It is going to happen.

Dr. PRESS. Let me go further than that. At most of these international meetings and even bilateral meetings—the kinds of papers presented are papers about to be published or have been published and papers that do not relate to the kind of embargoed technology of manufacturing know-how that would be subject to export licensing. It would be contrary to the American tradition to cut off scientists from talking to each other. Our human rights concerns would be turned right back on us and we don't want to do that. It is foreign to the American character.

So, when it comes to participation in international meetings I don't think we should tell our scientists not to go, not to have the kind of communication that is essential to their being successful scientists.

We are talking about collaborative projects. Our primary thrust is on collaborative bilateral cooperation between the U.S.S.R. and the United States. That is the area we want to improve.

Mr. TRAXLER. My colleague asked about high technology exports to the Soviet Union. I have some familiarity with that and what is going to happen in agricultural embargoes. Computers are on the no-no list and probably we are not even supplying them with the parts to keep the computers running which they have purchased already. I would assume they would find another source, probably the Japanese in the long run, and the United States will have lost a significant market.

Dr. PRESS. We are working very closely with our allies, the western allies and Japan, to make sure that they don't pick up on the export of the kind of technology and spare parts that we have embargoed. We feel that they have a stake in the Soviet behavior as much as we do.

We are doing the best we can through individual discussions with these nations to convince them that it is in the interests of the western world that we act together on these issues.

There may be some things that slip through one way or another through these routes, but we are trying to minimize this kind of end running around this policy.

Mr. TRAXLER. Thank you very much.

NSF BUDGET REQUEST FOR U.S.-U.S.S.R. AGREEMENTS

Mr. BOLAND. Looking at the National Science Foundation budget, there is a specific line item of $2,300,000 requested for fiscal year 1981 with respect to the U.S.-U.S.S.R. Cooperative Research Program. That is the same amount that was appropriated in fiscal year 1980.

Who actually oversees the expenditure of the $2.3 million? Do you have any input into that expenditure?

Dr. PRESS. About half of that goes to the National Academy of Sciences.

Mr. BOLAND. Do you know whether or not funds for fiscal year 1980 are still being obligated under that agreement?

Dr. PRESS. I think essentially the rate of expenditure on that has dropped to a halt because of the policy I have described.

Mr. BOLAND. The justifications for NSF, and we will be asking NSF about this, but because of your close relationship with this program—we want to get your assessment. The NSF justifications (p. H-15) indicate the the program for fiscal year 1981 will be identical to that in fiscal year 1980. One of the sub-program activities is Computer Applications in Management, funded at $600,000.

Are we still obligating any funds under that agreement for this particular technology?

Dr. PRESS. I would be surprised if any money is being spent in this area at this time because of the deferral of the program.

Mr. BOLAND. This is an area we will be exploring with NSF this afternoon.

Clearly, some of the programs that are targeted in the 1981 budget which are similar to those that are ongoing in the 1980 budget are areas of technology that I think perhaps a great number of the Members of Congress would be concerned about. I take it you are concerned about them, too?

Dr. PRESS. We have stopped them. We are asking for the flexibility in fiscal year 1981 to be able to turn these things on again if the Soviets do behave responsibly. I don't believe any of us can predict what will happen. If they don't act responsibly we will return the money to the United States Treasury.

REVIEW OF THE R. & D. PORTIONS OF THE BUDGET

Mr. BOLAND. The scientific community never seems to want to take a position or sacrifice any of its programs—with respect to balancing the budget or, for that matter, indicating its resolve when we get into situations like this. That gives, of course, this Subcommittee and the Full Committee and the Members of Congress some hesitation with respect to some of the programs in which this nation is engaged with the U.S.S.R.

Dr. PRESS. I can't speak for the whole scientific community but speaking personally and speaking as the Director of my Office, let me say I think inflation will hurt the scientific community as well as anybody else in the country. Scientists have a major stake in this and if bringing in a balanced budget will have an impact we will have to review those goals.

Mr. BOLAND. You have an excellent statement with respect to the inflationary impact upon the economy as a whole. When an effort is made by the Administration, itself, to balance the budget, and when reviews are suggested, not just for the current budget but the 1981 budget, it is the position of the Administration that everyone ought to participate in this effort and that no one should be excluded.

I take it that that is the position you take as the Adviser to the President on Science and Technology?

Dr. PRESS. I agree with that and I do take that position.

I would like to say our major tool in fighting inflation is improving productivity. That requires a new kind of knowledge and insight that science and technology can provide. As we review these budgets and can reassess them, we have to be sensitive to those programs which will enable this country to be more productive.

Mr. BOLAND. I think you indicate that toward the close of your statement and I want to commend you on it.

I think there are a number of areas that you highlight that we cannot afford to pass up despite the fact that we are in a tight budget situation. Why don't you continue, Dr. Press.

SCIENTIFIC AND TECHNOLOGICAL RELATIONS WITH CHINA

Dr. PRESS. With respect to China, one of the important elements of our new relationship with China is scientific and technological cooperation. I would like to tie this cooperation with China in with improved opportunities for American business to participate in the modernization of China.

In a relatively short time, just a little over a period of one year, we have developed about 15 areas of cooperation with the Chinese. There are a thousand Chinese students in this country engaged in studies here. We have on the order of 100 or so American scholars in China.

Mr. BOLAND. I think it is an important program.

Dr. PRESS. In many cases, in relationships with many countries, the fact that the present leadership has been trained in this country I think has helped us, especially in Africa and other areas.

China has emphasized technology. It is going to become a technocratic nation. For America to be training the future leaders of China, on balance, I think is in our interest.

We have a number of American companies involved with significant contracts with the Chinese. There are seven oil companies exploring the China Seas for petroleum. It is in the interests of our country to help China develop their resources and participate in world commerce and that is why we are doing these things with the Chinese.

None of this is in the way of a developmental program. We are not supporting the Chinese, not giving them money.

PROBLEMS OF THE DEVELOPING COUNTRIES

There are many problems that developing countries face which, if they have not achieved, they can achieve development goals. This involves how one increases the agricultural productivity when the soil is very poor. A breakthrough is absolutely required if the world's poor people are going to be fed in these developing countries by the year 2000. There is a resurgence of malaria and polio where the vaccines developed for Americans don't work in those countries.

If you think we have an energy problem, in these other countries their energy problems are very severe.

These helping programs are not expensive. They are low cost but the impact is immense and this is one area where they really respect the American contribution. So I have been pushing this kind of cooperation with developing countries.

Mr. BOLAND. With respect to that, in the 2nd paragraph on page 5 of your statement, I notice you indicate, "We work very closely with the departments and agencies of the government in designing, implementing and reviewing our international S&T programs. We continue to work especially closely with Assistant Secretary of State Pickering and depend greatly on his support."

I understand he chairs this particular committee, or does the State Department chair the committee?

Dr. PRESS. We have the Council for Science and Technology which I chair.

NATIONAL SECURITY AND DEFENSE R&D

Let me move on to what we do in the National Security and Defense R&D areas. I chair three National Security Council Policy Review Committees—one dealing with China Science and Technology, our Space Requirements, and our Review of Telecommunication Policy—and I serve on a great many other NSC Policy Review Committees.

At the President's request, I have convened a number of outside specialists and consultants to provide him with the kind of independent advice on crucial areas such as the MX and cruise missile weapons development program, the nuclear weapons programs, the South Atlantic event which may not have been a nuclear explosion, and certain other arms control issues.

In the preparation of the Defense R&D budget, I participate in that activity. The Secretary of Defense asked me to bring in some outside experts to review his overall research program. I did that and he implemented recommendations of that panel.

Mr. BOLAND. Let me just ask a question about the last paragraph on page six. It reads: "The Secretary of Defense has issued a policy statement clarifying the Department's view of the role of basic research. DOD is also using some of its real growth in basic research to provide funding to new performers, especially researchers from universities."

We don't want a long explanation, but in a few words what is the Secretary of Defense's view on basic research?

Dr. PRESS. Our report indicates basic research was squeezed out and he feels taking the long view of defense needs basic research today represents the new systems in the Defense Department 10, 15, 20 years from now.

The Secretary feels that we can go too far in terms of perfectionism, getting the highest technology can be over expensive and counterproductive. Nevertheless, in the area of competition with the Soviets, research and development is our prime card. We are so much better than they are that to underfund these projects is simply to restrict ourself when we can perform in the best way.

SPACE POLICY

In the area of space policy, the Administation feels that the highly visible, high technology engineering feats like sending a man to the moon or a man to mars is something that we should not be undertaking in the next 20 or so years. Rather, we should realize the investments of $100 billion or so over the period of our

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space program and emphasize applications for the good of humanity from the space program and also emphasize the scientific exploration of space.

That is our prime concern so we have what we consider to be a balanced program of scientific exploration and application.

In the area of application scientific research can contribute to increasing agricultural production. We have a continuing operating program in the area of remote sensing and we had designated a lead agency in the government to direct that effort.

We feel that the next generation of communications technology is critical. So we want to bring NASA back into that area. Space satellite technology has already revolutionized communication transmissions. The economic returns from that program alone, have been significant. We feel that it is time for further advances in satellite communications; so we have embarked on a program for NASA to re-enter that field.

The exploration of space has captured the imagination of the whole world and of young people in this country. It is a program that is worthy of a great nation and so we feel that that should be an essential element of our space program. The highly visible multi-billion dollar programs of the kinds that I have mentioned—building space stations or satellite power systems or sending men on extended missions throughout the planetary system—we feel should not take place prematurely. Perhaps in the next century, rather than in the remaining part of this century, is a more appropriate time for such effort.

We are again reassessing the space program as we are with all of these other programs in view of our need to balance the budget, but we will try to protect this underlying philosophy I mentioned.

REVIEW OF THE NASA FISCAL YEAR 1981 BUDGET

Mr. BOLAND. As I understand it, you were one of those that engaged in serious discussions on cutbacks in the 1981 budget, and the NASA budget was an area that particular and specific attention was paid to. I don't know what the target of the cutback is and I am not going to ask you because I think it would be unfair. But various estimates have been seen in the paper. One suggested as much as a $750 million cutback in the 1981 budget for NASA. One of the areas that has been talked about, of course, is a cutback in the shuttle.

Do you think that the shuttle program, the space transportation program, should be held harmless in fiscal year 1981?

Dr. PRESS. Yes, I do. It should be our first priority for protection within the NASA budget. I say that for a number of reasons. For one thing, to slip the program is counterproductive economically speaking.

Secondly, we have a great many commercial agreements in terms of future communications satellites, agreements with our own industry, and agreements with other countries where there will be very severe economic losses if the shuttle is slipped. But perhaps most important, our defense programs rely heavily on the shuttle maintaining its schedule and for that reason, above all, we should protect the schedule.

Mr. BOLAND. In your judgment, does the national security require that the schedules be maintained?

Dr. PRESS. If the schedule is not maintained, I think the Defense Department would propose the acquisition of expendable launch vehicles which would be as expensive or more expensive.

Mr. BOLAND. If the NASA budget, and particularly the space shuttle activity is reduced or cut back substantially in 1981, then, of course, the deliveries or the orbiters O–99 and 103 will slip and that could wipe away the major justifications for the $300 million supplemental NASA has requested. Is that correct?

Dr. PRESS. Although the final conclusion has not yet been reached, I would be surprised if we proposed a slip of the shuttle schedule as part of the budgetary reassessment.

Mr. BOLAND. Are you satisfied with the timing of the delivery, with the schedule of the delivery of the orbiters, themselves?

Dr. PRESS. Do you mean the current schedule?

Mr. BOLAND. Yes.

Dr. PRESS. I think if that current schedule were met, then all of the obligations that I referred to, especially the Defense ones, can also be met and our needs would be taken care of.

Mr. BOLAND. In the area of space, the last sentence in your statement says, "The Shuttle will provide a cost effective way to launch and retrieve satellites and conduct repairs in space. It, therefore, may be desirable to continue the development while deferring certain other missions for a year or two."

Would you care to give us an indication of what those missions might be that could be deferred?

Dr. PRESS. We are examining all of the continuing NASA programs and the continuing ones in the 1981 budget. There is no question that NASA, like other agencies, will have to be part of the budgetary reassessment, but I think there is great sensitivity in the Administration not to make these budget cuts in such a way as to gut NASA, to change the basic philosophy of our overall space program.

We don't view this effort to balance the budget as one that will change in a fundamental way what we expect of the American space program. So certain things may have to be deferred and slowed down and in other areas we may decide to go ahead, perhaps at a slower rate, perhaps at a full rate. But we feel we can come in with a defensible space program which maintains the basic philosophy of a balanced space program and yet is responsive to our need to reassess the budget in order to balance the budget.

THE GALILEO PROGRAM

Mr. BOLAND. Would the space program be affected drastically if we canceled Galileo?

Dr. PRESS. Galileo represents essentially the only planetary program we will have for the whole program of the 1980's. If we cancelled out Galileo, what you are saying for the entire decade essentially, we will give up the exploration of the planets. That is a very severe penalty. We should consider that carefully before we go down that route.

Mr. BOLAND. That has developed into a very expensive program. It is $250 to $300 million more than the original estimate which is a lot of dollars.

Dr. PRESS. Half the dollars are spent for Galileo. To cancel now would be throwing away half of the investment.

THE SPACE TELESCOPE PROGRAM

Mr. BOLAND. What about the large space telescope? Can we slow that down?

Dr. PRESS. The space telescope is an extraordinary breakthrough in astronomy. It will enable us to do something we canot do from the earth. But, unlike Galileo, it does not have a window. It does not have a prescribed time it has to go, so we are certainly looking into the possibility of slipping that somewhat, but it is an important mission.

Mr. COUGHLIN. I don't think I got an answer to a couple of questions here that the Chairman asked. Is it possible to make the kinds of cuts that I have read about in NASA without slipping?

Dr. PRESS. If you are referring to the $750 million cut, again let me preface my response by saying I don't know what the final figure will be.

Mr. COUGHLIN. Is it possible to make a cut in NASA without slipping the shuttle?

Dr. PRESS. I don't think we are going to do that but let me respond to your question. I think it could be possible to do that but NASA would never be the same if we did.

Mr. COUGHLIN. The second question goes to the Galileo, which, as you know, the Subcommittee recommended deferring initially and that could go to a totally different window; is that correct?

Dr. PRESS. Four or five years down the road, and I think you would have to start over again. You would be throwing away the 50 percent investment you already made.

Mr. COUGHLIN. That was the argument that was posed when we initially rejected Galileo's first start and the scientific community has the marvelous ability to "You scratch my back and I will scratch yours." Even people not remotely associated with Galileo came out of the woodwork to insist that the program go and now we are embarked on a very expensive program which maybe, if it had not been started, would have some impact on being in the position we are in.

Mr. BOLAND. Incidentally, Congressman Coughlin, it is possible to re-examine Galileo and reduce some aspects of that mission to preserve the essential aspect of trying to find out about Jupiter and its chemistry, to let some things go, keep within the window and have a justifiable program with reduced expenditure without too much waste of what you have already spent.

Mr. COUGHLIN. When the Jupiter orbiter probe was originally before the Subcommittee, at least in my judgment, NASA very specifically testified that it could be done in one of either of two windows. When the program developed difficulties, when it appeared that it would slide or have to be split or what have you, then the testimony changed that the later window was not as desirable or was not possible or is very fuzzy as to why suddenly

you could not use the later window. What is the disadvantage of the later window?

Dr. PRESS. I don't think the program developed difficulties. I think it was because of the shuttle slip they couldn't count on sending the full probe and orbiter on a single shuttle mission. That forced them to split the mission into two parts.

But let me look into that. I am not familiar with the later window they refer to.

Do you remember that later window option?

Mr. HUBERMAN. No, not in detail.

Mr. COUGHLIN. There was a window every 6 or 7 years.

Dr. PRESS. Seven years.

THE JAPANESE RESEARCH EFFORT

Mr. TRAXLER. I am going to be meeting with some members of the Japanese Diet at lunch. The Japanese society as a culture are very interesting; they do things somewhat different than we do. It appears that they make some national determinations as to what their national goals are going to be and it is a collective sort of decision. This is from my perspective. This is really a question.

From my perspective, it is a coalition and cooperative effort on the part of the government and industry and labor and the scientific community. As a manufacturing-exporting nation having to do this to survive, they seem to cast about the world for kinds of industry areas that they could develop expertise and production facilities in, and in a sense, simply overwhelm other producing nations in those limited design, carefully drawn areas. I bring to mind their optics industry, their electronics, and what appears to be now a clearly defined national effort in the computer industry.

Would you comment on how the Japanese research effort contrasts with ours?

Dr. PRESS. I think the thrust of your question is correct. In the past, the Japanese did exploit the research results of other countries, particularly of the United States, in developing new ideas into commercial processes and products. Their technology and their high technology industry have now reached the stage where they have to start doing their own research and not exploiting the research of other countries, and they are beginning to invest more in the kinds of research we do in this country—basic research—simply to stay ahead.

The Japanese, as we, will be experiencing severe competition from the middle-level developing countries which have lower labor costs, countries like Taiwan, which are also developing these technologies and highly industrialized technological industry.

To stay ahead, we have to create that new knowledge and that is why the Japanese are investing in more research and are talking to us about cooperative research.

Mr. TRAXLER. What is the government role in R&D?

Dr. PRESS. The government is a patron of R&D, especially in industry to a major extent, to an extent that goes well beyond the role of our own government.

Nevertheless, I should say that I don't feel a strong movement in this country on the part of private industry to solicit the kind of

government sponsorship of R&D that the Japanese government performs. There are too many controls that go along with this kind of intrusion in the private sector. But it has helped the Japanese perform very well in developing high technology exports in certain areas leading to the rest of the world.

UNIVERSITY-GOVERNMENT-INDUSTRY COOPERATIVE RESEARCH PROGRAMS

Mr. TRAXLER. I think there are some indications our industries are beginning to change and they are looking more toward cooperative research centers based on a trilateral——

Dr. PRESS. Do you mean university-government-industry?

Mr. TRAXLER. Yes.

Dr. PRESS. What American industry wants from the government is to support industrial research. I have had hundreds of industrial leaders come in and tell me these are the areas we stay out of because the return is uncertain. The government should do it and we should concentrate on using those research results, applying them, demonstrating them and developing our markets. That is the preferred role for the government. They don't want the government to directly help them develop a product. They would like to do that on their own.

Mr. TRAXLER. How would you characterize within that definition—how about your cooperative automotive research program?

COOPERATIVE AUTOMOTIVE RESEARCH PROGRAM

Dr. PRESS. I was going to get to that. We are experimenting with a number of new kinds of institutional arrangements—an ocean margin drilling program, a joint venture between the oil industry and the government, and the automotive program. Both are in final stages of negotiations with industry. I think they will be cooperative.

The automotive program is not a situation where we will be building engines or cars or complete units. What we want to do is create the new kind of basic knowledge that will be useful in developing new concepts of automobiles in the post-1990 period.

We were impressed that essentially every automobile company in this country is very pleased to get things started. We have had inquires from foreign automobile companies to join the club and make a contribution.

Mr. TRAXLER. I understand VW may build another assembly plant here in the United States.

Dr. PRESS. American VW is a partner in this program.

Mr. TRAXLER. I notice the Administration is proposing an investment of $800 million over the decade and the industry participating in an area of $50 million a year.

Dr. PRESS. Up to 50 million dollars each year.

Mr. TRAXLER. I think the government's share was predicated upon the windfall profits tax, making certain money available for this purpose. I understand that that is not the case, however, as the conference report is finalized. Do you have any plans for where

that money will come from or will we be looking at the General Fund or back off from the program?

Dr. PRESS. We are right in the middle of examining that. I don't quite know what the outcome will be, but my office is committed to seeing that program go ahead and I would exert every effort to convince the appropriate Cabinet Secretaries and OMB to do the same.

Mr. TRAXLER. Thank you, Mr. Chairman.

OCEAN MARGIN DRILLING PROGRAM

Dr. BOLAND. While we are on the innovation part of your statement, let me ask you about the Ocean Margin Drilling Program.

Last December, I wrote a letter to the President expressing support for the new proposed Ocean Margin Drilling Program—using the ship Glomar Explorer. Since I wrote the President, the Legislative Authorizing Committee chaired by George Brown of California, has asked some tough questions about the expenditure of $700 million for this program. As has been pointed out, for example, the cost per hole of "Explorer" drilling is estimated roughly at $50,000,000 for each hole, while the cost for drilling a "Challenger" hole was only about $500,000 per hole. It was pointed out that at a $50 million cost per hole, only nine holes could be drilled under the new program in ten years.

Would you tell us whether or not you believe that sufficiently significant scientific objectives can be achieved at those costs and are the scientific results worth the cost?

Dr. PRESS. I am sure it is very difficult to justify to the taxpayers an expenditure of $50 million to drill a hole. I think we have to explain to the public that this is the last remaining unexplored province on earth, and to explore this province can only be done through this kind of drilling. This one vessel is the only one in the whole world that is capable of undertaking it.

Each hole will provide us with a wealth of information, of the whole history of the Atlantic Ocean and with the first insight about potential resources in this completely unexplored area which is under our own control as a nation.

I think both scientifically and in terms of providing us with a means for assessing the resource possibilities of this province that this is justification for the program.

Let me give you one example. The reef structure off Mexico that is responsible for the huge Mexican oil production in shallow water also occurs off our coast, but in this case off deeper water. It just happens to be in the deeper water of the continental margin that can only be explored by the Glomar Explorer technology. That is a very exciting possible resource for the future and which we want to test by means of this program. I don't want to underestimate the scientific results for this, and I would like to remind you that this program was brought to us by those scientists involved in the Challenger program who feel that the exploitation over the past year of Challenger technology has been extremely useful. The possibilities of Glomar Explorer technology are so significant that they have endorsed this program.

So, because of the scientific results and the resource results, I think it is a valuable program and the fact that we have joint funding—50-50 with industry—is again a new kind of institutional mechanism that we should encourage in this country instead of adversarial relationships between government and industry. We should try to work more and more on these joint ventures.

Mr. BOLAND. How firm would you say the industry's support is?

Dr. PRESS. It varies from company to company but we have seven or eight major companies, not all twelve or fifteen that we solicited but a sufficient number, seven or eight, including some of the majors who want to go with us through the first stage of this program.

So I would say that industry is skeptical but willing to take the first step with us. I would also say the Government should be skeptical in terms of whether the technology is feasible, whether the costs are realistic and we, too, want to take only the first step of engineering evaluation of the program to see whether we can bring it in really close to the price that we propose.

Mr. BOLAND. As you have indicated, the results of the drilling by the Glomar Challenger has resulted in some of the most exceptional scientific results ever achieved under that program by the National Science Foundation, and I don't think we have any quarrel with that. That is your position, too, isn't it?

Dr. PRESS. Yes.

Mr. TRAXLER. Dr. Press, what water depths are we talking about the Glomar operating in?

Dr. PRESS. Six thousand to 12 thousand feet and drilling 20 thousand feet down further.

Mr. TRAXLER. I understand the industry is developing floating drilling platforms.

Dr. PRESS. Up to six thousand feet.

Mr. TRAXLER. When you said that the areas we were concerned about are within, I assume you mean, the Territorial waters of the United States?

Dr. PRESS. Two hundred mile limit.

Mr. TRAXLER. I am not an oceanographer. At those distances we would exceed the 6,000 feet that the new portable floating rigs will operate in.

Dr. PRESS. That is right.

Mr. BOLAND. Do you have a statement in the area of Energy?

NUCLEAR ENERGY ACTIVITIES

Dr. PRESS. Starting with nuclear energy, my office has been closely involved with the accident at Three Mile Island, with the establishment of the Kemeny Commission and responding to the Kemeny Commission report and coming forward with a series of proposals by the President for structuring the Nuclear Regulatory Commission, strengthening the role of the chairman, having it concentrate on safety and proper training of the operators of nuclear reactors.

We have also played a major role in the President's waste management proposals that came forward within the past month. We feel that the management of nuclear waste has long been over-

looked and we now have a firm policy. We are embarked on the proper road finally, once and for all, I feel, and we are following that even beyond the role we played in formulating the proposals.

CARBON DIOXIDE AND CLIMATIC CHANGE

Mr. BOLAND. You have an interesting paragraph on carbon dioxide on page 8 of your statement.

Dr. PRESS. We are concerned not only with near-term issues but with the possible extremely significant distant issue related to energy, namely the growing carbon dioxide content of the atmosphere induced by man as we burn things. As we cut down our forests and use our coal we increase the carbon dioxide content of the air.

Many scientists feel in the next century that this will cause climatic changes. It is the changing pattern of rainfall that will result. It seems that the subtropical arid belts, the dry belts of the subtropics, will begin spreading northward into our most important farming regions if the CO_2 content of the atmosphere doubles sometime in the next century.

We want to monitor that program, that possibility, so we have had panels looking into it.

We are also now examining for the first time the economic and political consequences to the world for such climatic changes. I think sometime in the next ten years we will learn more about the CO_2 climatic change possibility to the extent that it will be affecting our energy strategy.

Whether it means greater reliance on nuclear, solar and nonfossil fuels remains to be seen, but that certainly is a possibility. We will follow this very, very closely. I think it is one of the important coming issues.

Mr. BOLAND. You indicate that projections of future carbon dioxide concentrations will double by the next century. I take it that this creates almost a greenhouse effect on the whole world, doesn't it?

Dr. PRESS. Exactly, that is the concern. It enhances that.

ABIOGENIC METHANE

Mr. BOLAND. The 2nd paragraph on page 9 of your statement gave me a little problem, it reads: "suggesting that the nation mount a major new program to explore for and develop methane derived from nonbiological sources, i.e., 'abiogenic methane,' as a potentially major contribution to the nation's energy problems." You are not recommending any particular effort in this area?

Dr. PRESS. No.

I received a letter from five Nobel Prize winners suggesting that this may be a new source of energy. Anytime five Nobel Prize winners independently sign a letter to me, I have to take it seriously. The NSF reviewed this and the conclusion was although it is possible, it is sufficiently difficult to reach and therefore we should not engage at this time in a major program to develop this uncertain resource.

Mr. BOLAND. Your statement says, "The hypothesis that there is a substantial amount of abiogenic methane in the crust—entrapped

during the formation of the earth itself—has been promoted over the last several years by Professor Tommy Gold of Cornell University." How difficult is it to extract the gas, itself, from the crust?

Dr. PRESS. The problem, if it is present, is that it is so diffuse that its concentration at any one point would be very difficult to extract.

NEW SOURCES OF ENERGY

Mr. COUGHLIN. In the area of energy, I know whenever I go home my people stand up and say, "What are you doing about new sources of energy" and it always gets very fuzzy and it is fuzzy in my own mind, I would have to say, in terms of what potential new sources of energy are the most likely to be fruitful. I would think that considering the current energy crisis, your office would be very involved in that kind of analysis. Have you done that type of analysis?

Dr. PRESS. Yes, we have.

Mr. COUGHLIN. Sources that would be cost beneficial and produce substantial sources of energy?

Dr. PRESS. We have done the type of analysis where we have examined what technology can contribute to energy supplies in the next ten years, the intermediate term the next ten or 15 years, and the long term.

Mr. COUGHLIN. Have you gone through oil shale and gasification and all those things?

Dr. PRESS. Solar plays a significant role in the long term. In the near term the emphasis is on conservation, in the use of coal, the use of nuclear energy and natural gas. We have made that study.

Mr. COUGHLIN. I would like to see a copy of such a study if you have it.

Recently I heard, and this is the sort of thing that keeps happening, I guess, some people in California have developed a way to beef up water so you could use it in motor vehicles. Are you familiar with that proposal?

Dr. PRESS. We get a large number of suggestions about water additives to gasoline, breaking water down and making hydrogen and so on. We take them seriously and submit them for review to experts outside, to the Energy Department or to the National Science Foundation.

Up to now we have not uncovered any magic formula, any cheap way of getting energy. It would be very nice if we could do so, but I think the laws of physics and thermodynamics are such that there will be no cheap source or breakthrough.

I think our best route is to make our automobiles more efficient, less fuel consuming, and less polluting. Conservation and development of these alternate energy sources is also the way to go.

Mr. COUGHLIN. Thank you.

Mr. BOLAND. Why don't you continue with Health and Agriculture programs?

HEALTH RESEARCH PROGRAMS

Dr. PRESS. In our health research programs, we want to concentrate on some of the basic aspects of health research. When one

thinks in terms of the breakthroughs of the past that flow from our support of research in the health area, one hopes that in the future we can do more of this. That is why we are supportive of a tilt in our health research budget back toward basic research.

If we can develop, for example, anti-viral compounds to attack antibodies, that could be an extraordinary breakthrough in disease control. I think we will achieve that goal perhaps in the next decade.

All of the possibilities of genetic engineering will produce a revolution in our ability to manufacture certain kinds of drugs, to attack certain kinds of diseases and to develop a whole new industry of biotechnology based upon new forms of life created through genetic engineering.

That is the kind of research we want to support in our biomedical research budgets.

RESEARCH AND DEVELOPMENT FOR AGRICULTURE

In the area of agriculture, of course, perhaps more than any other area we have seen the fruits of research and how it has paid off. It has been estimated we get 50 per cent return on our investment over the years from agriculture R&D. We are feeding not only ourselves but the rest of the entire world, and we are the envy of the entire world. This has not been duplicated by the Soviet Union, China or even the advanced nations, and all of this is based upon the results of research.

The new hybrid corn, the new strains of wheat and the great increase in our productivity of livestock have brought enormous returns to this country. It is one of our major exports today and one of the major contributors to our balance of trade.

Surprisingly, and in a worrisome fashion, our rate of productivity in agriculture seems to be leveling off. We feel that we need a new surge of R&D in agriculture, bringing in new performers who can perhaps repeat once again this revolution in agriculture.

Mr. BOLAND. How much more improvement is there in this area?

Dr. PRESS. Before the advent of genetic engineering I would have been somewhat conservative in answering your question, but now with the possibilities of using different ways to develop these new forms of crops which use less fertilizer, use sunlight more efficiently, and use less water, I think that is where the revolution is going to go in agriculture and that is what we should be doing.

I think it is dangerous to predict the future of research but in this particular area, because of the rapidity of the progress of this new technology, I think we should be reasonably optimistic and we should make these investments.

REGULATORY POLICY

In area of regulatory policy, the President is committed to regulatory reform, avoiding duplicative regulations, making them more efficient, and assessing the economic impact of regulations so that we meet our environmental goals, but not with such an economic penalty that it turns out to harm the country as well.

I think it is possible to meet these environmental goals but to be more sensitive to specifying the regulations in such a way that

they minimize the costs, and maximize our ability to innovate. We have been involved in a number of different ways of defining regulatory policy, primarily emphasizing the need for a proper scientific and technological base to these regulations.

In the statement, there are a number of different examples that are mentioned—carcinogens, effluents from diesel engines, national toxicology program, our increased concern about radiation hazards and toxic substances in the environment and chemical wastes.

THE RADIATION COUNCIL

Mr. BOLAND. Let me just ask a question about the Radiation Council that you talk about on page 12. As I understand it, there has been no Congressional authorization for the Council. What is happening with the Council at present?

Dr. PRESS. It has just been established by Executive Order one month ago.

Dr. OMENN. The first meeting has taken place and they are recruiting staff. The costs are being borne by EPA.

Mr. BOLAND. Are you familiar with Section 608 of the Treasury, Postal Service and General Government Appropriation Act for 1980? I will quote it for you.

> No part of any appropriation contained in this or any other act, shall be available to finance interdepartmental boards, commissions, councils, committees, or similar groups under Section 214 of the Independent Offices Appropriations Act, 1941, which do not have prior and specific Congressional approval of such method of finance support.

I think that basically puts the Radiation Council out of business unless Congress provides an authorization, doesn't it?

We had the EPA up here last week and Mr. Hawkins' response to a question I addressed to him was "until there is a separate appropriation requested by the Agency we are going to have to await the establishment of the activity of the Council. What EPA intends to do in the interim is to coordinate the steps as we have done in the past."

PRODUCTIVITY AND INNOVATION

Dr. PRESS. Let me go to the last section on productivity and innovation.

There is a general perception that there is an innovation lag in the country. It is very difficult to prove this in a quantifiable way, but if you ask the ordinary citizen on the street, he will tell you about the color television sets that come from Japan, the automobiles of high technological quality that come from abroad and list a number of products that he is familiar with which seem to be technologically advanced but not American in origin.

If you ask industrial leaders about this issue, they will say yes, there is an innovation lag and a great many of them will say this is due to disincentives to innovate which result from Federal policy.

If you ask academic scholars they will list a number of factors which they believe are contributing to a lack of innovation—government patent policy, and the lack of availability of capital to invest in more productive plants. They will also say that perhaps

industry, itself, has brought into management positions people who are more concerned with near-term profits than the long-term products that the company would be manufacturing.

I am not sure which of these factors are the important ones. They all may contribute partially. But whether or not there is an innovation lag in this country, the more we innovate, the better off we are because the new industries created by innovation have records of very rapid increased numbers of jobs, of contributing to our exports and our balance of payments.

We completed this year a major review of the whole innovation issue, especially the Federal role. We had input from industry, labor, and the academic community. We had participation from more than 20 government agencies. We brought these issues to the President, he made a number of decisions, and we did send a message to Congress based upon these decisions.

We feel that the President's recommendations and requests of the Congress are a beginning. At the highest level we are concerned about innovation and productivity and we want to start down the road of providing more incentives for industry to innovate.

The proposals we brought to the Congress cover a great many different areas—some new institutional cooperation between universities and industries, the establishment of certain types of generic centers that can help with industrial problems, a revision of government patent policy to enable government-owned patents to be taken up and developed by industry which is not occurring now, an improvement of the Patent Office to protect private patents to a greater extent than is the case now so that industry would be willing to invest in the patents and develop them into important products, and a review of antitrust regulations that affect the ability of companies to cooperate with each other in the area of basic research and those joint ventures between government and industry that I have referred to. We deferred for the future a review of tax policy emphasizing those possible tax proposals that would foster innovation.

The question of innovation is an old issue that has been around for a long time but I believe that this is the first time that the President has become involved, that he has brought recommendations to the Congress.

Mr. BOLAND. This issue has been around for a long time but more conversation has been held about it over the past year than at any time I can remember.

What does industry have to say about what inhibits them from really getting into innovation on a grander scale? Is it tax policy, is it antitrust laws——

Dr. PRESS. Tax policy, regulatory policy, and to a certain extent antitrust laws. Large industry does not want budgetary relief through the budget; they don't want handouts from the government to help them innovate.

There may be room for helping small industry innovate by using programs of the National Science Foundation and other agencies but by and large industry wants relief from regulations and wants such things as rapid depreciation, perhaps R&D tax credits and other incentives to innovate.

Mr. BOLAND. Mr. Coughlin?

PRODUCTIVITY AND INFLATION

Mr. COUGHLIN. Thank you, Mr. Chairman. What you have just been saying is of great interest to me because I agree with what the Chairman says. There has been a great deal of talk but little action in this whole area. It seems to me that inflation is not the mystery that it is sometimes looked upon as. It is a question of productivity and producing the same goods for less money or the same amount of money and that involves both lessening the drag which you were addressing in the first part of your testimony and what the President is addressing in his program to try to cut the Federal budget because the largest sector of the budget is Federal government. But it involves investment in better tools to work with and increasing productivity.

TAX POLICY AND INNOVATION

To say that you have deferred consideration of tax policy when that is the No. 1 priority of the industrial sector of the society in terms of increasing innovation and productivity, to me is making a dreadful mistake. It also goes to the question you initially raised in having cutbacks in the kind of research to provide productivity which seems to me is also involved.

Dr. PRESS. Let me clarify that. When I said deferral of tax policy, I meant when the President brings to Congress major proposals for changes in tax policy, within those proposals we will consider those dedicated toward bringing the kind of relief that will enable industry to innovate.

What he did not want to do was bring a tax proposal to Congress dealing solely with this issue and no other issue. He wants to bring in a comprehensive tax policy at the right time, in his judgment, and at that time innovation will be considered. He does not want a piecemeal approach to tax policy. He wants this all at the same time.

Mr. COUGHLIN. If we are serious about attacking inflation and the Administration is giving evidence it is serious in terms to the approach to the budget, hand in hand with that goes increasing productivity through investment, innovation and better productivity.

Last year I asked whether you would recommend tax incentives to induce industry for doing research and development work and your answer was we need to know if those incentives pay off.

Have you made that study in the ensuing year as to whether that pays off?

Dr. PRESS. Speaking personally, I think the supply side of the economy, that dealing with issues of productivity, has to be an important element in tax policy and that will be a recommendation from my standpoint. Tax policy is formulated with the Secretary of the Treasury, the Council of the Economic Advisers, and the Domestic Policy Staff. They play the major role in formulating tax policy. I believe that tax policy is an important element in innovation and I will make by views known at the right time.

Mr. COUGHLIN. That is comforting to me that one input on this equation is coming out in terms of needing a two-pronged approach and not just a one-pronged approach.

Thank you, Mr. Chairman.

INTERGOVERNMENTAL SCIENCE, ENGINEERING, AND TECHNOLOGY ADVISORY PANEL

Mr. BOLAND. Can you give us a brief statement on Intergovernmental Science and Technology? We will have a couple of questions on that in the justifications.

Dr. PRESS. Congress mandated that I chair the Intergovernmental Science, Engineering, and Technology Advisory Panel. My co-chairman is Governor Jim Hunt of North Carolina.

The main thrust of that Panel is to see what can be done to sensitize Federal agencies to the needs of state and local government. It has been estimated that some $8 billion of the Federal R&D budget could be of some use to state and local governments. The expenditures of state and local governments are such a large factor in the national economy that any way we can make them be more productive would be a very significant contribution, so I am using ISETAP, this Panel, to review Federal programs and have input in the early stages of formulation of Federal programs, so that the Federal administrators know about the needs of state and local governments as they formulate their own priorities.

We have been successful in a number of areas in sensitizing Federal officials so that they have retuned their budgets and become more sensitive to the problems of state and local government.

I feel that ISETAP is performing better than ever before and we are beginning to have the kind of impact envisaged by Congress when they established this Panel.

COORDINATION OF RESEARCH AND DEVELOPMENT

On the coordination of research and development, we are using the Federal Coordinating Council. We have prepared a summary booklet on those activities which I will submit as part of my testimony. This will bring you up to date on how we are performing in that area.

OSTP FISCAL YEAR BUDGET REQUEST

Finally, on the budget request for my Office, we are requesting $2.9 million for the work of my Office in fiscal year 1981. This will support our small core staff, our consultants, our temporary employees and the kind of outside contracts that we rely upon to conduct our work.

For example, our work on carbon dioxide relies very heavily on a contract with the National Academy of Sciences who brought in the leading experts in the country to help us evaluate this particular issue. By means of our consultants and our contractual work we have been able to perform all of the things I have described on this relatively modest budget and I hope you will consider that budget sympathetically, Mr. Chairman.

Mr. BOLAND. Mr. Coughlin?

RECOMMENDATIONS FROM THE R&D BUDGET REVIEW

Mr. COUGHLIN. Thank you, Mr. Chairman.

I think you do an amazing amount with a modest budget.

Initially, the Chairman asked a question about the suggested cuts in the science and technology field and I would guess that you have a part in recommending where cuts would be made. Do you have a part in that?

Dr. PRESS. Yes.

Mr. COUGHLIN. Can you tell us where you recommend cuts?

Dr. PRESS. If I can speak generally in response to your question, because these are recommendations to the President in a sense. I am not sure he has read them as yet, but he has them and for me to speak openly about them before he has seen them and made up his mind might not be proper.

In making these cuts, I am trying to preserve the philosophy we used in the development of science and technology budgets over the past three years, to preserve that philosophy as best we can. We want to maintain the strength of American science. We are particularly concerned about innovation. There are certain national needs for our country in terms of energy. We want to preserve our scientific teams throughout the country and not have them fall apart.

Mr. COUGHLIN. Where do you feel you can then make cuts?

Dr. PRESS. They occur in every area.

Mr. COUGHLIN. You would not specify?

Dr. PRESS. It is difficult to do so at this time because the review is still in the process.

EPA EXPENDITURES FOR TECHNICAL ASSISTANCE

Mr. COUGHLIN. The EPA is spending money for technical assistance. Exactly what has been done in these areas?

Dr. PRESS. I work very closely with Doug Costle. He makes very good use of his science panel, a panel that works at the very top of the Agency that helps him review some of the important environment issues where technology is a significant factor. On any significant proposed regulation which has a strong input from experimental results and laboratory results, he will ask this panel to evaluate those results before he makes up his mind on the final form of that regulation. So we have helped him organize his department and the areas addressed by this panel.

Also we have helped him increase his own research budget because it is good environmental research. If you find a better way in which to cast a given regulation because of research rules, you can save the country an enormous amount of money by minimizing the economic impact. That is one of the budgets that I have helped to protect and allow to grow more so than others.

Dr. OMENN. Reports are prepared for our Office. Workshops have been conducted and panel members and resource people get together where critical needs are identified for health effects, hydrogeology of sites, technical engineering approaches, and so forth.

OSTP OBLIGATIONS BY MONTH

Mr. COUGHLIN. There has been publicity about which agencies obligating funds in the final few months of the fiscal year. How has your obligation rate been running?

Mr. MONTGOMERY. It is about on budget. We are trying to take steps so that we don't have a big bubble at the end of the fiscal year.

Mr. COUGHLIN. What percentage was obligated?

Mr. MONTGOMERY. I don't have that here now. I would have to calculate it for you. A large amount of our obligations involves salaries and these are spread out evenly month to month. We try to make sure also that we spread our obligations for contractual support. Some times it is difficult to program this money because we use contractual support to respond to issues as they occur, high priority items which are sometimes hard to predict, but I will calculate that figure for you and submit it.

Mr. COUGHLIN. If you could submit a month-to-month breakdown, it would be helpful.

[The information follows:]

Fiscal year 1979 obligations by month

[In thousands of dollars]

October	$210
November	285
December	69
January	75
February	140
March	93
April	220
May	228
June	228
July	231
August	257
September	401

Note.—OSTP obligations for fiscal year 1980 as of February 29, 1980 totaled $1,192,000. This is 45 percent of OSTP's appropriation excluding requested supplemental.

THE JUPITER PROBE

Mr. BOLAND. Galileo was going to be launched in a single mission in 1982. That is now out of the question. NASA has to look at a dual mission, the probe and orbiter. We gave some consideration to canceling that portion of Galileo when we learned of the overrun. What about that option? We could still save between $75 and $100 million. Why is the probe so essential?

Dr. PRESS. First, let me say as part of the budgetary reassessment we are looking into the options you just mentioned. The probe is important because on the probe will be sensors that will provide us with the chemical constitution of Jupiter from the very beginning of its atmosphere as far in as the probe will continue to send back information. It is very difficult to gauge the constitution of a planet simply from an orbiter. It can be done but the results are not too precise and can only provide information on the top surface layers. But Jupiter is quite a planet. Had it been slightly larger, Earth would have had two Suns instead of one. Jupiter for some strange reason is radiating immense amounts of energy. The

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origin is extremely important for us to learn about scientifically and that is why a probe seems to be such an important project.

CENTRAL SOURCE FOR DATA ON FEDERALLY SUPPORTED RESEARCH

Mr. COUGHLIN. I have a couple of general questions. Last year you indicated that work is progressing on a source of confidential information regarding the contents of Federally-supported research projects. What is the status of this at this time?

Mr. SMITH. I think you are referring to the area of science and technical information. We have had over the past year a committee made up of the R&D agencies that are the funders of research and development and hence the producers of science and technical information, working to try to develop a policy that would give us a much better feel than we have at the present time for the kinds of information that ought to be put into centralized systems such as the National Technical Information Service, what agencies ought to have in the way of their own information policies, where we should rely more on the private sector, and so forth.

I would say this has been an incredibly difficult job, and the way information has literally exploded, including the Federal departments and agencies, over the last decade or so is very impressive. I think that by summer we should be able to report to you our policy that we hope we can put into place to help guide the R&D agencies in their own information activities, their appropriation requests, where we are going to depend more on the technical information service.

FUSION RESEARCH

Mr. COUGHLIN. I have one further question I wanted to ask on energy and that was the progress of fusion research.

I remember when I was on the first task force and entered the House Science Committee back in 1969 or 1970, we went to the physics lab at Princeton and they were doing some of the early work on fusion. What kind of progress has there been and is there hope or are we really pouring money down the rat hole?

Dr. PRESS. One is magnetic and the other is the initial climatic.

Mr. COUGHLIN. As a scientist how do you feel we are doing?

Dr. PRESS. I think as far as the progress is concerned in the magnetic fusion area, the progress has been quite good. There have been some surprising results that we did not anticipate last year in magnetic fusion but it is somewhat encouraging. So in the proposed fiscal year 1981 budget we have allowed for fusion growth, especially magnetic fusion, because of these results. I think our fusion budget exceeds that of the rest of the world combined. It offers almost limitless sources of energy not as purely clean as some people propose but clearly cleaner than fission energy.

I would say that the scientific progress is on target. We are moving just as we had hoped, perhaps even more rapidly and perhaps the big problem in the next decade is the engineering aspects. We will have to develop all kinds of new materials that are radiation damage resistant that can take the strong shocks of these pulses of neutrons that they will have to experience, so the

next stage—and it will be expensive—will be the engineering stage but the whole thing is moving along acceptably.

Mr. COUGHLIN. Is this moving along toward a Manhattan or Apollo type project?

Dr. PRESS. I don't think so. To spend large sums of money before you know the basic materials is likely to be wasteful. You want to be sure all of the talented people in the country are engaged in an important area like this, but beyond this I think that it is likely to be counterproductive. If you push too hard and if, as a result of that, you have failures and disappointments when extremely large budgets are involved, you might condemn an important area of technology prematurely, so I prefer the rate we are going at right now rather than a huge infusion of money.

Mr. COUGHLIN. Thank you. I have to leave to go to another meeting. It has been a very enlightening morning from this Member's standpoint and we appreciate your service to the country. We are pleased to have your appearance before the Committee.

Mr. SABO [presiding]. I am sorry I missed your earlier testimony. I was off at another Subcommittee meeting.

I have a number of questions which may be related to what you talked about earlier.

BUDGET ESTIMATES FOR ISETAP AND FCCSET

For the record, would you update the tables on pages 57 and 58 of last year's hearings regarding the Advisory Panel and the Coordination Council. If the actual costs for 1979 varied significantly from that estimated last year, provide and explanation for the record.

[The information follows:]

INTERGOVERNMENTAL SCIENCE, ENGINEERING, AND TECHNOLOGY ADVISORY PANEL

Object Class	Fiscal Year 1979 Budget Request	Fiscal Year 1979 Actual	Fiscal Year 1980 Budget Request	Fiscal Year 1980 Current Estimate	Fiscal Year 1981 Budget Request
Staff personnel compensation ...	$ 56,000	$ 38,500	$ 58,000	$ 5,000	$
Consultant compensation	43,000	15,800	41,000	20,000	20,000
Overtime, holiday, other	-	2,000	-	1,000	1,000
Reimbursable detail	-	4,000	-	55,000	72,000
Personnel benefits	5,000	3,500	7,000	-	-
Staff travel	5,000	6,800	5,600	19,000	20,000
Local travel	-	-	-	-	-
Consultant travel.....	47,000	38,500	45,800	48,000	48,000
Vehicle rental.....	-	-	-	-	-
Transportation of things	-	-	-	-	-
Rents, communications and utilities	-	-	-	-	-
Printing and reproduction	7,500	2,000	8,000	5,000	8,000
Other contractual services	-	21,000	-	24,000	25,000
Supplies and materials	-	-	-	-	-
Equipment.....	-	-	-	-	-
Total	$163,500	$132,100	$165,400	$177,000	$194,000

Discussion of Estimate Changes

(1) OSTP staff support for ISETAP has been changed to reimbursable detail for FY 80 and 81. Secretarial support is expected to be on a reimbursable basis for FY 81.
(2) Consultant compensation is lower than FY 79 plan because fewer panel members claimed compensation than originally estimated and some study work was done under contract. Increase in FY 80 and 81 results from greater number of Task Force meetings.
(3) Staff travel is estimated to increase for FY 80 and 81 because meeting schedule calls for more meetings to be held in local jurisdictions instead of Washington.
(4) Consultant travel is estimated to increase for FY 80 and 81 because more Task Force meetings are planned.

FEDERAL COORDINATING COUNCIL FOR SCIENCE, ENGINEERING, AND TECHNOLOGY

Object Class	Fiscal Year 1979 Budget Request	Fiscal Year 1979 Actual	Fiscal Year 1980 Budget Request	Fiscal Year 1980 Current Estimate	Fiscal Year 1981 Budget Request
Staff personnel compensation ..	$16,000	$14,500	$16,000	$16,000	$16,600
Consultant compensation	-	-	-	-	-
Overtime, holiday, other	-	-	-	-	-
Reimbursable detail	-	-	-	-	-
Personnel benefits	1,300	1,200	1,300	1,300	1,500
Staff travel	-	-	-	-	-
Local travel	-	-	-	-	-
Consultant travel	-	-	-	-	-
Vehicle rental	-	-	-	-	-
Transportation of things	-	-	-	-	-
Rents, communications and utilities.....	-	-	-	-	-
Printing and reproduction	8,000	4,000	8,000	8,000	8,000
Other contractual services	-	-	-	-	-
Supplies and materials	-	-	-	-	-
Equipment	-	-	-	-	-
Total	$25,300	$19,700	$25,300	$25,300	$26,100

REPRESENTATION ALLOWANCE

Mr. SABO. On Page 5 of the justifications is a copy of the appropriation language you are requesting for fiscal year 1981. You are requesting that official reception and representation expenses be increased by $500, from $1,000 to $1,500. You made the same request in 1980 and the Congress did not provide it. How much of the $1,000 did you obligate in fiscal year 1979?

Mr. MONTGOMERY. We obligated the total amount and a large percentage of it was related to the international activities of the office.

Mr. SABO. Why are you requesting something the Congress denied in the 1980 budget?

Dr. PRESS. The growth of our international programs has been so rapid and this aspect of international relations turns out to be important in the eyes of my foreign counterparts. They feel we should have that opportunity to be responsive. Let me give you an example. I went to China with a delegation this past fall. We were concerned simply not only with scientific and technological cooperation but the development of commercial relations with China. While there we made an agreement that would bring perhaps a billion dollars worth of business to this country. The Chinese hosted us at a reception and in Chinese culture it is proper protocol, proper custom, to respond in kind. We were not able to do so because of our limited budget.

I think in their eyes in a sense we lost face and we were demeaning by not being able to do so.

CURRENT EMPLOYMENT LEVEL

Mr. SABO. You are requesting funding for 24 positions. How many are currently filled?

Mr. MONTGOMERY. They are all filled.

Mr. SABO. What lapse rate is included in the $850,000 for personnel compensation in 1981?

Mr. MONTGOMERY. I used a lapse rate of about 3 per cent for permanent and other positions. The average number of positions we had filled last year was 24.

TEMPORARY POSITIONS

Mr. SABO. On page 7 personnel compensation, the 1980 estimated cost of temporary positions is $153,000. Last year, in the 1980 budget, the request was $92,000. Why have you increased the amount of funds for temporary positions in 1980 and how do you account for this change?

Mr. MONTGOMERY. We have a mix of professional and support staff in the temporary position area. I have estimated two of 7 temporary positions as professional and that is what the calculation comes out to for those positions. I think, looking at the work of the office, that we need that type of support.

ESTIMATED TRAVEL EXPENDITURES

Mr. SABO. Last year's budget justification estimated staff travel to be $39,000 in 1979 and $50,000 in 1980. This year's justification, page 7, shows staff travel to have been $103,000 in 1979 and $120,000 is estimated for 1980.

What accounts for the large increase in staff travel and does this reflect a different method of doing business?

Dr. PRESS. As you know, my Office was essentially reestablished by Congress a few months before I showed up and it takes time to establish programs both domestically and internationally, so you will see growth over the years as we start to perform those tasks which Congress originally had in mind.

Travel of the staff is an essential element in designing and implementing the programs that we are developing with Japan, China, our Western allies, and with the developing countries. This represents an increasing burden on us to go to these places in order to achieve the goals.

For travel within our own country, as we develop our consultants and all of the panels in the different areas that we have to perform in, this will show up as an increasing travel budget, in addition to the inflationary increase in travel. What you are seeing here is our Office growing into those tasks and obligations that Congress wanted us to undertake when they established our Office.

Mr. SABO. What were the total travel costs for staff and consultants?

Mr. MONTGOMERY. From 1979 to 1980?

Mr. SABO. And in comparison to last year's estimate.

Mr. MONTGOMERY. I can tell you——

Mr. SABO. You may provide it for the record. Dr. Press your indication in last year's testimony that "Most of the travel is not for people who work full-time in my Office. We travel very little. It is to bring the expert whose advice we need so badly in all of these complicated issues across the board to Washington."

Dr. PRESS. That is still the predominant burden on our travel.

Mr. SABO. Supply for the record a comparison of the travel for staff and consultants for 1979 actual, 1980 estimate and 1980 current.

[The information follows:]

OSTP TRAVEL EXPENSES

	Fiscal year 1979, actual	Fiscal year 1980, budget request	Fiscal year 1980, current estimate
Staff	$103,000	$50,000	$110,000
Consultant	121,000	248,000	155,000
Local	4,000	2,000	5,000
Total	228,000	300,000	270,000

Note.—As OSTP programs have evolved, the staff has been required to travel more frequently both for domestic and international activities than during the formative stage of the Office. This has resulted in an increase in the percentage of staff travel to the total travel expense that was estimated at the time of the fiscal 1979 budget submission. Travel obligations for fiscal year 1980 as of February 29, 1980 include $46,000 for staff and $93,000 for consultants.

CONTRACTUAL SERVICES

Mr. SABO. You are again requesting a large increase in contracts—$216,000 or 36 percent. From $604,000 in 1980 to $820,000 in 1981. Last year, OSTP requested $285,000 increase for contractual services and Congress reduced that to $203,000. In light of the discussions about reductions in the 1980 budget, why should this item not be cut to a more modest increase?

Dr. PRESS. Although the budget of my Office is very modest, $2.9 million, we impact an enormous R&D budget of the nation. We do so by participating in the budgetary process. We do so by coordinating programs across government agencies. With a 24 person professional staff we can't hope to impact a $35- $40 billion national R&D budget. So, we have to make use of outside advice that we get from individual consultants or by contracts that we let to professional societies, such as the National Academy of Sciences. I would submit that for this modest increase to get this outside advice, we have the possibility of saving the country enormous amounts of money by rendering proper advice in the budgetary process to Congress through my testimony as well as to the President, by the use of these outside consultants and contractors.

Mr. SABO. What were the results from the $374,000 you spent on program contracts in 1979?

Mr. MONTGOMERY. There is a list of contracts that we initiated in 1979 included in the justification.

Mr. SABO. What did they involve?

Dr. PRESS. Before you came in, Mr. Chairman, Chairman Boland complimented our office for the impact it was having for the number of important, diverse areas that we have contributed to over the past year. We couldn't have done that without our outside consultants and the contracts that we let.

Mr. SABO. How were the results used?

Dr. PRESS. The results are used in reports to Congress, and in the advice we give to the President. The results are used in the position that I take, in the budgetary process, and my recommendations to the President.

The results are used in the way that I perform my coordinating function to avoid duplication between government agencies and so on.

The results are used in some extremely important areas, for example, the carbon dioxide issue we spent some 15 minutes talking about and the climatic change. I relied very heavily on a contract with the National Academy of Sciences in that area.

SUPPLEMENTAL FOR INCREASED PAY COSTS

Mr. SABO. Last year OSTP requested a $37,000 supplemental for increased pay costs. Congress appropriated $20,000. However, I note that you lapsed $59,000 at the end of 1979. Now there is nothing wrong with lapsing funds at the end of the year, but what accounted for the $59,000 lapse?

Mr. MONTGOMERY. As the year progressed, we budgeted our money very closely. The authorization for the supplemental did not come until very late in the year, so we had to keep a very tight

reign on expenditures for most of the year. That is the reason we had the money lapse.

Mr. SABO. That sounds good. You are requesting an $87,000 supplemental for increased paycosts in 1980. Is OSTP absorbing any of the costs for the pay increase? If so, how much?

Mr. MONTGOMERY. We have a very small budget and the amount of the supplemental is the amount I calculated for the pay raise that is for our current staff. This totals $87,000.

Mr. SABO. That assumes no absorption.

Mr. MONTGOMERY. It assumes no absorption, but we are budgeting for not over expending our authorized personnel expenditures.

Mr. SABO. What happens with a late supplemental?

Mr. MONTGOMERY. We would get into the same situation as before. This prevents us right now from adding to our staff in any substantial way. We have to take a very tight budget look at any personnel expenditures.

AUTOMOTIVE RESEARCH

Mr. SABO. I have been wondering who I should direct these questions too as I go along and I think you may be the appropriate person. It strikes me—as I observe what we do on energy, with dollars going here and there in research—we do very little for the potential of the automobile. I remain totally bewildered why we are not doing more.

Dr. PRESS. We looked into that about a year-and-a-half ago and we were impressed that the Government performs basic reseach for other industrial sectors like the aeronautical sector, to the level of hundreds of millions of dollars. Whereas in the automotive industry, it has been variously estimated that our total effort could be said to be between $10, $20, and $30 million. Maybe not even that much.

Mr. SABO. There was talk about joint funding with the auto companies.

Dr. PRESS. That is why we proposed this joint venture with the automotive industry amounting to a billion dollars over ten years.

Mr. SABO. That makes me nervous. We all have our different villains on energy depending on perspective. For some the villains are the oil companies, for others the villain is government and you can quarrel a great deal about that. In my judgment the biggest villain has been the auto industry. The only reason we have moved toward increasing gas mileage is because the government mandated it. Now the auto industry is outmoded and can't produce the small cars people want to buy.

It just seems to me the payoff for any basic research in redesigning the auto or that type of individualized travel is incredibly high in comparison to all the money we spend on alternative energy sources—just name it—the payoffs are there.

The potential for the auto is still very high, I think, for its appropriate use.

I just came from a meeting with my other Subcommittee that was reviewing the budget of the Federal Aviation Agency. My question to them was, if you had a family of four, on an energy basis, should you go by car or by plane. They didn't want to answer

me because, the fact is, you should go by car, not by plane on an energy basis.

There have been huge increases in transit travel that can't compete with a modest increase in auto mileage in terms of energy savings, but we research this and we research that and do very little on, what seems to me, the most basic and the most important part of the whole problem.

Dr. PRESS. Let me say two things. I believe next year we will peak in consumption of gasoline. After that, we will go down. That is due to a combination of the Federal government's fuel efficiency standards, and the automotive industry meeting those standards as they become more and more severe over time. We as a nation have finally awakened to the fact that there is an energy crisis, that we have to become a conserving society and the automobile is a major sink for energy and that is happening.

What we have in the automotive program is developing two kinds of material, the kind of new knowledge that will dramatically change the way we build cars in the post-1990 period. We feel we have to bring all sorts of new performers, new researchers into this problem that have never been tapped before, like engineering departments of some of our good universities who have never worked on automobiles. They are willing to do so, but they have never been funded before to tackle such problems. I think that is a mistake. We have gotten our universities into biomedical and disease. We have gotten them into lasers and devices and they have contributed to our national economy significantly, but we have not gotten them into this extremely important segment of American life, the automobile.

Mr. SABO. How seriously have you thought about the merits of DOT doing research jointly with the auto companies? I have a feeling we would be much better off having it removed from both the historical producers and the historic regulators.

Dr. PRESS. I think it is a mistake to cut the automotive industry for two reasons. For one thing, their participation will ensure that the research is targeted toward the development of future automobiles. If you cut it off from the user of this research, the research will go off in its own direction without the kind of close connection with the eventual product that it should have. Even though it is basic research, it should have in mind the final goal and should end up in an automobile.

Not having the automobile companies involved and putting money into it would raise this possibility of ivory tower research, rather than targeted basic research. That is why I value their contribution, not because they are paying half of it, but their participation would keep the goal on target.

Mr. SABO. Would they have equal right to it.

Dr. PRESS. Let me send you a copy of the proposed agreements defining their rights and the Government rights to the research.

Mr. SABO. There was a bill around here last year to give NASA some responsibility in terms of automotive research. I thought there was merit to that.

Dr. PRESS. NASA is the world's best space agency. I am not sure it is the place for developing automobiles and I am not sure they are overly anxious to undertake this job.

Mr. SABO. It might be a good new mission for them.

Dr. PRESS. I think if NASA wants to contribute to the basic research, we should like to have their proposals. We solicited their participation in this program, and, frankly, we got better proposals from the National Science Foundation and the Department of Transportation. I would say the Department of Transportation in its old image and approach to basic research might have wanted or justified your skepticism about their role.

Mr. SABO. I just dealt with DOT a few days ago and renewed my skepticism.

Dr. PRESS. The new Secretary has asked me to review his Department. I think his eagerness to have his mission agency as good as the Defense Department is in its mission, is something we should encourage and this program could be the first step in improving that Department's ability to undertake the kind of thing that HEW does so well through the National Institute of Health, that the Department of Defense does so well through the Advanced Research Office and the Department of Energy does through its Energy Research. I think we should strive to improve that situation.

USE OF DIESEL ENGINES

Dr. OMENN. Another area of more immediate payoff, is the whole use of diesel engines. Here is an area where EPA and DOT were operating independently where our Office provided some leadership. We stepped in and brought the three agencies together with industry and we tried to assure that really quite urgent decisions were based on good scientific decisions, and more immediate decisions will be available. There will be a better flow of information and smoother transition. We do so in the public interest.

Mr. SABO. Thank you very much. We appreciate your presence here today. The justification will be inserted in the record at this point. The Committee stands adjourned.

[The justification follows:]

TABLE OF CONTENTS

I.

BACKGROUND INFORMATION

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Introduction

The Office of Science and Technology Policy (OSTP) was created by the National Science and Technology Policy, Organization, and Priorities Act of 1976 (Public Law 94-282). The Office serves as a source of science and technology policy analysis for the President and for other organizations within the Executive Office of the President; provides coordination of research and development programs of the Federal government; and conducts reviews and analyses, with the Office of Management and Budget, of research and development programs of the Federal government.

Major Objectives

Major objectives of the OSTP include the following:

- Advise the President on scientific and technological considerations involved in areas of national and international concern.
- Assist the Office of Management and Budget with reviews of proposed budgets for Federal R&D programs.
- Advise the National Security Council on the scientific and technological factors related to national security and international issues.
- Advise the Domestic Policy Staff and other EOP units on matters concerning science and technology.
- Provide general leadership and coordination of the research and development programs of the Federal government; analyze problems and developments in science and technology affecting more than one Federal agency and recommend policies and procedures for dealing with them.
- Encourage a stronger partnership between Federal research funders, State and local governments, and the scientific community.
- Provide Executive Branch perspectives regarding science and technology policy to the Congress.

Activities and Accomplishments

Policy issues that are or have been addressed during the past year are summarized below. They represent the type of work the OSTP has undertaken during the past year.

National Security, International and Space Affairs

As directed by the President, the Director of OSTP headed high-level delegations to Japan, China, the Soviet Union, Venezuela, Brazil, Peru and Barbados. These visits served to enhance S&T cooperation between the countries and regions involved. During the year, OSTP continued planning for the establishment of the Institute for Scientific and Technological Cooperation. In addition, the President's civil space policy was elaborated to include the establishment of an operational land remote sensing system. The office also assisted in the comprehensive test ban treaty negotiations, in analyses of new strategic missile systems and in other issues pertaining to national security.

Natural Resources and Commercial Services

The staff provided leadership for the OSTP's overall assessments of Federal and private sector research and development and the formulation of a number of decision and policy documents including the messages to the Congress on Science and Technology and on Industrial Innovation. Other activities have centered on: the initiation of government-industry cooperative research programs in basic automotive research and ocean margin drilling; completion of the Presidential review of radioactive waste management; nuclear safety and Nuclear Regulatory Commission reorganization; water and non-fuel mineral R&D policy; and regulation and regulatory reform, particularly in the area of transportation. Responsibilities for implementation of the National Earthquake Hazards Reduction Program and Federal Dam Safety Program were transferred to the Federal Emergency Management Agency.

Human Resources, Social and Economic Services

The OSTP helped the Executive Branch, Congress, and the scientific community formulate a plan to assure the continuity and stability of funding for basic biomedical research and stimulated implementation of changes in grant application and reporting requirements designed to ease the administrative burden on scientists. The Office contributed to the development of mechanisms to improve the management and quality of environmental and agricultural research. A framework for Federal policies concerning identification, characterization, and control of human carcinogens was completed and published. Research and technical needs for disposal of hazardous chemicals were defined. Agency roles and the quality of research on the health effects of low level ionizing radiation were analyzed. A national aquaculture plan was completed. An analysis of formal university-industry research relationships was published, and evaluations of joint government-industry research programs related to pharmaceutical agents for developing countries and food processing were initiated. The examination of Federal policy in the reimbursement and appropriate use of medical technologies was encouraged.

The OSTP augments staff capabilities by obtaining outside advice through contractual analysis, advisory groups, individual consultants and interagency panels. The Office's consultant list presently includes 81 experts with experience in a wide range of scientific and technological areas. Selected issues for which contractual analyses were initiated during FY 1979 are listed below:

CONTRACT TITLE	CONTRACTOR	AMOUNT OF AWARD
Studies of Rules and Regulations Concerning Non-fuel Minerals	Environmental Law Institute	$46,500.00
S&T Policy of Selected South American Countries	Futures Group	$28,400.00
Study of Non-fuel Minerals	Resources for the Future	$58,500.00
Individual Susceptibility and Health and Environmental Regulations	The Conservation Foundation	$20,000.00
Carbon Dioxide and Climatic Change: A Scientific Assessment	National Academy of Sciences	$13,500.00
Analysis of Selected International Issues	National Academy of Sciences	$17,000.00
Education and Employment of Women in Academia	National Academy of Sciences	$32,900.00
Support of Planning Staff Activity for Cooperative Automotive Research Program	Donovan, Hamester & Rattien, Inc.	$19,500.00
Status of Biological and Medical Research on Stress	Institute of Medicine	$80,000.00
Clinical Investigations in Developing Countries	Institute of Medicine	$57,500.00

Committees of the Federal Coordinating Council for Science, Engineering, and Technology undertook analyses of a wide range of policy issues, producing major reports on dam safety; ocean pollution research, development, and monitoring; government patent policy; and Federal procurement of R&D. During 1979, the following committees and subcommittees were in existence:

- Committee on Atmosphere and Oceans
- Committee on Food and Renewable Resources
- Committee on Health and Medicine
- Committee on Ocean Pollution Research, Development, and Monitoring
- Committee on International Science, Engineering and Technology
- Committee on Intellectual Property and Information
- Ad Hoc Committee on Review of Bilateral S&T Agreements (Terminated)
- Ad Hoc Committee on Dam Safety (Terminated)
- Ad Hoc Committee on the Institute for Scientific and Technological Cooperation
- Ad Hoc Committee on OMB Circular A-76
- Ad Hoc Committee on Automotive Research
- Ad Hoc Committee on Science and Technical Information Policy
- Joint Subcommittee on Aquaculture
- Joint Subcommittee on Human Nutrition Research

State and local government officials have helped OSTP, through the Intergovernmental Science, Engineering, and Technology Advisory Panel, to:

- Establish a process to identify and set priorities on significant State and local problems which science and technology could help solve. Problem areas include energy, environment, transportation, and safety.
- Pinpoint Federal R&D and technical assistance needed to solve specific problems, including hazardous waste, LANDSAT data, fire protection, and problems of the elderly.
- Formulate White House policy responsive to State and local needs for science and technology. ISETAP was specifically requested in the President's Science and Technology Message to increase efforts in planning for technical assistance and R&D for problem solving. This general direction was specifically reinforced in the Rural Policy charge to help set a rural research agenda and to help assess and use 1980 census data.

II.

APPROPRIATION LANGUAGE

Federal Funds

General and special funds:

Salaries and Expenses

For necessary expenses of the Office of Science and Technology Policy, in carrying out the purposes of the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6601 and 6671), hire of passenger motor vehicles, services as authorized by 5 U.S.C. 3109, not to exceed [$1,000] $1,500 for official reception and representation expenses, and rental of conference rooms in the District of Columbia, [$2,625,000] $2,948,000 (Department of Housing and Urban Development-Independent Agencies Appropriation Act, 1980.)

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III.

EXPLANATION OF THE FISCAL YEAR 1981 BUDGET
AND MAJOR INCREASES AND DECREASES

The $2.948 million estimated OSTP budget for FY 81 shows an increase of $236 thousand from the FY 1980 authorization plus the requested pay raise supplemental. This budget provides for activities of the Office at a level consistent with the role OSTP has established within the Executive Office of the President. Activities of the Office have been tailored to a small permanent staff assisted by experts external to the Office who can be called upon as needs arise.

Totals by major object class are:

- Personnel Compensation and Benefits--$1,463,000. This is an increase of $11,000 from FY 1980 estimate. Of the total, $850,000 is for full-time permanent positions. Reimbursable detail and temporary personnel utilization remains at the same level as FY 1980. The increase over FY 1980 results from anticipated in-grade and promotion raises and does not provide for cost of living adjustments.

- Travel--$283,000. Increase of $13,000 reflects increased airfares.

- Transportation of Things--$5,000. No change.

- Rents, Communications, and Utilities--$302,000. $15,000 increase budgeted to cover scheduled GSA rent and other rate increases.

- Printing and Reproduction--$35,000. No change.

- Other Contractual Services--$820,000. Increase of $216,000 in program and other contracts reflects greater contractual support for external issues analysis from FY 80 level.

- Supplies and Materials--$20,000. Decrease of $9,000.

- Equipment--$20,000. Decrease of $10,000.

IV.

OFFICE OF SCIENCE AND TECHNOLOGY POLICY
SALARIES AND EXPENSES
SUMMARY OF OBLIGATIONS BY OBJECT

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981	Difference FY 1981/80
Permanent Staff				
Positions	24	24	24	0
Personnel Compensation				
Permanent Positions	$ 741,000	$ 842,000	$ 850,000	+ $ 8,000
Temporary Positions	70,000	153,000	155,000	+ 2,000
Overtime, Holiday and Other	9,000	13,000	13,000	0
Consultant Compensation	130,000	169,000	169,000	0
Reimbursable Detail and Other	218,000	180,000	180,000	0
Subtotal	$1,168,000	$1,357,000	$1,367,000	+ $10,000
Personnel Benefits	$ 76,000	$ 95,000	$ 96,000	+ $ 1,000
Subtotal, Personnel Comp & Benefits	$1,244,000	$1,452,000	$1,463,000	+ $11,000
Travel				
Staff	$ 103,000	$ 120,000	$ 126,000	+ $ 6,000
Consultant	121,000	146,000	153,000	+ 7,000
Local & Miscellaneous	4,000	4,000	4,000	0
Subtotal	$ 228,000	$ 270,000	$ 283,000	+ $13,000

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981	Differences FY 1981/80
Transportation of Things	$ 2,000	$ 5,000	$ 5,000	$ 0
Rentals & Communications				
Space Rental	$ 187,000	$ 200,000	$ 211,000	+ $ 11,000
Equipment and Other Rentals	39,000	21,000	23,000	+ 2,000
Telephone, Telegraph & Postage	63,000	66,000	68,000	+ 2,000
Subtotal	$ 289,000	$ 287,000	$ 302,000	+ $ 15,000
Printing & Reproduction	$ 58,000	$ 35,000	$ 35,000	$ 0
Other Contractual Services				
Other Admin Contracts	$ 147,000	$ 150,000	$ 150,000	$ 0
Program Contracts	374,000	454,000	670,000	+ 216,000
Subtotal	$ 521,000	$ 604,000	$ 820,000	+ $216,000
Supplies & Materials	$ 46,000	$ 29,000	$ 20,000	- $ 9,000
Equipment	$ 49,000	$ 30,000	$ 20,000	- $ 10,000
TOTALS:	$2,437,000	$2,712,000	$2,948,000	+ $236,000

TUESDAY, MARCH 11, 1980.

NATIONAL SCIENCE FOUNDATION

WITNESSES

NATIONAL SCIENCE BOARD

DR. RICHARD C. ATKINSON, DIRECTOR, NATIONAL SCIENCE FOUNDATION

DR. NORMAN HACKERMAN, PRESIDENT, RICE UNIVERSITY AND CHAIRMAN

DR. MARIAN ELLIOTT KOSHLAND, PROFESSOR OF BACTERIOLOGY AND IMMUNOLOGY, UNIVERSITY OF CALIFORNIA, BERKELEY,

NATIONAL SCIENCE FOUNDATION

DR. GEORGE C. PIMENTEL, DEPUTY DIRECTOR

DR. HARVEY AVERCH, ASSISTANT DIRECTOR FOR SCIENTIFIC, TECHNOLOGICAL AND INTERNATIONAL AFFAIRS

DR. ELOISE E. CLARK, ASSISTANT DIRECTOR FOR BIOLOGICAL, BEHAVIORAL AND SOCIAL SCIENCES

CHARLES H. HERZ, GENERAL COUNSEL

DR. FRANCIS S. JOHNSON, ASSISTANT DIRECTOR FOR ASTRONOMICAL, ATMOSPHERIC, EARTH, AND OCEAN SCIENCES

DR. WILLIAM KLEMPERER, ASSISTANT DIRECTOR FOR MATHEMATICAL AND PHYSICAL SCIENCES

DR. F. JAMES RUTHERFORD, ASSISTANT DIRECTOR FOR SCIENCE EDUCATION

DR. JACK T. SANDERSON, ASSISTANT DIRECTOR FOR ENGINEERING AND APPLIED SCIENCE

THOMAS UBOIS, ASSISTANT DIRECTOR FOR ADMINISTRATION AND ACTING DIRECTOR, OFFICE OF GOVERNMENT AND PUBLIC PROGRAMS

DR. M. KENT WILSON, DIRECTOR, OFFICE OF PLANNING AND RESOURCES MANAGEMENT

	Appropriation	Positions
1979 actual	$911,000,000	1,260
1980 estimate	[1] 997,090,000	1,274
1981 request	1,148,000,000	1,293
Increase	+150,910,000	+19

[1] Includes supplemental request of $840,000 for increased military pay costs.

Mr. BOLAND. The Committee will come to order.

We are delighted to have with us today the National Science Foundation.

We will place the biographical sketches of Dr. Klemperer and Dr. Johnson in the record at this point.

[The biographical sketches follow:]

Dr. William Klemperer

Dr. William Klemperer became Assistant Director for Mathematical and Physical Sciences (MPS) in November 1979. In this position he is responsible for the development, coordination, direction, and evaluation of programs under the Divisions that comprise MPS: Mathematical and Computer Sciences, Physics, Chemistry, and Materials Research.

Dr. Klemperer is on leave from Harvard University where he holds the position of Erving Professor of Chemistry. Dr. Klemperer joined Harvard University in 1954.

Born in New York City in 1927, having served in the U.S. Naval Air Corps 1944–1946, Dr. Klemperer graduated from Harvard University in 1950 with an A.B. in Chemistry. He was awarded a Ph.D. in Chemistry by the University of California, Berkeley in 1954, having studied with Dr. George C. Pimentel.

Dr. Klemperer's research interests lie primaily in the area of molecular spectroscopy and molecular structure. His early work was devoted to the infrared spectroscopy of gas phase high temperature species. These infrared spectroscopic studies of lithium hydride led him to the molecular beam electric resonance study of lithium hydride in 1960. Further work in the area of molecular beam spectroscopy on high temperature species led to precision structural and charge distribution parameters of highly refractory materials. A research interest developing from this work led to the study of the measurement of electric dipole moments of molecules in excited electronic states by both optical spectroscopy and molecular beam radio frequency spectroscopy.

An interest developed during a sabbatical year at Cambridge, England is the theoretical description of molecule formation in the interstellar medium. His work in this area was devoted to an attempt to understand the mechanism of formation of molecules observed by modern radioastronomy, and led to the correct identification of the unknown species designated "Xogen" by Snyder and Buehl as the HCO^+ ion. This was the first polyatomic ion discovered in the interstellar medium.

A recently developed interest is the study of van der Waals moleculars by molecular beam electric resonance spectroscopy, leading to the most precise structural determinations of weakly bound complexes which are of use in understanding the nature of intermolecular forces.

Dr. Klemperer has been a member of the National Academy of Sciences since 1969. He is also a fellow of the American Physical Society, a member of the American Academy of Arts and Sciences, and a member of the American Chemical Society, and a Fellow of the Franklin Institute. In 1978 he received the John Price Wetherill Medal from the Franklin Institute, and in 1980 he receives the Irving Langmuir Award in Chemical Physics.

Dr. Klemperer has been a consultant to the Bell Laboratories, and the Manufacturing Chemists Association.

Dr. and Mrs. Klemperer presently reside in Washington, D.C.

Dr. Francis S. Johnson

Dr. Francis S. Johnson became the Assistant Director for Astronomical, Atmospheric, Earth, and Ocean Sciences (AAEO) in November 1979. In this position he is responsible for the development, coordination, direction, and evaluation of programs under the Divisions that constitute AAEO: Astronomical Sciences, Atmospheric Sciences, Earth Sciences, Ocean Sciences, and Polar Programs.

Prior to his NSF appointment, Dr. Johnson was the Cecil H. and Ida M. Green Honors Professor of Natural Sciences at the University of Texas at Dallas, and also served as Executive Dean of Graduate Studies and Research. Dr. Johnson joined the predecessor institution to the University of Texas in 1961 and served as Acting President from 1969 until 1971 and as the Director of the Center for Advanced Studies there from 1971 until 1974. Earlier he served as manager of Space Physics Research at Lockheed Missiles and Space Company in Palo Alto, California and as Head of the Upper Atmosphere Research Section of the U.S. Naval Research Laboratory in Washington, D.C. During World War II, he served as a meteorologist in the Army Air Force.

Dr. Johnson was born in 1918 in Omak, Washington; received a B.S. in physics from the University of Alberta (Canada) in 1940, and an M.A. in 1942 and a Ph.D in meteorology in 1958 from the University of California at Los Angeles. His main research interests are in the fields of upper atmosphere and space physics, planetary science, and solar radiation and he has authored and co-authored numerous publications in these areas.

Included among his awards, Dr. Johnson has received the Space Science Award from the American Institute of Aeronautics and Astronautics, the Henryk Arctowski Medal from the National Academy of Sciences, the Exceptional Scientific Achievement Medal from the National Aeronautics and Space Administration (NASA), the John A. Fleming Award from the American Geophysical Union, and the Meritorious Civilian Service Award from the Air Force.

Dr. Johnson is active in many professional societies, including the American Association for the Advancement of Science, the American Astronomical Society, the American Geophysical Union, the American Institute of Aeronautics and Astronautics, the American Meteorological Society, the American Physical Society, the Committee on Space Research (U.S. Representative and Vice President, 1975–81), the Special Committee on Solar-Terrestrial Physics, the Institute for Electrical and Electronics Engineers, and Sigma Xi. Over the years, he has served in an advisory capacity to many government agencies including the National Oceanic and Atmospheric Administration, NASA, the National Bureau of Standards, the U.S. Air Force and the National Academy of Sciences.

Dr. and Mrs. Johnson reside in Arlington, Virginia.

Mr. BOLAND. I read your statement, Dr. Atkinson. It is always a fine statement; you justify all the National Science Foundation programs.

In fiscal year 1981, the National Science Foundation is requesting appropriations totaling $1,148,000,000. This is an increase of $150,910,000 above fiscal year 1980 when the supplemental request of $840,000 is considered. The number of positions increased from 1,260 in 1979 to 1,274 in 1980 to 1,293 in 1981.

Dr. Atkinson, why don't you go ahead with your statement.

Dr. ATKINSON. Mr. Boland, I will try to be brief. I am glad you——

Mr. BOLAND. You don't have to be brief. You have only 16 pages. We had Dr. Press here earlier today. He had 19 pages. I've never known anyone in the government that does more with less money and core staff than he does. That office really is impacted with great responsibility.

Dr. ATKINSON. We have a special relationship to that office by law; the Foundation is required to provide long-term policy research in support of OSTP activities.

Mr. BOLAND. I know you have. You have a special role, as I understand, with the joint agreement between the United States and the Union of Soviet Socialist Republics. We had some discussion about that this morning. And will discuss it again this afternoon.

Do you leave most of the cooperative activities to the National Academy of Sciences?

Dr. ATKINSON. No. We have an agreement that the National Academy is responsible for certain activities and there is a separate responsibility for the foundation; the U.S.-USSR Cooperative Research program is one monitored by the National Science Foundation.

NATIONAL SCIENCE BOARD

Mr. BOLAND. You have 25 Members of the National Science Board?

Dr. ATKINSON. 24 plus the Director of NSF.

Mr. BOLAND. You are a member of the Board?

Dr. ATKINSON. Yes, an ex officio member.

Mr. BOLAND. Do we have any new members added since the hearings last year?

Dr. HACKERMAN. Not since last year.

Mr. BOLAND. We will place the names of all of the Members of the Board, including their particular responsibilities within the organizations they represent, in the record at this point.

Are they all university scientists?

Dr. ATKINSON. No. Some are from industry, small colleges, and the public sector.

[The National Science Board follows:]

NATIONAL SCIENCE BOARD

Dr. Norman Hackerman (Chairman, National Science Board), President, Rice University, P.O. Box 1892, Houston, Texas 77001

Dr. Grover E. Murray (Vice Chairman, National Science Board), University Professor, Texas Tech University and Texas Tech University School of Medicine, P.O. Box 4680, Tech Station, Lubbock, Texas 79409

Dr. Raymond L. Bisplinghoff, Vice President for Research and Development, Tyco Laboratories, Inc., Tyco Park, Exeter, New Hampshire 03833

Dr. Lewis M. Branscomb, Vice President and Chief Scientist, International Business Machines, Inc., Armonk, New York 10504

Dr. Jewel Plummer Cobb, Dean and Professor of Biology, Douglass College, Rutgers—The State University of New Jersey, New Brunswick, New Jersey 08903

Dr. Lloyd M. Cooke, Vice Chairman, Economic Development Council of New York City, Inc., 260 Madison Avenue, New York, New York 10016

Dr. Eugene H. Cota-Robles, Professor of Biology, Biology Board of Studies, Thimann Laboratories, University of California at Santa Cruz, Santa Cruz, California 95064

Mr. Herbert D. Doan, Chairman, Doan Resources Corporation, 110 East Grove Street, Midland, Michigan 48640

Dr. Ernestine Friedl, Dean of Arts and Sciences and Trinity College, and Professor of Anthropology, 216 Allen Building, Duke University, Durham, North Carolina 27706

Dr. John R. Hogness, President, Association of Academic Health Centers, 11 Dupont Circle, N.W., Suite 210, Washington, D.C. 20036

Dr. W. N. Hubbard, Jr., President, The Upjohn Company, Kalamazoo, Michigan 49001

Dr. William F. Hueg, Jr., Professor of Agronomy and Deputy Vice President and Dean, Institute of Agriculture, Forestry, and Home Economics, 201 Coffey Hall, University of Minnesota, St. Paul, Minnesota 55108

Dr. Michael Kasha, Director, Institute of Molecular Biophysics and Professor of Physical Chemistry, Florida State University, Tallahassee, Florida 32306

Dr. Marian E. Koshland, Professor of Bacteriology and Immunology, Department of Bacteriology and Immunology, University of California at Berkeley, Berkeley, California 94720

Dr. Saunders Mac Lane, Max Mason Distinguished Service Professor of Mathematics, Department of Mathematics, Eckhart 325, University of Chicago, 5734 University Avenue, Chicago, Illinois 60637

Dr. Walter E. Massey, Director, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

Dr. Joseph M. Pettit, President, Georgia Institute of Technology, Atlanta, Georgia 30332

Dr. David V. Ragone, Dean, College of Engineering, University of Michigan, Ann Arbor, Michigan 48109

Dr. Donald B. Rice, Jr., President, The Rand Corporation, 1700 Main Street, Santa Monica, California 90406

Dr. Alexander Rich, Sedgwick Professor of Biophysics, Department of Biology, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

Dr. Edwin E. Salpeter, J. G. White Professor of Physical Sciences, 308 Newman Laboratory of Nuclear Studies, Cornell University, Ithaca, New York 14853

Dr. L. Donald Shields, President, California State University at Fullerton, Fullerton, California 92634

Dr. Charles P. Slichter, Professor of Physics and in the Center for Advanced Study, Room 311, Loomis Laboratory of Physics, University of Illinois, Urbana, Illinois 61801

Dr. James H. Zumberge, President, Southern Methodist University, Dallas, Texas 75275

MEMBER EX OFFICIO

Dr. Richard C. Atkinson (Chairman, Executive Committee), Director, National Science Foundation, Washington, D.C. 20550

Mr. BOLAND. Why don't you go ahead with your statement?

GENERAL STATEMENT

Dr. ATKINSON. I will summarize my written statement.

The 1970's have been extraordinary years for science. A few examples of advances related to the NSF support are the theory of plate tectonics; research on the genetic code, in particular the work on recombinant DNA; laser chemistry; cloning techniques, and economic theory.

Why do I call attention to these particular examples?

In all of them NSF played a central role, and research results occurred at a rate faster than anyone anticipated.

Dr. Koshland is a world authority in the area of recombinant DNA research. That term was new to the scientific language 10 years ago. Yet if you look at the financial section of any newspaper today, you will see one account after another of the industrial activity in this field. Similarly, the theory of plate tectonics is now critical in the area of oil and mineral exploration. And NSF-supported basic research on submicron structures has encouraged joint research activities by industrial and university scientists of the highest character.

Consider two other examples. Dr. Pimentel is a world authority on the chemical laser. Ten to 12 years ago, that was a dreamy idea considered only in university laboratories. Since then, laser chemistry and the impact of lasers on society have advanced rapidly. In the same way, scientists have amazed themselves at the speed with which cloning techniques have been developed. They are working now on new types of potato plants with remarkable increases in yields and also on plants that can be cultivated in salt water.

The point I am trying to make here is the tremendous significance of basic research. The old notion that scientists did research and 15 years later their work might have some application, is pretty well behind us. The speed at which some of these areas move is surprising.

I also want to call attention to a couple of changes in role. Ten years ago NSF supported 13 percent of the Federal effort in basic research.

Today, through the sponsorship of this Committee, NSF's support of the Federal effort in basic research stands at 18 percent. The Foundation also plays a critical role in the support of basic research in the universities and colleges. Ten years ago NSF supported 25 percent of these efforts; today, NSF supports 28 percent of basic research in universities and colleges

Applied research in the Foundation is a small effort in dollars; for every $10 NSF spends in basic research, it funds only $1 in

applied research, but it is an important function of the Foundation. I want to emphasize that it is not applied research driven by national needs; that is an activity for the various mission agencies of the government. But it is applied research that is driven by science considerations. We are concerned with moving research of a basic character into an applied mode as quickly as possible, even though we don't always anticipate the exact direction that applied research will take.

Finally, I want to call attention to NSF's science education activities. The Foundation clearly has a unique role to play vis-a-vis the new Department of Education.

I should note that Dr. Rutherford, an effective leader of our science education directorate, will be moving to the Department of Education. The President has nominated him to be the Assistant Secretary for Research and Improvement in the new department. His effective planning and developing of programs at NSF puts him a good step——

Mr. BOLAND. I hope he enjoys the new department. I feel it is one area that should have remained where it was, but in any event that did not come to pass, so we wish you luck.

I am sure with the expertise and knowledge you gleaned with the Foundation you can do the same over there too.

NSF 1981 BUDGET THRUSTS

Dr. ATKINSON. Mr. Boland, let me briefly emphasize some of the factors contributing to the fiscal year 1981 budget. Among them are coordination with other agencies, the President's Domestic Policy Review on industrial innovation and the Five-Year-Outlook on needs and opportunities in science and technology.

The President's budget message selected four areas for special attention in fiscal year 1981. One area was energy, another was defense, the third was employment and training for youth and the fourth was basic research.

Between 1967 and 1980, the Federal support for basic research measured in constant dollars looks fairly good: an eight percent increase for federally-supported basic research. I can talk in terms of percent of GNP and make a less favorable case, but in constant dollars, there is an increase of eight percent. When I break that down and look at the different fields of basic research, I find some variations:

—In the environmental sciences, 34 percent increase.
—In the medical and life sciences, a 19 percent increase.
—In the engineering sciences, a 22 percent increase and
—The social sciences, a 7 percent increase.

Given those numbers, how can I report to you an average increase of 8 percent in constant dollars, between 1967 and 1980?

The reason is that mathematical and physical sciences during that period underwent a 14 percent decrease in constant dollars. That is the key to an examination of NSF's budget. The percentages in different categories show extreme differences, and the budget strongly emphasizes the physical sciences, mathematics, and computer science.

We also have a strong emphasis on engineering and applied science activities. Why engineering? I commented that there has been a healthy growth in the support of engineering activities. There also has been a healthy growth in the mission agencies. But I think that in engineering research too much of the money is allocated to specific efforts; there must be an open window for the best ideas in the engineering fields. Consequently, the NSF budget contains a significant increase for the engineering programs.

INDUSTRY/UNIVERSITY RESEARCH

The President's Domestic Policy Review on industrial innovation also brought some key issues to NSF's attention. One is the effort to link university research with industry research. NSF's budget bears a significant increase for an industry/university cooperative research program. In essence, it involves joint research projects proposed by scientists in universities and scientists in industry. NSF has had such an experimental program underway for two years; some absolute gems of research have been created. These successes drew attention in the Domestic Policy Review, and NSF's budget was increased to expand the program. The program produces not only research; it also builds bridges between industry and university scientists.

We also are requesting funds for industry/university cooperative research centers of the sort I have described to you in the past, such as the MIT Polymer Research Center. In these projects, a group of industries contributes significant dollars to a university research center. Together, industry scientists and university scientists plan the research agenda. The planning process ensures that the work is readily available to industrial applications.

A similar effort is requested in the Small Business Innovation Program. The program's purpose is to encourage fundamental research by the small business community and was recommended by the President's Domestic Policy Review.

Finally, let me note the ocean margin drilling program, a major effort to extend our scientific drilling program from the deep oceans to the ocean margins. The program will be extended over 12 years, industry will fund half of the cost and much of industry's expertise will be involved in the planning and conduct of the research.

In the past I have mentioned frequently the role of fundamental research in United States productivity. Among the problems of characterizing that role are the thousand different strands of relevant research.

Professor Paul Samuelson, an MIT economist, summarizes that role as follows:

"More than one-half the growth in United States productivity is due to the advance of scientific knowledge quite aside from society's laborious thrift and sacrifice of current consumption standards in the interest of more productive capital for the future."

In short Dr. Samuelson is saying that advances of scientific knowledge account for 50 percent of the United States growth rate in productivity.

[The statement follows:]

Mr. Chairman and Members of the Subcommittee:

I am pleased to have this opportunity to present the Foundation's fiscal year 1981 budget request. This request totals $1,148 million and is 15.5 percent above the fiscal year 1980 program level of $993.8 million. It allows for real growth in the level of effort of most NSF supported activities and is a fiscally sound response to current science needs and opportunities.

Our Nat.on's future is closely tied to the strength of our scientific enterprise. In such essential areas as food for the world's growing population, new sources of energy, the fight against disease, and the assurance of national security, we are profoundly dependent on the new knowledge and technologies that grow out of scientific research. Beyond these fundamental concerns, science must provide a base for technological developments necessary to sustain ou economy in the face of increasing competition from abroad, and must show us how to protect the life-giving environment of our planet.

The National Science Foundation plays an increasingly important role in the federal support of fundamental research. NSF now provides about one-fifth of all federal support for basic research--up from 13% in 1969. In the nation's colleges and universities, NSF now provides about 28% of all federal funds for the conduct of basic research, compared to 25% in 1969.

The Foundation is unique among federal agencies, in that it is the only one responsible for supporting research in all fields of science and engineering, and in science education. Its efforts are designed to support the development of the

knowledge, tools, and skills across all fields of science that provide an underpinning for solving many of the Nation's problems, in both the public and private sectors. Nevertheless, it is crucial that we recognize the importance of a multiplicity of funding sources and performers in maintaining the effectiveness of our scientific enterprise. It is important and necessary that the mission agencies support of basic research continue to provide a foundation for their applied research and development activities.

Mr. Chairman, there are several important current trends in science that I would like to bring to the attention of this committee. These trends are internal, in the sense that they are driven by the dynamics of science itself rather than by demands or constraints imposed by society.

These trends are:

- A stronger interdependence among many of the historically well-established science disciplines;

- Increasing linkages of basic and applied science;

- A rise in joint efforts involving industrial, academic, and other performers of research; and

- A growth in international cooperation in relation to major research undertakings.

These trends are all quite healthy, and they allow for many new science opportunities. They indicate that science is a dynamic entity, changing and developing as it grows, and becoming more unified and integrated as it also becomes more complex. Individual scientists become more highly specialized as they pursue the exploration of particular phenomena. But, in many areas of science, we are discovering that the theoretical developments in one discipline are applicable to those in others, and hitherto inexplicable phenomena become understandable as this convergence occurs. This is highly productive for the development of new fundamental knowledge as well as new applications.

Our sense of where technologies are limited because of inadequate knowledge and of how advances in knowledge might lead to new technologies has grown tremendously during the past century. In the past, we expected the passage of years or even decades between an advance in fundamental knowledge and a useful application of that knowledge. Today, however, we see much shorter time lags, and, in some fields, discovery and application proceed in a smoothly articulated fashion.

In surface science, for instance, advances in understanding the behavior of individual atoms on the surface of metals give us some very good leads for techniques to control corrosion--a chemistry problem that costs the U.S. economy an estimated $70 billion annually. Advances in understanding the crystallinity of metals--through basic research using the most advanced techniques of high resolution electron microscopy--have immediate application to improving the strength, fatigue life, and corrosion properties of structural metals.

Our grasp of the geophysical dynamics of the earth has undergone a revolution with the theory of plate tectonics and its confirmation in the ocean cores obtained through the NSF-supported Deep Sea Drilling Project. This, in turn, has enhanced our understanding of the dynamics of earthquakes and climate as well as of the formation and location of fossil fuels and mineral deposits.

Our understanding of the genetic code and developments in recombinant DNA techniques--work which has become possible only in the past few years--has the potential for applications of incalculable benefit to mankind. Private industry is already engaged in the production of synthetic insulin, and recently the synthesis of human interferon, using recombinant DNA techniques, was accomplished. This is a major step forward in the search for ways to control viruses, with implications for diseases as varied as cancer and the common cold.

Despite the increasingly closer link between insight and application, we continue to benefit by distinguishing between basic and applied research. It is critical that we recognize that an applied approach, driven solely by the search for a solution to a particular problem, rather than by the development of scientific opportunities, will not necessarily yield results by itself. The advances I have described all resulted from work directed at understanding, not at finding a solution to, a practical problem. But they all had quick and important applications. They demonstrate that even though basic and applied research are distinguishable activities, we can expect to see closer linkages between them in the years ahead.

Partly in response to these first two trends, we have seen a third--an increased tendency for cooperation between academic and industrial scientists in the performance of research. Industry is mainly focused on applications, of course, because it wants a product. As discoveries in basic science have become more relevant to commercial products, industry has turned to academic researchers for help. Also, academic researchers have sought industrial connections, especially in such fields as engineering and materials science, because industry has special facilities and special knowledge frequently gained from concentrating on applied problems.

It is in the public interest that NSF, among other agencies, try to bring academic and industrial researchers together through industry-university cooperative programs. The driving force behind such cooperation is the increasingly tight linkage between basic and applied research. One result has been the proliferation of small, innovative high-technology firms that "spinoff" from the joint research activities of universities and industrial firms and that have an important bearing on the Nation's productivity.

Finally, there is a trend toward increased cooperation in science among nations. This is most evident in "big science," where the problems require observation on a global scale, and necessary resources in money and manpower often exceed the capabilities of individual countries. It is especially apparent in the earth, ocean and atmospheric sciences, where NSF programs such as the International Phase of Ocean Drilling, the International Decade of Ocean Exploration, and large-scale - atmospheric research programs have been outstanding successes. International cooperation on a smaller scale is also increasingly common and mutually beneficial. Collaboration between scientists in different countries is evident in all science areas. Many international conferences, workshops, and other meetings take place each year, and the number has increased as Japan and the European countries have advanced their research capabilities.

We have also seen an increase in bilateral science agreements with countries that are less developed scientifically. There are benefits to both sides from such agreements. Collaborating nations seek to improve their scientific capability, and often seek special research opportunities related to development. These countries,in turn, provide U.S. scientists with access to unique sites and resources. In some countries, including China, we also seek to use cooperation in science and technology as a way to build trust and confidence and to improve relations generally.

The important role that science and technology have come to play in international affairs will increase during this decade. For example, one of the outcomes of the increasing strength of science abroad is that technology has become more competitive. The consequences of this for international trade, coupled with indications of declining productivity in U.S. industry, are important external factors affecting American science and technology. Intensive investments in R&D by West Germany and Japan have resulted in high productivity growth rates and leading positions in selected fields. This challenge by other nations to U.S. scientific preeminence is already being translated into severe competition in high technology markets.

SPECIAL BUDGET EMPHASES IN FY 1981

I would now like to discuss some of the special emphases in the Foundation's FY 1981 budget request.

Basic Research

Basic research remains the essential cornerstone of U.S. science, and its support is the primary mission of NSF. Basic research is a highly important, long-term investment in the nation's future.

- It provides a continually expanding knowledge base, which increases man's understanding of fundamental natural laws, processes and phenomena;
- It leads, over the long run, to new and improved technologies and information of great benefit to society; and
- It prepares the Nation to meet emerging new problems and as yet unidentified, problems that it will surely encounter in the future.

The Foundation's basic research effort is designed to support science at a pace that will continue to give the U.S. a competitive edge in science among the nations of the world. In FY 1981, the Foundation's request for the conduct of basic research totals $951 million, an increase of 16.9 percent. This total also includes funding for the U.S. Antarctic research program.

Ocean Margin Drilling

The FY 1981 budget request will be matched by an equal amount from a number of U.S. petroleum companies, to embark on a ten-year program of drilling in the ocean margins.

The margins, located between the continental shelf and the ocean floor, represent the largest scientific unknown in geology today. They are also the largest unexplored area where we might expect to find hydrocarbons. The bulk of the sediments are in water more than 6,000 feet deep, too deep for any existing drill ship to handle with proper attention to environmental safeguards.

The project will attack the most important unresolved problems in the plate tectonics hypothesis, including those related to continental breakup and ocean basin formation. Besides its great scientific importance, work on the deeply submerged ocean margins will constitute the first major effort to establish the geologic framework for determining the natural resource potential of these areas.

To carry out this program, it will be necessary to drill and core up to 20,000 feet, in water depths from 6,000 feet to 13,000 feet, using equipment necessary for environmental protection. A riser and blowout prevention system must be developed. No existing deep ocean drilling platform has the ability to meet these requirements. But the Government-owned ship, Glomar Explorer, has been identified as an excellent candidate for conversion. Funds requested for FY 1981 will take the project up to the point of conversion of the ship, drilling system procurement, and site selection.

Industry/University Cooperative Research

A special challenge for the U.S. is to utilize fully the research capabilities of industry and universities in efforts that can lead to a strengthened, more vigorous U.S. research effort. Concern about international competition has contributed to proposals for enhanced teamwork between universities and industries that will lead to the development of new products and improved services. In FY 1981, NSF is proposing to increase its Industry/University Cooperative Research activities. These efforts are designed to couple more closely the activities of industries and universities and to provide improved opportunities for university and industrial research laboratories to keep American science at the cutting edge of progress. In this way we can help to give our industries a technical edge in worldwide competition.

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Small Business Innovation

NSF is moving aggressively to strengthen research which provides opportunities for small science and technology-based firms to make valuable contributions to the national research effort in FY 1981. The Foundation is requesting that the Small Business Innovation program be augmented, primarily in applied efforts.

Improvement of University Research Laboratories

The FY 1981 program request includes $14.25 million to upgrade university research laboratories. Many of these laboratories have outdated facilities which limit the research techniques or instrumentation which can be used. This frequently results in less than optimal return on the investment of Federal dollars for support of research. The FY 1981 budget request represents a beginning to alleviate this situation. This effort is planned as a matching grant program in which Federal funds will be matched by academic institutions with an equal amount of non-Federal funds.

HIGHLIGHTS OF MAJOR BUDGET LINE ITEMS

Mr. Chairman, I would now like to focus the attention of the Committee on some highlights of the Foundation's major budget line items.

Mathematical and Physical Sciences

We are requesting $264.2 million for Mathematical and Physical Sciences, an increase of $37.8 million over the FY 1980 Current Plan. Research results in these fields provide the underlying knowledge for the future technological developments upon which our economic and social well being so intimately depend. They also form much of the intellectural underpinning for engineering and the biological, environmental, and behavioral sciences, as well as provide many of the research instruments and techniques necessary to progress in these fields.

The needs and opportunities in the mathematical and physical sciences are especially great, and these areas have received special emphasis in this budget. FY 1981 budget highlights include:

- A 28% increase for computer science, aimed primarily at significantly improving the university-based capability in experimental computer science. The combination of new mathematical theories and modern integrated circuit technologies promises exciting advances in this area.

- Significant real growth in the average award size, particulary in Physics, Chemistry, and Materials Research.

- Enhanced support for research related to microstructures.

- Increased support for mathematics research, with emphasis on postdoctoral support and special projects involving greater interaction among mathematicians in differing subfields.

- Continued emphasis on a broad range of problems in chemistry, including especially such areas as catalysis, the use of lasers, and understanding chemical processes at the most fundamental level.

Astronomical, Atmospheric, Earth and Ocean Sciences

We are requesting $241.3 million for Astronomical, Atmospheric, Earth and Ocean Sciences, an increase of $23.4 million over the FY 1980 level.

This activity is responsible for most of the large scale scientific undertakings of the Foundation, including the major research centers such as the Kitt Peak National Observatory, the National Radio Astronomy Observatory, and the National Center for Atmospheric Research. It also supports the academic oceanographic research fleet and associated shared-support facilities.

Highlights for FY 1981 include:

-- Support for detailed design and specifications for a new 25-meter millimeter wave radio telescope, which will allow advanced investigations in astrochemistry and of star formation in regions not visible to optical telescopes.

-- Continued strong support of the National Center for Atmospheric Research and for a balanced program of university-based investigations in aeronomy, atmospheric chemistry, climate dynamics, experimental meteorology, and solar-terrestrial studies.

-- Continued efforts to upgrade the academic oceanographic research fleet, with emphasis on coastal ships that can be operated more efficiently. Shifts towards smaller, more efficient ships are a major part of our strategy for containing rapidly increasing costs in this area.

U.S. Antarctic Program

We are requesting $63.4 million for the U.S. Antarctic Program, an increase of $7.56 million over the FY 1980 level. The U.S. Antarctic Program supports national goals to: maintain the Antarctic Treaty, insure that the continent will continue to be used for peaceful purposes only, foster cooperative research to contribute to the solution of regional and worldwide problems, protect the environment, and insure equitable and wise use of living and nonliving resources.

The U.S. Antarctic Research Program subactivity supports multidisciplinary research on the Antarctic continent and in the adjacent oceans. The research is conducted at four Antarctic stations, from remote temporary field sites, and aboard ships. Remote sensing techniques, including satellites, aircraft, balloons, and unmanned stations, are used in the conduct of the research. Cooperative research programs with scientists of other nations are commonplace.

The U.S. Antartic Operations Support Program subactivity provides for the direct support of science activities and the maintenance of an effective U.S. presence in Antarctica.

The National Science Foundation is designated as the single source of funding and management for the U.S. Antarctic Program. The Department of Defense and the Department of Transportation provide operational support as requested by NSF on a cost-reimbursable basis. The Foundation also contracts for support services when such contracts are cost effective.

In FY 1981, planned emphases include:

- o Interdisciplinary research on the structure and function of the Antarctic marine ecosystem to provide information needed for the wise use and conservation of Antarctic marine living resources.

- o An increase of $6.26 million for operations, about forty percent of which is for repairs to a crash-damaged LC-130 aircraft and for modifications to extend the present service life of an older LC-130 aircraft.

- o Acceleration of the McMurdo Station physical facilities rehabilitation program.

Ocean Drilling Programs

The Foundation is requesting $27.3 million for this activity in FY 1981, including $17.3 million for the Deep Sea Drilling Project and $10.0 million for the Ocean Margin Drilling Program. These programs represent a unique worldwide effort to explore the earth's crust beneath the oceans.

The Ocean Margin Drilling Program, which will involve cooperation and support from both the Government and industry, has already been discussed.

The Deep Sea Drilling Project has been supported by NSF since FY 1966. It is managed for NSF by the University of California/Scripps Institution of Oceanography. Its research efforts are carried out by use of the drilling ship Glomar Challenger which is operated by its owner, Global Marine, Inc. Present NSF plans call for support of Glomar Challenger operations through FY 1981.

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NSF funding in FY 1981 for this project increases by about $1.4 million. This increase is necessary to cover increased costs for fuel, personnel, supplies, and related expenses. The Deep Sea Drilling Project is now in the International Phase of Ocean Drilling to which several foreign countries, including France, Germany, Japan, and the United Kingdom are expected to each contribute $1.25 million annually.

Biological, Behavioral and Social Sciences

We are requesting $182 million to support research in the Biological, Behavioral and Social Sciences or $15.5 million above the FY 1980 level. The Biological, Behavioral, and Social Sciences activity supports basic research that enhances the understanding of biological and social phenomena. The range of research supported includes physical and chemical investigations of the fundamental molecules of living organisms, the interrelations of organisms and their environments, the complex learning and behavior patterns of animals and human beings, and the functioning of social, economic and cultural institutions. Through such research new horizons will be identified for human development and health, for an improved quality of life, and for economic and social progress.

Because of the truly revolutionary developments that have occurred in our understanding of the genetic code and its implications for agriculture, pharmaceuticals and health-related problems, special emphasis will be focused on this important area. Support will also include increases for:

- Studies of cell-cell interactions to increase our understanding of self recognition of cells in development and differentiation, and of hormones and their receptors;

- Studies of biochemical and hormonal mechanisms underlying behavior;

- Anthropological research seeking human origins;

- Studies of economic instability, inflation, and unemployment, both domestic and international;

- Research on various aspects of the ecology of crop and forest pests, acid rain, global carbon dioxide, and other pressing ecological problems; and

- Projects in long-term ecological research.

Engineering and Applied Science

We are requesting $137 million for the Engineering and Applied Science activity, an increase of $25.2 million over the FY 1980 level. The Foundation's Engineering and Applied Science activity seeks to strengthen the Nation's engineering and applied science research base and enhance the links between fundamental research and applications. This is accomplished by identifying and supporting basic research across a broad spectrum of the engineering sciences, applied research, and related activities that have potential for contributing to the understanding of significant societal problems.

During 1979, the Foundation formed the Engineering and Applied Science (EAS) Directorate by combining the Foundation's Engineering activities with the programs of the former Applied Science and Research Applications Directorate. Many activities of the two were highly complementary. As a result, NSF is now better able to:

- Strengthen the engineering programs of the Foundation and give them a more central role;
- Enhance programs of applied and problem-focused research by providing closer links to the science and engineering on which they depend; and
- Recognize the key role of engineering in the transfer of science into technology.

Highlights of the FY 1981 budget for EAS include:

- A significantly increased investment in university-based engineering. In particular, attention will be focused on micro-structures and computer engineering research. This effort will address areas where the U.S. has recently been lagging in comparison to foreign countries, in a field which has high potential for productivity improvement and industrial innovation.
- Increased support for engineering energetics, with an emphasis on plasma chemistry and arc technology.

- Thermodynamics and mass transfer, with support for research in novel and energy-efficient separation processes.

- Examination of the impact on the economy of a transition from heavily-regulated to less-regulated industries and services.

Scientific, Technological and International Affairs

We are requesting $28.85 million for the Scientific, Technological, and International Affairs activity. That is an increase of $2.75 million over the FY 1980 level. This program promotes the understanding and effective functioning of the Nation's scientific and technological enterprise. It also supports activities designed to provide information and systematic analysis of the Nation's Science and Technology (S&T) enterprise and to enhance domestic and international exchange of S&T information.

Highlights for FY 1981 include:

- Expansion of the cooperative research thrust in Western Europe and Japan, where scientific and technical capabilities in some fields rival or surpass those in the U.S. and where U.S. scientists can benefit most from such cooperation;

- Continuation of the new science in developing countries thrust that relates science and technology to problems of development in Asia, Africa, Latin American, and the Caribbean;

- Increased support for additional risk analysis activities to improve methods for evaluating long-term comparative risks and benefits of alternative technologies;

- Support of two special projects designed to update the Nation's information and data concerning the industrial activity of small R&D firms and the R&D of independent nonprofit institutions; and

- Enhanced support of research on information transfer and related human behavior.

Cross-Directorate Programs

The FY 1981 request for this activity totals $51.95 million, an increase of $26.4 million above the FY 1980 level. This activity consists of twelve programs, either prescribed by the Congress or developed by the Foundation in recent years in response to specific needs and opportunities. The designation "Cross-Directorate" indicates that the programs in this activity are of agency-wide relevance. In most cases, their objectives are unique and do not easily interlock with those of traditional NSF research or science education programs. In this presentation, these programs are more visible in the NSF budget and can be given appropriate oversight and review by top Foundation management, the National Science Board, and the Congress.

Highlights of this activity in FY 1981 include:

- Support for greater cooperation between researchers in universities and industry;

- Continued support for research equipment at 2-year and 4-year colleges and universities that lack doctoral programs in the sciences and engineering or that have only small doctoral programs;

- New support for modernizing and upgrading university research laboratories;

- Increased funding for broadening research ties between the United States and the People's Republic of China;

- Support for minority scientists at institutions with large minority student populations to initiate research programs and enhance the research competitiveness of these scientists; and

- Increased support for improving the research capability and competitiveness of scientists at institutions located in States having relatively low Federal research funding.

Science Education

The Foundation is requesting $85.7 million for its Science Education activities. This is an increase of $7.5 million over the FY 1980 level. With the passage of the Department of Education Organization Act, the Congress has reaffirmed the role of NSF in Science Education by specifying five areas of responsibility for the Foundation. These are: scientific career development; continuing education of scientific personnel; increasing participation of women, minorities and the handicapped in careers in science; conduct of R&D applied to science learning at all educational levels; and informing the general public of the nature of science and technology and of attendant values and public policy issues.

In pursuing these responsibilities, the Foundation will place special emphasis on four priority thrusts. The first of these is the improvement of science education for the early adolescent. This involves an increased effort at a point of high educational opportunity, the junior high/middle school years.

The second is improved access for under-represented minorities and women in careers in science and engineering. The matter of career access, while related to the early adolescence thrust, is of sufficient importance that NSF will continue to address it as a special science education concern.

The third relates to out-of-classroom or informal science learning experiences. This is an important factor in the general development of the public's understanding of science, and is of great importance in interesting and motivating children to study science. The motivational aspects of informal science learning in the current decade are expected to play an important role in the development of the scientists of the future.

This year a fourth priority has been added to the above continuing concerns--the revitalization of college science teaching. For the past several years, a series of events in undergraduate education have affected the quality of college science teaching. Declining student enrollments have reduced the need for new faculty, and changing patterns in the job market have made the content of many course offerings obsolete. To counter this trend, the Foundation is proposing a new thrust in FY 1981 to update the subject-matter competence of college science faculty.

Special Foreign Currency

We are proposing a $5.5 million Special Foreign Currency program for FY 1981; the same level as in FY 1980. For several years, NSF has undertaken a number of cooperative science programs with nations where the U.S. has local currencies on deposit in amounts declared by the U.S. Treasury Department to be excess to normal U.S. Government needs. This program has produced beneficial cooperative research efforts with Egypt, India, Pakistan, and several other countries and has given U.S. scientists opportunities for cooperative research otherwise unavailable to them. Excess foreign currencies have also been used effectively in the translation of foreign science journals, textbooks, and other publications. The use of these excess currencies causes no dollar drain on the U.S. and provides an opportunity for U.S. science to benefit from the use of currencies generated by the sale of U.S. agricultural commodities overseas.

Program Development and Management

The budget includes $60.8 million for the Program Development and Management activity. This activity covers NSF administrative expenses. Funds are included for a full-time permanent staff of 1,293, an increase of 19 over FY 1980. Also covered are the costs associated with the Foundation's peer review system and the provision of central support service needed in the Foundation's day-to-day activities. Program Development and Management expenses are 5.3 percent of the total NSF budget in FY 1981, compared to 6.1 percent in FY 1980. The FY 1981 request of $60.8 million is an increase of $236,238, or 0.4 percent over the FY 1980 level of $60.56 million.

This concludes my formal testimony. I would be happy to respond to any questions you may have.

NATIONAL SCIENCE FOUNDATION
BUDGET SUMMARY

(Millions of Dollars)

Budget Activity	FY 1979 Actual	FY 1980			FY 1981 New Obligational Authority	Differences	
		FY 1980 Program Funded by Congress	Prior Year Funds Carried Over	FY 1980 Current Plan		New Obligational Authority FY 1981/80	Total Program FY 1981/80
Research and Related Activities Appropriation:							
Mathematical and Physical Sciences	$208.9	$226.2	$.2	$226.4	$264.2	$38.0	$37.8
Astronomical, Atmospheric, Earth, and Ocean Sciences	211.6	217.9	—0—	217.9	241.3	23.4	23.4
U.S. Antarctic Program	51.1	55.8	—0—	55.8	63.4	7.6	7.6
Ocean Drilling Programs	11.8	19.5	—0—	19.5	27.3	7.8	7.8
Biological, Behavioral, and Social Sciences	154.7	166.5	—0—	166.5	182.0	15.5	15.5
Engineering and Applied Science	109.9	111.6	.2	111.8	137.0	25.4	25.2
Scientific, Technological, and International Affairs	23.6	26.1	—0—	26.1	28.8	2.7	2.7
Cross Directorate Programs	16.8	25.1	.4	25.5	52.0	26.9	26.5
Program Development and Mangement	54.7	58.1	2.5	60.6	60.8	2.7	.2
Subtotal	$842.9	$906.8	$3.3	$910.1	$1,056.8	$150.0	$146.7
Science Education Activities Appropriation:							
Scientific Personnel Improvement	$33.1	$31.6	—0—	$31.6	$35.2	$3.6	$3.6
Science Education Resources Improvement	28.6	24.0	—0—	24.0	24.2	.2	.2
Science Education Development and Research	12.0	14.9	—0—	14.9	17.5	2.6	2.6
Science and Society	6.3	7.7	—0—	7.7	8.8	1.1	1.1
Subtotal	$80.0	$78.2	—0—	$78.2	$85.7	$7.5	$7.5
Special Foreign Currency Appropriation	$4.0	$5.5	—0—	$5.5	$5.5	—0—	—0—
Total, NSF	$926.9	$990.5	$3.3	[1]$993.8	$1,148.0	$157.5	$154.2

[1]Includes proposed supplemental of $840,000 for increased pay costs of Navy personnel engaged in the U.S. Antarctic Program and excludes $6,584,000 transferred to the Department of Education.

GROWTH OF BASIC RESEARCH

Mr. BOLAND. The total program for basic research in the 1981 justifications is $952 million. Is that correct?

Dr. ATKINSON. Right.

Mr. BOLAND. Let me go through a few statements and see whether or not you agree with them. We have been over some of this ground in the last two years—but I want to re-state some of these conclusions for the record. It all concerns constant dollars, real dollars, inflation, about everything else thrown in.

The levels of support reported for basic research are highly dependent on how the various agencies in the Federal government choose to classify their funds. Two different agencies supporting very similar research projects might classify their funds entirely different—one as basic research and the other as applied research. Would that be a fair assumption?

Dr. ATKINSON. No, I wouldn't quite agree.

The categorization can be interpreted differently by different people at different times. The key is that we try to maintain a constant categorization from year to year. In other words, we try to ensure in our data base that every agency is classifying the same way from year to year. I think the trends are correct, but I could agree with you that shifts of one sort or another in those exact values might be justified, depending on the analysis.

Mr. BOLAND. We have a graph that reveals that the cause of the post-1967 decline in constant dollar Federal obligations for basic research was primarily the result of reductions in obligations by NASA, the Department of Defense and the Department of Energy and its precursors. Would that graph be correct?

Dr. ATKINSON. Mr. Boland, In my opening remarks, I discussed trends between 1967 and 1980. I think the graph you are talking about is correct.

Mr. BOLAND. You have also indicated that there was a very strong sustained period of growth of Federal obligations in constant dollars for basic research from about 1956 to 1967. Is that correct?

Dr. ATKINSON. Yes.

Mr. BOLAND. In fact, even neglecting NASA's contribution which was significant, the average annual growth was roughly in excess of 17 percent per year during that period. Would you agree with that?

Dr. ATKINSON. I don't know those figures, but they seem about right. You recall that was a special period after Sputnik.

Mr. BOLAND. As you have indicated, there was a period of strong growth which was followed by a period of seven or eight years in which obligations declined and then fluctuated erratically by a few percentage points until, in 1975, the Federal obligations for basic research in constant dollars again began to climb rather strongly.

Finally, you would agree that Federal obligations in constant dollars for basic research surpassed the 1967 levels which you often cite in discussions of the adequacy of research support—obligations surpassed that level, which was a peak year, in 1977 and 1978 based on your own data. Is that correct?

Dr. ATKINSON. The figure I cited was an eight percent increase in constant dollars by 1980.

RESEARCH BUDGETS AND CONSTANT DOLLARS

Mr. BOLAND. Now following that line of establishing the facts over the past few years, I want to raise with you again what I think is a fundamental problem in trying to determine what the level of support should be for the Foundation—and, for that matter, other basic research. Arguments by yourself and OSTP for supporting increased basic research budgets generally compare current levels of constant dollar Federal obligations with those in 1967. That is correct, isn't it?

Dr. ATKINSON. Yes.

Mr. BOLAND. You always pick the year of 1967.

Dr. ATKINSON. It is a convenient year to pick, and it is a high year.

Mr. BOLAND. And that seems to imply that the constant dollar obligation levels of 1967 were representative of amounts devoted to research over a period of years. But the fact is that is not the case. 1967 was an anomaly, wouldn't you say?

Dr. ATKINSON. It was certainly a peak year in the curve.

Mr. BOLAND. What we think you are doing is comparing levels of support with 1967 and that conveys a misleading impression that that year was the established rate of research support.

Dr. ATKINSON. If we were trying to convey that impression and base it on those arguments, yes, we are misleading you.

Mr. BOLAND. All right. So that kind of comparison, of course, paints a uniquely pessimistic picture of post-1967 levels of research support; doesn't it?

Dr. ATKINSON. I don't think it is that simple, Mr. Boland. I am willing to accept your point, but there are other measures to look at. I would argue that each person must deliberate in these measures in his own mind and decide.

GREENBERG ARTICLE ON BASIC RESEARCH

Mr. BOLAND. Daniel Greenberg seemed to agree with the scenario that we have been establishing here. Do you know Mr. Greenberg?

Dr. ATKINSON. Yes, and I probably know that article. Can you turn it around?

Mr. BOLAND. I can't give you the date, but I am sure you know the article titled "Such Groaning from Scientists."

He says, "One of the wonders of our scientific community is the durability of its sense of siege and privation in a society that by any measure has been very good to it."

Dr. ATKINSON. I must point out that the article is talking about averages. I wrote to Mr. Greenberg after that column appeared, and I examined an array of different sciences. It is true that environmental science has had a large increase, and that certain medical fields have had large increases. But physical sciences have had a sharp decrease.

Mr. BOLAND. He goes on to say, "Scientists themselves frequently complain that the public has turned against them. But upon close examination, it turns out that this is their devil theory for explaining the drop-off in the enormous budget boosts that research received in the 1960s. That the growth couldn't go on like that

indefinitely is clear to anyone who understands compound interest, but many elders of the profession prefer the hostility interpretation."

You don't prefer that interpretation, do you?

Dr. ATKINSON. I will agree with what you said there.

Mrs. BOGGS. Have you considered running for Congress?

Mr. BOLAND. Mr. Greenberg seems to know what he is talking about.

Here is an interesting statement: "With that understood, what has to be registered is that the Federal budget for research and development has risen in two years from $26.4 billion to $30.7 billion."

You indicated it has gone to $34 billion. Did you say that the Federal budget in 2 years has risen from $26 to $34?

Dr. ATKINSON. Dr. Koshland must have given him those figures.

Mr. BOLAND. What about this statement, has it risen in 2 years from $26 to $30 billion?

Dr. ATKINSON. That is the Federal R&D budget.

Mr. BOLAND. The Federal budget.

Dr. ATKINSON. It may well be.

Mr. BOLAND. He goes on to say, "Even allowing for inflationary slippage, those sums do not suggest parsimony. What's lacking, of course, is the wild growth and bounce of the go-go era of space activity. Our researchers now grudgingly have to pick and choose among interesting possibilities rather than say they'll take them all."

I always thought you were picking interesting possibilities.

Dr. ATKINSON. Mr. Boland, we are, but what he is characterizing is the world we live in.

I mean, the difficulty of choices is much more severe today than it was even three or four years ago.

FEDERAL R&D BUDGET

Mr. BOLAND. The total Federal R&D budget in 1981 estimate is $36.1 billion.

Dr. HACKERMAN. Of that $36.1 billion, Federal obligations for conduct of basic research in fiscal year 1981 are estimated to be $5.1 billion.

Mr. BOLAND. Would anybody like to add to that?

Dr. HACKERMAN. The development portion of the R&D budget is much larger than the research portion. Development costs a lot of money; it includes demonstration plants and things of that sort. The basic research portion increased from 4.1 to 4.5 billion dollars (estimated) in fiscal year 1980 and is estimated to be $5.1 billion in 1981.

Dr. PIMENTEL. There has been over the past decade or so a change in the relative amount of GNP devoted to R&D by the United States and by some of the industrially advanced countries. Ours is slipping slowly and theirs are rising. That trend has paralleled the change in our relative competitive position; it certainly is a matter for attention.

BUDGET REDUCTIONS

Mr. BOLAND. Now, last week the President asked the agencies to look at a potential series of cutbacks in 1981 and 1980 for various agencies. Did you get a target reduction as part of that exercise?

Dr. ATKINSON. Yes, we did.

Mr. BOLAND. What was that target reduction?

Dr. ATKINSON. Mr. Boland, I believe you will have to ask the White House.

Mr. BOLAND. Okay. But was it substantial?

Dr. ATKINSON. It was substantial.

Mr. BOLAND. Did it get you under a billion dollars?

Dr. ATKINSON. No.

Dr. PIMENTEL. It is larger than a bread box.

Mr. BOLAND. I am sure if you got a target you must have indicated where those reductions would come and what programs would be cut back.

You should have a little advice for us at this time.

Dr. ATKINSON. Mr. Boland, you have our zero-based budget. The reductions we are proposing to OMB correspond to the ZBB ordering, except in two areas. We have a more significant reduction in the U.S.-U.S.S.R. program and——

Mr. BOLAND. That is an easy one though, Dick.

Dr. ATKINSON. Yes.

U.S.-U.S.S.R. COOPERATIVE RESEARCH

Mr. BOLAND. Is your United States-U.S.S.R. Cooperative Research Program—about $3.2 million for 1981?

Dr. ATKINSON. That is exactly it.

Mr. BOLAND. That isn't much. Your actual for 1979 was $3.3 million. Now with the recent Soviet incursion in Afghanistan, I would think you could cut it all out.

Dr. ATKINSON. All of the funds referred to as U.S.-U.S.S.R. funds are funds that go to American scientists. We do not support any activity of Soviet scientists. The funding is for our part of the joint effort with the Soviets. It is United States research that is being supported.

Mr. BOLAND. That may be true, but isn't it research which benefits the U.S.S.R.?

Dr. ATKINSON. And should benefit the U.S.

Mr. BOLAND. In the area of computer technology, I notice you estimate $600,000 for fiscal year 1981.

Dr. ATKINSON. But you will note——

Mr. BOLAND. I imagine you will strike that.

Dr. ATKINSON. I don't know how we would strike details of that program. The research is not in the area of computer electronics or even advanced systems programming; it is in the area of large-scale data management programs. I think everyone judges that to be a non-sensitive area.

FISCAL YEAR 1981 BUDGET ADJUSTMENTS

Mr. BOLAND. If your budget was reduced by $50 million for fiscal year 1981, would we be able to determine from the zero based budget justifications, what has the highest priority?

Dr. ATKINSON. I can certainly comment.

Mr. BOLAND. You could help us with that.

Dr. ATKINSON. There would be no problem if I were to comment.

Mr. BOLAND. Do you want to comment any further?

Dr. ATKINSON. What I didn't finish saying on the ZBB ordering is this; the other issue is the ocean drilling program. It would be modified. The budget requests $10 million in fiscal year 1981 with a matching contribution of $10 million from industry. That is for a one-year planning phase. Actually it is much more involved than the term planning implies.

But there is enough feeling from industry and from the initial work that has been done that we could afford to stretch the planning into a two-year program. That would mean a $5 million reduction in fiscal year 1981.

Mr. BOLAND. If we asked for a little help, a cut of $100 million, you would be able to target the programs or suggest the programs that might be cut.

Dr. ATKINSON. We would step through the ZBB; taking a good part of the effort in industry/university cooperative research and some of the innovation efforts recommended by the President's domestic policy review. We would protect the basic research programs, particularly in the physical sciences.

Mr. BOLAND. If we asked for a little help on reducing the budget by $150 million, you would probably give me your resignation.

Dr. ATKINSON. I don't think I would offer it to you, Mr. Boland; I would think about it.

Mr. BOLAND. You won't have to think about that offer. I guess what you are saying is that the Science and the Research and Development functions should not be excluded from efforts to balance the budget in 1981? They ought to be considered part of the whole package, am I correct?

Dr. ATKINSON. Do you want my personal views?

Mr. BOLAND. Yes, but let's hear Dr. Pimentel's views first.

Dr. PIMENTEL. That would be inconsistent with our ZBB process in which we indicated that at sufficient budget levels NSF could undertake initiatives. If the budget levels retreated significantly, the initiatives would be sacrificed.

Mr. BOLAND. Now, I will hear your view and then Dr. Hackerman's.

Dr. ATKINSON. My view corresponds with Dr. Pimentel's.

Dr. HACKERMAN. My view is that the Foundation's request is part of the President's total budget request for fiscal year 1981.

Mr. BOLAND. Dr. Koshland, do you have anything to say?

Dr. KOSHLAND. I agree with Dr. Hackerman.

Mr. BOLAND. Is there anybody in the room who disagrees with Dr. Hackerman?

Nobody. All right.

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EAS REORGANIZATION

Now I understand, from reading the justifications, that you have once again reorganized ASRA, Applied Science Research Applications. We have had some problems with that reorganization: ASRA was—I think we said last year—the son of RANN. We have had a couple of reorganizations in this area over the past years?

Dr. ATKINSON. Three years.

Mr. BOLAND. Why have you reorganized this program again? You are apparently incorporating engineering into this function and increasing the total to $137 million. Isn't that correct?

Dr. ATKINSON. Yes.

Mr. BOLAND. Isn't that an area that you could possibly cut back? What was the first year of the RANN program?

Dr. PIMENTEL. 1971.

Mr. BOLAND. You got along fine without it before 1971, didn't you? The RANN program was formed sometime in 1971.

Dr. SANDERSON. Yes.

Mr. BOLAND. What was the first appropriation? Was it $60 million in 1971?

Dr. SANDERSON. The first formal request was around $80 million in fiscal year 1972. However RANN was formed in fiscal year 1971 and the budget for the activity in fiscal year 1971 was actually around $34 million.

Mr. BOLAND. What about any possible cuts in that program, Dr. Atkinson?

ENGINEERING AND APPLIED SCIENCE

Dr. ATKINSON. Mr. Boland, it would be wrong to link the engineering and applied science effort with the original RANN effort.

Historically, the Foundation has always supported a strong engineering effort. This Committee has been familiar with that work; it has been some of the strongest work done anywhere in the country. NSF's engineering programs in basic research stand with physics, chemistry and some others among the best work that NSF does. In the engineering and applied science effort, a major component is the engineering programs.

But the RANN program has undergone systematic cuts in dollars over the past five years. What we have now is a small effort in problem-focused research and a small effort in what we call applied research. This program is an open window to the best proposals in applied research; it responds to those proposals strictly according to their quality.

In most Federal agencies, research is aimed at specific applications; many areas of applied research do not receive attention unless the applied research happens to fit the mission agency's specialty. At NSF, we attempt to maintain a balance of effort. It is a small part of the NSF budget; for every $10 NSF spends in basic research, it spends only $1 in applied research. We believe there should be an open window to permit the pursuit of the best ideas in applied research.

Mr. BOLAND. You apparently weren't very satisfied with the way the Applied Science directorate was working; otherwise you would not be reorganizing again.

Dr. ATKINSON. Mr. Boland, the large part of the research supported by the RANN program was excellent research, but there was too much emphasis on directing the program from Washington and not enough concern with the scientific opportunities. The NSF reorganizations have stressed scientific opportunities.

Mr. BOLAND. I thought that the whole purpose of the RANN program when it was instituted, would be research-driven by national needs?

Dr. ATKINSON. That was certainly——

Mr. BOLAND. As a matter of fact, the acronym suggested it.

Dr. ATKINSON. That is correct. I may be speaking too freely here. Obviously I can't speak for the world at large and say NSF is not interested in national needs. What I am trying to say is this: the way to devise an effective applied research program—where NSF lacks a specific mission responsibility—is to drive the program with scientific opportunities rather than with needs.

Mr. BOLAND. How much of the $137 million that you request in fiscal year 1981 could be better carried out by mission agencies?

Dr. ATKINSON. There is no question about the Foundation's role in the engineering sciences. The applied research effort amounts to only $18 million in the open-window program I described earlier. No other part of the Federal government has such an open-window character.

Everything else in NSF's budget for applied research is aimed at specific areas. For example the funding for problem-focused research amounts to $30 million. About $18 million of that amount is allocated to the earthquake program. The remaining dollars are in other focused programs.

We believe some of these focused efforts should be in that directorate.

Mr. BOLAND. I suppose one of the problems that those of us who sit on this side of the table have is that when you have reorganizations that come within a relatively short period of time, you wonder whether or not the programs in which the directorate is engaged are really worthwhile programs; I am sure they are worthwhile, but whether or not NSF really ought to be in this field.

Dr. ATKINSON. As I said, the dollars that could be characterized in the RANN program of four or five years ago have been reduced significantly. A reorganization that joins engineering with applied research should not result in a reduction of the engineering programs.

OCEAN MARGIN DRILLING

Mr. BOLAND. You talked about Ocean Margin Drilling in your statement.

On December 11, I wrote the President expressing support for the new proposed Ocean Margin Drilling Program using the ship—"Glomar Explorer." I extended that support because first, since 1968, the drill ship Glomar Challenger, with support of the Foundation, has drilled about 500 holes in the sea floor resulting in some of the most exceptional scientific results ever achieved through a Foundation grant.

The second, the oil and gas industry is willing to support fifty percent of the $700 million cost of this program and that kind of support for a truly basic research program from industry is unique, is it not?

Dr. ATKINSON. Yes.

Mr. BOLAND. How much reliance can you put upon industry's willingness to pick up fifty percent of the $700 million tab?

Dr. ATKINSON. Eight companies are committed to the first phase. Commitments to the second phase cannot be obtained until the plans are definite and costs are identified, but I judge that more than eight companies will be involved and committed to the full program.

There is a great deal of excitement in the scientific and industrial communities for the project; I think they have found the joint planning effort to be an interesting exercise. It is part of the industry/university cooperation that NSF is trying to foster.

Mr. BOLAND. I also emphasized to the President one of the important spinoffs, of course, is being able to determine whether or not there is evidence of significant hydrocarbons at the ocean margin. You have buttressed that. Also, the most significant reason, perhaps, is the potential for outstanding basic science discoveries.

Now, since I addressed the letter to the President, the Legislative Authorization Committee, chaired by George Brown of California, has asked some very tough questions about the expenditure of $700 million for this program. It has been pointed out by Mr. Brown that the cost per hole of Explorer drilling is estimated at $50 million for each hole while the cost for drilling a Challenger hole was only about $500,000 per hole. That Committee pointed out that at $50 million cost per hole, only nine holes could be drilled under the new program in ten years.

So I guess the obvious question is, do you still feel and does the Board feel that sufficiently significant scientific objectives can be achieved at those costs and are the scientific results worth the cost?

Dr. ATKINSON. I think Dr. Johnson should respond.

Dr. JOHNSON. The main focus of this program would be the continental margins, where the marine sediments are the thickest that you find anywhere in the oceans. Half of all the marine sediments are just off the continental margins. That gives you some idea as to the massive amount of sediment in the region we are focusing on.

There is no other way of exploring these sediments and evaluating two critical parameters with regard to them: One is the organic content and the other is the thermal history through which they have gone. These are two key questions with regard to formulation of petroleum deposits. There is no other way to get this critical information on these deep sediments other than by direct sampling through drilling.

Since the sediments are deep, it takes a very deep hole to get through them. When you compare the cost of Challenger holes and Explorer holes, it would actually cost the Challenger about the same amount to drill to this same distance. Challenger can't drill as far as Explorer could, but if it were able to, it would cost almost as much as it would cost with the Explorer.

The big difference in the cost per hole is because Explorer will drill very deep holes. The average depth of Challenger holes has been about a thousand feet whereas Explorer will drill holes as deep as 20,000 feet.

SCIENTIFIC SUPPORT FOR OCEAN MARGIN DRILLING

Mr. BOLAND. Also, let me ask Dr. Hackerman, and Dr. Atkinson, if you fully support the ocean margin drilling?

Dr. HACKERMAN. The Board followed closely the development of this proposed program and believes it can be of great scientific importance. The Board endorsed its objectives and supports its objectives.

Mr. BOLAND. Unqualifiedly, no dissent?

Dr. HACKERMAN. No. If I were to tell you nobody in the scientific community was unhappy about it, I would be wrong. While supporting its implementation, I noted that such a large effort could not be undertaken within existing science budgets without seriously distorting other important scientific efforts.

Mr. BOLAND. Dr. Koshland.

Dr. KOSHLAND. That is right and that is why the National Science Board recommended that it should be listed as a separate line item in the budget of the National Science Foundation, so that the level of NSF funds devoted to it would be clear.

Mr. BOLAND. There has been some suggestion that the oil and gas industry doesn't want the government drilling anywhere where oil may be found—and this money is a way of insuring that that won't happen.

Dr. ATKINSON. Why do you say that?

Dr. HACKERMAN. Let me say that no one is quite certain about where oil might be found.

In other words, OMD may drill where no oil is expected and then find it, but we don't expect this to happen. The objective of the program is to examine the geology of the ocean margins and provide new scientific knowledge.

Mr. BOLAND. You don't doubt you will have the cooperation of the industry itself? You have no written commitments I take it, do you?

Dr. ATKINSON. No, we don't. The signing of the agreement will take place in two stages; a signing for the first-year agreement and then a signing for the subsequent years in a single agreement.

FUNDING OF OMD

Mr. BOLAND. How about the suggestion that perhaps this ought to be funded under some other agency or department like the Department of Energy or the United States Geological Survey?

Dr. ATKINSON. In some of the early discussions, we talked of funding from the three agencies. But there is a sound rationale for identifying a single agency to manage the program and defend it before the Congress. Yes, the U.S. Geological Survey and the Department of Energy have important roles in this area of research but a single funding focus is best.

Mr. BOLAND. I wouldn't disagree with that. It is my feeling, and I am sure of the Members of the Subcommittee that it would be

better managed in one place—and that place should probably be the National Science Foundation since it has run the Glomar Challenger program.

Dr. ATKINSON. Let me also comment that NSF has an excellent record in managing the Very Large Array and the Antarctic program. The ocean margin drilling program represents major funding for the Foundation, but I think the expertise exists to do the job properly.

SUPPORT OF PHYSICAL SCIENCES

Mr. BOLAND. A February 8, 1980 article in Science Magazine, states that roughly 83 percent of the Foundation's budget goes toward basic research. Is that correct?

Dr. ATKINSON. That is correct. It is 83 percent.

Mr. BOLAND. It also indicates that a new twist appears in the 1981 budget in that particularly large increases in the physical, mathematical and engineering sciences occur. It points out that these sciences have been taking a beating over the last twelve years at the hands of the life sciences—cancer research, and so forth. The implication of the Science Magazine article is that the support of physical sciences ought to grow at the same rate as the support of life sciences and environmental sciences. That seems to miss the major point that increases in support to any one field of science should be determined on the basis of its own needs and of its scientific and intellectual growth.

Can you demonstrate to us that the quality of the physical sciences is deteriorating because the quantity of support has been at the same rate of increase as the life sciences?

Dr. ATKINSON. Dr. Hackerman, would you like to answer that?

Dr. HACKERMAN. I believe there is a lot of life in the physical sciences and a lot of extremely interesting work going on in that field. It is a fact that the number of full-time physical scientists employed at doctorate-granting institutions diminished in 1979 and that the instrumentation and facilities with which they work has also become less "state-of-the-art," less advanced.

Mr. BOLAND. What about the life sciences growing at the expense of the physical sciences?

Dr. HACKERMAN. I do not accept that. Since 1972, Federal basic research support in the life sciences has been greater than in the physical sciences, but both have grown, particularly since 1976.

Dr. ATKINSON. One aspect of this issue relates to your earlier question about categorization of research. We would maintain that the research that NSF has supported in the biological sciences has not had a corresponding increase, either at NIH or at NSF. These gross categories, as you point out, must be checked with some care.

Dr. HACKERMAN. Furthermore, advances in the life and other sciences cannot be made without corresponding prior advances in the physical sciences. They are interrelated, and depend on one another both for their capability of understanding nature and for their use of facilities that permit one to be much more inquisitive in nature than without those facilities.

Dr. PIMENTEL. One of the manifestations of change, which I, too, would not characterize as a deterioration of U.S. physical sciences,

is that more and more state-of-the-art developments and new discoveries are happening abroad. I can give you a few examples.

In my own field, the discovery of multi-photon dissociation using high-energy lasers occurred in the Soviet Union. In certain areas of research Japan is very advanced, and Germany has attained advances in accelerator and synchrotron radiation research

To a certain extent, I can cite the multi-photon discovery as an example of access to the most modern, sophisticated, and expensive equipment. I myself could not undertake the experiments that were involved simply because I didn't have the instrumentation or the funds to buy it.

Mr. BOLAND. Mr. Coughlin?

Mr. COUGHLIN. Thank you very much, Mr. Chairman.

BASIC RESEARCH IN PRODUCTIVITY

The January 28, 1980, press release announcing the fiscal year 1981 budget quotes Dr. Atkinson as saying:

> The budget increase for NSF clearly emphasizes the President's often expressed understanding of this importance of science and its role in providing the knowledge required for social and economic progress, greater productivity, improved health and a more secure nation.

These, in particular economic progress and greater productivity, are things of which we haven't seen much recently. I wonder if you could cite what the National Science Foundation can do to correct this?

Dr. ATKINSON. That is a long story.

Mr. COUGHLIN. It will have to be brief.

Dr. ATKINSON. Let me comment. Before you came in, I quoted Professor Samuelson, the MIT economist—because his statement on this topic is persuasive. It reads as follows:

> More than one-half the growth in United States productivity is due to the advance of scientific knowledge quite aside from society's laborious thrift and sacrifice of current consumption standards in the interest of more productive capital for the future.

The analyses over the past 10 years have begun to identify the critical role of basic science in increases in productivity. Dr. Koshland works in recombinant DNA research, an area new to the scientific scene 10 years ago. Now financial sections of the newspapers carry accounts of new ventures and new companies. There is no question that the role of basic research in productivity is well established.

In this connection, I am concerned about Internal Revenue Service Regulation 861. It involves deductions for research and overseas sales of U.S. companies. For example, 30 percent of a company's sales are made overseas, then even though it does all of its research in the United States, the company can deduct only 70 percent of its research effort against its taxes.

The regulation is encouraging American companies to take their research out of the United States to other countries.

Mr. COUGHLIN. Have you recommended repeal of that?

Dr. ATKINSON. I am much concerned with that regulation.

Mr. COUGHLIN. More than concern, recommend repeal.

Dr. ATKINSON. It is the sort of thing that does impact on productivity in this country.

ENGINEERING AND APPLIED SCIENCE

Mr. COUGHLIN. The RANN program, as you know, is one about which I had reservations when it was first put in place by the House Science Committee. Are you going to scrap that now?

Dr. ATKINSON. The Foundation plans a strong role in applied research, but over time NSF has come to a somewhat different view about how the programs should be managed and directed. The change is represented in the current NSF plan.

Mr. COUGHLIN. If you had a cut in the National Science budget, is that where you would cut it?

Dr. ATKINSON. No. I would follow the ZBB cuts. Applied research is a small effort now; I would not want to see it cut more deeply.

Mr. COUGHLIN. I take it the Chairman has asked for, and you are submitting, your ZBB priority rating analysis?

Dr. ATKINSON. Yes.

END-OF-YEAR OBLIGATIONS

Mr. COUGHLIN. There has been recent publicity in some agencies that have obligated large sums of money at the end of the fiscal year. Can you provide for the record the obligation made by the National Science Foundation?

Dr. ATKINSON. Yes, we can. We are not in that mode. We tend to obligate varying amounts during the year but we do not have a significant burst of obligations at the end of the year.

Mr. COUGHLIN. You have two-year money?

Dr. PIMENTEL. We have two-year money, except for science education; it has one-year money.

[The information follows:]

NATIONAL SCIENCE FOUNDATION
COMPARISON OF APPROPRIATIONS AND
AUGUST/SEPTEMBER OBLIGATIONS
FY 1978-FY1979
($ in Millions)

Appropriation Account	Total Appropriation 1/	Aug./Sept. Obligations	Percent Aug./Sept.
FY 1979			
Research and Related Activities	$842.9	$179.8	21%
Science Education Activities	80.0	30.0	37
Special Foreign Currency	4.0	0.8	20
FY 1979 Total	$926.9	$210.6	22.7
FY 1978			
Research and Related Activities	$777.9	$116.7	15%
Science Education Activities	73.9	28.8	39
Special Foreign Currency	5.4	3.1	57
FY 1978 Total	$857.2	$148.6	17.3

1/ Includes new obligational authority and funds carried over from prior year, where applicable.

PROGRAMS WITH SIGNIFICANT PROBLEMS
IF A LIMITATION WAS PLACED ON OBLIGATIONS
DURING THE LAST TWO MONTHS OF THE FISCAL YEAR

A. Research and Related Activities Appropriation - 49-0100

- This is a two-year appropriation (was annual account in FY 1974) with an annual obligation rate in excess of $900 million. This account funds the bulk of NSF program activities which consist primarily of grants to colleges, universities and non-profit institutes for the conduct of basic scientific research. The grants are made largely in response to unsolicited proposals. Restricting the obligation rate in the last two months of a fiscal year would present two major problems. First, if there might happen to be delays in the NSF peer review process the obligation rate in the last two months could easily exceed 20%. Secondly, limitation could conceivably preclude NSF from making a series of large awards or initiating a new program thrust in August or September. This would present a serious problem since most NSF performers are geared to academic year operations which start in the Fall and end in the Spring. NSF would not be able to get cash advances out for research project operations due to lack of obligation authority.

- Obligation trends for the last three fiscal years in this account for August and September are:

--- FY 1979 - 21%
--- FY 1978 - 15%
--- FY 1977 - 20%

B. Science Education Activities Appropriation - 49-0106

- This is a one year appropriation with an annual obligation rate of about $85 million. A limitation on the last two months obligations would present a major problem since this is a grant program where a large part of the obligations are made in August and September for fellowships, traineeships, and education projects to be accomplished during an academic year. If a limitation were imposed on this appropriation, the award dates would have to be moved up thereby upsetting the timing of NSF peer review operations and related administrative activities causing expensive inefficiencies in agency operations.

- Obligations trend August - September for this account are:

--- FY 1979 - 37%
--- FY 1978 - 39%
--- FY 1977 - 35%

C. NSF Special Foreign Currency Program - 49-0102

- This is a two year appropriation which has been annual in the past and has an annual obligation level of about $5 million. The problems created by a limitation are similar to those of the Research and Related Activities appropriation.

- Recent August - September obligation trends are:

--- FY 1979 - 19%
--- FY 1978 - 57%
--- FY 1977 - 12%

Mr. COUGHLIN. Thank you, Mr. Chairman.
Mr. BOLAND. Mrs. Boggs?

FUTURE OF SCIENCE EDUCATION PROGRAMS

Mrs. BOGGS. Thank you, Mr. Chairman.

Dr. Atkinson, you have pointed out that the intensive involvement in RANN by West Germany and Japan have resulted in high productivity growth rates; in a leading position in selected fields; and that one of the reasons for this is the increasing strength of science abroad.

We are being challenged apparently by other nations to scientific preeminence, and that is being translated into severe competition in high technology markets.

This is having an adverse impact upon our balance of payments posture and yet, cuts are being considered in the field of science education.

If that is a correct assumption on my part, how does that agree with the idea that science education can indeed produce the kind of scientists that will be able to increase our productivity and, therefore, increase our competitive stature with the rest of the world?

Dr. ATKINSON. Mrs. Boggs, did Dr. Press talk about the President's special request related to science education?

Mr. BOLAND. Dr. Press did not indicate what the targets may be.

Dr. ATKINSON. About two weeks ago, I received a letter jointly addressed to Secretary Hufstedler and to me. The President requested a study due July 1, on the issue of current and future scientific and engineering manpower.

There is increasing concern about scientific manpower both at the bachelor-degree level for engineers and the doctoral level in certain areas of science such as solid state physics and computer science.

In his letter, the President referred to his familiarity with the amount of calculus studied by the average student in the Soviet Union. I think the issue of scientific manpower is a critical problem that we must understand in much greater depth than we do now.

Mrs. BOGGS. Will there be no decision before July 1 to cut the science education budget?

Dr. ATKINSON. I was hoping I was going to bypass that question. I think there could be significant cuts in the science education budget.

Mrs. BOGGS. Is such a suggestion compatible with increasing our productivity and, therefore, our competitive posture in the world?

Dr. ATKINSON. It is a question of making these cuts in the entire NSF budget. Different viewpoints are expressed within the National Science Board and within the scientific community. NSF's special thrust in fiscal year 1981 is primarily in the physical sciences; it would be the first item that NSF would want to protect.

INSTRUMENTATION NEEDS

Mrs. BOGGS. I understood, that you had some difficulties in being competitive with Germany and Japan because of lack of instrumentation.

Dr. PIMENTEL. I felt I was quite competitive but I would have been more so with the instrumentation.

Mrs. BOGGS. My apologies. Of course you are. But this is also an area that I would like to ask about. In the area of science education, of course, the colleges and universities depend very much on the funds for instrumentation in replacing their outmoded equipment. Will this be cut as well?

Dr. ATKINSON. It might be. The fiscal year 1981 budget contains a good increase for instrumentation for colleges as opposed to advanced research groups. The idea is to improve the quality of science education through students access to sophisticated equipment. Faculty in schools of engineering, for example, are concerned by the lack of access to sophisticated equipment. Like other areas of science education, funding for such equipment would take a somewhat greater decrease than the basic research component.

Dr. PIMENTEL. If NSF takes a large cut, it will be painful for the Foundation and science education may have to take a somewhat larger cut in order to protect some of the principal thrusts. However, the two- and four-year college instrumentation program is in the cross-directorate program, and we expect it will be protected somewhat.

NATIONAL CENTER FOR MARINE TECHNOLOGY

Mrs. BOGGS. Following along with science education, can you tell me what the plans are for the proposed National Center for Marine Technology?

Dr. ATKINSON. We have a proposal in the Engineering and Applied Science Directorate.

Dr. SANDERSON. We held a workshop a few months ago looking at the need for additional research in marine sciences and ocean engineering. That workshop brought together approximately two dozen of the outstanding scientists and engineers, both from industry and from the academic community, to look at the research needs including research facilities.

An earlier feasibility study had been completed on the subject. We have recommendations for such a center from this committee, particularly for research facilities that will expand the current shallow water research, as well as address some issues of ship design for shallow water maneuvering. Unfortunately, in the overall ranking of priorities, it is not included in the budget this year.

Mrs. BOGGS. Thank you, Mr. Chairman.

Mr. BOLAND. Mr. Sabo?

GEOGRAPHIC DISTRIBUTION OF RESEARCH FUNDS

Mr. SABO. Thank you, Mr. Chairman. I have a couple questions.

According to your testimony, 28 percent of all Federal research funds comes under conduct of NSF.

Dr. ATKINSON. Yes.

Mr. SABO. I am curious about the process you use in making those awards. When I take a look at the 1979 summary of where our monies went, you could almost call it the aid to California bill.

Dr. ATKINSON. I think the University of Minnesota does quite well.

Mr. SABO. I know our State has about two percent of the population, we are high technology State with a large major research university, and high technology industry. The total grants that come to our State are approximately one percent. Now, I tend not to be greedy, but I do look at things.

I look at California and not quite 20 percent of the total pot ends up in California. That makes me curious.

Dr. ATKINSON. There have been several studies on this question. Let me say first that the entire process is done in the open; every principal investigator can examine the reviews of his proposal. The scientific community knows what proposals have been funded. One of the ways that we might come to some understanding is to pick a few professors from the University of Minnesota, sit down, and talk about the process.

I do not think you would find a reasonably representative group at the University of Minnesota who would say the NSF is biased in its selection of reviewers or distribution of funds. It is true we are biased because we are trying to respond to excellence but that excellence is not determined by geography.

Let me tell you how a Californian would feel. Against measures of scientific excellence such as the number of Ph.D.s, the number of members of the National Academy of Sciences; and the number of postdoctoral fellows who choose to work in California universities, the State of California is underfunded.

Mr. SABO. I would expect if you follow a pattern of what currently exists that is simply going to reinforce the status quo.

Dr. ATKINSON. There is some truth to that, but again, it depends on what a university wants to do. If a university wants to promote excellence——

Mr. SABO. I hear that word floated around regularly, but I never know what it means.

Dr. ATKINSON. To give you an example, Oklahoma State University has been working hard to promote excellence. It has taken a number of steps. The funding from NSF to Oklahoma State has gone up steadily; it is tied to new initiatives taken by the university to improve the quality of its research.

It is true NSF responds to excellence, but NSF responds in a public manner. Every scientist in this country can know exactly how the dollars are distributed, including what proposals NSF is supporting.

If anyone thinks it is unfair, he should speak up. I don't think you are going to find the scientific community as a group speaking up on this issue. I am sure you will find one or two people who will be unhappy, but if you have a group at the University of Minnesota, I think they will say, "Yes, it is fair."

Mr. SABO. I just look at gross numbers, and something tells me that your process is a little out of kilter.

Dr. PIMENTEL. It is true that California gets the largest single total of NSF dollars and New York places second. But if you look at those two States on the basis of NSF dollars per capita, California is seventh and New York is tenth. And if you look at Federal dollars per capita, California is seventh, New York close to 23rd. Certainly it can be said that on a per capita basis these States are

not egregiously out of line. Looking only at the total dollars doesn't tell the whole story.

Mr. SABO. Mr. Chairman, I just look at gross figures and they tell me something is out of whack in the whole process.

Dr. ATKINSON. Something is out of whack if you look only at basic research dollars from the NSF. It is true our distribution is not a uniform distribution. But take another measure of those same States, California and New York and Massachusetts. They are one, two and three in NSF funds; in Federal spending per Federal tax dollars paid, California is 24th, New York is 40th, and Massachusetts is 33d. I must say that I can understand complaints from many States, but I find it hard to understand how Minnesota can feel this way.

Mr. SABO. Again, I look at the figures. I think in total grant money we get just slightly over one percent. If we did not have the strong research orientation in both higher education and the private sector, I might understand that.

Dr. ATKINSON. Unfortunately, I don't have the Minnesota numbers before me. I have the top 10 and the bottom 10.

Mr. SABO. In 1979, it seems to me it was a little over $9 million.

Dr. ATKINSON. Minnesota as a State is 24th in NSF funding. In NSF funding per capita, it is 22nd. In non-NSF, Federal R&D support, it is 16th.

Mr. SABO. I would like to see some of that information because the gross figures do not look appropriate to me.

[The information follows:]

State of Minnesota
Ranking of Federal NSF R&D Data

I. Rankings by Selected Measures, 1978

	Rank
A. Demographic	
General Population	19
Ph.D.s (Science and Engineering)	20
Graduate Students (Science and Engineering)	21
B. Funding	
Federal Research and Development	20
NSF Research	24
Other Federal Research at Universities	16
C. Funding Per Capita	
Federal R&D	30
NSF Research	22
Other Federal Research at Universities	16

II. Funding and Demographic Trends, 1975-1978

A. Percentage Shares

	1975	1976	1977	1978
NSF Funds	0.7%	0.9%	0.8%	1.2%
General Population	1.8	1.8	1.8	1.8
Ph.D.s (S&E)	1.7	1.7	1.7	1.7
Graduate Students (S&E)	1.8	1.7	1.6	1.6

B. Rankings, NSF Funds/Demographic Measures

	1975	1976	1977	1978
NSF Funds Per Capita	36	30	35	22
NSF Funds Per Ph.D. (S&E)	38	31	32	23
NSF Funds Per Graduate Student (S&E)	44	32	37	23

COOPERATIVE AUTOMOBILE RESEARCH PROGRAM

Mr. SABO. As I have listened to the discussion in the energy area, I am convinced that one area where we do little and could have the largest impact is in the area of both applied and basic research as it relates to the automobile.

We desperately search for the new and exotic when the largest contribution might be gained through modifications of what is.

I am just curious as to whether NSF is involved, or is contemplating getting involved, in basic research on how we propel ourselves in a more decentralized manner in this country.

Dr. ATKINSON. An item that is not represented in NSF's budget but much discussed is a cooperative automobile research program. NSF will not be the lead agency but, in conjunction with the Department of Energy, will play a key role in the car program. For our part of it we will emphasize industry-university cooperative efforts, linking university scientists with industrial scientists in joint projects.

Mr. SABO. What would your role be?

Dr. ATKINSON. We would be funding some joint research efforts. NSF's plans are not public, and they are not definite.

Mr. SABO. When are we likely to hear about this? I have heard about it about two or three times in generalities.

Dr. PIMENTEL. This program may be delayed if the budget cuts are as large as projected. It may be one of the deferred programs.

Mr. SABO. Thank you, Mr. Chairman.

Mr. BOLAND. Thank you.

U.S.-U.S.S.R. COOPERATIVE RESEARCH PROGRAM

We talked about the U.S.-U.S.S.R. Cooperative Research agreement. You indicated that you had $3.2 million in the 1980 budget, and the same in the 1981 budget. Are you still continuing to obligate the $3.2 million for fiscal year 1980?

Dr. PIMENTEL. We may not obligate all of that. We are looking into the state of our obligations at this particular moment and it is conceivable that in the course of adjusting the budget cuts that may be one of the items that will be sacrificed.

Mr. BOLAND. Is your answer that you are still obligating or that you are not obligating 1980 funds as part of the U.S.-U.S.S.R. cooperative agreement?

Dr. AVERCH. We have the funds. However, the Administration is taking a program-by-program look at items within the $3.2 million. So, there is no guarantee we will obligate the full amount. The Administration will decide what to fund on a case-by-case basis. We are trying to balance benefits to us against pain to the Russians.

Mr. BOLAND. Have you obligated any of the $3.2 million and can you indicate how much?

Dr. PIMENTEL. Somewhere between two and two-and-a-half million presently obligated.

Mr. BOLAND. How would you look upon a limitation in the Appropriation Act which would indicate our displeasure with the Soviet Union after the invasion of Afghanistan? That is a simple, straightforward message, isn't it?

Dr. AVERCH. Mr. Boland, as I said before, the House Authorization Committee——

Mr. BOLAND. Did you get the same question there?

Dr. AVERCH. Yes, sir. It is a matter of balancing pain to them versus benefits to us while not destroying the larger framework of the agreement with the Soviets. Whether we like it or not, we will have to continue talking with the Soviets in some form.

Most of the scientific community feels that it would be a tragedy if we were to break the agreement completely and have no interaction. It would be tragic in the sense of losing scientific contracts that are important to us, access to scientific developments that we would like to have knowledge of, and I include our ability to assess Soviet capabilities in that. Also conceivably, it could harm some people you want to help in the Soviet Union by cutting their contacts with the U.S. scientific community off completely. The fate of "Refusniks," the dissidents, people like Sakharov, in my own view, would be much worse if we cut off all contact.

Mr. BOLAND. I guess one of the problems we have is whether or not the scientific community is willing to make its sacrifices to balance the budget as the Administration apparently is going to do and desires. And whether or not the scientific community has any desire to show its resolve when there are conditions in the world which clearly indicate that resolution is necessary if we are going to send the right message to countries that violate a nation's sovereignty.

Dr. AVERCH. The message sent by the National Academy of Sciences about two weeks ago is indicative of the scientific community's feelings.

MATHEMATICAL AND PHYSICAL SCIENCES

Mr. BOLAND. We will now turn to mathematical and physical sciences. The increase for mathematical and physical sciences is $37 million for fiscal year 1981. On page A-3, below the table, it is stated that the 16.7 percent increase in the MPS budget for the fiscal year 1981 represents significant real growth. Do you have any idea how much growth there will be in this area for the Department of Energy, DOD or NASA in the coming year?

Dr. KLEMPERER. I am sorry, I really don't.

Mr. BOLAND. You may supply that for the record.

[The information follows:]

SUPPORT FOR BASIC RESEARCH IN THE MPS DISCIPLINES IN OTHER AGENCIES

In the MPS disciplines in the Department of Energy, the fiscal year 1981 budget request for basic research is $683.6 million, an increase of $59.8 million, or 9.6 percent, over fiscal year 1980. The DOD fiscal year 1981 budget request for basic research in the mathematical and physical sciences is $241.4 million, an increase of $39.4 million, or 19.5 percent, over fiscal year 1980, not including DARPA funds. Of this amount, slightly less than one-half provides research support to academic institutions. Total support of basic research in NASA increases by 8.5 percent to $581 million in fiscal year 1981. However, research related to space sciences is emphasized, and only a very small fraction of this total bears any direct relation to MPS funding.

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EROSION OF RESEARCH SUPPORT IN MPS DISCIPLINE

Mr. BOLAND. On page A-3 again, there is a statement which indicates that: "overall Federal support for research in the MPS disciplines has eroded to the point where adequate funding is no longer available to the most highly qualified investigators."

Won't the increases being sought for increased MPS research at DOD, DOE and NASA cure this problem?

Dr. KLEMPERER. Of course it will be interactive. It, again, depends on the manner of delivery of these research funds. Of course the increases in other agencies would help. I think the manner of funding of research by different agencies is quite different.

I think the National Science Foundation does play a unique role in funding the very best investigators.

Mr. BOLAND. Can you give the Committee an account of the effects of the physical sciences support erosion that you have indicated has occurred?

Dr. KLEMPERER. Typically in chemistry and material science, which I think have large impacts on our societies. Our average grant is about 60 to 70 percent of what is really needed by the investigator so this will slow down a typical investigator. Likewise, the grants themselves are quite competitive so that we are funding approximately 70 percent of highly meritorious grants. So that we are funding in the fields of chemistry and material science at about 50 percent of what we would like to be funding, and I think that the base of people who are applying to us is even slipping as individuals are rejected. They don't apply a third and fourth time to be rejected steadily. So I would say we are underfunding highly qualified investigators and certainly large areas of scientific effort such as the production of technological data probably suffer badly already because it is not as innovative as other proposals. So I would say there is a general diminution of effort in these areas.

PH. D. MATHEMATICIANS

Mr. BOLAND. On page A-I-2 under Mathematical Sciences, it states that approximately 80 percent of the recipients of the Ph. D. in the mathematical sciences take academic positions. By providing a 17.7 percent increase for mathematics, aren't you simply creating a further market for new Ph. D. mathematicians in the same places where they were before?

Dr. KLEMPERER. A large amount of the increase is for alternative modes of support. In other words, what we want to do there is to provide truly effective advanced training for post-Ph. D.'s and even faculty members.

The model of great success in the United States in mathematics has been the Institute for Advanced Studies in Princeton where some of the foremost mathematicians are now or were at one time, in the course of their training or education or scientific career. So that a lot of this money will be spent on really new modes of support of mathematics rather than simply——

Mr. BOLAND. Where are the Ph. D.'s going to be doing their research?

Dr. KLEMPERER. At a variety of universities. The mathematicians have grouped the universities into three classes: the very elite of

which there are about five—Harvard, Princeton, etc., the large very good schools, i.e. large State schools; and then the so-called third tier.

Mr. BOLAND. But isn't there a need for Ph. D. mathematicians in industry and business, outside of the universities, Federal agencies and laboratories?

Dr. ATKINSON. The statement needs correction. What you are referring to is 80 percent of the Ph. D.'s in core mathematics—pure mathematics. But the cohort includes the mathematical sciences in general—computer science, operations research, a range of other areas—where the percent of mathematicians going to non-university jobs would be much larger. What we have seen is a decline in the number of Ph. D.'s in core or pure mathematics and a shift into these more applied areas of mathematics.

MATHEMATICS INSTITUTE

Mr. BOLAND. Page A-I-14 in the last paragraph states that of the proposed increase of $1,050,000, or roughly 45 percent, $800,000 will be used for supportive research "in modes of support" of research in addition to research project support. Is this for the Research Institute of Mathematics that has caused so much controversy?

Dr. KLEMPERER. It may be.

Mr. BOLAND. Is it?

Dr. ATKINSON. It may be. A decision has not yet been made.

Dr. PIMENTEL. We have proposals before us but with the option that we may accept none. The option is clearly stated in our request for proposals.

Dr. ATKINSON. That is absolutely right. I think the question of how good a mathematics institute could be is being weighed against other forms of alternative modes, so we are trying to let the best man win.

Mr. BOLAND. Thank you, gentlemen. The Committee stands adjourned until 10 o'clock tomorrow morning.

WEDNESDAY, MARCH 12, 1980.

MATHEMATICAL AND PHYSICAL SCIENCES

Mr. BOLAND. The Committee will come to order. Let me restate the last question from yesterday's hearing.

We will turn to the Mathematical and Physical Sciences section. On A-I-14, the last paragraph indicates that the proposed increase $1,050,000 or roughly 45 percent of that, $800,000, will be used for supportive research "in modes of support of research in addition to research project support."

MATHEMATICS INSTITUTE

Is this for the Research Institute of Mathematics that has caused so much controversy?

Dr. KLEMPERER. Only if desired by the mathematical community.

Mr. BOLAND. I am sure you have seen the Science magazine article.

Dr. KLEMPERER. Yes, sir.

Mr. BOLAND. There are a couple of quotes here that I am sure you are familiar with but let me refresh your memory.

The opening paragraph says:

> For the past two years, a number of eminent mathematicians have been carrying on a crusade against the National Science Foundation (NSF). Their aim is to prevent the NSF from diverting $2 million, which is about 10 percent of the Foundation's mathematics budget, to a proposed mathematics institute.
>
> Inevitably, supporters of the institute have gotten pulled into the fray as university has been pitted against university and, in one case, even brother against brother. The dispute offers a rare glimpse of how major projects can be pushed through the NSF and how difficult it can be to stop them.
>
> In January of 1978, the NSF tried again to get official backing for the institute from the mathematics society. It asked the science policy committee to reverse its 1976 decision, but the committee deadlocked.

Why do you think that such an Institute is necessary in the face of so much criticism from mathematicians? Is it worth it?

Dr. PIMENTEL. We have been particularly sensitive to this variance of opinion among the mathematicians. Dr. Klemperer has set up a special review process to make sure that we have direct competition in the decision process between the proposed Mathematics Institute and other possible means of improving the mathematical sciences.

This review process will involve three panels. The third will be explicitly charged with making comparative decisions between the Mathematics Institute and other possible uses of that money in mathematics. The panel will be made up of representatives of those who favor the Mathematics Institute and other scientists who have expressed alternate opinions.

I think Dr. Klemperer has provided us a review process that will guarantee the decision is not merely a matter of momentum.

Mr. BOLAND. Apparently there is considerable controversy within the mathematics community with reference to the Institute. I will quote another paragraph.

"Taken aback by Slichter's questions, the NSF staff contradicted itself several times in trying to justify the Institute. First it said, yes, the mathematicians wanted the Institute. Then it said that it was not sure the mathematicians wanted the Institute, but if they did not want it they would not send in good proposals for Institute projects.

"Slichter pointed out that calling for proposals is no way to find out what the mathematicians want."

This is pretty good philosophy not only in this area but also in the grant area. Obviously, you are not going to set it up unless there is some consensus within the community. Why don't you respond to these statements?

Dr. ATKINSON. Our job is to stimulate discussion on these issues.

Mr. BOLAND. And you have done it here.

Dr. ATKINSON. That is our job. But in some of the early discussions it was inferred that if NSF had a mathematics institute there would also be new money for mathematics. That led to some of the confusion. What we have tried to convey is that there are only so many dollars set aside to support mathematical science and that the issue is the best way of supporting it.

The review process Dr. Klemperer has set up guarantees good discussion and a balance of different opportunities. It is not a question of adding on an institute versus not adding an institute. The question is, how do you want to spend the dollars set aside for mathematical science? That is the question being debated. It is a good debate, and I am pleased that there is so much discussion on the matter.

Mr. BOLAND. I assume that what is contained in this article in the Science magazine is basically correct.

Dr. ATKINSON. Yes, it is.

Mr. BOLAND. Have you ever seen the article?

Dr. ATKINSON. Yes, I have.

Mr. BOLAND. When did you first see the article?

Dr. PIMENTEL. Within two hours after the Science magazine entered the Foundation. I have a folder full of similar material.

DECISION ON MATHEMATICS INSTITUTE

Mr. BOLAND. Who came up with the idea of establishing the Institute?

Dr. ATKINSON. It is not a new idea, it has been in the mathematics community for 50 years. A distinguished institute at Princeton University has been critical to the development of mathematics in the United States. The issue is whether the mix of support is right.

Mr. BOLAND. I am sure when you come to the decision it will be the right one and as I understand, you haven't come to that conclusion yet.

Dr. KLEMPERER. No. We are trying to let the mathematics community decide what is the best way to provide a high degree of interaction in advanced mathematics and we are trying to evaluate effectively all the ways of doing this.

Dr. ATKINSON. Keep in mind it isn't whether we will have an institute or take it away. We trust this Committee will tell NSF how much money it can spend in mathematics.

Mr. BOLAND. You have never had unanimity with respect to your proposals anyhow within the mathematics community, have you?

Dr. ATKINSON. But there has been a history of the view that may be described as follows: If you can get a big project added on, you will get more money in the field of science. That is the view we work against.

Mr. BOLAND. That is exactly what happens, too.

Dr. ATKINSON. We don't want to argue whether the Institute is on or off.

Mr. BOLAND. I think you are right. That is why we are faced with a $1,148,000,000 budget for fiscal year 1981.

The National Science Foundation is 30 years old this year.

Dr. ATKINSON. Exactly.

COMPUTER SCIENCES

Mr. BOLAND. On page A–II–1, we find that you are requesting an increase of $5.1 million in fiscal year 1981 above the level of $18.2 million for computer research.

On page A–II–4, in the second paragraph, the legend states that $3.7 million will be used in the Special Projects Program element

for "longer range support of experimental research." What do you have in mind here?

Dr. KLEMPERER. To permit universities to begin to partake of experimental programs in computer science. Activities in universities in this area are virtually all theoretical, and we feel it is necessary that there be an experimental component to test theories as they are developed and to promote the development of further theory.

We are not doing this at present.

Mr. BOLAND. We are not establishing a computer science institute, are we?

Dr. KLEMPERER. No.

Mr. BOLAND. On page A-II-13, there is an indication that the Foundation does not intend to extend the duration of your grants in computer sciences—so what is your plan for "long-range support"?

Dr. KLEMPERER. These are planned to be approximately 5-year grants for experimental computer science. They will be competitive grants. Proposals will be submitted with the view that if granted they will have a duration of five years. Obviously, renewal is possible at the end in competition with other requests.

Mr. BOLAND. At the top of page A-II-6 it states that "the longer range support" for experimental computer research is a new initiative begun in the fiscal year 1980—and that the effort is closely coordinated with DOD, DOE, NASA and NIH, and that the support for experimental research provided for DOD at three or four institutions is much greater than that available to any other institutions.

I am sure you are not trying to compete with DOD but what kind of commitment have you taken up here? How extensive is this going to be particularly in view of what these other agencies are doing in this area?

Dr. KLEMPERER. Yes. First of all, we are in close contact with the Department of Defense on computer science and we really want to interleave our activities effectively with this agency. The type of commitment towards universities is flexible in the sense that we will honor both requests for large grants, that is, of the order of a million dollars a year, and also much smaller ones. We are planning a network so that different universities' computer groups can communicate effectively. We will be able to respond to the best proposals of the university community, and we are trying to effectively interact with the Department of Defense so that we do not in any way do the same thing they are doing and yet interleave our activities to obtain maximum efficiency.

INDUSTRY RESEARCH IN COMPUTER SCIENCE

Mr. BOLAND. The amount requested for 1981 is a 20 percent increase for computer sciences. I think we can agree that this is an area where business, industry and the Government are all supplying a significant amount of research, both basic and applied.

Dr. ATKINSON. No. I don't think that I would agree.

Mr. BOLAND. The next question is: Why should NSF add to an already healthy level of research activity in this area?

Dr. ATKINSON. Industry representatives in the computer field will argue that this is one of the important thrusts in the Federal budget.

Mr. BOLAND. What are they not doing that you are going to do?

Dr. ATKINSON. Industry research in computer science tends to be focused on development of software with immediate application. In the Defense Department, such research tends to be focused on defense-related issues. The development of new languages, and new concepts in computer science has fallen almost entirely to the National Science Foundation.

We provide a type of research on the frontier; it develops the new languages and new approaches to computer architecture. I think NSF's role in computer science is unique. I have said repeatedly in this Committee that I am concerned by the level of funding provided by the Federal government for computer science.

Mr. BOLAND. You have, indeed. For the record, I would like the NSF to indicate the breakthroughs that have come as a result of the research in computer science.

[The information follows:]

SIGNIFICANT CONSEQUENCES OF NSF SUPPORT OF COMPUTER RESEARCH

Four examples of significant NSF influence on computer research are:

(1) From 1956 through 1972, NSF provided a total of approximately $75,000,000 to help universities establish computer facilities for research. This supported research in computer software that established the present technology of programming languages, operating systems, text editing or other word processing systems, office automation, and other presently "hot" lines of development. It also gave the U.S. a generation of people trained as computer scientists and computer users and a resulting generation time advantage over other competitors such as Japan or Germany in computer systems technology.

(2) The first support for research in computer time sharing was provided by NSF with a grant to MIT in 1962. This work was then picked up by the Advanced Research Projects Agency of the Department of Defense with greatly expanded support to develop the time sharing systems which are used throughout the world today.

(3) The concept of computational complexity was first introduced by Dr. Juris Hartmanis while he was a research scientist at General Electric Corporation but he was unable to obtain support from General Electric to continue research on this highly theoretical and abstruse topic at a satisfactory rate. He left General Electric to found the computer science department at Cornell University where he and his students continued working on the theory with support from NSF. This field quickly matured into the theoretical foundation of computer science and has found application in hardware, software and algorithm design throughout the world, including applications within General Electric Corporation itself.

(4) An algorithm called the "perfect shuffle", which can be shown to be the best possible algorithm for use in many important scientific or engineering calculations, was developed by Professor Harold Stone, University of Massachusetts, while he was doing research on parallel computing methods with NSF support. The use of this algorithm as the basis for design of ultra high-speed computers using Very Large Scale Integrated Circuits (VLSI) is now being explored by researchers at New York University and Burroughs Corporation.

RESEARCH RESULTS

Dr. ATKINSON. We published this week a booklet on how basic research reaps unexpected rewards. The booklet resulted from our concern with some titles of NSF research grants. We wanted to publish a document on research that at first didn't seem to be significant but which led to important developments. I will provide it for the Committee files.

Mr. BOLAND. The Physics program subactivity is detailed on page A-III-1 where you are requesting an increase of $10,139,000 to a total of $73,500,000 for 1981.

On page A-III-5, I note that you intend to continue supporting the new Institute for Theoretical Physics.

Dr. KLEMPERER. Yes.

Mr. BOLAND. Hasn't this institute been a target of strong criticism within the physics community?

Dr. KLEMPERER. It certainly has. I think we have enough information to indicate that it is a success in the following sense: One-third of the people that go now to the Institute for Theoretical Physics bring at least part of their own support. For eight possible post-doctoral positions available next year there are 200 applicants. That it is perceived certainly by a sector of the physics community, that this is a desirable place to be. And if people provide their own support to be at a place, this indicates it is not simply because they have nothing better to do.

Mr. BOLAND. As I understand it, there were some objections on the part of the Senate Committee to this Institute. Is that correct?

Dr. ATKINSON. There was some discussion and some uneasiness, but no construction is involved. At the end of five years if this Institute has not proved to be a wise expenditure of funds in the physics community, we are prepared to phase it out.

Mr. BOLAND. Do you recall what the Senate Subcommittee on Appropriations cricitisms were?

Dr. ATKINSON. It might have been similar to the criticism of the mathematics institute; that NSF was trying out an idea, and it wasn't the high priority of the physics community.

Mr. BOLAND. Have you received much correspondence with respect to this particular Institute either for or in opposition to it?

Dr. ATKINSON. Before the decision, there was a great deal of correspondence. Since then, it has been an established fact, and what we established has been a tremendous success——

Mr. BOLAND. Prior to making the decision, what would you say the public consensus was on this issue?

Dr. KLEMPERER. I think it was probably split. I don't know if there was a consensus—there was certainly not unanimous support.

Dr. ATKINSON. These are public matters, brought before the National Science Board. There is a great debate on these issues.

Dr. PIMENTEL. It is fair to say there was a division within the physics community, but by no means was it as extreme as came out in the——

Mr. BOLAND. Did you consult, for instance, with the American Institute of Physics, and the Institute for Advanced Study, in your evaluation of the decision to establish the Institute for Theoretical Physics?

Dr. ATKINSON. We had wide consultation; I don't recall whether we discussed it with the American Institute of Physics.

Mr. BOLAND. Wouldn't that have been a good forum?

Dr. ATKINSON. Mr. Boland, We tend not to consult with societies because we are less interested in getting the societies responses.

We tend to consult with distinguished scientists in the field. We don't want a society voting something up or down; we prefer the counsel of the best scientists.

NATIONAL SCIENCE BOARD VIEW

Mr. BOLAND. What about the decision of the National Science Board itself? What was its position on this issue?

Dr. HACKERMAN. The Board unanimously approved the proposed award.

Dr. ATKINSON. The person finally selected as director is Professor Walter Kohn, a distinguished scientist. As I say, the Institute is a five-year effort and it will be carefully evaluated.

Mr. BOLAND. You don't think there has been any failure on the part of the NSF review procedure, particularly in the light of the criticism that has been directed at the Mathematical Institute and this Institute?

Dr. ATKINSON. Yes. Our job is clearly to make sure that the physics community gives us its best advice and that it feels it has been properly consulted. In the early discussions of the Theoretical Physics Institute, there was some feeling that we had not consulted broadly enough.

Dr. PIMENTEL. I can add I presided over a Director's Action Review Board on the Theoretical Physics Institute, and I also was present in the National Science Board program review. In each arena the type of challenging questions you are asking of us were asked and discussed at great length. Certainly the review process was critical and we do believe that the judgment, though not unanimous, was the proper one.

CORNELL ELECTRON STORAGE RING

Mr. BOLAND. On pages A–III–4 and 5, the justifications discuss the Cornell Electron Storage Ring. As I recall, it was indicated by NSF that the Cornell Electron Storage Ring was of such great importance that there was general agreement that it should be built at a possible sacrifice in funding of other-NSF supported high energy physics projects. The thrust of NSF's statements were essentially that the consequences of that sacrifice would be assimilated without an increase in constant dollar funding of the high energy physics effort.

Why now is there a request for $2.7 million to "restore vitality of university-based user groups by providing instrumentation and technical support which was restricted during the CESR conversion"?

It appears that in the past you indicated you could assimilate the additional cost of the CESR without a change in the overall total of the physics budget and now you are going back on that statement and feel you need some additional funds. What went wrong here?

Dr. KLEMPERER. Particle physics is a rapidly developing field of admittedly high cost.

Mr. BOLAND. But, it is not really a new field.

Dr. KLEMPERER. The discoveries that have been made in the last three years have really profoundly changed the nature of this field. This year's Nobel Prize in Physics went to theorists who have

predicted the type of discoveries that have been made. It is a field of tremendous flux and excitement. It is one of the most attractive fields to young physicists. So one really does not want to stifle a field which really is so fundamental in physical science.

Dr. PIMENTEL. We argue this does not represent an add-on. To the contrary, it reaches into the overall physics budget and focuses money there at the expense of other programs—exactly as was said earlier in the statement you quoted.

Mr. BOLAND. Mr. Conte?

Mr. CONTE. I won't be long. Thank you, Mr. Chairman.

RECIPIENTS OF RESEARCH GRANTS

I would like to concentrate, Dr. Atkinson, for a moment on the recipients of research grants from the National Science Foundation. In the introduction to NSF containing the fiscal year 1981 justification it is stated that the grants account for approximately 28 percent of all Federal support received by academic institutions for basic research.

My question is what other categories of persons besides those at academic institutions are eligible for NSF grants? I am speaking about individual research grant awards, not institutional.

Dr. ATKINSON. Most of NSF's funds are directed at university science activities. The Foundation also funds a certain number of activities in industry and in nonprofit organizations, but the portion of the total effort not directed at universities probably would be less than 10 percent.

Mr. CONTE. Are there any applicant restrictions that apply to all research grants within NSF regardless of program activities?

Dr. ATKINSON. If the proposal comes in from a for-profit firm, it could be received. But the language clearly indicates that only under special circumstances of unusual national opportunity would NSF fund the project.

Mr. CONTE. Are other researchers of other Federal agencies eligible for grants?

Dr. ATKINSON. No, they are not. There can be exceptions, of course, but the general view is that NSF does not fund researchers in other Federal agencies. We believe that the Congress allocates funds to those agencies for support of their research, and NSF should not then permit agency scientists to apply to NSF for support.

Mr. CONTE. There was a recommendation in the 1964 Independent Agency appropriations bill that no part of the Foundation's funds be transferred to another agency of the government for research.

At the time this was interpreted to mean that individual researchers in other Federal agencies could not apply to NSF for research grants. This legislative provision is no longer carried in the bill handled by Mr. Boland. However, I am curious as to whether NSF continues these restrictions in practice.

Dr. ATKINSON. Yes, we do. There are exceptions. We do fund special collections in meteorites and sea organisms at the Smithsonian. There is some polar research but in general we would not

fund a scientist at another Federal agency, a Federal laboratory, or a nonprofit organization primarily supported by Federal funds.

Mr. CONTE. If it is all right with the Chairman, could you provide for the record, information on grants made by NSF to researchers in other Federal agencies last year. You just mentioned a few.

Dr. ATKINSON. Yes, I will give you a listing of all such grants.

[The information follows:]

Researchers Funded by National Science Foundation
at Other Federal Agencies

The following awards made by the National Science Foundation (NSF) in FY 1979 funded researchers in other Federal Agencies who because of their unique expertise, association with non-Federal researchers, their access to government-owned facilities or other factors, were made exceptions to the general NSF policy of not funding Federal researchers:

Smithsonian Institution

- Collaborative Research on the Torngat Archaeological Project - $39,789
- Cooperative Systematics and Analysis of Polar Biological Materials - $99,927

Geological Survey

- Research on Techniques of Geochemical, Geophysical and Geological Exploration in the Sonoran Environment - $68,000
- Geology of the Ohio Range, Antarctica - $10,718
- Geologic Investigation of the Dufek Intrusion, Antarctica - $20,000
- Crystallization of Pyroxenes and Pyroxene - Bearing Rocks - $21,400
- Oxygen Fugacities of Extraterrestrial Materials and Redox Reactions - $4,600
- Trace Elements in Planetary Material by Activation Analysis - $19,000

National Oceanic and Atmospheric Administration

- North Pacific Experiment (NORPAX): Studies of Equatorial Dynamics and Long-Period Transport Variations in the Central Pacific - $75,000
- Near Surface Circulation Studies: A Component of the Coastal Upwelling Ecosystems Analysis Program - $35,000

Bureau of Standards

- Probability Distribution of Extreme Wind Speeds - $68,262

Department of Agriculture

- Basic and Applied Studies of Pathogenic Microorganisms in Grasshopers and Locusts - $11,116.

Mr. CONTE. Mr. Chairman, I have quite a few other questions but not pertaining to this matter and I will submit them for the record.

Mr. BOLAND. Are they in any particular area?

Mr. CONTE. They are mostly on research.

Dr. ATKINSON. May I just inquire about the motivation here? Are you concerned that we are funding too much or too little?

Mr. CONTE. Not enough.

Mr. BOLAND. Thank you very much, Mr. Conte. I know you are busy, although this is probably the most interesting hearing taking place on the Hill today. We will place your additional questions in the record at this point.

[The questions follow:]

Question. The introduction to NSF contained in your justifications makes reference to the fact that more than 200 small business firms are involved in NSF-supported research. Further along in the budget justifications there is a request for an additional $10 million for a program to "draw upon the research capabilities of the nation's small businesses to move the most promising research toward commercialization as quickly as possible".

As a long time member of the House Small Business Committee this is a matter of particular interest to me and I wonder whether you could elaborate on the types of firms and projects that have and would receive assistance under this program?

Answer. In 1977 NSF introduced a new program on an experimental basis now entitled "Small Business Innovation Research". The three-phased program solicited proposals from science and technology based small business firms in a number of topic areas. Some 329 proposals were received; 42 phase I and 21 phase II awards were made. In the second solicitation in 1979 four hundred and eight proposals were received and 54 phase I awards resulted. In 1980 five hundred and thirty proposals were received from 43 states and the District of Columbia which are now being reviewed.

Phase I involves six-months up to $25,000 awards to determine the technical feasibility of the idea and the capabilities of the small business. Phase II awards are for 1-2 years and average $200,000. Phase III involves private venture capital or large company support in a development phase to pursue commercial objectives from the government research funded in phases I and II. Commercial rights to patents are also made available to the small firm contingent upon its receiving the phase III funding from a third party.

Question. Your justification also states that the National Science Foundation is responsible for strengthening science education at all educational levels.

What NSF programs have been transferred to the new Department of Education, which programs stayed with NSF, and what were the determining factors?

Answer. The Department of Education Organization Act of 1979 (Public Law 99-88) transferred to the new Department the Minority Institutions Science Improvement Program and that portion of the Pre-college Teacher Development in Science Program serving teachers in kindergarten through grade four. All other elements of the Science Education Program Activity remained in the National Science Foundation.

The determining factors were the language of Section 304 of Public Law 99-88 and that portion of the Joint Explanatory Statement of the Committee of Conference (House Report No. 95-459) pertaining to Section 304.

Question. With regard to NSF Science Education Resources Improvement Program, can you tell us how many two-year applications were received last year? What percentage of the total applications did the two-year schools represent? What percentage of the final awards?

Answer. The table below presents the information requested in these questions.

2-YEAR COLLEGE PARTICIPATION IN SERI PROGRAMS, FISCAL YEAR 1979

	Proposals received			Grants				
		2-year colleges		Total		2-year colleges		
	Total	Number	percent	Number	Success rate (percent)	Number	percent	Success rate (percent)
CAUSE	307	69	22	72	24	16	22	23
IDSE	117	3	3	36	30	1	3	33
ISEP	1,457	145	10	385	19	22	6	15
LOCI	514	68	13	151	29	18	12	26
MISIP	61	22	37	39	63	11	28	50

Question. $1.7 million is being requested in fiscal year 1981 for detailed design and specifications leading to the construction of a new 25 meter diameter millimeter wave radio telescope for astronomy research. Isn't there an NSF sponsored millimeter wave telescope at the University of Massachusetts?

Answer. Yes, there is an NSF-sponsored millimeter wave telescope at the Quabbin Reservoir run by the Five College Radio Observatory (FCRAO). It was built in the mid 1970's, its reflector is 45 feet in diameter and primarily serves the research needs of the radio astronomers at the University of Massachusetts. In contrast, the proposed 25 meter (82 foot) antenna to be built in the 1980's has 3⅓ times the collecting area and will be a national instrument serving the research needs of radio astronomers across the nation. The combination of newer design techniques, a higher precision surface and the exceptionally high altitude and low latitude of the site at Mauna Kea, Hawaii will permit the 25 meter antenna users to observe more effectively at more than twice the frequency range of the FCRAO antenna. It will enable them to observe objects in the Southern Hemisphere that are either not accessible to the FCRAO antenna (e.g. the Southern Milky Way) or are so low on the southern Massachusetts horizon that observations are much more difficult to make (e.g. the center of our Milky Way Galaxy).

The advent of the 25 meter antenna will not remove the need for millimeter wave antennas in the Northern Hemisphere such as the FCRAO antenna. Both instruments are needed for as full a coverage of the northern and southern skies as possible.

Question. While on the topic of astronomy research, I was interested and proud to note mention in your budget justifications of the announcement last year by three astronomers at the University of Massachusetts of the first experimental evidence supporting the existence of gravitational waves. Could you take a moment to explain in layman's terms the importance of this discovery?

Answer. A prediction of Einstein's theory of general relativity is that energy can be carried off from any mass by a form of radiation known as gravitational radiation (or waves). This radiation travels at the speed of light. It carries energy, and is emitted by any object whenever the object experiences an acceleration. The amount of energy carried by gravitational waves is extraordinarily small, so it is extremely difficult to detect. It is an astronomical phenomenon (where one has very large masses and energies) that one has the best hope of detecting these waves. The discovery by the University of Massachusetts indicates that Einstein's prediction is correct. Furthermore, the measurements enable relativists to discount some alternate theories of relativity. This discovery lends impetus to attempts to build detectors that would actually measure the gravitational radiation traversing the Earth (i.e. gravitational receivers). A century ago scientists began the experimental study of electromagnetic radiation, which has resulted in our current radio, television, and radar technology. Today we are on the threshold of the experimental study of an entirely new type of physical radiation.

Question. On page 16 you list some of the major research questions being addressed by NSF supported researchers. Among them is the question of how plants and animals interact with the atmosphere to control atmospheric carbon dioxide and respond to acid rain. $13 million is requested in your ecosystem budget for acid rain investigations. From previous testimony from EPA officials, we know EPA is allocating research resources to the acid rain problem as well. Is there cooperation between your two agencies in the matter of acid rain research?

Answer. The National Science Foundation supports researchers to investigate phenomena which relate to "acid rain", but money is not set aside for acid rain as

such. A recent survey of all programs throughout NSF that fund projects related to acid rain placed the effort at about $8.8 million. The $13 million requested is for the total ecosystem studies which include a smaller fraction related to acid rain. For example, ecosystem research is deemed important because it examines ecological associations for individual plants and entire communities that must be understood before effects of acid rain can be understood. This work supports watershed measurements in several places of the U.S., detailed examination of nitrogen and sulphur cycles and budgets that must be known in order to understand sources and sinks of NO_x and SO_x, and basic studies in which detailed models of system function are being constructed. It is this work that will be needed by EPA and other management agencies before acid rain can be put in perspective and before plans for the specific studies on acid rain *per se* can be started. At this time, no projects on acid rain are funded jointly. Cooperation is maintained through efforts of the Federal Interagency "Acid Rain Coordination Committee" and its subcommittees, as well as through contacts made by program managers of EPA and NSF. Information available on the subject and on funded projects has been exchanged. NSF will continue to fund research fundamental to the overall problem of acid rain through studies on ecosystems and watersheds, plant and animal effects, simulation modeling, and other work proposed by the scientists of the U.S. that passes the peer review system. This information will be available at all times to EPA program managers and researchers.

Question. In addition to the acid rain problem, concern is being expresssed in many quarters about the level of carbon dioxide in the atmosphere and particularly about the potential effect of increased carbon dioxide levels caused by synfuel production on global climate. Is NSF supporting any cooperative research with the Department of Energy on this matter?

Answer. National Science Foundation is funding several major efforts related directly to the question of global carbon, as well as funding programs of total system nature which are important for building and understanding gains or losses of carbon in various systems. Much of the work is centered in two divisions, ATM (division of Atmospheric Sciences) and DEB (division of Environmental Biology). The level of research funded by NSF in 1979 was $4.25 million, much of that indirectly related. Approximately $2.66 million was directly related to global carbon questions. The work includes monitoring fluctuating CO_2 levels on Mauna Loa, construction of complex climate dynamics models at National Center for Atmospheric Research in Boulder, Colorado, construction of world carbon budgets in oceans and nearly all terrestrial biota where the information exists, and highly specific laboratory research conducted at the Phytotron of Duke University. In several instances, NSF and DOE are funding complementary phases of the research at institutions such as Oak Ridge National Laboratory, Marine Biological Laboratory, and Scripps Institution. Both MOAA and DOE have provided about $0.3 million to NSF for funding of basic problems. Program officers of both NSF and DOE coordinate many of their activities with one another, although in most instances funding of programs proceeds independently. Interagency coordination insures appropriate responsibility between variously applied and fundamental science needs.

Question. Under Engineering and Applied Sciences, mention is made of NSF supported research on the question of how national fiscal, monetary and regulatory policies affect the cost and management of programs by state and local government. How much money is being used to support research in this area?

Answer. In fiscal year 1979, awards were made to seven (7) grantees in the Public Services Delivery and Urban Problems area relating to the above topics. These seven awards totaled $882,888. It is expected that approximately $500,000 will be spent in awards on these topics in fiscal year 1980.

Question. It strikes me that this is a matter that is comfortably within the research purview of the Advisory Council on Intergovernmental Relations. What makes National Science Foundation uniquely capable of supporting this type of research?

Answer. The Advisory Council on Intergovernmental Relations *is not* a grant giving agency. Staff conduct studies under direction of the Commission. Only occasionally will staff contract to members of the research community for work which directly supports staff analysis. The National Science Foundation closely coordinates its research on these topics with the Advisory Council on Intergovernmental Relations and they are supportive of our efforts to fund scholars for research on these topics.

Question. On page 55 under Program Development and Management, an increase of $25,000 is requested for consultant compensation to fund approximately 250 more consultant days for outside experts to provide oversight and advice concerning NSF.

What is the total amount being requested in fiscal year 1981 for consultant services?

How many consultant days were used by NSF last year?

Why is this increase necessary?

Answer. The total fiscal year 1981 request for consultant compensation, including compensation for members of the National Science Board is $575,000.

In fiscal year 1979, approximately 4,300 days of consultant services (excluding NSB) were utilized in program oversight and the proposal review process.

The additional 250 days are required for the following: 50 days each for expanded oversight and proposal review in: Mathematical and Physical Sciences; Astronomical, Atmospheric, Earth and Ocean Sciences. They will be used primarily to help reduce the total time between the receipt of a proposal and final action. 50 days for programs in Engineering and Applied Science including the expanded program directed toward greater involvement of small business in the Foundation's research programs; and 100 days for new or expanded Cross-Directorate programs such as the University Research Facilities Program and the Industry/University Cooperative Research Program.

Question. Under the Intergovernmental Programs, there is a mention of an Energy Management Program organized and operated by the New England Innovation Group which uses new technologies to determine insulation characteristics in public and private buildings.

First, what is the New England Innovation Group and can you tell us more about these energy management efforts?

How is information about their research discoveries being disseminated for practical application in other parts of the country?

Answer. The New England Innovation Group is a nonprofit intergovernmental, regional organization founded in 1975 under an NSF grant to the Rhode Island League of Cities and Towns to assist local and State governments in the six state New England region and solve pressing problems through the application of scientific and technical resources.

It is governed by a 19 member board of trustees of elected and appointed State and local government officials and representatives of private industry, federal laboratories, and universities. Its President is Vincent A. Cianci, Jr., Mayor of the City of Providence, Rhode Island. It employs a small core staff of scientists, public administrators, and technology agents to provide research, technical assistance, and information services to government agencies in the region. It also provides a brokerage function to link other resources such as the federal laboratories and universities to governments with problems amenable to scientific and technological solutions.

It has conducted energy audits in a number of schools and other public buildings in New England using thermography (an infra-red heat detecting device) to identify heat losses in buildings.

It plans to conduct workshops throughout New England to disseminate the results of its work. Written reports are also available through its offices at 128 N. Main Street, Providence, Rhode Island, 02903. It also is currently using the "EIES," electronic information exchange system, (a computerized information retrieval and telecommunications system) to communicate with other innovation groups around the country.

Further information may be obtained from its Executive Director, Mr. Robert A. Cox.

Question. Your environmental biology budget summary identifies advances in population genetics. Specific mention is made of using mathematical modeling techniques to study the inheritance of susceptibility to disease. Could you explain or provide me later with additional information about this study?

Answer. From our present genetic base, the inheritance of variability in human traits that we best understand can be described in terms of genetic variability at single genes or at several genes affecting the same trait. As the number of genes involved in a trait increases, the underlying genetic base becomes more and more difficult to assess and mathematical modeling is necessary. But even more difficult is the understanding of the inheritance and evolution of susceptibility to disease. This is due to the interaction of the genetics of the susceptibility and the transmission patterns of the disease itself, i.e., whether there is familial transmission (parent to offspring) or contagious transmission (from one individual to another across the population). This problem is in contrast to that of congenital genetic disease caused by differences in the genetic information that directly affect metabolism or structure of the human body.

This research undertaken by Dr. Marcus Feldman of Stanford University will develop a series of computer simulation models aimed at explaining the interaction

of genetically inherited characteristics and culturally transmitted traits. The models are based on non-linear statistical distributions of inherited traits in human and other populations. Part of the basis for analysis of these data is a more complete understanding of how genetic inheritance is affected by fluctuating environments. Therefore, a large part of Dr. Feldman's modeling effort will simulate the effects of environmental variation on the interaction of culturally and genetically transmitted characteristics.

The class of traits selected for modeling are those diseases for which evidence suggests a genetically inherited susceptibility, *i.e.*, disease and susceptibility must co-occur before illness can develop, such as for hepatitis B. Non-linear models which describe genetic control will be integrated with statistical models of non-genetic transmission dynamics. By developing computer models based on the statistical frequencies of genetic and cultural aspects of the disease, an understanding of the fundamentals of disease transmission can be developed. The larger question of "nature-nurture" can also be approached using these techniques.

Discussion of recent advances in theoretical models which combine epidemiology and population genetics are extremely involved and cannot be adequately described and discussed in a short response. Details of the models can be found in two recent scientific articles: Uyenoyama, M. K. and M. W. Feldman. 1978. The genetics of sex ratio distortion by cytoplasmic infection under maternal and contagious transmission; An epidemiological study. Theoretical Population Biology, Vol. 14: 471–497. Uyenoyama, M. K., M. W. Feldman and L. L. Cavalli-Sforza. 1979. Evolutionary effects of contagious and familial transmission. Proceedings of National Academy of Science, Vol. 76: 420–424.

Question. Likewise, I am very interested in having additional information about the Science and Technology program to Aid the Handicapped under your Problem Focused Research activity.

Answer. To provide more information on the Science and Technology to Aid the Handicapped Program, we attach two documents. The first is a two-page program announcement that is in current circulation. The second is a brief description of current grants, entitled "Science and Technology to Aid the Handicapped: Program Summary (fiscal 1979)."

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NATIONAL SCIENCE FOUNDATION
DIRECTORATE FOR ENGINEERING AND APPLIED SCIENCE
DIVISION OF PROBLEM-FOCUSED RESEARCH

SCIENCE AND TECHNOLOGY TO AID THE HANDICAPPED

SUMMARY

The Division of Problem-Focused Research of the National Science Foundation will award approximately $2.3 million in Fiscal Year 1980 to continue its multidisciplinary research program for Science and Technology to Aid the Handicapped. As defined for purposes of this program, handicapped persons are those who have a physical or mental impairment which substantially limits their vocational, educational, or social activity.

ELIGIBILITY FOR SUPPORT

This program will support fundamental, scientific research which may ultimately lead to products, treatment methods, or societal and environmental changes of significant benefit to the handicapped. To be eligible for support under this program, each proposal must satisfy both of the following criteria:

1. Scientific and Technical Quality.

   The proposed methodology is based on sound scientific principles and is appropriate for achieving the stated objectives.

2. Ultimate Impact on the Handicapped.

   The need that is addressed by the proposed research is of high priority to the handicapped, and there is good probability that the research will be successful in helping to meet that need.

Other factors that will be considered are possible duplication of research being funded by other agencies; evidence of the ability of the investigator(s) to carry out the proposed work; and the probability that the research will lead to important discoveries or significant conceptual generalizations within its own field and possibly other fields of science.

WHO MAY SUBMIT

Unsolicited proposals may be submitted by U.S. colleges, universities, public or private research firms, and organizations and industrial firms, whether operating on a profit or not-for-profit basis, and unaffiliated scientists in the United States. Cost-sharing is required and no fees may be paid.

SUBMISSION DATES

Closing dates for submission of proposals are:

March 25, July 25, November 25

Announcement of awards will be made within six months of the applicable closing date. The requested starting date should allow at least six months from the applicable closing date for processing and evaluation. Funding for proposals received after March 25, 1980 is dependent upon continued congressional appropriations for the program in Fiscal Year 1981 (beginning October 1, 1980).

SELECTION PROCESS

All proposal will receive a comprehensive peer review that is based on criteria established by the National Science Board and specified in Grants for Scientific Research (NSF 78-41), pp. 9-10. Reviewers will be asked to judge each proposal on its scientific and technical merit and on its potential benefit ot the handicapped.

Brevity will facilitate review. The project description normally should not exceed 15 single-spaced pages; however, somewhat greater length may be appropriate for multiple-investigator proposals.

HOW TO SUBMIT

Proposals should be prepared and submitted in accordance with procedures set forth in NSF 78-41 which may be obtained at no cost by request to Forms & Publications Unit, National Science Foundation, 1800 G Street, N.W., Washington, D.C. 20550. The NSF Grant Policy Manual (Revised October 1979) for sale by the Superintendent, U.S. Government Printing Office, Washington, D.C. 20402 at $9.00 per subscription, may be consulted for guidance as to costs which may be included in the budget.

Fifteen copies of each proposal should be submitted to the Central Processing Section, National Science Foundation, Washington, D.C. 20550. The cover page of the proposal should include the notation: Attention: Science and Technology to Aid the Handicapped Program. A Cover Page (Appendix I) and Summary Proposal Budget (Appendix III) are contained in NSF 78-41.

REQUEST FOR ADDITIONAL INFORMATION

Additional details can be obtained from Donald R. McNeal, Division of Problem-Focused Research, National Science Foundation, Washington, D.C. 20550. The telephone number is (202) 632-3027.

SCIENCE AND TECHNOLOGY TO AID THE HANDICAPPED

Program Summary

Fiscal 1979

Title: Study of Fast Feature Extraction for Blind Mobility

Principal Investigator: Collins, Carter C.

Institution: Smith-Kettlewell Institute of Visual Sciences

Location: San Francisco, CA

Award: $184,208, Standard Grant, PFR 79-06299

Duration: 24 months

Targeted Disability: Blind

This research will investigate the feasibility of employing real time automatic obstacle and landmark recognition for increasing and improving the mobility of the blind. Mobility continues to be a major problem for the blind, despite the use of guide dogs and long canes. Data from a miniature television camera will be processed in real time to provide information about obstacles and navigational landmarks. This data will be presented to the blind pedestrian by means of machine-generated speech and tactile coding (in the form of a matrix of vibratory elements in contact with the skin). A small television camera is currently available. An algorithm for image recognition will be developed and implemented using the latest microprocessor technology to achieve the required computational speed in a small, lightweight package. Tactile coding and machine-generated speech are currently available, but what information to present and how best to do it must be determined.

Title: Electrical Stimulation of the Skin as a Basis for Sensory Protheses

Principal Investigator: Dobelle, William H.

Institution: Columbia University

Location: New York, NY

Award: $234,306, Continuing Grant. PFR 79-17634

Duration: 30 months

Targeted Disability: Blind, Deaf, Neurologically Impaired and Amputee

A systematic investigation of electrocutaneous display methods will be conducted, using psychophysical techniques, to provide a body of basic information about the ability of human observers to perceive complex, dynamic patterns of input imposed on the skin. Alternate sensory input techniques are desparately needed for persons who have suffered severe sensory losses (the blind, the deaf, and persons who have lost body sensation through amputation or damage to the nervous system). Electrical current will be applied through an 8x8 matrix of electrodes imposed on the surface of the skin. Stimulus parameters will be selected to yield optimum discriminability and identifyability of electrocutaneous patterns. Questions related to apparent movement on the skin produced by sequential activation of neighboring electrodes and masking interactions between sequentially presented stimuli will be investigated. In short, this research will identify parameters and techniques of elecrocutaneous stimulation to maximize the information rate through a given set of electrodes.

Title: An Ocular-Controlled Intelligent Speech Prosthesis

Principal Investigator: Colby, Kenneth M.

Institution: University of California - Los Angeles

Location: Los Angeles, CA

Award: $371,050, Continuing Grant PFR 79-17358

Duration: 24 months

Targeted Disability: Nonvocal

This research will investigate the feasibility of using ocular-control to generate synthetic-speech to provide a means of communication for persons who are unable to speak intelligibly. Currently, available communication aids are controlled by a keyboard or a binary switch. Many nonvocal persons do not have sufficient manual dexterity to operate a keyboard, and a binary switch slows the input so that the construction of even a simple utterance is a long and difficult task. Ocular-control systems (using infrared light optics to monitor eye position relative to head position) and intelligent speech generating systems are currently available. The two systems will be interfaced and tested on various nonvocal populations, including those who have suffered damage to language areas of the brain. Key questions to be answered are the speed and accuracy of speech generation using ocular-control, the ease of use, and the amount of information which can be transmitted.

Title: Automatic Measurement of Laryngeal Vibratory Patterns

Principal Investigator: Childers, Donald G.

Institution: University of Florida

Location: Gainesville, Florida

Award: $143,788, Standard Grant PFR 78-16965

Duration: 24 months

Targeted Disability: Deaf and Hearing Impaired

This study will establish a relationship between laryngeal vibratory motion and the sound produced. These results could eventually be used to design better machine aids for teaching speech to the deaf. Films of laryngeal motion along with simultaneously recorded sound output have already been obtained from subjects with a normal organ for voice production and normally functioning vocal cords. Hardware and software techniques for the automatic processing and data reduction of the laryngeal film data will be developed. These data will be analyzed and correlated with simultaneously recorded phonations. The reduced data will then be made available to people in the scientific community who are interested in testing hypotheses concerning the speech mechanism and developing a comprehensive theory of speech production.

Title: Replacement of Sensory Capabilities for the Physically Handicapped

Principal Investigator: Cowsar, Donald R.

Institution: Southern Research Institute

Award: $347,125, Continuing Grant PFR 79-15314

Duration: 36 months

Targeted Disability: Neurologically Impaired

This research will develop a material which can be fabricated into a thin sheet to partially replace the senses of touch and pain in neurologically injured patients. Loss of these sensations produces severe functional impairment and can cause incapacitating injuries because normal warning mechanisms of the body are inactivated. A conductive elastomer will be developed in which the electrical conductance is related to static pressure. These pressure sensors will be fabricated into a 12x12 array to form a thin flexible sheet that can be used to determine a pressure profile over a surface on which it is placed. Highly conductive strips of elastomer will connect each sensor to the measuring curcuit. The key research goal is to develop a conductive elastomer in which the pressure-conductance relationships is reproducible, hysteresis is minimal, and recovery is sufficiently rapid that the dynamics of changing pressures in various clinical applications can be accurately measured.

Title: Neurophysiologically-Based Adaptive Controllers for Assistive Devices

Principal Investigator: Hogan, Neville

Institution: Massachusetts Institute of Technology

Location: Cambridge, MA

Award: $138,038, Standard Grant PFR 79-17348

Duration: 24 months

Targeted Disability: Amputee

This project will develop a controller for interfacing a disabled user with an assistance device (such as an artificial limb), taking advantage of the state-of-the-art in both technology and neurophysiology. Myoelectric activity (the natural electrical activity of muscle) will be used for communication between man and machine. The controller will use the natural patterns of simultaneous contraction of opposing muscles to control the adjustment of an artificial limb. The manner in which the human operator adjusts parameters of his musculoskeletal system (such as its mechanical stiffness) in the performance of normal movements will be investigated, and the results of this investigation will be used to design a controller to provide an upper-extremity prosthesis with the same adjustable capabilities as the natural limb. A wearable, versatile artificial limb simulator which can be programmed to mimic the behavior of any proposed artificial limb design is available for this investigation. The final design will be implemented in a self-contained artificial limb.

Title: Needs and Design Concepts for Voice-Output Communication Aids

Principal Investigator: Boehm, Bruce J.

Institution: Telesensory Systems, Inc.

Location: Palo Alto, CA

Award: $156,020, Standard Grant PFR 79-17629

Duration: 18 months

Targeted Disability: Nonvocal

Requirements and specifications will be established for low-cost voice-output modules to aid vocally disabled individuals in communicating more effectively. It is estimated that there are 750,000 persons in the United States who are unable to speak intelligibly. Machine generated speech offers an opportunity for these individuals to communicate effectively, however, no one has yet investigated the basic research issues related to the appropriateness of a technology that speaks for the user as opposed to a technology that speaks to the user. This project will identify those factors that are important in the design of voice prostheses for nonvocal persons. Existing communication aids will be evaluated and consumer requirements will be analyzed. Alternative approaches will then be formulated and tested. On the basis of results from these tests, design concepts for useful, practical voice-output communication

aids will be developed and disseminated.

Title: Application of Personal Computing to Assist the Handicapped

Principal Investigator: Hazan, Paul L.

Institution: Applied Physics Laboratory, Johns Hopkins University

Location: Laurel, Maryland

Award: $20,000, Standard Grant PFR 79-21124

Duration: 5 months

Targeted Disability: General

The purpose of this project is to manage and administer the problem definition phase of a second project to organize a series of regional and national competitions among individual personal computer users. These competitions will direct the creative imagination of a broad spectrum of the general public toward innovative uses of home computers to assist the handicapped. An Advisory Committee, which includes handicapped individuals, will be formed to define the program, establish the evaluation procedure and develop an overall publicity plan. Service organizations and professional societies will be contacted to support and administer the regional and national competitions.

Title: Children's Auditory Discrimination and Perception of Monosyllabic Words

Principal Investigator: Elliott, Lois L.

Institution: Northwestern University

Location: Evanston, Illinois

Award: $225,170, Standard Grant PFR 79-06496

Duration: 36 months

Targeted Disability: Hearing Impaired and Language Delayed Children

The objective of this research is to gain increased understanding of the processes that underlie children's auditory perception of simple, monosyllabic words. Although normal children will be studied, project results may have potential applicability to handicapped populations, such as hearing-impaired (moderate loss) and language-delayed children. Previous research has demonstrated that auditory perceptual "threshold" for monosyllabic nouns that are standardized to be within the receptive vocabularies of inner-city, three-year-old children decrease as a function of chronological age and do not asymptote until the age of ten years. This project will seek answers

to the question of exactly what perceptual processes are associated with this developmental change. Four hypotheses pertaining to differences between children's and adults perception of words will be tested. Results of these experimental tests will be used to refine a proposed working model of word perception.

Title: Visual Feedback Speech Training for the Deaf

Principal Investigator: Gish, Walter C.

Institution: Integrated Sciences Corporation

Location: Santa Monica, CA

Award: $118,801, Phase II, Small Business Solicitation PFR 78-21347

Duration: 18 months

Targeted Disability: Deaf and Hearing Impaired

This project is the initial phase of an effort to develop a visual feedback system to assist in teaching the deaf to speak. Previous visual aid systems have not been successful because they were not able to extract speaker invariant features of speech, particularly for the high pitched voices of women and children. The aim of this phase of the research is to provide an analysis of speech into components based on a linear speech production model and an accurate parameterization of these components. The speech signal will first be separated into voiced and unvoiced components. The voiced component will be further separated into two components corresponding to the glottal volume velocity waveform and vocal tract impulse response. Finally, the spectral envelope of the vocal tract impluse will be parameterized. The next phase of this program would use this data to determine the speaker invariant features of speech sounds.

Title: Integrated Electro-Mechanical Transducer Systems

Principal Investigator: Linvill, John G.

Institution: Stanford University

Location: Stanford, CA

Award: $150,000, Continuing Grant. Jointly funded with the Division of Engineering ENG 78-22167

Duration: 36 months

Targeted Disability: Blind and Vision Impaired

Electrical, mechanical and piezoelectric properties of the polymer polyvinylidene fluoride (PVF_2) will be studied to determine the material and fabrication technologies necessary to build devices using PVF_2. This polymer is different from other piezoelectric materials in that it can be manufactured in thin, flexible sheets, exhibiting piezoelectricity in both the transverse and thickness modes. Potential applications for PVF_2 include tactile stimulation elements for the Optacon (a reading aid for the blind) and imagining array elements (for a mobility aid for the blind).

Title: Microprocessor-Based Prosthetic Control

Principal Investigator: Gustafson, Donald E.

Institution: Scientific Systems

Location: Cambridge, MA

Award: $159,597, Phase II, Small Business Solicitation PFR 78-21670

Duration: 24 months

Targeted Disability: Amputee

This research is concerned with the design of a system to provide control signals for a multifunctional prosthesis from a set of myoelectric signals (signals normally produced by contracting muscules) which are recorded from the surface of the skin. Techniques to control a multifunctional, upper-extremity prosthesis rapidly and reliably are not currently available. In this project, temporal and spatial variations in myoelectric signals recorded from at least four electrodes will be analyzed in an attempt to extract all available information. The signals will be modelled as multivariate Markov processes. A multiple-model Kalman filter will be designed to detect and identify each intended prosthesis function. Electrode locations will be analyzed to maximize discrimination accuracy and to determine the minimum number of required electrodes. The optimal sampling rate of the myoelectric signals will also be determined. The feasibility of microprocessor implementation will be evaluated through simulation.

Question. There is growing concern about our seeming over-dependence on imported minerals and the need to move ahead to develop our domestic mineral resources. Considering the fact that minerals play as important a role in our economic stability and national well being as domestic energy and water supplies, comment on NSF supported research in this area, including research to improve the efficiency of separating minerals from low grade ore. Expand on this.

Answer. NSF has recognized the importance of impending problems in this area. It is our view that science and technology are vital components of a secure mineral future.

Although the problems of reliance on foreign sources of chromium, titanium, cobalt and manganese are quite evident, NSF supported research is not commodity oriented. Through a broad range of basic and applied research programs, NSF fosters a flow of new scientific knowledge contributing to long range solutions to our mineral resource needs. Non-fuel mineral commodities are the only subject of NSF research support since energy resource topics are referred to the Department of Energy.

NSF support of non-fuel minerals research has been implemented as follows:

In Fiscal Years 1976–77, NSF supported problem focused research in mineral exploration, processing and economics and in waste resources, substitute materials, and conservation. The program was discontinued in 1978.

In non-fuel mineral processing, NSF has provided $4 million of applied research support over the period of Fiscal Years 1973–79. This research entitled "Project Summaries: Mineral Resources Science and Technology," is described in the material supplied for the Committee files.

NSF's basic research contributions in non-fuel minerals have been coordinated and stimulated by its new program of Integrated Basic Research (IBR). Under the topic *Deep Mineral Resources,* IBR in Fiscal Year 1979 has provided $1.2 million in new funds for basic research related to exploration of blind ore deposits and deep solution mining. These funds have supplemented basic research program funds for a total of $5 million in minerals related research support. This research, entitled "Deep Mineral Resources," is described in the information supplied for the Committee files.

HIGH ENERGY PHYSICS

Mr. BOLAND. Give us a brief summary at this time of what the proposed funding levels are for the High Energy Physics Program in the Department of Energy.

Dr. KLEMPERER. Certainly. They provide over 90 percent of the funds in that area, while we provide only about eight or nine percent of the total budget.

Mr. BOLAND. How is DOE's effort coordinated with the Foundation's effort?

Dr. KLEMPERER. In several ways. We are invited to and do attend meetings of the High Energy Physics Advisory Panel, (HEPAP). There is coordination at the program level. I am in contact personally with Mr. Frieman who is the Director of Research.

Mr. BOLAND. Are any other agencies involved?

Dr. KLEMPERER. In the support of high energy physics it is really the Department of Energy that has assumed it as a national thrust.

Mr. BOLAND. In the High Energy Physics area, does NSF primarily support the operating funds for some of these High Energy Physics capital projects?

Dr. KLEMPERER. Only at the Cornell Electron Storage Ring. We do not support operating funds at the Department of Energy installations.

Mr. BOLAND. There seems to be a tendency for NSF to request funds for construction of equipment and/or facilities—and then we find that those funds are incorporated into operating funds of the various basic research programs. For example, in the case of the

Michigan State heavy-ion cyclotron, where construction is largely complete, further program increases are being justified and it appears that these increases are being melded into the operating base of various programs without further mention. The point is that once the capital expenditure takes place, it shouldn't be reflected in the base—at least not automatically. What about that?

Dr. ATKINSON. Let me refer to your earlier remark about the Cornell Electron Storage Ring. I pointed out that NSF shifted funds from research support into construction there because we felt the construction was important.

In the physics proposal, it is critical to think of a set-aside that we have decided to invest in high energy physics. The decision involves the optimum mix at any given time. And that is the problem we face.

The High Energy Physics Advisory Panel that Dr. Klemperer discussed is a group of scientists from all over the country with representation from DOE and from NSF. In a public way, the group reviews the full range of programs in construction and research and makes recommendations on how these agencies should develop their programs.

This year, for example, the construction funding for the Michigan State accelerator was shifted to DOE. That was a calculated decision resulting from the advice given by this group to the two agencies.

Mr. BOLAND. The bottom line is once the facility is built you are locked into operation.

Dr. KLEMPERER. Yes.

Mr. BOLAND. No.

Dr. PIMENTEL. In our long range planning, we not only must concentrate enough agency funds to complete the construction but also must look to the ability of the program to operate the equipment.

Mr. BOLAND. Is there any reason why NSF could not have some kind of special account for construction and operation of these large facilities?

Dr. ATKINSON. The key issue for NSF is a five-year plan presented to the National Science Board. Whenever NSF begins a major construction effort, it is exactly clear what the timing shall be and how the funds shall be distributed. The five-year plan is critical for these major projects.

The Cornell storage ring we believe represents a shifting of funds within a pool set aside for physics. It is not a question of construction, but a question of the optimal mix of activities within a scientific discipline.

Mr. BOLAND. Is there any reason why the NSF should not have a separate line item in the budget for acquisition of all capital items?

Dr. ATKINSON. No. We could do so; we haven't organized our budget that way.

Mr. BOLAND. Would that be a problem if you had to structure it that way?

Dr. ATKINSON. We could do it for the FY 1981 budget if you would like.

Mr. BOLAND. You don't have to do it for this budget.

CHEMISTRY PROGRAM

On page A-IV-1, the justifications detail the chemistry program subactivity. You are requesting an increase of about $8 million above the 1980 current plan of $51.4 million to $59.5 million in 1981. That is roughly a 17 percent increase and it appears to be almost evenly applied to all the program elements detailed on that page. Are all fields of chemistry equally needy and equally deserving? Weren't there any particular fields or sub-fields which seem to merit special attention on the basis of the promise of recent discoveries?

Dr. KLEMPERER. Certainly there are particular excitements in chemistry. The reason that we see a relatively uniform distribution in chemistry is in practically all of these areas we are underfunding first rate research activity, and we feel that the balance in chemistry has to be broad. It is not a field in which a single discovery is likely to so significantly alter the whole field that one should drop particular activities. I can give you an example, the field of analytical chemistry which you might feel is the most fundamental, is vital to environmental concerns. The field of synthesis of organic compounds is vital to the pharmaceutical and biological area. The field of physical chemistry or quantum chemistry is the underpinning of all advances in chemistry.

If we pull out of one area to feed another, we might really do damage to the field. We are trying to support the best proposals across a broad front in a field that has a lot of first-class work and is underfunded and which we feel is of tremendous importance to ultimately national needs.

Mr. BOLAND. You say it is underfunded?

Dr. KLEMPERER. I feel it is; yes, sir.

Mr. BOLAND. Is that the major recent thrust in chemistry that can't be pursued adequately because of the lack of research support?

Dr. KLEMPERER. I think that if we look at our average grants in chemistry they run at about 70 percent of what we feel would be desirable. This slows research and it inhibits the use of modern instrumentation. I speak of chemistry but this is characteristic of other areas. We are underfunded in this field compared to what investigators could profitably use in an efficient way. We tend to restrict imagination therefore.

Mr. BOLAND. Let's look at the last paragraph on page A-4-4.

Dr. KLEMPERER. You must realize, Mr. Boland, I am a chemist.

Mr. BOLAND. On page A-IV-6, the justifications indicate that DOE, NIH, and DOD combine with NSF to support chemistry research. What are the specific plans of each of these other agencies with respect to chemistry research in fiscal year 1981?

Dr. KLEMPERER. With respect to the National Institute of Health we are very dependent on that agency to fund about 80 percent of synthetic organic chemistry, a central field in chemistry. With respect to the Department of Energy, the funding of chemistry there is broad and is more in the area of the physical chemistry.

MATERIALS RESEARCH

Mr. BOLAND. On page A-V-5, the justifications outline the changes between the original fiscal year 1980 budget request and the fiscal year 1980 current plan. It is noted that the relative support of the materials research subactivity was increased in 1980 on the recommendation of Congress. What particular committee of Congress indicated that increase in activity?

Dr. KLEMPERER. I believe this was the House Authorization Subcommittee.

Dr. ATKINSON. Congressman Brown's Subcommittee.

Mr. BOLAND. What was the reason for the recommendation?

Dr. KLEMPERER. I think it was the importance of materials to national needs. One feels this is vital to the question of critical materials.

Mr. BOLAND. If you were required to reduce the total NSF budget $50 million—would material research be one of the areas that might possibly be affected?

Dr. KLEMPERER. It would do a lot of damage to cut this back in the sense that if we ask how do we understand problems such as corrosion where there are billions of dollars in the national economy involved, the problem is a lack of basic understanding. I don't see how we can solve these types of problems in an efficient manner without a serious study of the nature of materials. The cost of doing any new thing is going to be very high if we don't have a solid base of understanding.

Mr. BOLAND. Also, from where within the mathematical and physical sciences directorate would you be inclined to take its share of the $50 million potential reduction?

Dr. ATKINSON. Our high priority is basic research in the mathematical and physical sciences for the reason I gave yesterday; that is the place where we would want to preserve the effort.

Mr. BOLAND. You agree with that, George?

Dr. PIMENTEL. I want to point out that the Materials Research Division has the lowest percentage increase within the directorate. That is the result of a deliberate, carefully weighed decision. I think a further cut would unbalance the program.

ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES

Mr. BOLAND. The Astronomical, Atmospheric, Earth and Ocean Sciences Directorate is requesting a $23.4 million increase in 1981. That increase is detailed on page B-1.

ASTRONOMY RESEARCH

On page B-I-1, we find that the increase for the Astronomical Sciences Program subactivity is only $3.2 million in 1981. That represents only a 5-percent increase—which, of course, is not keeping pace with inflation. In fact, the 1980 level for this subactivity did not keep pace with inflation.

Also, I notice on page B-I-7, you indicated that "cost increases will require reduction in university research equivalent to about five average-sized astronomy grants, and continued tightening of national center operations."

The thrust of that comment and when one looks at the numbers suggests that the budget for the Astronomical Sciences these past two years has been quite tight.

Dr. PIMENTEL. The funding is clearly related to our plans for the VLA; in the original planning the VLA was not viewed as an increment to astronomy that would be there for all time. Then the VLA project was phased out. If those funds were evaluated for their best contribution to the scientific community at large, these reductions would represent completion of the VLA construction.

Mr. BOLAND. The trend of allocations has been declining or at least tightened in this area than in other activities?

Dr. PIMENTEL. No, I wouldn't say it is tighter.

Dr. JOHNSON. It is about the same as it is in the other divisions of the directorate. Overall, this is a request for nine percent in additional funds for the directorate and—knowing what inflation is that represents some cutback and exists in all areas. Astronomy may look, with the numbers you have mentioned, as if it had a bigger, more difficult situation than the other divisions. That apparent situation is alleviated by the release of construction funds for the VLA—

Mr. BOLAND. What about the operating budgets at the Centers? Are they going to be quite tight in fiscal year 1981?

Dr. JOHNSON. All centers virtually have had to reduce their number of personnel. Overall the number of employees of all centers has gone up. The VLA has affected that. We have quite a large crew working on the VLA so our total employees in centers has increased but at the individual centers it has in general gone down.

Dr. ATKINSON. I want to inject a remark; it is important. We are reducing personnel at some of the centers supported by NSF. We want to ensure a wise balance between the center activities and the rest of NSF's activities. In a tight budget it is easiest to maintain laboratories funded by NSF and to cut back on the support of individual investigators. We are working very hard to avoid the easy cuts.

Mr. BOLAND. As I understand it, the budget for this area is not any tighter than it is for other Directorates.

Dr. PIMENTEL. The $4.5 million represents the completion of VLA construction. If that $4.5 million is subtracted, the Astronomy budget is going up 14.7 percent. But we have additional operating costs at the VLA and those are causing a general tightening.

25 METER DIAMETER MILLIMETER WAVE TELESCOPE

Mr. BOLAND. You indicated that the centers are being reduced, and the next question is, why then are you building a new major telescope?

You are proposing on page B-3 to initiate detailed design for a new 25 meter diameter millimeter wave telescope costing $27 million. The point is why are we starting another new major telescope—when basically you don't have enough funds to operate the existing facility—including the new large array which is just being finished this year?

Dr. ATKINSON. We intended to begin the planning last year, but we delayed it a year. The telescope is high on our scientific priority

list, and we may have to cut out other activities. The main purpose is to have instrumentation at the advanced edge of the art.

Dr. PIMENTEL. A hiatus was put in for exactly the reason you are asking about: we would be able to support the operation of this new facility. Part of the long-range planning discussion had to do with whether we should start construction in 1980. We decided to delay not only construction but also planning, and in FY 1981 we have only a $1.7 million item for plans.

Mr. BOLAND. What do you need it for?

Dr. JOHNSON. Important research proposals which are now being limited by restrictions in wave length coverage and the lack of sensitivity and resolution of the existing millimeter wave length telescope.

Mr. BOLAND. Why do you have to have it this year?

Dr. JOHNSON. There is the opportunity in this spectral region to see what is going on in chemistry in space. There is a tremendously complicated amount of chemistry going on in space where just a few years back it was believed whatever that was in space was very, very simple indeed.

There are a lot of molecules which seem to relate to the possibility of the generation of life, and all of this has come out of radio-astronomy so this will be a very important instrument. It should be noted that by the time the 25-meter is built, over seven years will have elapsed.

Dr. PIMENTEL. It is one of the most exciting fields in astronomy. We supported the existing 36 foot telescope which represents one of the most important contributions to this field right now. It was a modest telescope investment and is definitely obsolete; it does not have the advantage of access to the Southern Hemisphere, but we might be able to arrange for this new point.

Mr. BOLAND. Can you indicate whether this is a target for reduction under review?

Dr. JOHNSON. It is certainly a possibility.

Mr. BOLAND. It's a brand new facility.

Dr. JOHNSON. There are other telescopes at that site. As Dr. Pimentel has indicated, this would basically replace an existing instrument at a different site.

Mr. BOLAND. Is it essential that we acquire greater capability with a new facility early on?

Dr. JOHNSON. It's not really sensitive in time with regard to making the observation. It is time to make use of this technology for better astronomical observations.

Mr. BOLAND. Also, during the budgetary review process, was there some concern expressed with respect to the reduction of operating telescope facilities?

Dr. ATKINSON. Absolutely. The balance is the big issue here.

Dr. JOHNSON. We must give very careful attention to the balance between the individual grants and the expenditures in centers, and we try to keep that at what we judge to be an appropriate level.

Mr. BOLAND. Would there be any serious consequences if we postpone this start for two or three years until the economy starts to cool off?

Dr. JOHNSON. It would be a failure to take advantage of an opportunity that exists to proceed. If we can't afford it, this is right. It could be delayed.

Mr. BOLAND. We will leave it right there and turn to the Atmospheric Sciences program subactivity.

ATMOSPHERIC SCIENCES

You are requesting $71.1 million in 1981—an increase of $7,931,000 over the 1980 level.

On page B-II-4, there is an interesting notation under significant recent achievements, which indicates that, "in four spring storms in the Northeastern United States, 78 percent of the acid in the rain was accumulated in the air below the cloud. This implies origins within nearby regions rather than long-range transport by the air above the cloud."

That is a kind of interesting statement, because last week we had Doug Costle before this Committee, and your statement seems to fly directly in the face of the information he told us. He clearly implied that the major problem with acid rain is the long-range transport—particularly from the middle west down wind into the New England area. He pointed out for example, that the average life of the sulfur emitted from the typical stack is roughly three days or 300 miles—but that a substantial additional amount of sulfur continues on up to 1,000 to 1,500 miles. I notice that your program is in cooperation with EPA—but it doesn't appear as though the two of you are talking on the same wave length.

Dr. JOHNSON. We work closely with them and with other agencies. The question that you formulate there is right at the heart of our program. Our program is to develop a better understanding of what is really going on in these chemical cycles that lead to acid rain; the observation, as mentioned here, suggests that it is nearby sources with the pollution being washed out by rain falling from clouds higher up, one could not argue with that very much.

On the other hand, you are citing some observations somewhat to the contrary, and those are things which simply have to be better observed so that such statements can be made with greater precision and one can determine with greater precision how far away the sources are on the average.

There is a lot of uncertainty in this area as to the cycles, especially the sulfur cycle.

Mr. BOLAND. Mr. Coughlin?

TRANSPORT OF AIR POLLUTIONS

Mr. COUGHLIN. Do you have a study involved in tracking sulfur emissions and tracking the atmospheric emissions?

Dr. JOHNSON. Well, there are programs for tracking atmospheric emissions, of course, but for the actual transport on a large scale of those pollutants, I don't know specifically. The studies are more limited in area right now.

Mr. COUGHLIN. What specific studies do you have in this area?

Dr. JOHNSON. I have to consult the record to see what the individual projects are on this, but they are aimed at better understanding of the acid rainfall and the atmosphere. This is confused a

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little bit by whether you look just at the rainfall or whether you look at the acidity in the streams and lakes.

We are concentrating on the——

Mr. COUGHLIN. I am talking about the transport of polluted air.

Dr. ATKINSON. This is a major problem. Last August, the President called for an interagency committee to ensure coordination among the various agencies.

Mr. COUGHLIN. Involved in international relations, too?

Are you working on that portion of the problem?

Dr. JOHNSON. Our concentration is on the acid rain. There are a couple of interesting comments here, noting, of course, the trends towards greater problems in this area growing out of increased use of coal. Shifting from oil to coal on the whole is going to exacerbate the problem with acid rain, unless the sulfur is taken out of the coal.

Mr. COUGHLIN. Let me come back to what I asked first. The transport of air pollutants containing sulfur, in particular, are you doing studies on that?

Dr. JOHNSON. The studies do not recognize national boundaries. The long-range transport aspect is a sensitive topic in international relations.

Dr. ATKINSON. The answer is yes, we are.

Mr. COUGHLIN. When will you expect those studies to be complete?

Dr. JOHNSON. Our studies are on the physics of the situation, the atmospheric behavior that is involved in this, not the political aspects.

Mr. COUGHLIN. I am talking about the transport. Is that what the physics is?

Dr. JOHNSON. Yes.

Mr. COUGHLIN. The patterns of transport of air pollutants.

UNDERSTANDING TRANSPORT PATTERNS

Dr. ATKINSON. Our job would be to develop methods, techniques and approaches to the study of those patterns, to devise effective measurement procedures, and to understand the phenomenon.

Dr. JOHNSON. I would also say that the understanding of it is still at a fairly early stage, so the answers you are seeking are not readily at hand. It's going to be a while before this is well-understood, because it is a very massive undertaking to really get a good observation on such a large complex system as this.

Mr. COUGHLIN. There seems to be some dispute in the scientific community as to exactly what the transportation patterns of pollutants in the United States are; this is a fairly major problem, and I would think your Foundation would be very heavily involved in studying it.

Dr. JOHNSON. This has to concentrate on the life time of the pollutants in the atmosphere. It's a question of whether the pollutants live long enough before they are washed out.

Mr. COUGHLIN. You say there is no dispute?

Dr. JOHNSON. The weather maps adequately portray the motions of the air. What is uncertain is how the pollutants disperse in the air, and how far they are carried, the dispersal of the pollutants

from sources, in which air currents do they spread, and how far do they go before they get washed out by a precipitation process.

These are massive things to investigate, and it takes a lot of field operation to answer questions of that sort, and that is why the answers are not forthcoming very quickly.

Dr. ATKINSON. That is why we have an apparent conflict. One study can report 78 percent local pollution. Another investigator can report a longer-range transport. The difference becomes an issue. If we had the different investigators sitting at the table, there would be agreement.

Mr. COUGHLIN. How soon do you expect to get some answers?

Dr. JOHNSON. Some answers are forthcoming right now, such as the one that is cited here. However, there is room for doubt or for contrary opinions based upon the present investigations. These will continue to improve, but it is going to be a gradual process.

There is no precise answer to your question. We can't say two years from now we will be able to answer the question to your satisfaction. We will be able to answer it better than we can today, but there is still going to be a lot of room for questions around such a complicated issue.

Dr. PIMENTEL. We are dealing with priority areas. To quote two places in our budget book, we indicated priority areas, determination of the sources and sinks of trace substances in the atmosphere and their chemical, dynamic and energetic roles on the atmosphere and on each other, and ocean-atmosphere, ice-land coupling processes that will aid in understanding and modeling the climate system. In other words, where do the pollutants come from, and where do they go when they disappear?

The final network will permit an organized research program to evaluate the global scale dimensions as well as the transport in the atmosphere. We are trying to provide a fundamental understanding that will be used to answer questions like yours. It would not be possible to say in two years we will have all the answers you need.

Dr. ATKINSON. The process will lead eventually to regulations, and it is important that we first understand the basic science. It is a mistake to generate regulations based on isolated studies.

Mr. COUGHLIN. Thank you.

CLOUD PHYSICS

Mr. BOLAND. On page B-II-7, the justifications indicate that the increase of $4,331,000 for the Atmospheric Sciences Project support, which is detailed in the table on B-II-10, will be used to restore basic research such as cloud physics. That was cut back when the Applied Science and Research Applications Weather Modifications Program was terminated during fiscal year 1979.

As I recall that program, it was terminated because it received low marks in a very critical review at the Foundation. Why did you terminate that program?

Dr. ATKINSON. What was terminated, Mr. Chairman, was the program known as NHRE, the National Hail Research Experiment. This was done at the end of fiscal year 1978 because the hypothesis being tested, that is the one put forward by the Soviets, did not

seem to apply to clouds in Northeast Colorado. Actually, a great deal of knowledge was gleaned from NHRE, so from a scientific viewpoint it was not a failure. What failed was the Soviet hypothesis of cloud seeding to minimize hail damage. NHRE was a part of the ASRA Weather Modification Program.

The remains of that program were transferred to the Division of Atmospheric Sciences in February 1978 in order to develop a program in understanding the basic physics and chemistry involved in modifying the weather. Thus that program, now known as the Experimental Meteorology and Weather Modification Program, is being built up to achieve that objective.

Still other remnants of the Old Weather Modification Program were retained in other parts of ASRA. Isn't that right, Jack.

Dr. SANDERSON. You are correct, we terminated that program because of the overall review of the RANN Program. At the time we reviewed it, it was decided that the original concept which was to apply scientific capability using a model developed by the Russians simply would not work.

[Additional information follows:]

NSF support for basic atmospheric sciences research in such areas as cloud physics is estimated to total $9.0 million in fiscal year 1977; $7.9 million in fiscal year 1978; and $8.8 million in fiscal year 1979. These funds were provided by the program elements in Meteorology, Weather Modification and as a follow-on to the Weather Modification effort, Experimental Meteorology. With the establishment of the ASRA Directorate in February 1978, the Weather Modification effort was terminated and certain elements of the program transferred to AAEO to form the basis of the new Experimental Meteorology program.

Initiated in the summer of 1972, the National Hail Research Experiment was the center piece of the research applications effort in weather modification. By 1978 the Experiment indicated that the methods, patterned in part after the Russian experience, employed to induce or alter precipitation patterns could not be demonstrated statistically. The cloud processes research effort indicated that the Russian model was not applicable to the Colorado test site. Consequently, it was concluded that further basic research would have to be undertaken to elucidate those mechanisms which might induce precitation in cloud formations and that further applied research efforts were not appropriate at that time.

GLOBAL ATMOSPHERIC RESEARCH

Mr. BOLAND. On page B–II–10, there is an indication that you are continuing support for the Global Atmospheric Research Program at the same level in 1981 as 1980—$5,600,000. I thought that program was going to be terminated in 1980?

Dr. JOHNSON. I don't know.

Mr. BOLAND. What about that?

Dr. ATKINSON. We planned to terminate the International Decade of Ocean Exploration. The question was whether the program would be a separate item in our budget process or a mix of such research supported by NSF. At the moment, we have decided to maintain the larger-scale research experiments in this area as a separate budget item.

Mr. BOLAND. We have it next year in 1981.

Dr. ATKINSON. There is quite a bit of discussion on this issue. Some argue that if we don't maintain a separate item for such large-scale experiments they will not survive.

Others argue that as long as funds are set aside for large-scale experiments, they will be done independently of the quality of the science.

We want to support large-scale experiments, but we also want to support only those of high quality. The National Science Board has grappled with this issue at its last two meetings.

Dr. JOHNSON. Mr. Boland, I have an answer to your question. What we are referring to is the GARP Atlantic Tropical Experiment (GATE). The field phase of GATE was completed in 1974.

Mr. BOLAND. But the preceding paragraph says some of the major analysis projects will have been complete by fiscal year 1980. Therefore, the planned funding level of $600,000, a decrease of $630,000 for fiscal year 1981, reflects the planned phasing out of this effort.

Dr. JOHNSON. That is true, yes, but what we are doing is phasing out the analysis phase of GATE which we have supported for 5 or so years. Of course, analyses still are going on, but the level of activity is decreasing. GATE is only one project of the Global Atmospheric Research Program (GARP).

Mr. COUGHLIN. What percent of the GARP project does the United States contribute?

Dr. JOHNSON. I don't know the overall budget on that.

It is not very extensive participation from other nations, so we don't have the——

Mr. COUGHLIN. Does the United States contribute about 75 percent?

Dr. JOHNSON. I doubt that. I don't have the numbers to respond, but there are a great number of other countries contributing aircraft.

Dr. ATKINSON We will supply that for the record, but we know the United States contributes less than half.

[The information follows:]

COSTS FOR THE FIRST GARP GLOBAL EXPERIMENT (FGGE) ALSO KNOWN AS THE GLOBAL WEATHER EXPERIMENT (GWE)

The GWE field phase terminated in December 1979 after having run for one year (1 December 1978 to 30 November 1979) and after a warmup year from 1 December 1977 to 30 November 1978. The data processing phase and some of the analysis phase will be started in FY 1980 and will continue for a minimum of five years.

The following information has been assembled by the World Weather Program Office of the National Oceanic and Atmospheric Administration and the GARP Program at the NSF.

FY 1979:	NOAA & NASA (GWE)	$ 8,712,000[1]
	NSF GARP Program (MONEX)	3,343,000
	NSF GARP Program (GWE)	612,000
	NSF Oceanography & Polar Program (GWE)	322,000
	NSF International Programs (MONEX)	1,400,000*
	TOTAL U.S.	$14,389,000
	TOTAL GWE (non-U.S.)	$200,000,000 (estimate)
	U.S. Contribution 6.7%	

FY 1980:	NOAA & NASA (GWE)	$ 3,835,000[1]
	NSF GARP (MONEX)	2,600,000
	NSF GARP (GWE)	600,000
	NSF Oceanography & Polar Programs (GWE)	100,000
	NSF International Programs (MONEX)	250,000
	TOTAL U.S.	$ 7,385,000
	TOTAL GWE (non-U.S.)	$50,000,000 (estimate)
	U.S. Contribution 12.9%	

[1] This number does not include platforms such as satellites that have been justified for other purposes.

* This is the dollar equivalent of special foreign currency funds - Indian rupees.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Mr. BOLAND. On page B-II-18, the budget for the National Center for Atmospheric Research is displayed. You are requesting $29.9 million, an increase of $3.3 million over 1980.

The National Center for Atmospheric Research is totally supported by NSF. Has the NSF or OMB or OSTP ever attempted to enlist joint support for NCAR from agencies such as NOAA, NASA, EPA, and DOD?

Dr. JOHNSON. There is some such support going to NCAR now. There is some work through other agencies being done. Some of the scientists are involved in NASA projects. We are also embarking upon a program for cost recovery at NCAR for all activities done for other agencies.

At the present time, involvement with NCAR, for example, by NASA, occurs when there is a simultaneity of interest and NCAR contributes to the total effort. NASA may provide a good deal of money for some scientists in the satellite program.

Ordinarily up until the present time the salary of NCAR Senior Scientists involved was paid by NCAR; we are working on asking for total cost recovery for any efforts of this sort.

Dr. ATKINSON. For the past two years, we have been discussing with NCAR the possibility of pulling in more support from other agencies, and I think we will see movement in that direction. Our main concern is to protect the center as a basic research facility for university scientists, so we want them to have a broader base of support from other agencies.

But we don't want them to become Beltway bandits, seeking funds from wherever they can get them and undermining the capability to perform basic research.

Mr. BOLAND. Until this year the administration of this Center and that of the University Corporation for Atmospheric Research, which manages NCAR under support from NSF, have been through the same individual with presumably the same support staff. However, beginning this summer, there will be a separation of these functions, with the President of UCAR located in Washington and the Director of NCAR located in Boulder.

What was the rationale for establishing those separate offices?

Dr. JOHNSON. From the very beginning, the concept has been that the Corporation UCAR would be representative of the university community. Its Board of Trustees is made up of representatives from the university community. UCAR's responsibility is to operate NCAR. Those two functions, the President of UCAR and the Director of NCAR should really be separate activities.

They have been filled by the same individual in the past. This has given rise to management questions. We often ask in what capacity the individual is acting, as a representative of the university community, as President of UCAR, or as a representative of the NCAR efforts, Director of NCAR.

We think it is a healthy move to separate those two functions.

Mr. BOLAND. What about the administrative support services and the management fee for operating NCAR? Are they going to be increased as a result of this change?

Dr. JOHNSON. We are not anticipating any increase at this time, although this may have a small impact on it. It's the salary of one individual that is involved which I think has been split between the two accounts in the past.

EARTHQUAKE RESEARCH STUDIES

Mr. BOLAND. For the Earth Sciences Program subactivity, you are requesting $27.9 million in 1981—an increase of $2.6 million above the 1980 level. I noticed that the largest single program increase under Earth Sciences is the Earthquake Related Research area which on page B-III-6 increases $600,000 to $7.2 million in 1981.

As you know the U.S. Geological Survey has a large Earthquake project which includes geological research and earth movements and earthquake prediction. How is this work on prediction that NSF is funding coordinated with the work of the Geological Survey?

Dr. JOHNSON. Well, the NSF program is not an earthquake prediction program. It's a program to study the fundamental nature of the earthquake process. The Geological Survey program is concentrated on the prediction problem. We work very closely with them.

Mr. BOLAND. Is this the total, $7.2 million, of all earthquake research supported by the Foundation that is not carried under the Earthquake Hazards Mitigation Program which is funded through ASRA?

Dr. JOHNSON. Yes, this is the total of the work that is done on fundamental earthquake studies. The Hazards Mitigation Program is funded in another directorate.

Dr. ATKINSON. The answer is yes.

Mr. BOLAND. Since earthquake research is carried out in detail by the U.S. Geological Survey—why is such a large part of NSF's geophysical budget used for earthquake related research?

Dr. JOHNSON. This is the means by which the unsolicited ideas of the academic community are brought to bear on this problem. The Geological Survey does not support fundamental research in the academic community in the same degree that NSF does. We are an Agency for marshalling the strengths of that community.

Mr. BOLAND. Are there other areas of geophysical research which may merit funds—but which are not being supported because of the heavy emphasis on earthquake related research?

Dr. JOHNSON. There is budgetary pressure on all areas. In that sense, the answer would be yes but we are able to keep it appropriately balanced. Earthquake research is good research that cuts across all the areas of geophysics.

SHIP CONSTRUCTION

Mr. BOLAND. On page B-IV-1, it indicates that the request for the Ocean Sciences Program Subactivity is $9,381,000 above the 1980 level. That is a 14 percent increase in operating funds. However, in the discussion under "progress in ship construction/conversions" on page B-IV-3, it appears that $3 million was spent on ship construction in 1979 and in 1980 and will no longer be needed in 1981.

Does this mean that the actual increase in 1981 is more like $12.4 million rather than the $9.4 million stated—because the $3 million spent on ship construction in 1980 was built into the base in 1981? Is that correct?

Dr. JOHNSON. No; I am not sure where the item is, but this budget, as presented here, includes funds for an oceanographic ship as a replacement for a larger, more expensive ship currently being operated.

We have a real problem in oceanographic ships associated with the increased cost of fuel, and some of our ships are larger than we need. Therefore we need to replace them with new ships of a somewhat smaller size. When we do this we can recover the cost of this lower operating cost in about seven years, but as fuel prices increase, we are apt to recover the costs in more like five years. We do have this program for building replacement of existing ships.

Mr. BOLAND. The actual 1981 increase would be about $12.5 million, the $9.4 million plus the $3.1 million, rather than the increase that you have indicated in your justifications. Would that be correct?

Dr. JOHNSON Yes, sir; 3.6 of that is for a replacement ship in 1981.

Mr. BOLAND. The paragraph indicates that "The review and the assignment of both fiscal year 1979 and fiscal year 1980 ships has as its first consideration the achievement of the best possible improvement of the overall academic fleet inventory and a concomitant savings in annual operating costs." It doesn't say anything about a new ship here.

Dr. JOHNSON. I realize that, and $3.6 million for a replacement ship is included in the amount that you are referring to.

Mr. BOLAND. If it is, do you think it should have been mentioned somewhere in the justifications? You say that it was——

Dr. ATKINSON. B-IV-22. We mentioned it only in the highlights. The second paragraph from the bottom.

U.S. ANTARCTIC PROGRAM

Mr. BOLAND. Turn to the U.S. Antarctic Program. On page C-1 you are requesting $63,400,000 in 1981, an increase of $7,560,000 above the current level. Would it be fair to say that this issue on where do we go from here in the Antarctic is beginning to come to a head?

Dr. JOHNSON. As to our future presence in Antarctica?

Mr. BOLAND. As to the amount and duration of activity that we are engaged in there?

Dr. JOHNSON. This is a special responsibilty that the NSF carries out by direction of the National Security Council.

We are the American agent for presence in Antarctica and by national policy we have the four permanent stations that exist there.

What we have before us is essentially the cost of maintaining that presence, at a constant level of effort.

Mr. BOLAND. Where do we go from here? We have been involved in an awful lot of research down there.

Didn't the Treaty signatories get together last year in Washington and discuss the exploitation of Antarctica's mineral and marine resources?

Dr. JOHNSON. This has been discussed and if things turn in the future to exploitation of the resources in Antarctica at that time NSF should be discharged from its special responsiblity on this program.

Mr. BOLAND. What was the outcome of that meeting among the Treaty signatories?

Dr. JOHNSON I don't have the answer on that. I can get for you a statement of what the outcome of those discussions was.

[The information follows:]

CONSERVATION AND MANAGEMENT OF RESOURCES DISCUSSED AT TENTH ANTARCTIC TREATY CONSULTATIVE MEETING

Antarctic mineral resources, marine living resources, and the further protection of the antarctic environment were among the major concerns at the Tenth Antarctic Treaty Consultative Meeting, 17 September to 5 October 1979, in Washington, D.C.

Nine recommendations were adopted unanimously at the meeting, bringing the number of recommendations made since the first consultative meeting (1962) to 127. The recommendations are intended to further the principles and objectives of the Antarctic Treaty. By far the largest number of recommendations (71 of 127) augment the treaty's protection of the antarctic environment.

At the tenth meeting the representatives reaffirmed their commitment to continued ecosystem research and to the development of a Convention on the Conservation of Antarctic Marine Living Resources based on a series of meetings already held to elaborate the convention.

Other discussions focused on the effects of possible exploration for and exploitation of mineral resources. The representatives concluded that a regime for the management of antarctic mineral resources is of prime importance and that it must include means for:

° assessing the possible impact of mineral resource activities on the antarctic environment;

° determining whether mineral resource activities will be acceptable; and

° governing the ecological, technological, political, legal, and economic aspects of mineral resource activities if they are determined to be acceptable.

The regime would include rules protecting the antarctic environment and requiring that any mineral resource activities be in compliance with those rules.

Special meetings, similar to those held to discuss the Convention on the Conservation of Antarctic Marine Living Resources, will be arranged so the treaty nations can begin work toward a draft regime for mineral resources.

Texts of the nine recommendations adopted unanimously at the meeting appear in the December 1979 issue of the Antarctic Journal of the United States.

Mr. BOLAND. I am looking at the Business Week of August 27, 1979, where it said:

"Next month the Treaty signatories are to get together in Washington and discuss exploitation of the Antarctic's minerals and marine resources."

Is there anything at this time that prevents 15 or 20 of the oil companies from forming a consortium to begin exploratory drilling in the Weddell Sea?

Dr. PIMENTEL. There is. I believe that meeting took place, and there was no change in the present status. Such exploration is precluded by the signatories.

Dr. HACKERMAN. By their mutual agreement to exercise voluntary restraint.

Dr. ATKINSON. Of course other countries are fishing for krill in Antarctic waters.

Mr. BOLAND. I take it that the position of the NSF and also the State Department is that we should not permit exploitation of natural resources, particularly oil at this time. Is that a fair statement?

Dr. HACKERMAN. Excessive exploitation of other resources, including marine life, should not be permitted.

Mr. COUGHLIN. Mr. Chairman, but other countries are harvesting krill down there.

Dr. JOHNSON. Yes, but not in great quantities. Japan and Russia——

Dr. HACKERMAN. They can use fairly sophisticated techniques.

Dr. ATKINSON. They are large takes.

Mr. COUGHLIN. This is in violation of the Treaty?

Dr. HACKERMAN. No; the Treaty does not address resource issues. That is why special conventions on resource conservation and use are now under negotiation.

Mr. COUGHLIN. Are we harvesting any krill down there?

Dr. JOHNSON. No; nor is it perceived likely that we will have the desire to do so.

Dr. ATKINSON. That biological world in Antarctica drives the biological structure of much of the oceans. If it is severely disturbed, it may have an impact throughout the world. We need a deeper understanding of the driving features in that region before something is done that might destroy the whole ocean marine life.

Dr. HACKERMAN. The major concern is that it is part of a food chain which encompasses a good part of the Earth.

Dr. JOHNSON At the Tenth Consultative Meeting it was agreed to initiate a series of informal discussions regarding issues raised in preliminary negotiation of a possible convention for mineral resource exploration and exploitation in Antarctica.

None of the meetings have yet been scheduled.

Mr. COUGHLIN. Why aren't we harvesting krill?

Dr. JOHNSON Well, I don't think there is much economic incentive. It's too far down there. We are not that interested in the use of krill as a Nation is my belief.

Dr. ATKINSON. Private industry has not identified the Antarctic as an area for fishing. It may well be that it requires a country like Poland or Japan to put together the sort of equipment.

Dr. JOHNSON. It is also true there exist strong concerns about it, growing out of the view that it is important first to examine the food chain in Antarctica waters, and be sure one doesn't severely upset the ecology down there.

Dr. PIMENTEL. It's apparently not appropriate for human food consumption; so the potential immediate uses contemplated are fertilizer or animal feeding, and currently the situation would not be economical.

Dr. ATKINSON. The animal then has the same taste as the krill.

LC–130 AIRCRAFT

Mr. BOLAND. Under the Operation and Support Program on page C–II–5, the budget request contains an increase of more than 13 percent for this program. About 85 percent of that increase is in the operation and support program—all of which is not actually performing any research. About 40 percent of that operation support increase is for the repair to two LC–130 aircraft. How many LC-130s are you currently operating?

Dr. JOHNSON. Seven, 2 of which are near the end of their legal life. They are the two to undergo service life extensions——

Mr. BOLAND. Haven't you operated the program with four planes in the past?

Dr. JOHNSON. In actual fact, of this number of seven, only five were available for use during the past season.

Mr. BOLAND. How old are the LC–130's?

Dr. JOHNSON. Some are old airplanes. I don't know the dates on which they were procured.

Dr. HACKERMAN. Some of them are fairly new. There are two of them that are two or three years old, three are six years old, and, the other two are twenty-two years old.

Mr. BOLAND. On page C–II–5, it says that the "maintenance costs are largely fixed depending on the number of aircraft, their age, and the hours of operation, however, fiscal year 1981 funds will support the post-recovery repair of the damaged LC–130 aircraft that will be recovered from East Antarctica in 1980 and 1981." What do they cost?

Dr. HACKERMAN. The number I remember is about $13.5 million.

Mr. BOLAND. Of those, is that the only one you are repairing?

Dr. JOHNSON. There are two of the planes now operational that require service life extensions in order to be good for another 10,000 hours of operation or ten years whichever comes first. This one that we intend to recover in Antarctica, which has been there since 1971, would constitute the eighth aircraft.

Dr. ATKINSON. This area is a major problem for us: the LC–130s and the helicopters. We are re-examining the situation since the military is changing over to another type of helicopter. The issue of aircraft support is before us now in the planning of the program; it is a five to 12-year issue.

Dr. JOHNSON. Three of our older planes including the one that crashed were built in 1958.

The others were built from 1973 to 1977.

Mr. BOLAND. We have been putting $50 to $60 million into this program for many years. How would you rate the basic research return on that expenditure of money?

Dr. JOHNSON. Well, I think that is well regarded in terms of the science output and that it stands up well in comparison with other projects. It is good quality research. It is a $9.3 million program of research grants. Of the remaining $54.1 million for operations, $9.5 million is for direct support of those science projects during the period the scientists are working in Antarctica, $9.3 million is for major construction and procurement and $35.2 million is the cost of maintaining the bases, etc. That is, the cost of being there.

Thus, buried in "operations support," or the cost of being there are some services rendered to the research program that one would have to pay if the same thing were done outside the Antarctic. It might be better to think of it as a $20 million research program, with the remainder being the costs associated with being in the Antarctic, and operating and repairing the bases, transportation and life support system.

Mr. BOLAND. Our being there is something more than basic research?

Dr. JOHNSON. It's the matter of national policy that we maintain the level of presence we have there.

Dr. ATKINSON. Exciting science is going on there, and Dr. Hackerman may want to speak to it. In the past two years, we have been much more pleased with the quality of science.

Dr. HACKERMAN. The last couple of years have indeed been very good, partly because there are some very able young people who have chosen to go down there, that makes a great deal of difference.

It's a unique place. It's one of the only good places to study ice, which I think is of value. It's an important place as far as atmospheric charactistics are concerned.

Mr. COUGHLIN. How much can you study ice?

Dr. HACKERMAN. Ninety percent of all of the fresh water in the world sits down there in the world of ice, and you can study its movement and the way it gets into the ocean, what that does as far as ocean currents are concerned, what impact it has further north, even beyond the equator, the effect it has on the atmosphere, and the temperature changes that it causes.

Dr. ATKINSON. Six or seven years ago, we had not identified the critical role played by that area of the world in driving the atmosphere. We are beginning to establish the same kinds of links in the food chain; the work is exciting.

Dr. JOHNSON. The ice down there is worth noting. There would be climate changes resulting in melting some of that ice; it won't take very much of a thrust in that direction to be underwater here.

Dr. ATKINSON. A major conference sponsored by the Saudi government considered the idea of moving icebergs from Antarctica into other areas as a source of water.

U.S. ANTARCTIC PROGRAM BUDGET

Mr. BOLAND. Under your ZBB exercise, is the 1981 level a minimum, current, or improved funding for the Antarctic Research Program?

Dr. JOHNSON. The Antarctic Program hardly fits under the ZBB very well. We have those other constraints with regard to that program. We don't have the same opportunities for trade-offs there that exist in other programs. If we are going to be there, we have got to meet the logistic expenses.

Dr. ATKINSON. We have thought about closing a station, and we may do so. But there is a minimum level of operation support that must be maintained; not to have an appropriate level of science, given that operating support, would be a mistake.

Dr. JOHNSON. Probably the biggest alternative there, or the one that would make the most difference, would be if we decided to abandon the opportunity for air support. That costs a good deal, but it adds importantly to our presence there. We are the mobile nation in the Antarctic, and that is by virtue of air support.

Mr. BOLAND. Who drives the budget for this activity, the NSF or the National Security Council?

Dr. JOHNSON. Well, they don't take part in the individual project decisions or in the preparation of the budget, but it is their decision which basically establishes the constant level of activity which we maintain there.

Because of the great increase in cost of fuel and the fact that that makes significant increases in the cost of this activity, we are looking at options, and we may be looking at questions as to whether there are other levels or other modes of presence in Antarctica that would be acceptable.

It is not an easy problem. If you are going to be there, it does take this minimum level of presence in order to be able to operate in a significant way.

Dr. PIMENTEL. NSF's program there is driven by the science we see and can afford there. It's important science, it is a unique place and the problem is that operation support makes it expensive.

If we were to propose a major change in U.S. presence and scientific level, questions would be asked, and we would have to give good answers. But I think we are determining the level in response to what we consider to be extremely important science accompanied by a large program of operations support.

OCEAN MARGIN DRILLING CONTINUED

Mr. BOLAND. The ocean drilling programs are displayed on D–1, where you are requesting $27.3 million in 1981—an increase of $7,825,000 above the current 1980 level. We have already discussed in some detail the Ocean Margin Drilling project. Apparently, most of the deep holes using riser and well control would take about a year each to drill. If that much time and expense per well is involved, why do you want to drill off-structure? I know that the oil companies want to drill off-structure—possibly so there is no problem of the government being in on the oil drilling business—but can't you get excellent basic science by drilling on-structure—as well as off-structure?

Dr. JOHNSON. Well, if one were to run into a petroleum deposit with large commercial potential it could eliminate the prospect of completing the scientific investigation so, from a scientific viewpoint, it would be better to drill in locations where oil and gas are not likely.

From the technological point of view in going into this much deeper water, you want some experience with this equipment operating in such deep waters before you encounter petroleum.

You avoid on-structure until you have acquired enough experience until you feel sure you can handle problems that arise. Even if you drilled on-structure, and by so doing found petroleum, that in itself would only be a very small step towards the evaluation of what petroleum is there.

You would have to drill many more wells before you have any real concept as to the extent of the reservoir, so I think that all of those things add up to make it a very wise decision in this program to avoid drilling on-structure.

DEEP SEA DRILLING PROGRAM

Mr. BOLAND. We will turn to page D-6. Last year we asked if the fiscal year 1981 would be the last year for the deep sea drilling project. Your response was rather "iffy"—but hasn't the Glomar Challenger begun to exhaust the potential good science return in that program? Are we not beginning to have a problem here of diminishing marginal return?

Dr. JOHNSON. No; that is not the case. Over 700 holes have been drilled and this sounds like a lot but in terms of the area that is being investigated this corresponds to drilling one hole in an area the size of California plus Oregon plus Washington State.

Another thing which has a big impact on this program is the recent development of the hydraulic piston core. It is something which only now has come into use and has proved to be a very fine new instrument for getting undisturbed samples from the ocean bottom, and these are especially useful to paleoclimatic investigations.

The community that is interested in that is very distressed at the prospect of the Challenger operation ceasing at the end of 1981.

Mr. BOLAND. I noticed on page D-6 that just two years ago the net cost of this program to the United States was only $10,600,000—after you deducted the foreign contribution. Now, the net cost is $17.3 million. That is a 70 percent increase in just 2 years. What about that?

Dr. JOHNSON. That year was an anomaly. I would have to get the schedule over the years to substantiate that statement, but there was one year where the appropriated funds were particularly low, and the use of foreign funds was particularly high in order to carry the program along.

Mr. BOLAND. It would seem that we are continuing to pick up the larger share of a program that was supposed to end in fiscal year 1980?

Dr. JOHNSON. When the international participation started, the international participants were paying $1 million a year each. That now is at the level of $1¼ million, and if there is an extension of

the Challenger beyond 1981, probably just for one year, we are talking in terms of $2 million.

Well, Germany has indicated their willingness to pay a $2 million fee if the program could be continued in 1982, and England had indicated the likelihood of it. We are conducting discussions with the French today.

BIOLOGICAL, BEHAVIORAL AND SOCIAL SCIENCES

Mr. BOLAND. We will turn to the Biological, Behavioral and Social Sciences directorate.

The budget request for fiscal year 1980 was $172,250,000 and the current plan is $166,531,000. That is a drop of $6 million. Then on E-2 you indicate why in one sentence you dropped that figure $6 million. It indicates that the current level in 1980 reflects adjustments resulting from funds actually appropriated.

What about this?

Dr. CLARK. The $166 million was the appropriated, it is the amount authorized on the House Floor.

Mr. BOLAND. So the authorization bill held it to $166.5 million in 1980?

Dr. CLARK. That is right. I have a question mark by that number myself. I will have to supply the information for the record.

[The information follows:]

DIFFERENCE IN FUNDING LEVELS BETWEEN THE FISCAL YEAR 1980 BUDGET REQUEST AND THE FISCAL YEAR 1980 CURRENT PLAN IN THE FISCAL YEAR 1981 BUDGET FOR BIOLOGICAL, BEHAVIORAL AND SOCIAL SCIENCES

The original fiscal year 1980 budget estimate to the Congress for the Biological, Behavioral, and Social Sciences was $173.5 million. This estimate has been reduced in three steps starting with P.L. 96-44, the NSF Authorization Act for fiscal year 1980, which limited Biological, Behavioral, and Social Sciences to $170 million. The second step resulted from the transfer of $1.25 million in estimates for regional instrumentation facilities and similar programs to the new Cross-Directorate Programs activity. The third step adjusted the resulting estimates ($168.75 million) to operate within amounts actually appropriated. Thus an appropriation reduction of 1.3 percent ($2,219,000) resulted in the current plan of $166,531,000.

BASIC RESEARCH FUNDING

Mr. BOLAND. The appropriation for the National Science Foundation reduced the total request for basic research by only $7 million. It would appear that most of that reduction was applied to this Directorate. Is that right?

Dr. ATKINSON. We didn't have a choice in that matter.

Mr. BOLAND. Each year the Congress makes some effort to attempt to determine whether basic scientific research is well-balanced, non-duplicative, and properly attuned to the needs of society. We have been told repeatedly in recent years that our technological advantage over Japan and Western Europe is slipping away—even in the face of substantial increases in basic research budgets in the past 3 or 4 years. Both of those trends lead to the suspicion that we are not running our basic R&D program properly.

What about the biological area? What major changes in your approach to basic R&D would you make in this Directorate in order to improve our technological posture in the world?

Dr. CLARK. This may be where an article from this week's Newsweek, called, "How Molecular Biology is Spawning an Industry" demonstrates where the research programs come in. Developments in these fields are happening at an incredibly fast pace.

Dr. ATKINSON. NSF has a unique role in the history of support of recombinant DNA research and cloning research. These are areas with dramatic implications.

Dr. CLARK. It's clearer that more and more, in terms of popular phrasing, bio-technology is going to find its way into the industrial sector.

RECOMBINANT DNA RESEARCH

Mr. BOLAND. Yesterday, you talked briefly about the DNA recombinant research. What new developments in this area have transpired in the past year?

Dr. CLARK. The synthesis of interferon and insulin using these methods, are two new developments.

In addition, what we have discovered about the composition and function of chromosomes from higher cells, including the kinds of cells in the human being are dramatic. These findings were also developed from the use of recombinant DNA techniques. It has been shown the genes have spaces in them; they occur in segments, and we don't know why, this means there are much more complicated genetic structures and expressions of biochemical activities than we had been aware of before.

Dr. ATKINSON. This issue of Newsweek magazine has a good account of these events.

Dr. CLARK. One of the most significant things that the Committee should be aware of is that earlier there had been a fair amount of concern and discussion because of the potential harm that might result from such techniques, and now over the last five years there is now evidence to suggest that the speculation was way off base. The NIH guidelines, under which all the research is done, have now been modified and biological and physical containment levels have been lowered.

Mr. BOLAND. I presume you have been in compliance with the NIH research guidelines?

Dr. ATKINSON. It is more than compliance; we worked closely with NIH in planning the guidelines.

Mr. BOLAND. You probably helped to establish them.

Dr. CLARK. Yes, we did, as a matter of fact. Or provided support for the first conference that led to them.

Mr. BOLAND. Were controls over this research adequate prior to the establishment of the guidelines?

Dr. CLARK. Yes, sir; I think they were adequate.

Dr. ATKINSON. In retrospect they were adequate. This is a beautiful example of the scientific community alerting society to problems. Many people have said the scientists overreacted. At the time, I think, it was an appropriate reaction. Society and the scientific community have resolved the issue and have come to an appropriate arrangement.

Dr. CLARK. I would say the important thing about the guidelines, even though they set down conditions under which experiments

should be done, were really not restrictive guidelines at all in terms of stopping research. They just developed a cautionary approach as to how the experiments should be carried out.

Dr. ATKINSON. If there hadn't been rational discussion of these matters, if the guidelines had become more restrictive other countries would have advanced in this area of research. Many scientists were concerned, and there was some indication of such advances in other countries.

LANGUAGE ACQUISITION

Mr. BOLAND. On page E-II-4, under the Behavioral and Neural Science Program subactivity, there is a description of the mathematical theory of learnability. The justification describes this as a "major advance."

It also states on page E-II-5, that "a valid theory of language acquisition will be a giant advance." It is a little difficult to understand what is so terribly significant about this research? Children learn a language—basically I would assume because they associate it with their peers and their parents who are speaking it. What is the great "major advance" here?

Dr. CLARK. These two investigators are writing a very lengthy book. They have developed an entirely new theory that attempts to model or state in mathematical terms some of the relationships of language. It appears their empirical data suggests that the mathematical approach they have pioneered toward understanding this level of language acquisition is accurate.

Dr. ATKINSON. That we can begin to think of a mathematical theory of language acquisition is a conceptual breakthrough.

Mr. BOLAND. Why?

Dr. ATKINSON. Not everyone learns to read, and no one can learn to read until he or she has acquired a language. Learning how a language is acquired——

Mr. BOLAND. How does one learn to read?

Dr. ATKINSON. We don't know. That is one of the problems. That is why we have the issue—and the theories about it.

Dr. CLARK. It is also true that language, of course, is one of the unique characteristics of the human being, and insofar as it is, it is also one of the mental activities that the brain uses. So by the study of language we also begin to get a handle on how the mind works, so that there is a very definite relationship for understanding mental processes.

Mr. BOLAND. What are the specific properties that the language must have in order to make it possible for a child to learn a language?

Dr. CLARK. I don't believe we can define it in quite such precise detail but I would like to provide an amplified answer for the record.

[The information follows:]

RESEARCH ON LANGUAGE ACQUISITION

Research on language acquisition is one of the most important areas in understanding the development of the child. Learning of an effectively useable language is the basis for all cognitive processes, including reading and thought--those things which may make human beings unique.

While most children, although not all, do learn a basic language at home through interaction with parents and siblings, the process by which this occurs is unknown. What factors in the parent's spoken interaction with the child are most important for the process of acquisition to occur? What characteristics of the child, biological and psychological, are essential? What are the characteristics the language must have to make it possible to acquire? These questions have no clear answers. They represent three aspects of the problem of language acquisition. The latter question is being addressed by Drs. Wexler and Culicover. They are engaged in a task of immense difficulty and slow rewards, but one whose importance for the fields of linguistics and developmental psychology is enormous. They have developed a formal, mathematically precise theory, of the learnability of language, from which precise predictions may be tested empirically. Their book: Formal Principles of Language Acquisition, currently in press, will explore a number of linguistic principles governing the growth of language in the young child. Such principles derived from the theory, appear to be universal principles, applying to all languages, and are not specific to English. The current research is important to linguistic theory generally, since the discovery of universal linguistic properties is a fundamental goal of linguistic science. What specific properties must a language have in order for a child to learn it? We do not yet know in detail, but the theoretical principles being investigated by Drs. Wexler and Culicover provide a basis for discovering those properties.

Mr. BOLAND. How much did this research cost?
Dr. CLARK. I will provide that for the record.
[The information follows:]

COST OF RESEARCH ON LANGUAGE ACQUISITION

Drs. Wexler and Culicover have been supported for a number of years by NSF. From July 1, 1977 to June 30, 1979, they were supported by a grant of $25,000 (BNS 74-23469 A01). Because of the excellence and great promise of their research, they were awarded a 5-year continuing grant beginning July 1, 1979 (BNS 78-27044) which provided funds at an average annual rate of about $26,000.

DEEP LAKE CORE PROJECT

Mr. BOLAND. On page E-II-11, under the Anthropological Science Program Element, you are requesting an additional $900,000 to allow for a deep lake core project in tropical Africa in the search of human origins. What is the total cost of this program?

Dr. CLARK. The Anthropology Program?

Mr. BOLAND. The deep lake core project under this program.

Dr. CLARK. It is under review now. The planning phase is on the order of about $200,000. The plans envision probably a four to five year effort funded at about a million dollars a year. It is a project that has been under development for some time. There was a conference in 1977 on improving the research approach. It involved a group of scientists that included geologists, ecologists, and archaeologists, so it will be an interdisciplinary undertaking.

TIME USE STUDIES

Mr. BOLAND. On page E-II-3, under Significant Recent Achievements, there is a discussion of a study which apparently has revealed that better educated parents will spend more time for child care on an average than less educated parents.

It is difficult for me to understand—why we need to spend money to study that. The conclusion of the study should have been obvious before the study was made. What about that? I suppose better educated parents would spend more time and money for child care. But I am not sure that is always the case.

Dr. CLARK. I don't think the study says more money.

Dr. PIMENTEL. It is more time. The question is how important is that? I think that is an important aspect of trying to bring more of a population into the reaches of education.

Dr. CLARK. You know the kind of question that you are raising is one that is often leveled against projects in the social sciences as I expect you know as well as I. That result is provided just as one example from a long series or rather a time use study that has been conducted at the University of Michigan.

It is a repeated time series study. About 15 years ago the initial study was made; it was repeated in 1975. What is being found is that overall patterns of time use have changed in the intervening years. Of course, we know that, too, compared to ten years ago or 15 years ago, but through such studies we are able to improve our planning and to provide quantitative information that we might not otherwise have.

Dr. ATKINSON. This study is designed to give us an understanding of how the typical American in different groups spends his or her time. One issue that——

Mr. BOLAND. Don't we already know that?

Dr. ATKINSON. No, I don't think we do. This study gives an indication of how much time young people spend in front of the TV set as a function of family background and as a function of age. That is important to know. This type of study provides such information.

UNDERSTANDING PRODUCTIVITY

Let me give you another example: productivity. How productive is the American worker? This time survey has produced an interesting finding. In certain industries—where it is said the American worker is not productive—he is not productive because of the training time involved.

These studies help to unravel some of the issues involved in understanding matters like productivity.

Mr. BOLAND. How does your statement about productivity relate to this study?

Dr. ATKINSON. The study involves samples of the workers, and part of the study asks how a worker spends his time. They are breaking time on the job into time spent in production versus time spent in training and so on. The breakout has established some relationships we were not aware of.

In certain industries it is said productivity is low; it may be because an unusually long training time is involved.

Dr. CLARK. The Michigan study is a study that has touched on a number of factors in an individual's life.

Mr. BOLAND. I am still a bit confused as to how the productivity study relates to the learning study?

Dr. ATKINSON. I am speaking of only one study; the time research is part of the learning study. It asks how does an individual spend his time: How much time for eating breakfast, for visiting with his wife, for working on the job. When he is at work how much time is spent on production, on coffee breaks, on training, or on talking to union officials.

It is an effort to understand how an American distributes his or her time. And to note how the distribution changes over time can be important. What has happened, for example, with the amount of time spent before a TV set?

PARENTS AND CHILD CARE

Mr. BOLAND. I thought the study indicated that better educated parents spend more time for child care on an average than less educated parents.

Dr. ATKINSON. That finding results from the study's questioning of parents; for example, how does your child spend his time? The time record will show how much time the parent spent with the child.

Mr. BOLAND. Probably 95 percent of the people would know that in the first place.

Dr. ATKINSON. I am not sure this is an intuitive example. Is it clear to you that parents from lower educational backgrounds necessarily spend less time with their children?

Mr. BOLAND. What about the children who are placed in day care centers where perhaps the education and training may be better?

Dr. ATKINSON. That is something the time records also can show. How much of the time is spent in day care centers, how much with the parent?

COST OF TIME USE STUDIES

Mr. BOLAND. Has the study been completed?

Dr. CLARK. Yes, sir.

Mr. BOLAND. How much money was spent on this study?

Dr. CLARK. Let me give you this for the record. The study was a comprehensive time use study. This example represents only one element of the total study. I can provide that and also attempt to answer what the per question cost might have been. It is a large data series.

Dr. ATKINSON. The series is in a data bank so that investigators may analyze it from their different perspectives. I am familiar with this study because I was in Germany about five months ago; German scientists are replicating the study and examining cultural differences between German and American use of time.

Mr. BOLAND. Are you planning any extension of this work?

Dr. CLARK. I hope so. It is considered one of the most important data bases.

Mr. BOLAND. How much are you estimating in this budget for additional funding? You may supply that for the record.

[The information follows:]

TIME-USE SURVEYS

National Time-Use Survey of 1965-66:
NSF share of costs = $40,000 over two years.
NSF supported the U.S. portion of a multinational comparative time-use project involving the Federal Republic of Germany, the German Democratic Republic, Bulgaria, Czechoslovakia, Hungary, Poland, Yugoslavia, Belgium, France, and Peru.
The sample was small and the survey instruments rather crude.
Aims: To establish a body of data on the characteristics of everyday life under different socio-economic and cultural conditions. To gather empirical information which could serve as a basis for testing theories and hypotheses about cross-national differences and similarities.

National Time-Use Survey of 1975-76.
NSF share of costs = $554,500. Other agency contributions = $42,000. This was a replication of the earlier study performed in the U.S. It involved a much larger sample of households and expanded the range of data collection techniques by experimenting with different methods.
Aims: To create time-series data on time-use. To develop more reliable data by comparing different collection methods. To experiment with new methods. To expand the amount of detail in the information collected.

National Time-Use Survey of 1980-81.
NSF support for the planning of the survey = $154,000. Proposal for full study under review.
Aims: To continue the time-series, but at a five rather than a ten year interval owing to the acceleration rapidity of social and economic events. To test hypotheses emanating from the existence of time-series data and the subsequent possibilities for modeling time-use. To introduce new verifiability checks. To introduce a longitudinal dimension into the time-series by re-studying a sample of the 1975-76 respondents.

Future of Time-Use Studies

It is expected in the long run that the collection of time-use data will be taken over by one or more governmental statistical agencies--possibly the newly established Division of Environmental and Nonmarket Economics, in the Bureau of Economic Analysis of the Department of Commerce, and/or the Bureau of the Census. These agencies are represented in all the planning and, together with one or more private foundations, may join in the support of the 1980-81 replication. Nonetheless, the measurement and understanding of time allocation still requires much experimental work in the nature of developing reliable estimates for individuals, testing the incremental value of matched non-diary information, and the like. The National Science Foundation thus continues to have an important role in furthering the methodology as well as insuring the viability of the highly significant time-series it has fostered this far.

TIME USE STUDIES BACKGROUND

Dr. ATKINSON. Mr. Boland, we ought to put a few questions to ourselves——

Mr. BOLAND. Why don't you put the questions to yourselves and answer them for the record.

[The questions follow:]

TIME-USE STUDIES

Question: **Why collect time-use data?**

Answer: A comprehensive method of accounting for social phenomena must underlie both understanding and interpretation of change. In the social sciences, there seem to be only three possible "currencies"--money, people, and time--in which such an accounting might be made. Data on money transactions are systematically gathered by a variety of governmental agencies, and standard sets of federal statistics on monetary transactions are produced regularly by the U.S. Department of Commerce and the U.S. Bureau of the Census. Such data are then used for a variety of scholarly and public policy purposes by academic, business, and government analysts. Data on people are obtained periodically by the U.S. Bureau of the Census, and the resulting materials are analyzed extensively by groups of users in the academic, public, and private sectors.

Data on time allocation are not, at least currently, part of any periodic data collection effort within the federal statistical establishment. The two major data collection efforts in this area have been conducted by the Survey Research Center at the Institute for Social Research, University of Michigan; both were partially financed by the National Science Foundation in connection with its interest in promoting new and better research resources for the social sciences.

Question: **What questions can these data answer?**

Answer: Economists interested in measuring productive activity, the rate of change in real output, and the level of material well-being, need to take into account a wider range of activities than those encompassed by paid employment. Thus, housework, childraising, volunteer activity, maintenance and repair of durables and housing, etc., all represent activities which enter significantly into any resonable notion of income and output. To the extent that these activities take place outside of the market, they cannot be measured or analyzed with the aid of financial transaction data. An obvious substitute, imperfect but still useful, is data on the allocation of time.

Family structure is an issue that has long been of concern to both sociologists and social psychologists. The role of women in American society, the role of parents in the socialization of children, the importance of the contributions of extended family members to the household, etc., are all topics that can be analyzed much more effectively with data on the allocation of time.

Question: **What findings have emerged?**

Answer: In addition to the items mentioned during the testimony--the significance of which were not known before these studies--there are examples in many areas such as the influence of changes in household technology on time and the role of leisure activities. Two additional topics of current concern are energy and labor supply.

A. Energy

The existence of baseline data in time use measurement opens important opportunities for assessing the effects of high energy prices on the dynamics of the household and for understanding the likely modes of adaptation to the new energy environment of the 1980's. For example, there are presently no reliable data on such basic measures as the number of dwellings unoccupied for extended periods of time during the day--data with important implications for potential reductions in energy used for heating and cooling--and little data available on the similarlity or dissimilarity of work schedules in multi-person households--data with important implications for car-pooling. The present time-use data base provides the best measures we have for these energy-related activities. They also form the basis for being able to measure what changes have taken place in these areas of activity due to the energy shortage.

B. Labor Supply

Virtually all analyses of household labor supply have been carried out using a measure of "hours worked" that was obtained either from establishment surveys on hours of paid employment reported by the employer, or from household surveys on reported hours worked "last week" or in a "typical week." Analyses conducted with the 1965-75 time-use date base suggest that both these conventional measures are subject to an upward bias, and are not accurate assessments of actual hours worked. The time-use data show that actual hours spent at the work place has increasingly incorporated proportions of time spent in on-the-job leisure or in on-the-job training and learning. Thus there appears to be a substantial decline in real labor market hours spent in productive activities--declines that are not picked up by conventional measures of nominal work hours. This may help to explain some of the decline in the rate of growth of labor productivity which has been reported for the past ten years.

BASIC RESEARCH IN POLITICAL SCIENCE

Mr. BOLAND. On page E-III-7, you indicate that the 1981 budget of $15,800,000 for Economics, Geography and Political Science will include work on the effects of Federal urban policies and the political processes of urban county communities. How does that research differ from the research supported and conducted by the Department of Housing and Urban Development?

Dr. CLARK. One key difference is we are the only source of support for providing basic research in the area. We provide the support for projects that come to us, unsolicited from the university academic community. We do not identify in advance a particular policy or project on which to conduct research.

Mr. BOLAND. You are providing basic research. How do you differ between basic and applied in this kind of activity?

Dr. ATKINSON. The request for proposal (RFP) concept is something keep in mind here. We are the only Agency that supports research independent of RFPs. We want work of a specific character and form.

Mr. BOLAND. They are a party to it and you are not.

Dr. ATKINSON. That is exactly the way I would have liked to have put it.

Mr. SABO. One of the last items listed for your research in this area is the impact of alternative bureaucratic institutions in policymaking and the delivery of public services.

What did you have in mind?

Dr. CLARK. There are any number of examples, no specific one identified by the comment. But it is intended to include studies of complex organizations by combinations of political scientists, sociologists, economists, who might examine the organizations from the point of view of optimal size, or efficiency or whatever. On what the impact or the influence of rotating the management of the organization might be for its long term viability.

Mr. SABO. Who are making these studies?

Dr. CLARK. University scientists, for the most part. In fact we support strong groups at Minnesota in both geography and political science.

Dr. ATKINSON. An example is jury trials. Several experiments are being conducted on the size of juries, the use of TV tapes by juries, and the impact of TV tapes on jury decisions.

Mr. SABO. Do you have freedom to experiment with that?

Dr. CLARK. Yes.

Dr. ATKINSON. Quite a bit of work is going on in that area.

Dr. CLARK. I know it turns out that you cannot have a jury smaller than five people. That is one of the consequences of that work. There are some courts that are working with five-member jury panels.

Mr. BOLAND. With respect to the study on the effects of Federal urban policies and the political processses of urban county communities, how many studies have you conducted in this area over the last five years? You may supply that for the record if you don't have it here.

Dr. CLARK. Not very many. Our geography program is a small one but we will certainly give you the number for the record.

[The information follows:]

EFFECTS OF FEDERAL URBAN POLICIES ON THE POLITICAL PROCESSES OF URBAN COMMUNITIES

A question of continuing basic interest in the social sciences concerns the effects of social and political institutions on one another. The growing Federal presence governing U.S. urban areas presents analysts with an opportunity to study the influence of the national government's policies on the lower level's decision processes. This pattern of influences is really very understudied. Mission agencies devote substantial resources to the evaluation of the effectiveness of specific programs; however, there has been little sustained attention to the impact Federal policies have on the larger and more enduring political processes of the states and cities.

An example of work addressing this need is an NSF supported study of ten San Francisco Bay area cities over a fifteen year period. This study seeks to compare across mission agency policies (Model Cities, Community Development Block Grants, and general Revenue Sharing) to assess their differential effects on minority access to local governmental institutions, and the responsiveness of these urban institutions to minority interests under different types of programs. Other related projects examine city revenue patterns, migration dynamics and racial segregation, all of which are influenced by Federal policies and programs.

Over the last five years the Division of Social and Economic Science has supported over fifteen projects that are relevant to the general question of the national government's policies effects on local social and political processes. The scientific quality of projects is increasing and it is expected that new contributions in this important research area will be realized in the next few years.

MIGRATION PATTERN RESEARCH

Mr. BOLAND. I notice on page E–III–9, you have listed as a topic area the "assimilation of recent immigrant groups and their adaption to U.S. society." That doesn't sound like basic research.

Dr. ATKINSON. It is. Again, it depends upon the definition. From a sociologist's viewpoint, understanding migration patterns is critical. I comment on this firsthand because the Mexican government is studying migration from their view. Under the U.S.-Mexico Science Agreement, we believe this research should become a bilateral effort.

BASIC RESEARCH BUDGET FOR EPA

Mr. BOLAND. On page E–IV–1, you are requesting $40.7 million for environmental biology programs subactivity. That is an increase of $3,336,000 over the current program. On E–IV–6, in the second paragraph, you discuss the coordination in relationship to other efforts—particularly the Departments of Agriculture, Interior and primarily Energy and the Environmental Protection Agency.

You indicate that they largely support applied environmental research. Roughly how much of the $300 million EPA research budget would you estimate is basic research rather than applied?

Dr. CLARK. At that level, no. I can supply the information for the record.

Mr. BOLAND. If you don't know the answer, how can you make this statement?

Dr. CLARK. Again, the answer Dr. Atkinson indicated, EPA does not have a general program for unsolicited research proposals. They generally specify that they want certain pollution measures in such and such a stream or watershed or so forth. But they are in the 1981 budget to encourage stronger university research, and I think there is a $14 million program for university centers, so that for the future there may be major areas of overlap with us.

[The information follows:]

ENVIRONMENTAL PROTECTION AGENCY SUPPORT OF BASIC RESEARCH

As reported in the Special Analyses - Budget of the U.S. Government - FY 81; "EPA obligations for basic research will increase $5 million to $19 million in FY 81. The basic research effort in EPA's interdisciplinary program was established in 1978 to identify and characterize emerging environmental problems before crises arise, provide a commitment of support to important long-term studies, and support the development of new knowledge about fundamental environmental principles and concepts. Program emphasis in FY 81 will be placed on carcinogens, environmental benefits, biological monitoring, integrated assessments of emerging or latent environmental problems. In addition, EPA will be contributing to a multiagency effort on acid rain."

The following table provides an estimate of EPA basic research dollars going for environmental biology and to universities - for all disciplines in FY 80 and FY 81.

EPA	FY 80 (est.)	FY 81 (est.)
Total basic research[a/]	$14M	$19M
Basic Research in Environmental Biology[b/]	(9M)	(13M)
Basic Research in universities (all disciplines)[b/]	(3M)	(4M)

a/ Source: Special Analyses - FY 81 Budget
b/ Estimate based on FY 78 (actual) support in these areas.

ASTRONOMY CENTERS OPERATIONS

Mr. BOLAND. Going back to the Astronomy Center Operations—one of the problems I am concerned with is the fact that you have cut back operation of the centers and also the operation of the Very Large Array facility to only 17 antennas.

Dr. JOHNSON. Perhaps only 19 at the moment but there are 27 and they will all be in operation by the end of 1980.

Mr. BOLAND. Could they all be in operation now?

Dr. JOHNSON. There is installation of some gear on them——

Mr. BOLAND. Then there are more than 17 that could be in operation?

Dr. JOHNSON. Yes. Nineteen are in operation and about 24 have been outfitted with electronics.

Mr. BOLAND. But aren't you cutting back in this area.

Dr. JOHNSON. Not in——

NATIONAL RESEARCH CENTERS

Mr. BOLAND. As I understand it you are cutting back the operation of the centers.

Dr. JOHNSON. Yes.

Mr. BOLAND. That brings us back again to the $27 million for the new 25 meter diameter millimeter project. You are cutting back in the operation of the centers in order to make provision for this new facility. I don't understand why you need the new facility at this time, particularly in view of the restraints that are going to be imposed on the budget.

Could this new project be delayed for a couple of years?

Dr. JOHNSON. Budgetary restraints, I think, might make it necessary to delay that project. Ultimately I think we need to construct that instrument because we can follow these arguments to say we should never replace any instruments. But as a matter of budgetary stringency at this time, I can accept that we cannot afford to go ahead with that instrument.

As I have indicated with some cuts of the size mentioned in this room, I cannot see any possibility of our proceeding with it.

Dr. ATKINSON. I would rather approach it in a different way and say, "Look, we are going to allocate so many dollars for astronomy. The scientific community should spend those wisely." It may mean we would go ahead with this project and close down three centers. We don't want to get in a position where we just continue to operate centers.

Mr. BOLAND. That sounds like a good approach. Are there any centers that may have outlived their usefulness?

Dr. ATKINSON. Never in the absolute sense, but it is the balance that counts. NSF fought hard to maintain this balance and to reduce some of the center activities, in the best interest of science.

The NCAR scientists have been under stress because of personnel cutbacks there; some are unhappy. But we are proud of that program, and again, it represents a balance of the total effort in atmospheric science. The same argument applies to research in astronomy.

Mr. BOLAND. I suppose the bottom line is—that it doesn't make much sense to fund better instruments if you can't allocate enough funds to operate them.

Dr. ATKINSON. That is true.

TRIBUTE TO DR. NORMAN HACKERMAN

Mr. BOLAND. I understand that this is the last appearance of Dr. Hackerman before this Subcommittee as a member of the National Science Board. He is leaving the National Science Board after 12 years.

Dr. HACKERMAN. That is right.

Mr. BOLAND. Twelve years is a long period of time. He first testified before this Subcommittee on February 29, 1972, eight years ago. He has been a member of the National Science Board since 1968; serving as its chairman since 1974. I guess that membership on the Board embraces as long a period a time as any member has ever served.

Dr. HACKERMAN. I think one or two of the earlier ones might have served longer.

Mr. BOLAND. In the judgment of this Subcommittee—and I know I speak for Members of the Subcommittee—I think Dr. Hackerman has been a tower of strength to the National Science Foundation over the years. He has contributed substantially to the growth and the impact the Foundation has had upon the policy that our government has engaged in with respect to the scientific endeavor in the United States.

He brings to this Committee a magnificent professional background, and, of course, has spoken with deep knowledge and understanding of the problems that the Foundation has faced in the years that he has been on the Board.

Dr. HACKERMAN. I don't know what the budget was 12 years ago. Whatever it was, it was a lot less.

Mr. BOLAND. You can take great pride in the fact that the budget is now almost a billion dollars. I don't know what it is going to be with the budgetary constraints. On behalf of this Subcommittee, I want to express our appreciation to you for your many appearances before this Committee and the expertise and direction you have given in that period of time.

In 1972, the budget was $622 million. You can take pride in the fact that you have doubled it. You can go back to Rice University and tell them you are responsible for at least developing in that section of the country the knowledge of the National Science Foundation that no one has ever had in that area.

Good luck to you and I am sure you will be back sometime. You are always welcome.

Dr. HACKERMAN. Thank you very much. I appreciate that.

Mr. BOLAND. With that we will recess and reconvene at 2 o'clock this afternoon.

AFTERNOON SESSION

Mr. BOLAND. The Committee will come to order. We will turn to the Engineering and Applied Science directorate.

60-770 O - 80 - 12

ENGINEERING AND APPLIED SCIENCE

Last year the Congress placed a limitation of $60.9 million on the old ASRA (Applied Science and Research Activity). Is that limitation being complied with in the new budget structure?

Dr. SANDERSON. Yes, sir, if you look at the current plan for 1980 after readjustments of activities, $59.4 million of the total EAS budget of $111.8 million for fiscal year 1980 is for applied science. There has been, within the approved reprograming authority for the directorate, some very minor shifts in recognition of the increased emphasis on the need for innovation and improving our competitiveness in science and technology.

EAS BUDGET REVIEW

Mr. BOLAND. I presume this area was looked at very carefully with respect to your budget review. Was there any thought given here to any particular reductions that might be applied to this directorate?

Dr. ATKINSON. You mean in the recent discussion?

Mr. BOLAND. Yes.

Dr. ATKINSON. Yes; some key aspects of the President's innovation review led to the special thrust in small business research, some of the university-industry programs, and some of the intergovernmental programs. They are high on our list of possible reductions.

Dr. PIMENTEL. We are trying to sustain the initiative but of course we will not be able to accelerate it as fast.

Dr. SANDERSON. As I am sure you are aware, all significant increases are always the first things looked at.

Mr. BOLAND. That is true. I do not think anybody would disagree that advances in industrial technology depend to some degree on a strong basic and engineering research. For this reason it would be in the best interest of industry to support the development of such a research base.

Dr. SANDERSON. Yes, I think it is; but I believe there are areas of research that do not quite meet the basic research requirement and are still not clearly enough defined in terms of mission or in terms of a business development but need to be pursued. It is that open-window approach to Engineering and Applied Science that we are trying to look at in this directorate.

UNIVERSITY-INDUSTRY RESEARCH

Mr. BOLAND. Why should NSF fund research that would be primarily of value to industry?

Dr. SANDERSON. The research we fund will be of significant interest and value to the industry and the economy, but rarely of any capturable benefit to any one company. It is longer-term research. With the exception of the small business program, it is almost invariably academic research. There have been a number of studies carried out on the return on investment in R&D and it has been found in many cases the return to the society as a whole is substantially greater than any one company can capture.

Mr. BOLAND. Wouldn't it be better to offer incentives to industry, for example through tax policy, to fund more basic and applied engineering research at universities?

Dr. SANDERSON. I think it would be perhaps very valuable if we could develop a tax policy to provide incentives to industry to do longer-term research and particularly to support longer-term research in universities relative to the needs of industry. While the industry needs this research five to ten years away and they want to be associated with the team doing the work, there is no way they can justify using their own resources to do it.

Mr. BOLAND. What is the attitude of industry with respect to the research that you do? Or does industry feel that there ought to be more done in this area?

Dr. SANDERSON. I can comment on this in a number of ways. I am in fairly close contact with the Industrial Research Institute which represents some 250 to 300 R&D-producing companies in the United States. They are strongly supportive of what we are doing. For example I have a number of industrial participants; among them on the EAS advisory committee, Dr. Place, vice president for R&D of Proctor & Gamble. There are also a number of others who believe this program warrants increased emphasis. There have been a number of papers written arguing for Federal support of innovative applied research which builds the core of knowledge with an ultimate application. This is still too far from the development of a final product or process so that no company can do it.

Mr. BOLAND. As I understand it, one of the objectives of the directorate is to improve cooperation in research between universities and industry.

Dr. ATKINSON. The industry-university program is distributed throughout NSF. Chemistry and applied engineering are special thrusts of the Foundation.

Mr. BOLAND. Is it your feeling that the Federal government should get involved in this relationship?

NATIONAL TECHNOLOGY FOUNDATION

Dr. ATKINSON. Part of the discussion supports the legislation offered by Mr. Brown. He argues there should be a National Technology Foundation, composed of this directorate, portions of Commerce Department and a few other programs. The argument is that the Federal government is not doing enough in pushing technology and applied research.

Mr. BOLAND. Why should the Federal government get involved?

Dr. ATKINSON. I think the step we are taking is a step in the right direction and a good one. I oppose a National Technology Foundation. If the Federal government organizes itself in such a way, it would slow efforts that could be more productive and innovative on their own. I dislike the idea of government-run laboratories. But bridging operations can be pursued, such as NSF's effort in small business research and in the industry-university cooperative research program.

Mr. BOLAND. If you established a National Techology Foundation could you give us any idea of what the growth might be in the years to come?

Dr. ATKINSON. I could not. But frankly, as I look at the bill, many other parts of NSF could be included. Our materials research program has an applied element. So does our computer science program. Rather than starting another foundation, NSF needs a broader base of support without injury to the basic research programs.

Dr. PIMENTEL. The national technology foundation might start at $500 million and grow to $800 million.

INDUSTRIAL INNOVATION EFFORTS

Mr. BOLAND. Under this activity, you are requesting $137 million in 1981 as opposed to $111,834,000 in fiscal year 1980, an increase of $25,166,000. The electrical computer and system engineering increases to $22.5 million from $17.6 million in 1980; and small business innovation and industrial technology increases to $18.2 million from $6 million in 1980. This subactivity has tripled in two years.

Dr. SANDERSON. Yes, sir, you remember the President's Domestic Policy Review on Industrial Innovation emphasized a number of key programs in government. Two of those key activities are located in the small business innovation and industrial technology category. The generic center is scheduled for a $2 million increase and the small business program is scheduled for a $10 million increase to $13 million. Both have been identified for diffusion across the government, which would represent a new and a vital role for NSF. The President's program from the industrial innovation review resulted in about a $55 million budget package of which some $12½ million are represented in this one line item, small business innovation and industrial technology.

PROBABILISTIC DESIGN

Mr. BOLAND. On page F–5, the civil and environmental engineering subactivity shows an increase of $825,000 in fiscal year 1981. The NSF also proposes to increase civil and environmental engineering by $2,770,000 in fiscal year 1981, and emphasize research on structural mechanics directed toward offshore environments.

It would seem that this research would primarily be of benefit to the oil companies that drill offshore and that make substantial profits. Why couldn't the oil companies support this research?

Dr. SANDERSON. This is basic research. The oil companies in general do not support this type of basic research. It is done in universities, which receive very little support. Also, it is important to recognize we are not talking about design of specific structures but probabilistic design methods which can be applied not only to oil rigs but to such things as offshore barricades.

Mr. BOLAND. Offshore barricades?

Dr. SANDERSON. Offshore construction facilities of all types, not just the "Texas tower" we all think about.

Mr. BOLAND. I can understand the tower and the offshore drilling mechanism, but not offshore barricades. It would seem to me even this particular research is highly beneficial to those drilling for oil offshore and perhaps they ought to be spending the money.

Dr. SANDERSON. It will be of benefit over the long term, but this is much more basic research. It is development of generic skills and will also be a benefit to offshore docking and a variety of structures which have to exist in extreme environments.

Dr. ATKINSON. A few years ago, people doubted the value of probabilistic design and some methods for optimization. Now there is pressure on the Foundation to do more in computer based probabilistic design. Only a few years ago, that was an innovative approach to these areas.

Dr. PIMENTEL. One of the possibilities is that offshore siting of nuclear power plants might be practical.

INDIRECT COST RATES

Mr. BOLAND. On page F-9, the justifications indicate indirect costs are increasing in 1981 by 23 percent above 1980—from $29.3 million to $36 million. Why this large increase which exceeds inflation?

This is an area we have been over many times in the past and have tried to solve the problem of indirect cost rates. Now we have an increase of some almost $6 million in this area. One quickly gets the idea that the universities are really getting in there with both hands. Would a reduced appropriation help NSF and universities count their Federal dollars more carefully?

Dr. SANDERSON. I would be very concerned if we felt changing the level of appropriation could change the indirect cost rates which are all audited cost rates which are given to us, in the case of universities, by the Department of Health, Education, and Welfare. We do not determine the cost, indirect cost rates for these activities.

The increase which you see reflects the increase which universities have had to absorb for things like light, heat, and fuel. There is also a higher indirect cost rate for a lot of industrial firms, universities and small business firms. You see both of these effects taking place in this line item.

Dr. ATKINSON. Mr. Boland, there is an increase in the budget, but the percent of direct costs and indirect costs is the same in both fiscal year 1979 and fiscal year 1981. I would be disturbed if there were a major increase.

COMPUTER ENGINEERING

Mr. BOLAND. On page F-I-6, the computer engineering program element you are asking for $2,150,000. This is a 150-percent increase. If this program is of such high priority, why did you reduce the request in 1980 from $1,200,000 to $1,000,000?

Dr. SANDERSON. The budget request to the current plan reduction was necessary as a part of an overall adjustment to live within the budget.

Mr. BOLAND. But why does a high-priority engineering program element have to take part in the reduction?

Dr. SANDERSON. Until the transfer of engineering into the new directorate, it was not identified as a separate program element and in fact was distributed in a variety of other parts of what was then the engineering division. It was simply the impact of the

overall reduction required within the directorate that that particular area took the cut. I can give you a more detailed explanation if you like; however, overall, the electrical, computer, and systems engineering part of the budget is the fastest-growing part of the directorate's budget and within that, computer engineering is the most rapidly growing. With technical breakthroughs and with the move toward smaller and smaller components, one can build on a computer chip the equivalent computing capacity of literally rooms full of equipment.

Dr. ATKINSON. It is a mistake to think the industry can do it on its own. The submicron laboratory at Cornell University has been a leader in the development of new approaches to submicron electronics. Any of the major companies will point to this laboratory as one of the best in the country. Several other universities—with their own funding from industry—are establishing laboratories like the one at Cornell. Stanford University, in conjunction with a group of universities in the West, has established such a lab.

Dr. PIMENTEL. Mr. Boland, even after the cut, the program was increased by 55 percent; this indicates that we were reserving a high priority in that area.

Dr. SANDERSON. A couple of areas are worth noting. Now that you are putting the entire computer on a chip you begin to have to program into the chip some of the software functions and some of the algorithms that would have previously been implemented in software. As a result, there are major research issues on the best way to build these computers-on-a-chip; whether it is better to build them with specialized functions or programmable connections. There are other strategic issues which are beginning to emerge which have to be addressed in this element of the program. For example, how one handles an interactive system where not only one part of the computing power but parts of the information distributed in different locations and these elements are interacting in a real time mode for analysis and sharing of data. This is a matter of vital and current concern to industry, government and almost every application of computers. The trend is toward distributive systems of computing and the algorithms are not developed for efficient use of these computers.

INDIRECT COST RATES

Mr. BOLAND. The increase for the Engineering and Applied Science activity appears to be substantially greater from 1980 to 1981. For example, greater than the biological directorate which increased 10 percent from $40.5 million to $44.3 million.

Dr. PIMENTEL. The increase in indirect costs in this directorate is in direct proportion to the increase in the total budget.

Dr. ATKINSON. There is a different mix of activities in this directorate. I do not think the indirect costs are higher in industry projects.

Mr. BOLAND. Would you explain that again?

Dr. ATKINSON. In our industry-university projects, industry generally pays for a major part of their effort. If they do not, the indirect cost rates are not any higher than those of universities.

Dr. SANDERSON. They are sometimes, in small business. Indirect cost rates are calculated by a variety of mechanisms. Some organizations calculate on total direct costs. Some organizations calculate on salaries and benefits. Historically, the numbers which you see here have evolved. In part—this may reflect the fact that there is not a tremendous amount of capital equipment purchased with a few exceptions in this directorate.

Mr. BOLAND. Do you review the guidelines established by the old Department of Health, Education and Welfare?

Dr. ATKINSON. NSF has provided input to the guidelines. Let us do an analysis of these indirect costs and provide it for the record.

Mr. BOLAND. Fine. Provide the information for the record.

[The information follows:]

INDIRECT COSTS OF THE ENGINEERING/APPLIED SCIENCES BUDGET

As is noted on page F-9 of the fiscal year 1981 Budget Request, the indirect costs of the EAS budget increase from $29.3 million in fiscal year 1980 to $36.0 million in fiscal year 1981. However, this increase of $6.7 million is in direct proportion to the increase in the entire EAS budget over fiscal year 1980. Or, put another way, indirect costs as a proportion of the total budget are the same in fiscal year 1980 and fiscal year 1981, namely 26.2 percent.

SOLID STATE AND MICRO STRUCTURES PROGRAM

Mr. BOLAND. Another large increase occurs in the solid state and micro structures engineering program element appearing on page F-I-8. The explanation on that page talks about solar energy conversion. Why isn't the Department of Energy funding these applications—or alternately, industry?

Dr. SANDERSON. The solid state and micro structure program element is working at the understanding of the limitation of the structural materials and fabrication techniques used in electronic components.

The heart of this program, in terms of demonstrating the potential for research here, is the submicron facilities structure at Cornell. They are experimenting with a number of techniques while working with components of hundredths of micrometers in size, and it is a unique facility. This is the only place in the country with the capability—academic research capability—to carry out these types of experiments. They are working in a variety of areas including some areas of new materials and new ways to fabricate materials that will contribute to a number of areas including computer sciences, solar energy and all the other areas which you have identified here.

CHEMISTRY AND CHEMICAL ENGINEERING

Mr. BOLAND. On page F-II-1, under the Chemical and Process Engineering Subactivity, it states that "the chemical and process engineering program provides support for basic engineering research relevant to the entire range of chemical, petrochemical, nuclear, et cetera. According to other NSF statistics, the CPI industry is one of the largest industrial sources of funding for basic scientific research. Given this, why is it necessary for NSF to have a major program or research in this area when it appears that industry is doing the job by itself?

Dr. ATKINSON. We do not think it is doing the job, and I do not think industry thinks it is doing the job. Industry scientists are concerned that the United States is under-investing in basic research. The Soviet Union devotes more of its research investment to chemistry and chemical engineering than does the United States. There is no question that industry strongly supports an expanded program. It is not that engineering has not had good support; it is that too much has been directed at specific goals, and the open window component of engineering science has been neglected.

EARTHQUAKE RELATED RESEARCH

Mr. BOLAND. On page F–III–2, the paragraph at the bottom of the page details significant recent achievements and you indicate that you are looking at buildings subjected to dynamic loads such as earthquakes, et cetera. Why isn't this activity funded under the Earthquake Hazards Mitigation Program?

Dr. SANDERSON. I think you are identifying one of the key benefits that resulted from the recent establishment of the engineering and applied science directorate.

There is a natural transition from civil engineering work from the basic to the applied work which is going on in the earthquake engineering program. The work here is in general much more fundamental, much more concerned with the theoretical development of basic capability which can be applied, as the section indicates, to a variety of problems of dynamic loading such as earthquakes, tornadoes, and other dynamic loadings of structures.

The earthquake program attempts to deal with frequency response distributions which are appropriate to buildings exposed to earthquakes. There are projects that could be identified in either category that could go back and forth; that is why it was important to get these activities side by side.

Mr. BOLAND. How much earthquake-related research has the Foundation been funding under the engineering program activity in the past three fiscal years?

Dr. SANDERSON. That is a hard definitional question because the research here is much more fundamental in character and could apply to many dynamic deflection problems other than earthquake.

Dr. ATKINSON. The phrase referring to earthquakes is unfortunate. It is the type of application that would result from this research, but it was not motivated by an effort to understand earthquakes.

Mr. BOLAND. Frankly, we are concerned that as we have held down the earthquake mitigation research program, you have simply offset those decreases by corresponding increases in other areas of the Foundation?

Dr. ATKINSON. That is not true at all.

Mr. BOLAND. Last year, we asked you what the earthquake research levels were in the earth sciences program. It is interesting to know that your response on page 160 of the hearings gives credence to a bit of our concern. Earthquake research was funded at a level of $3.5 million in 1977—but jumped to $6 million in 1979.

Now I would like to get from you what the total amount for earthquake-related research is by program sub-element within the Foundation outside of the Earthquake Hazards Mitigation Program, for fiscal years 1977, 1978, 1979, 1980, and 1981.

Dr. ATKINSON. We will give you those data, and it is important to provide them for those years. We can characterize some of this data as related to earthquake research, and it is important that we use the same concept for a comparison.

Mr. BOLAND. It would be good to have this for the record before we complete the hearings.

[The information follows:]

NSF Supported Earthquake Research
($ in Millions)

Program Element/Subelement	Activities Conducted	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981
Astronomical, Atmospheric, Earth and Ocean Sciences						
Earth Sciences Project Support Geophysics.....	Geophysical research the results of which may be applicable to earthquake prediction.	$3.5	$5.3	$6.0	$6.6	$7.2
Engineering and Applied Science Earthquake Hazards Mitigation..	Research aimed at understanding earthquakes in relation to constructed facilities and reduction of casulties, damage and social and economic disruption resulting from earthquakes.	9.3	17.7	16.5	17.9	19.4

In addition to the Earthquake Hazards Mitigation program found in the Problem-Focused Research (PFR) subactivity, there are three levels of potential research involvement in earthquake research found in the Civil and Mechanical Engineering (CME) efforts of the Foundation. These three levels are:

- o research which is primarily directed toward earthquakes;
- o fundamental research which is directly applicable to a wide variety of phenomena, including wind, storm, etc., and earthquakes; and
- o fundamental research which has no inherent connection with earthquakes, but develops the fundamental knowledge base in civil and geotechnical engineering and therefore benefits the entire spectrum of application in these areas over the long term.

Research of the first type is generally avoided in CME and is instead directed toward PFR. A perusal of all grant titles in FY 77, 78, and 79 did not reflect a single grant in this category. In FY 1980 there is the following:

CME 7913822
(Scott, Cal Tech) "Centrifuge Testing of Earth Retaining Structures under Seismic Loading"
1/23/80-1/22/81--$55,564

Research in the second level comprises research in which soils or structures are subjected to "dynamic" conditions, especially if the dynamics is of the "stochastic" (i.e., random) type, or if the structure is to be stabilized through "active control." Work of this type may have direct implication for earthquake research. However, it is not especially oriented that way and can as easily be applied to other phenomena of a dynamic type, such as wind, wave-structure interaction (e.g., off-shore), impact, effects of rotating machinery, etc. Examples are:

ENG 7722443
(Souivtses, Georgia Tech) "Nonlinear Stability Analysis of Unbrased Frames Subjected to Static and Dynamic Loads"

ENG 7682226 (Soong, SUNY at Buffalo)	"Active Control Systems for Civil Engineering Structures"
ENG 7715570 (Lutes, Rice University)	"Response of Structures to Stochastic Excitations"
CME 7901815 (Whitman, MIT)	"Modeling Dynamic Ground Shaking by Centrifuge"
CME 7923651 (Kelly-Sackman, Berkeley)	"Analysis of Interacting Equipment-Structure Systems"

It is estimated that about 40% of all structural mechanics and about 30% of all geotechnical engineering research falls into this category. It should be emphasized that it is basic to the profession and receives its motivation only partially and indirectly from earthquake concerns.

As regards the third level, most research in structural mechanics and in geotechnical engineering, and much research in other areas of civil and mechanical engineering has some potential value in connection with earthquakes. For example, the development of very high strength concrete has the broadest possible implication on the construction industry; obviously, of course, this includes construction in seismic areas. Similarly, all advances in soil sampling techniques or in structural design methodology lead to improvements in earthquake safety or economy.

It is estimated that practically all research in structural mechanics and in geotechnical engineering not listed in levels two and three falls into this rubric, in addition to contributions from solid mechanics. In fact, even outside CME there are earthquake-related research areas, such as in systems analysis, computer engineering, applied mathematics, etc.

FUNDAMENTAL ENGINEERING RESEARCH

Mr. BOLAND. How much of the engineering piece of this directorate is categorized as applied research?

Dr. SANDERSON. None of it. This is the basic engineering research. In budgeting, the engineering programs are carried along with the other basic research programs of the Foundation.

Dr. ATKINSON. This has always been fundamental research, and we consider it as important as the rest of the Foundation's basic research activities. We believe this shift was important in balancing the activities and bringing applied research closer to the basic work. I would be uneasy if any problem this Committee may have had with the RANN program in the past would in turn lead to special problems with engineering research. I think this Committee and everyone else has always regarded NSF's program of engineering research as first-rate.

Mr. BOLAND. If it was appropriate, why did you not do it two years ago?

Dr. ATKINSON. I tried to do it two years ago.

Mr. BOLAND. That is a good answer.

APPLIED SOCIAL AND BEHAVIORAL RESEARCH

On page F-V-1, the Applied Research subactivity is described. You are asking for $18.7 million in 1981. On page F-V-2, the justifications indicate you are supporting work in the "critical policy areas of inflation accounting and company pension liabilities, accounting standards, . . . work in psychology, political science, law . . ." et cetera.

This description of applied research appears to be very similar to the description under the Social Science area of what is supposedly basic research. What criteria do you use to differentiate these efforts?

Dr. SANDERSON. First, we coordinate very closely between the work which goes on in the applied social and behavioral science area and the work in Dr. Clark's shop. We are working in a real world environment in which one is concerned both with the quality of the research going on and the potential for more immediate payoff. We are generally working on shorter-term activities. One of the ways to recognize the distinction rather than try to extract an idealized description, is to look at the projects which we are supporting. You see not a sharp break between the two, but a clear shift in emphasis. These are probably the best coordinated programs in the Foundation at the time.

Mr. BOLAND. In this area, is any of the applied social research program intended to support the missions or tasks of specific agencies?

Dr. SANDERSON. We do not carry out any support of the work of an agency with a research component. Some of the work we do is of immediate interest particularly to other agencies such as the Department of Treasury, financial institutions, the Federal Reserve Board and various regulatory agencies.

But we do not set our priorities on the needs of other agencies.

Mr. BOLAND. So your activity in a sense does not support the mission agencies?

Dr. SANDERSON. It provides the knowledge base they use. One of the interesting things is our area of telecommunication policy. I looked in the phone book and noticed most of the top Federal officials were former grantees of ours. If you believe in transfer of knowledge through people, I would say we have probably provided a lot of support in that area.

Mr. BOLAND. You are not reimbursed for support initiatives in these areas?

Dr. SANDERSON. No. These people were not officials when they received NSF support. I'm referring to the long term impacts of past funding as a way to understand what we do.

Dr. ATKINSON. It has made a difference in the design of high-rise buildings, but we have been trying hard to get HUD to pick up this work. However, HUD says, "This is your job; we do not do basic research or applied research." They felt it was too basic, even though we called it applied, for HUD to support. Yet the research on high-rise buildings activity is important. I have worked with Dr. Press to persuade HUD of the importance of these issues.

Mr. BOLAND. What is the proportion of solicited as opposed to unsolicited research in the applied social research area?

Dr. SANDERSON. These are all unsolicited projects. What we have identified as a coherent area is based on evolution of proposals, certain areas have proved interesting. A lot of scientists want to work in, for instance, telecommunications policy. When there is a clustering of this type we will support special workshops to bring scientists together in the field for an exchange of ideas and information. This tends to be a self-reinforcing process but we do not send out program solicitations in this area. We announce our interest in these coherent areas through workshops and meetings of grantees.

RESEARCH ON THE EFFECTS OF GOVERNMENT REGULATIONS

Mr. BOLAND. On page F–V–4, the middle of the page, you indicate that the Applied Research Activity plans to undertake a new program to study the effects of government regulations on various economic sectors.

Why is the NSF funding this research? We touched on this last year. This is nearly identical with the justification for the existence of the Regulatory Council—which we also fund.

How much are you planning to devote to this activity in 1981, and why are you involved in this research?

Dr. SANDERSON. Primarily because the academic community is interested and excited about it. Other organizations, such as those you mentioned do not provide support for unsolicited proposals. We are a disinterested party in the type of research that can be supported. The research community has identified a number of very interesting examples to study. For example, a comparison of the changes in the railroad industry in Canada, which has been deregulated, with the status of status of the railroad industry in the United States, which continues to be heavily regulated, is a natural experiment. The changes in air transportation because of the airline industry deregulation is another experiment which one can study.

We anticipate the total in these categories to be $5.24 million next year. Of that, I would guess that something on the order of $2 to $2½ million will be in the regulation end of it.

Dr. ATKINSON. The distribution of research support among universities, the Federal government, and industry across all fields of science appears to be constant, except in the social sciences. In the past 10 years, there has been a shift to in-house government research or to the various firms that engage in research activities. NSF is virtually the only agency in the Federal government that approaches social science research without specific end results in mind. In the regulatory area, it is important that at least one agency responds to the best ideas without regard to agency objectives.

REDUCTION IN FUNDING FOR APPLIED SOCIAL SCIENCES RESEARCH

Mr. BOLAND. On page F-V-5, you are requesting $9 million for the Applied Social Behavioral Sciences Program Element. Frankly, the justifications description suggest that all of these areas should be funded by those agencies having primary responsibility. If we reduced this by $3 million, approximately one-third, where would you take the reduction?

Dr. SANDERSON. I am not sure at this point where I would take the reduction. I would have to give you that information for the record. I would say, if you reduce it by a third, with the hope that other agencies will pick it up, you should resign yourself to the fact that you are simply cutting out research because other agencies do not, as a rule, support this type of research. One of the areas of concern to me and to the Foundation is the interface between our research and the research of other organizations. I have had some study made of the social science support coming from other organizations and we are about the only agency in town that will respond to the academic community in an open, unsolicited proposal mode for the best research available.

Most of the social science research which is supported by other agencies is oriented toward large experimental programs or specific policy needs of the agencies involved where they need the answer to prove, substantiate, or develop a policy decision that they are faced with.

If you want an answer, I would have to supply it for the record.

[The information follows:]

EFFECTS OF A ONE-THIRD REDUCTION IN THE
APPLIED SOCIAL AND BEHAVIORAL SCIENCES PROGRAM ELEMENT

The Applied Social and Behavioral Sciences Program Element is a unique research program within the Foundation and the Federal Government. Its primary purpose is to provide support for scientifically meritorious research on problems of the investigators own choosing which fall between the basic, discipline-oriented work and the focused, more mission-oriented work supported elsewhere by government. Typically, this is work which is too "applied" or "policy oriented" to receive high priority in basic research programs and too "long-term" or "risky" to be supported by other Federal agencies. It may also go unsupported because it challenges established agency policies and program assumptions or else falls outside of the narrow program categories which frequently characterize the support given to the applied social and behavioral sciences elsewhere in government.

There is a clear and important public interest in the existence of such a strong applied capability within the NSF. It accelerates the realization of social benefits from the Foundation's support of basic research in these sciences. Equally important, the support is independent of the economic, technological, or policy assumptions and preferences of mission agencies. While proposals are carefully coordinated with relevant basic and mission-oriented programs to minimize the likelihood of duplication and to insure that best available, incremental investment of applied research dollars, funding decisions are made solely on the basis of scientific quality and the potential utility of results. Those who are funded are free to pursue and publish the results of their research, guided only by the canons of scientific evidence and the professional judgments of their peers.

There has been an extraordinary response from applied researchers in these scientific disciplines since the establishment of this program element in January 1978. The number of unsolicited proposals received since FY 1978 has increased by 60 percent. In addition, a Research Initiation program for young scientists in the social and behavioral sciences interested in a variety of applied, policy problems was initiated in November 1979. This year a total of 165 proposals were received in response to this announcement and, judging by the level of interest, the number could well be doubled by next year. Modeled after a comparable, highly successful program of Research Initiation for Young Engineers which has been in existence for over a decade, this new initiative represents an effort by the Foundation to interest young social and bahavioral scientists in applying their knowledge and training to a wide range of social, economic and policy issues of significance to the Nation.

Since the Applied Social and Behavioral Sciences Program element has received close to level-funding for FY 1979 and FY 1980, this has meant that requested support has had to be cut by an average of 25% and only about 1 out of 5 proposals could be supported. Increasingly, a number of significant research ideas are being declined for lack of funds.

A budget cut of the magnitude proposed in this question would substantially constrain the ability of this Program Element to be responsive to the extraordinary interest and exciting applied research ideas coming from the social and behavioral science research community. Since it is a unique program within the Foundation and the Federal Government, this would also slow down our ability to capture the benefits flowing from Federal support of basic research in these fields. Given the "open" nature of the Program, it is not possible to target a specific area which would be dropped if such a cut were made. The Program would still make every effort to support the most promising applied research. Thus, such a cut would be felt across the Program in the form of smaller budgets and a very low success ratio, conceivably reaching 1 out of 10.

EARTHQUAKE HAZARDS MITIGATION PROGRAM

Mr. BOLAND. On page F-VI-1, the problem focused research subactivity, you are requesting $30.5 million. It appears that most of the increase again occurs in the Earthquake Hazards Mitigation Program element.

It also appears that most of that increase occurs in the societal response sub-element—which as you know, the Committee has not supported in the past. How much have you spent on the societal response sub-element since its inception?

Dr. SANDERSON. I would have to supply that for the record.

SOCIETAL RESPONSE STUDIES

Mr. BOLAND. Also, how many studies have you conducted in this area?

Dr. SANDERSON. I know we have supported about 25 to 30 percent of the amount that was recommended for societal response by the Newmark advisory committee, for the earthquake hazards mitigation program.

Mr. BOLAND. How many more studies do you feel you have to conduct in this area?

Dr. SANDERSON. There are a variety of studies which I think are important. I would like to emphasize that the societal response element has a number of activities in which there is a great interest by both the research community and public officials. We are seeing cases where we believe it may soon be possible to make predictions of earthquake hazards. However, the liability laws may make it difficult to inform the public. On this topic, we have an interesting project being completed on the west coast with the cooperation of the Association of Bay Area Governments (ABAG). The State law in California made it less likely that a State official would issue an earthquake warning even if he received a credible prediction because of the question of liability. One of the results of the ABAG project has been the passage of legislation which it recommended that reduces the liability of State officials when they take appropriate actions, including issuing public warnings to reduce the impact of earthquakes.

The major part of the societal response programs, which has been very sharply decreased as a result of recent budget cuts is what one would describe as the policy aspects: how do you deliver warnings, how do you aid a community in responding to a warning, and how do you deliver aid if a disaster occurs?

[The information follows:]

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AWARDS MADE IN THE SOCIETAL
RESPONSE PROGRAM ELEMENT 1972 - 1980

I. Relevant Projects Supported by NSF Prior to Establishment of Societal Response/Policy Elements:

University of Colorado; G. White and J.E. Haas; "Assessment of Research on Natural Hazards"; April 1972, $723,900; 26 months.

University of Colorado; J.E. Hass; "The Relation of Post-Disaster Community Policy Issues to Restoration, Reconstruction and Future Vulnerability"; May 1973, $234,700; 15 months.

Total: $958,600

II. Projects Supported by NSF in Societal Response/Policy Elements Since Inception

University of Pennsylvania; H. Kuneuther; "Reducing Losses from Selected Natural Hazards: Role of the Public and Private Sector"; March 1975, $148,850; 12 months.

Northwestern University; H.P. Frisema; "Long-Range Economic Dislocations and Other Consequences of Natural Disasters"; June 1975; $91,150; April 1976, $45,200 ($136,350); 8 months.

Lewis and Clark College; J. Huffman; "Legal Constraints on the Planning and Development of Disaster Home Warning Systems"; July 1976; $16,400; 7 months.

University of Colorado; G. White; "Natural Hazards Research and Applications Information Center"; $200,500; March 1976; April 1978, $130,394; Jan. 1978, $24,800; June 1979, $18,340 ($374,034); 48 months.

University of Colorado, E. Haas; "Socioeconomic and Political Consequences of Earthquake Prediction"; May 1976; $427,100; 15 months.

University of Massachusetts; P. Rossi; "Research Program on Natural Disaster Recovery Processes: Relief, Rehabilitation, and Preparedness";May 1976; $496, 575; May 1977, $367,550 ($864,125); 28 months.

University of Pennsylvania; H. Kuneuther; "Mitigation and Recovery Policies for Natural Hazards"; September 1976, $197,600; 12 months.

University of Washington; M. Marts; "Social Implications of Volcano Hazards"; July 1976; $45,000; 16 months.

Colorado State University; H. Cochrane; "Inflationary Changes in Construction Costs Created by Earthquake Damage: Implications for Government Policy"; March 1977, $52,500; 12 months.

University of California, Santa Barbara; D. Mann; "Seismic Safety Preparedness by Local Governments in California; June 1977; $110,400, June 1978, $118,265 ($228,665); 24 months.

University of California, Los Angeles; R. Turner; "Community Response to Earthquake Threat in Southern California"; November 1976; $299,100; January 1978, $191,511; Jan. 1979, $168,862 ($659,473); 37 months.

University of Georgia, F. Bates; "A Longitudinal and Cross Cultural Study of the Post Impact Phases of a Major National Disaster: The February 6, 1976, Guatemalan Earthquake"; July 1977, $163,400; June 1978, $223,520; June 1979, $191,677 ($578,597); 48 months.

University of Denver; T. Drabek; "Search and Rescue Missions in Natural Disasters and Remote Settings"; Sept. 1977; $261,300; 24 months.

University of Minnesota; R. Leik; "Community Response to Natural Hazard Warnings"; April 1978; $492,899; July 1977; $260,750; March 1979, $231,925 ($985,574); 36 months.

Council of State Governments; "H. Sutton; "State Government Policy Options for the Utilization of Earthquake Prediction Technology"; January 1977; $177,500; August 1978, $86,930 ($264,430); 19 months.

University of Delaware; D. Wenger; "Disaster Knowledge and Beliefs and Emergency Planning"; June 1977; $34,300; 12 months.

Institute for Policy Research; A. Crawford; "Invitational Workshop on Comprehensive Emergency Preparedness"; March 1978; $14,632; 6 months.

National Academy of Sciences, C. Fritz; "Study of the Role of the Mass Media in Disaster Reporting"; Sept. 1978; $147,549; Sept. 1979, $150,485 (298,034); 24 months.

Midwest Research Institute; B. Liu; "Earthquake Risk and Damage Functions - An Integrated Preparedness and Planning Study for Central USA"; January 1978; $105,493; 12 months.

Association of Bay area Governments; T. Margerum; "Liabilities of Local Governments for Earthquake Hazard Reduction"; January 1978; $125,200; 12 months.

University of Pennsylvania; L. Miller; "Extentions and Utilization of Community Flood Model"; March 1978; $192,930; 12 months.

University of Colorado; R. Palm; "Dissemination of Information on Natural Hazards in the Urban Area"; September 1978; $104,397; 18 months.

Battelle Memorial Institute; R. Perry; "Factors Affecting the Design and Implementation of Community Disaster Evacuation Plans"; February 1978; $233,829; 18 months.

Ohio State University, E. L. Quarantelli; "Social Behavioral Responses to Chemical Hazards"; August 1978; $213,915; June 1977, $188,600; August 1979, $182,209 ($584,724); 36 months.

North Dakota State University; R. Bolin; "The Impact of Disaster Aid Programs on Long-Term Family Recovery: A Longitudinal Comparison of a Rural and Urban Site; January 1980; $103,015; 18 months.

Total: $7,036,552

STATE SCIENCE ENGINEERING AND TECHNOLOGY PROGRAM

Mr. BOLAND. On page F–VII–1, you are requesting $7 million for the Intergovernmental Program Subactivity. The increase occurs in the State Science, Engineering and Technology element. Was this a Congressional initiative and if so, from where?

Dr. SANDERSON. This was a Congressional initiative when it started. It has been supported very strongly recently by the White House and by ISETAP, the Intergovernmental Science Advisory Panel to Dr. Press. The first concept came from the Congress. We provided a series of planning grants, approximately $25,000, to both the legislative and executive branches of State governments to aid them in examining ways to build scientific and technological capability in the State government and to develop an implementation plan for doing this.

What you see here is experimental.

Mr. BOLAND. How much of that have you obligated to date in 1980?

Dr. SANDERSON. Essentially none of it. There is a program announcement soliciting proposals which was approved by the National Science Board at the January 1980 meeting. It will be obligated before the end of this fiscal year, but as of now, none of the funds have been obligated.

Mr. BOLAND. Do you have an idea how long you will request support for this activity and at what level?

Dr. SANDERSON. The State Science Engineering and Technology SSET Program was established as an experimental program. It was designed so that Federal programs would not exceed two-thirds of the cost in the first year and will decline to zero somewhere between the fifth and sixth year. So, I would anticipate that the funding level will decline unless the number of States involved increases. The program lifetime is projected to be about 5 to 7 years. In fact, the size of the program depends on how many States become involved in this activity and on our experience in the first year or so.

Mr. BOLAND. Have you any idea how many projects the $3 million will support?

Dr. SANDERSON. We hope to start 15 to 17 with the first $1½ million this year.

Mr. BOLAND. How long will these projects last?

Dr. SANDERSON. The entire program is planned for a lifetime of 5–7 years with an intermediate evaluation after two years. If performance is unsatisfactory, they will be phased out early. Projects in individual States are expected to be supported for about 5 years.

Mr. BOLAND. Do you conduct a ZBB exercise within the directorate?

Dr. SANDERSON. Yes.

Mr. BOLAND. How does this program rank in that ZBB exercise?

Dr. SANDERSON. It is within our minimum budget.

Mr. BOLAND. At this particular level?

Dr. SANDERSON. I think the $3 million level was within the budget level finally established by the President.

Mr. BOLAND. Dr. Sanderson?

Dr. SANDERSON. I simply wanted to state the SSET, at the time the zero base budget was developed last May, was shown in the cross-directorate category of programs although it is operated as part of the intergovernment activity in my directorate. A decision was made subsequent to the preparation of the ZBB package last time to show it along with the other intergovernmental activities rather than in the cross-directorate activity.

Dr. PIMENTEL. We felt SSET as a particular program had to be judged in our ZBB process against all our programs, not just the subprograms within EAS.

SMALL BUSINESS INNOVATION AND INDUSTRIAL TECHNOLOGY

Mr. BOLAND. On page F-VIII-1, the Small Business Innovation and Industrial Technology Sub-activity is requesting $18.2 million in 1981, an increase of $10.8 million above the 1980 level. The program is actually trebling from its 1980 budget request of $6 million.

The $10 million is a sizeable increase. I guess it can be said that past experience has shown that when programs undergo such rapid growth, money is often wasted. If the President reduces your budget request, is this an area where you would probably cut back on.

Dr. ATKINSON. Yes, but I must tell you in the earlier phases of the program we were only funding 12 percent of the proposals we received.

Mr. BOLAND. How many proposals did you receive?

Dr. SANDERSON. In the last solicitation we received 528 proposals.

Dr. ATKINSON. We funded 12 percent. The quality of the proposals has been remarkably good. Consequently the program drew the attention of the Domestic Policy Review, and more money was recommended for NSF in support of innovation research by small businesses.

Dr. SANDERSON. We have run the small business program with very limited categories of research in which we would accept proposals in order to cut down the number of proposals received.

I have no serious reservation about our ability to wisely expend these sums.

Mr. BOLAND. The goals of this program as described on page F-VIII-1 sound almost identical to those of NASA's technology utilization program. Are you familiar with that program?

Dr. ATKINSON. Yes. It only sounds a lot like it.

Mr. BOLAND. Can you distinguish between these programs?

Dr. SANDERSON. In fact, they are drastically different. The technology utilization program of NASA is designed primarily to take technologies or engineering capability which was developed for aerospace applications and make it available to small business or small companies so it is in fact an effort to take NASA developed technologies and package them in such a way that a small company can utilize it.

What we are doing in our program is to support research in small business or to support research in universities which is coupled fairly tightly with the needs of industry so that we are establishing the priorities for our research in part based upon the pro-

grammatic content of the directorate but also based upon a perceived market for the research activities. It is a totally different concept.

EXAMPLES OF SMALL BUSINESS AWARDS

Mr. BOLAND. Can you give us a few examples of the proposals you have received?

Dr. SANDERSON. Yes, sir. I can give you a couple of very good examples. One example started on research on high resolution photographic plates because of the need for such film in research in spectroscopy. A small business scientist developed a new concept for depositing photosensitive silver directly on a surface without the substrate. From his point of view this would make a much more precise resolution of spectral lines.

He attempted to develop this himself for a number of months. In response to our first solicitation he submitted a proposal to us; we became interested in this. In this program, we encourage and give a point of merit in the evaluation to those proposals to the second phase of the research that contain a commitment from a venture capital firm.

He tried to contact several venture capital firms and finally contacted the micro electronics industry. It turns out the major use for this process was not the spectral plates for which he originally developed this process but it provided a real breakthrough to make very precise electronic components at the sub micron range.

In the most recent solicitation we made 54 awards.

Mr. BOLAND. For the record, you may supply some of the other proposals.

[The information follows:]

AWARDS MADE IN THE SMALL
BUSINESS INNOVATION AND INDUSTRIAL TECHNOLOGY SUBACTIVITY

Energy Conservation in the Building Industry Using Industrial Waste; *Mir A. Ali,* Glass & Ceramics International Inc., Lomita, CA 90717; $24,996 for 6 months beginning October 1, 1979.

Waste management and the use of industrial by-products are important and vital aspects of energy savings, environmental protection and conservation of natural resources. The objective of this project is to investigate a unique and synergisti approach to utilize flyash and California pozzolans in the manufacture of building products like bricks, concerete blocks, tiles and pipes. Research will be carried out to develop bonded building products based primarily on flyash and pozzolans as the cementitious components and thus to minimize or element the amount of Portland cement which is an energy intensive product. The research will include (1) chemical and mineralogical characterization of varities of flyash and naturally occurring pozzolans (2) evaluation of cementitious characteristics and development of optimum curing treatments, (3) formulation of mixtures of flyash, natural pozzolan, sand or other lightweight materials and fabrication of bonded test specimens. Properties of the specimens, such as compressive strength, specific gravity, particle size, pozzolanic activity and freeze-thaw will be measured. An estimate will be made of the energy needs and costs of manufacture of such building products. Efforts will be made to establish the supply and economics of these materials.

X-Ray Optics for Projection Lithography; *Michael J. Boyle,* Advanced Research & Applications Corporation, Sunnyvale, CA 94086; $24,993 for 6 months beginning October 1, 1979.

The objective of the project is to investigate the feasibility of an advanced x-ray lithography system that should eliminate the present problem areas. X-ray lithography is an advanced approach for producing the submicron structures necessary for large scale and very large scale integrated semiconductor devices. The problem areas to be addressed include appropriate x-ray sources, fabrication of x-ray mask support substrates and masks, alignment of multiple masks and improvement in x-ray resist sensitivity. Analyses will be made of an x-ray imaging system with demagnification based upon grazing incidence optics. The project will determine the validity of this approach as a means of solving the present problems involved in x-ray lithography.

Magnetic Sheet Steel Lamination Detection; *Forest J. Carignan,* Advanced Mechanical Technology, Newton, MA 02158; $25,000 for 6 months beginning October 1, 1979.

The object of this project is to determine the feasibility of a technique to detect the presence of laminations in steel sheets at the time of production. The technique to be validated consists of subjecting the sheet to magnetic fields and measuring the residual magentism. The residual magnetism is an indication of the degree of lamination present. The theoretical limitations of the method will be investigated so that recommendations can be made for a prototype test unit. The approach consists of both theoretical analyses and experimental verification of the technique.

Results of the project, if successful, should lead to the development of a relatively inexpensive detector for the sheet steel industry that would allow early detection of hidden laminations. Such detection would eliminate the present needless waste of material, time, and energy due to defective steel sheets.

Computer Modeling of Electromagnetic Responses from Deep Mineral Resources; *Shu-Kong Chang,* Emtech Engineering Inc., Berkeley, CA; $24,691 for 6 months beginning October 1, 1979.

The objective of this project is to provide badly needed theoretical data for geophysical prospecting. A new computer modeling technique will be studied for the analysis of the electromagnetic response of ore bodies in the earth. This new technique uses a high efficiency finite element method which accurately and economically predicts the electromagnetic response of deep mineral resources. Results of this study will provide information needed to improve the accuracy of geophysical prospecting techniques utilizing the electromagnetic properties of buried ore bodies.

Mini Arc Welding/Brazing Technique; *Adriano Duccatti,* Amex Systems Inc., Hawthorne, CA 90250; $24,031 for 6 months beginning October 1, 1979.

There are several types of plasma discharges, i.e., corona, glow, arc, etc. The principal defining component for each type of discharge is current density. The normal arc discharge has current densities which are orders of magnitude greater than other types of plasma discharges. The mini arc process proposed has the same basic current density characteristics of an arc discharge, but the mini arc total current is small compared to large arc welding or arc brazing devices. The proposed mini arc column is on the order of a millimeter in diameter, and total currents are on the order of 10 amps or less. Normal arc welding devices operate at hundreds to thousands of amps. The mini arc has operating regimes that are optimal for materials joining and unique to arc processes. The present techniques for materials joining the electronics assembly may limit the use of optimum materials or induce high costs to meet materials specifications. The use of mini arc welding and brazing could permit the use of optimal materials for performance as well as have dramatic impact on manufacturing costs.

The approach is to utilize existing arc technology and scale the design to meet manufacturing criteria. The mini arc mode of operation will be considered for significant welding or brazing manufacturing requirements.

Photovoltaic Detectors for High Intensity X-Ray Measurement; *Gerald Entine,* Radiation Monitoring Devices Inc., Watertown, MA; $25,000 for 6 months beginning October 1, 1979.

The objective of this project is to analyze the basic physics of the newly invented cadmium-tellurium (CdTe) photovoltaic cell as a function of its crystal properties and the structure of the device. The feasibility of using this cell as a detector of high intensity radiation flux levels will be determined. Analyses will focus on limitations to its speed of response and performance in high fields and the nature of its photovoltaic mechanism. The results of the project should indicate the means of obtaining a very sensitive compact solid state X-ray detector for high speed nuclear instruments.

New Instrumentation for Temperature Measurement; *James L. Fergason,* American Liquid Xtal Chemical Corporation, Kent, OH 44240; $25,000 for 6 months beginning October 1, 1979.

The objective of the project is to study methods and techniques to produce nonconventional liquid crystal temperature sensors with both electronic and visual outputs. The results will be a sensor that can accurately measure temperature in the presence of electrical, magnetic, and/or sonic fields. Newly developed encapsulation techniques will be employed.

The need for these devices in medical and biological applications is becoming critical particularly in the use of local hypothermia in the treatment of cancer.

A Novel Technique for Fabrication Optoelectronic Materials; *Anton C. Greenwald,* Spire Corporation, Bedford, MA 01730; $25,000 for 6 months beginning October 1, 1979.

The objective of this project is to investigate the application of high-current ion implantation and pulsed electron beams to fabricate optoelectronic materials for heterostructural, injection electroluminescent devices and detectors. A high-current ion implanter will be used to implant P+, Al+, Ga+, and As+ ion species into gallium arsenide (GaAs) to concentration sufficienly high to alter thestoichiometry after implantation. A large-area pulse electron beam will be used to melt only the deposited radiation-damaged implanter layer, causing it to undergo rapid epitaxial regrowth upon cooling. Using this technique, it may be possible to produce materials which exhibit better uniformity over large areas. Also, new and as yet undefined heteroepitaxy structures may also be achievable for advanced device fabrication.

Affinity Crosslinking for Enzyme Technology; *Patrick E. Guire,* Bio-Metric Systems Inc., Minneapolis, MN 55435; $24,989 for 6 months beginning October 1, 1979.

The specificity of binding and efficiency of catalysis of enzymes and other binding proteins present large potential benefits to the economics and capabilities of catalyzed chemical conversion and analytical or detection systems. The objective of this project is to develop a new class of stepwise affinity crosslinking reagents that will covalently immobilize and stabilize enzymes and other binding proteins selectively from crude mixtures. Tri- and polyfunctional stepwise cross-linking reagents that contain both photoreactive and ligant groups will be synthesized. The photoaffinity carrier product will be designed to be hydrophilic and nonionic in order to minimize its propensity for nonspecific binding of proteins and thereby increase its specificity in the photochemical immobilization of antibody against the dinitrophenyl (DNP) group will be tested by companing the amount of anti-DNP antibody immobilized from equal concentrations in purified solutions, known mixtures and crude antiserum. One or more enzymes will be included in the mixture. The immobilization product will be assayed for DNP, binding capacity, enzyme activity and for total protein.

Correlation of the Material Properties of Tungsten Carbide with Drilling Performance in the Field; *Robert R. Hendrickson,* Terra Tek, Inc., Salt Lake City, UT; $148,891 for 12 months beginning August 1, 1979.

This award provides incremental funding to a project previously approved as a continuing grant (DAR 77-13273).

The objective of the research is to correlate the tungsten carbide insert's full-scale field performance with material properties. Sufficient evidence exists to indicate that such a project would provide quantitative guidelines for new carbides in rock fragmentation applications. Recent test technique innovation assures that pertinent material properties can be determined with test specimens prepared from the actual carbide inserts, thus eliminating any errors induced by separate pressing and sintering. Several drill-bit and carbide manufacturing companies are participating in the project.

A number of test bits of particular grades will be selected from the participating companies, and types of insert loads for the various bit applications will be analyzed. Inserts for the test bits will be selected in conjunction with the drill-bit manufacturers. Nondestructive tests will be performed on all inserts to avoid flaws, and sixteen material properties tests will be conducted on each carbide grade. Field tests will then be conducted and the results analyzed to provide criteria for carbide insert selection.

Growth of Ruby Crystals by the Heat Exchanger Method; *Chandra P. Khattak,* Crystal Systems Inc., Salem, MA 01970; $25,000 for 6 months beginning October 1, 1979.

Solid State laser systems are presently being considered for laser fusion applications. Two of the main obstacles in this area are the availability of large size crystals and uniform dopant distribution. This research is directed to grow ruby crystals by the Heat Exchanger Method (HEM) for laser applications. At the present time ruby is grown commercially in sizes up to one inch diameter. Besides lack of availability of large sizes, the distribution of Chromium dopant in the crystals is non-uniform making it difficult for use in stringent optical applications. In the HEM process, crystal growth occurs under stabilizing temperature gradients with no movement of crystal, crucible or heat zone. The solid-liquid interface is submerged and surrounded by the melt; therefore, very uniform temperature gradients exist at the interface. These features allow uniform distribution of dopant, homogeneity in grown crystals and controlled cool down to minimize normal stresses and prevent shattering.

During the proposed Phase I, it is intended to grow three-inch diameter ruby crystals by HEM and concentrate on the evaluation of crystal quality, distribution of chromium dopant, and uniformity of refractive index. Samples will be tested at the Lawrence Livermore Laboratory for stringent optical quality. The feedback from the quality assurance will be used to improve crystal growth process to achieve the desired objectives.

Semiconductor Processing by Electron Beam Pulse-Induced Surface Reactions; *Allen R. Kirkpatrick,* Spire Corporation, Bedford, MA 01730; $25,000 for 6 months beginning October 1, 1979.

New processing techniques are needed by the semiconductor industry to allow smaller and more sophisticated devices to be fabricated with reduced sequence complexity, improved yields and lower

costs. The phenomena associated with transient processing by pulsed beams can be directed towards fulfilling this need. An extremely versatile concept of total device fabrication can be based upon general replacement of standard thermal processes by applications of pulsed electron beams. By controlling pulse-induced surface reactions, it should be possible to utilize electron beam techniques for such procedures as dopant introduction, damage annealing, material growth, material alteration and etching. All processes can be conducted at ambient temperature and localized to any specific region selected. The overall objective of this project is to confirm the validity of this general processing concept. The conceptual feasibility will be established from the investigation of: (1) controlled silicon surface doping by electron beam pulsing in residual gas containing the selected dopant species, (2) controlled growth of thick (>1000A) oxide layers on silicon by pulse methods, (3) each of the above with a mask used to separate areas in which the particular processes do and do not occur, and (4) all of the above without allowing the silicon substrate temperature to exceed arbitrary maximum values of say room temperature and 600°.

Laser-Purification of Silane; *Robert T. Kung,* W. J. Schafer Associates, Wakefield, MA 01880; $23,350 for 6 months beginning October 1, 1979.

Material purification is a general area in which the important characteristics of lasers, such as monochromaticity, high intensity, and short pulse length can be fully utilized to destructively interact with undesirable impurities. Such a process can be highly cost effective and energy efficient, since generally little energy is consumed by the bulk of the desirable material. The objective of this project is to investagate laser induced purification of silane (SiH_4). High purity SiH_4 is very desirable in the fabrication of high efficiency solar cells. In general, purity is very important in the performance of most semiconductor devices. This project will identify the purity level of SiH_4 attainable using the multi-frequency laser purification scheme. Concurrently, laser specifications and the range of operating pressures, required for a purification process consistant with various kinetic rate considerations, will be determined.

Vacuum Deposited Silver Halide as an Electron Resist; *Joseph I. Masters,* Ionomet Company, Waban, MA 02168; $24,987 for 6 months beginning October 1, 1979.

The objective of this project is to investigate the utilization of vapor-deposited thin layers of silver halides as a microlithographic resist material in the production of integrated circuits. These materials are expected to be capable of very high resolution and are known to possess significantly greater electron, ion, or x-ray sensitivity than the photopolymer resists now used. The goal is to demonstrate the feasibility of evaporated silver halide as an electron resist by reconfirming high electron sensitivity on silicon substrates and determining the chemical compatibility and etch resistance of the thin film of silver halide. If successful, the results should lead to a new technique to increase the miniaturization and production speed of integrated circuit chips.

Clonal Propagation of Jojoba Via Tissue Culture; *Jiro Matsuyama,* K. M. Nursery Inc., Carpinteria, CA 93013; $24,724 for 6 months beginning October 1, 1979.

Previous studies have resulted in proposing that jojoba will someday become a significant source of superior quality oil. Moreover, it will be cultivatable as a "new" crop in the vast areas of land that are now idle because of poor climate and soil. Successful jojoba culture will result also in new employment opportunities and new sources of revenues for the relatively impoverished regions. But successful extensive culture of jojoba will require resolution of some major crop problems. For example, how can superior genetic selections be reproduced quickly in the large numbers that are needed to fill plantation-size acreages? The proposed project is intended to generate within the period of investigation a tissue culture method that will answer the question satisfactorily. The envisioned procedure will involve two steps: (1) rapid multiplication of shoots, and (2) rooting of individual shoots.

Research on the Optimization of Viscous Fluid Mixing; *Anthony Prentakis,* Ampec Corporation, Cambridge, MA 02139; $20,475 for 6 months beginning October 1, 1979.

The recent explosive advances in solid-state technology have resulted in dramatic and continuing decreases in the cost of electronic components. The cost of finished devices, however, is often constrained by the cost of packaging (often exceeding 50% of the cost of the finished device) which is generally labor-intensive. AMPEC Corporation has developed techniques for packaging a wide variety of electronic devices in solid epoxy castings (Automatic Monolithic Packaging of Electronic Components) which have resulted in considerable savings to clients. Widespread acceptance of these techniques depends largely on the availability of reliable and inexpensive epoxy mixing technology.

The mixing of viscous fluids is very important in many areas besides epoxy handling. However, a complete theory of mixing at low Reynolds numbers has not been formulated. This research is intended to identify the basic parameters important to mixing and to develop a theory sufficiently complete to (a) allow the identification of a single calculated parameter which can serve as an accurate index of the quality of mixing in any fluid systems and (b) identify the minimum theoretical energy requirements and mixing devices which approach that minimum.

SMALL BUSINESS AWARDS AND VENTURE CAPITAL

Dr. ATKINSON. The venture capital component is unique. Many small businesses are eager to get the NSF approval, not because of the money, but because approval draws attention to them in the venture capital markets.

Dr. SANDERSON. One of our grantees in the small business award just received the New York State prize in engineering for the research conducted under the project which we funded. This is another index that these projects represent very high quality research.

Mr. BOLAND. Do you want to describe that here?

Dr. ATKINSON. The program has three phases. NSF supports a first phase at $25,000 for preliminary pilot research. If that proves worthwhile, NSF entertains a proposal for the second phase of support. The second phase proposal must be accompanied by an identification of venture capital willing to support development of the new process or product, if the second phase is successful.

Mr. BOLAND. Phase three?

Dr. ATKINSON. Phase three is a non-NSF phase. It is pursued by the company on its own. By then the capital should be so clearly identified and the application so clearly developed that the company knows how to proceed.

INDUSTRIAL TECHNOLOGY PROGRAM

Mr. BOLAND. On page F-VIII-6, you are asking for $5.2 million in 1981 for the industrial technology program element. In your view, Dr. Sanderson, does this program have a high priority? It appears that it does because you are doubling your money from the 1980 current plan is that correct?

Dr. SANDERSON. Yes, sir. This is a very important activity. If you are familiar with all of the discussions that went on, the need for the support of generic technologies which underlie a variety of U.S. industries, that was a major component identified in the President's Domestic Policy Review. The increase which you see here is to provide the Foundation with resources to start at least one additional such center.

The Department of Commerce also has in their budget the funds for three such centers. The primary model for this concept is the center which the National Science Foundation had started earlier. You have heard me describe before the Polymer Processing Center at MIT. That was one of the most widely discussed prototypes for the entire concept of generic technology centers.

Dr. ATKINSON. This is one of the big debates in this government, and from one government to another. The Germans and the Japanese have pressed ahead on centers of this sort. In this government we have debated whether the government should be running such centers or whether they should be run via another framework.

We think we have the right answer here. We would like to press ahead with not only one additional center but possibly three or four. If the cooperative automobile research proposal were approved, I think our approach would be two or three joint university-industry centers, where NSF provides more funding to get projects underway.

Dr. SANDERSON. This package of activities along with the Foundation-wide university-industry cooperation really represents a unique approach of the Foundation and the U.S. Government to building the bridges between the brain trust which we have developed in our basic research community the universities, and U.S. industry, which is the motivating force to develop new products and processses and bring them to the market.

With our societal structure, I believe it represents a very sound approach. It is not the approach the Germans used, or the Japanese, because they have much more direct government involvement in their programs. Unless we want to change our value system drastically, I don't think we can adopt their solution, but I think what we are doing here may represent a U.S. approach to the problem of building back this communication between the basic research community and U.S. industry.

An interesting statistic, one major Massachusetts technical university of which I am aware, in the forties and fifties, about 12½ percent of their funds were coming directly from industry. At the present time it is down to about three percent. Not only does this represent a change in the source of support which changes the character of the research activities but also it represents a real breakdown in communication between the economically productive sectors of the economy, the private production sector and the research community.

Dr. ATKINSON. That was our real input to the Domestic Policy Review, namely, the role of bridging this gap. We have proposed the generic technology concept as one step in that direction.

Mr. BOLAND. Why did you take a reduction in 1980 in this area?

Dr. SANDERSON. Last year the appropriation had a ceiling on the programs in the ASRA directorate. That ceiling was below the request. If you add to that the Congressional requirements to initiate new programs, we were squeezed.

Mr. BOLAND. What about the 1981 ZBB levels for this program?

Dr. ATKINSON. Almost everything related to the Domestic Policy Review does not have a high ranking for NSF. We feel our mission is fundamental research. This effort would be near the edge of the cuts.

Dr. SANDERSON. In the ZBB material an entire package of materials related to Domestic Policy Review was submitted as a separate package.

GEOLOGICAL SURVEY EARTHQUAKE RESEARCH

Mr. BOLAND. The Interior Subcommittee is interested in earthquake research funding. What is your total funding to the United States Geological Survey for research on earthquakes.

Dr. SANDERSON. The budget for this year is about one million one hundred-thousand dollars. I will provide the total amount for the record.

[The information follows:]

NSF FUNDING OF U.S. GEOLOGICAL
SURVEY EARTHQUAKE RESEARCH

As a vital component of the National Earthquake Strong-Motion program, the Foundation has provided support to the USGS to maintain and operate a national strong-motion instrument network. The principal efforts of this research program are to:

- Design appropriate strong-motion instrument networks and arrays to provide data on regional attenuation, local site effects, and soil failures;
- Design appropriate instrumentation to study the response of representative types of structures at potentially damaging levels of response;
- Evaluate procedures for instrument maintenance, and develop new instrumentation to improve instrument quality and reliability;
- Develop an efficient system for collecting and labeling records from a major earthquake;
- Catalogue and archive the existing strong-motion records, and
- Establish a system for standard processing, management, and dissemination of the strong-motion data.

During the eight Fiscal Years 1973 through 1980, the support to USGS by NSF totals $5,330,404.

ACQUISITION OF SEISMIC DATA

Dr. SANDERSON. We support the strong ground motion array, the instruments which are installed and maintained by the USGS in a number of seismically active areas in order to get more experimental data on the strong ground forces which actually occur as a result of earthquakes.

It turns out that data is very scarce and it is very important if you are interested in designing structure that can withstand earthquake forces.

It is a very complex problem understanding the actual forces at a given building site.

Dr. ATKINSON. One of our active components is the U.S.-China exchange.

SCIENTIFIC TECHNOLOGICAL AND INTERNATIONAL AFFAIRS

Mr. TRAXLER [presiding]. Turn to the Scientific, Technological, and International Affairs sub-activity. You are requesting $28.8 million for the Scientific, Technological, and International Affairs Directorate. That is an increase of about $2.7 million above the current plan for 1980.

On page G–II–1 and 2 can you explain why the NSF is performing studies of international spread of innovations via the foreign subsidiaries of U.S. based enterprises; and the future regional distribution of national synthetic fuel facilities—an area of definite interest and responsibility in the Department of Energy?

Dr. AVERCH. NSF also has responsibility for providing S&T policy research and analysis to the Office of Science and Technology Policy and to OMB. We are in energy policy to the extent that it supports the Executive Office of the President. The Department of Energy, of course, does have access to our work and it provides an alternative source of information for decisionmakers.

Mr. TRAXLER. Is that an alternative or a duplicate source of information?

Dr. AVERCH. An alternative.

Mr. TRAXLER. Are you aware of the many studies that have already been performed in this area?

Dr. AVERCH. Years ago the Science Adviser was within the NSF and there was an internal Office of Energy R&D Policy. NSF was, necessarily, quite active in the science and technology policy aspect of energy.

Our current thrust looks at larger national trade-offs and does not infringe upon the specific domain of the Energy Department.

The number of energy studies has dropped markedly since the Science Adviser left.

Mr. TRAXLER. We know "energy" research is a buzz word. I want to make sure we are not duplicating research and spending the same dollar twice.

Dr. AVERCH. No. Our energy research has to do with science and technology policies concerned with energy. We do not have a general purpose program in energy.

Mr. TRAXLER. Good. Did you obtain reviews of the proposals of these studies from the Department of Commerce and the Department of Energy?

Dr. AVERCH. The budget proposals?

Mr. TRAXLER. No; the proposals for the studies.

Dr. AVERCH. Oh, yes. There is a practice in the policy research domain of obtaining both technical reviews from the scientific community and also consulting with agency personnel. So, any energy proposal considered by us would have been coordinated with, and in many cases reviewed by the cognizant experts in the Department of Energy.

I should make clear that such reviews are not formal agency reviews. The agency has no control over the work. Rather, we ask the expert in the Energy Department for comments or perspective.

INTERNATIONAL ECONOMIC POLICY PROGRAM

Mr. TRAXLER. On page G–II–6, it states that an International Economic Policy Program has just been established to address such questions as "in what directions might the international monitoring system proceed to insure a stable economic environment for international and domestic commerce." And, "is international coordination of domestic economic policy having major international repercussions feasible."

Why are you mounting a new program that clearly duplicates the work that the Treasury Department and the departments that they are responsible for and have undoubtedly major study projects in existence over the past several years?

Dr. AVERCH. This is an initiative that came at the request of the White House and directly from those in the White House who have responsibility for international economic policy. Again, cutting across the agencies, it was felt that alternative sources of information were needed. In this particular case it was also believed that the university community had been moving away from this kind of social science research.

The White House felt that, given the international economic problems we face, some incentive should be provided for the academic community to engage in larger issues of international economic policy that are not so much a concern to Treasury or to Commerce but to the country as a whole.

It was put in NSF I think, because we have done work on aspects of international economic policy, particularly technology transfer. Also, our record of dealing fairly with both decisionmakers and with the universities is well known.

BEHAVIORAL ASPECTS OF INFORMATION TRANSFER

Mr. TRAXLER. Turn to page G–IV–6, the justifications discuss the major research questions of the behavioral aspects of information transfer for which you are requesting $1.6 million. We talked about this last year. You indicated here that the three main directions for research remained unchanged.

How much money have you spent on this activity since its inception? Also give us some examples of what you have learned and how long do you suppose you'll have to continue funding this area of research?

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Dr. AVERCH. We have spent in proportion to the budget. Information science is considered a basic science and we expect to support it as long as it competes well with other sciences.

A number of different examples of information science research are listed for you in our significant achievements. One might say that information science is perhaps closer to application than most basic research. When the Congressional members use computers and the Congressional Research Service uses indexing schemes, they are based on fundamental work in information science and that is the kind of work we would expect to continue to support. I will supply additional information for the record.

[The information follows:]

A total of $1,267,267 has been awarded for this activity since its inception.

The Behavioral Aspects of Information Transfer program element is concerned with the human factors involved in information transfer, and especially with improving the transfer of information between people and machines.

The Kemeny Report analysis of the Three Mile Island accident (Ref 1) cited as major causes poorly designed control panels having information transfer rates and other features incompatible with human processing abilities. A recent article (Ref 2) cites the urgent need for better understanding of how displays, controls, and procedures should be designed to provide the information needed to control complex and dangerous systems including but not limited to nuclear power plants and air traffic control, and stresses the lack of data on human errors. All fourteen projects funded under the Behavioral Aspects of Information Transfer program element are still in progress and all are concerned with these and similar human factors problems. Their titles are:

- "Decision-making and information processing in real-time network models."
- "Modeling of human behavior in seeking and generating information." This project's goal is to develop analytical techniques for the design of computer systems which can adapt the human-computer interface to best meet the needs of the particular system user at the moment.
- "Human requirements in information retrieval." The principal investigator is a distinguished human factors expert, past President of the Human Factors Society and of the Society of Engineering Psychologists. The project seeks to obtain quantitative data on aspects of human-information retrieval system interactions.
- "Designing information systems for more effective use in decision making."

- "A reliability theoretic construct for document usage and information flow."
- "Research on behavioral variables related to information systems." This project's goal is to develop an interactive information system for use by research scientists.
- "Human attention and performance limitation in processing visual information."
- "Research in natural language man-machine interaction."
- "Representation, retrieval, and reorganization of conceptual information." Intended to provide new insights into memory and cognitive performance which will yield baseline data for assessing information processing systems.
- "Text processing effects and memory recall." Concerned with the nature of mechanisms capable of performing inferences similar to human reasoning with the goal of developing information systems attuned to user knowledge requirements.
- "Information processing of logographic and alphabetic writing symbols." Should words or symbols appear on control panels? This project is expected to contribute to the design of more efficient man-machine interfaces.
- "Electronic information exchange in research on devices for the disabled."
- "Computer terminal requirements for on-line catalogs in libraries."
- "ANSI Committee Z39." Committee Z39 of the American National Standards Institute develops standards relevant to information systems, library activities, and information and data handling in all media.

References

Ref 1. Report of the President's Commission on the Accident at Three Mile Island, Washington, DC, October, 1979.

Ref. 2. "Human error in nuclear power plants," Technology Review, February, 1980, pp. 22-33.

STIA ZBB BUDGET

Mr. TRAXLER. Dr. Averch, do you also use ZBB within your Directorate to rank the programs and the various program levels within those programs?

Dr. AVERCH. Yes.

Mr. TRAXLER. For the record, would you provide us with your own ZBB analysis of your programs from top to bottom with the highest ranking program through the bottom ranking program.

[The information follows:]

ASSISTANT DIRECTOR -- STIA

DECISION UNIT OVERVIEW AND DECISION PACKAGE DOCUMENT -- FY 1981 ZBB

LEVEL	INTERNATIONAL PROGRAMS	POLICY RESEARCH & ANALYSIS	SCIENCE RESOURCES STUDIES	INFORMATION SCIENCE AND TECHNOLOGY	TOTAL
MINIMUM LEVEL	$ 10.9	$ 5.6*	$ 2.9	$ 4.7	$ 24.1*
INCREMENTAL 1	$ 0.9 $ 11.8	$ 0.2 $ 5.8	$ 0.3 $ 3.2	$ 0.5 $ 5.2	$ 1.9 $ 26.0
PRESIDENT'S TARGET	$ 1.1 $ 12.9	$ 0.1 $ 5.9	$ 0.2 $ 3.4	$ 0.2 $ 5.4	$ 1.6 $ 27.6
NSF REQUEST	$ 0.2 $ 13.1	$ 0.4 $ 6.3	$ 0.2 $ 3.6	$ 0.9 $ 6.3	$ 1.7 $ 29.3

* After the NSF budget was submitted to the Office of Management and Budget, the Executive Office of the President requested a program in International Economic Policy. It was subsequently included in the core program of Policy Research and Analysis, at the Minimum Level ($750,000).

FY 1981 KEY FEATURES

At the Minimum*: Maintaining base support for the most productive areas retains priority. Under minimum level constraints, however, standing commitments and legislatively fixed requirements force reductions across all STIA programs even in the most significant ones. Increasing costs associated with international scientific organizations' dues and administration force reductions in all on-going international cooperative research activities. Although still identified as program thrusts, cooperative activities between the U.S. and scientifically advanced countries of Western Europe, developing countries of the world, and China decrease to levels below those set in FY 1980. Other activities in regions of East Asia, the Pacific, Latin America, and Africa are further curtailed, reaching levels near those in FY 1979. --- In Policy Research and Analysis, programmatic awards, support for mandated reports, and for specially requested ad hoc analytical efforts, as well as extramural policy research projects will not only be held without increase for the third consecutive year, they will be taxed further by a 3.5% reduction in FY 1981. This funding level is considered the absolute minimum at which Policy Research and Analysis can provide the responsive research-based policy analysis increasingly sought by members of the Executive Offices and Congress. --- At the minimum level, Science Resources Studies must commit three-fourths of its available funds to development and maintenance of its data base. At the same time, large additional costs for a special postcensal survey of scientists and engineers force cuts in all other areas of program activity. --- Since NSF is the major Federal supporter of research in information science and technology, a core program of basic and applied research is protected, although maintained at ten percent below the FY 1980 level.

* After the NSF budget was submitted to the Office of Management and Budget, the Executive Office of the President requested a program in International Economic Policy. It was subsequently included in the core program of Policy Research and Analysis, at the Minimum Level ($750,000).

At the President's Target: A total increase of $3.5 million above the minimum level provides support for strategically planned thrusts in FY 1981, while restoring all other activities to their operative FY 1980 level. International Programs receive a $2.0 million increment directed primarily toward building U.S.-Western European S&T cooperation; science assistance to developing countries under NSB approved guidelines; and continued scientific cooperation with China. Also within the $2.0 million increase, funds for the international travel of U.S. scientists and engineers rise by fifteen percent.---Policy Research and Analysis, with an increase of $0.3 million, returns to the level held for the last two fiscal years and introduces a new thrust of great interest to the Congress: risk assessment activities, an exploration of society's costs and benefits associated with alternative technologies.---An increase of $0.5 million for Science Resources Studies enables focused data collection and reporting on two topics of importance to public policy makers: small R&D firms and R&D nonprofit institutions.---A $0.7 million addition to the core program in Information Science and Technology falls short of offsetting inflation but permits essential planning for new efforts in application of advanced information technology, an area of activity recommended by the Director's Science Information Task Force.

At the NSF Request: International Programs utilize an additional $0.2 million above the Target Level to extend science assistance to more developing countries.---With an increase of $0.4 million, Policy Research and Analysis rounds out an integrated study program of key S&T related public policy issues. Subjects addressed include innovation processes, socioeconomic effects of S&T, and risk assessment as it pertains to the environment, energy, resources, and new technologies.---The $0.2 million received by Science Resources Studies at this level permits continued development of new science indicators and a study of the effects of mandatory retirement on the country's supply and utilization of scientists and engineers.---Real increases totaling $0.9 million in the Information Science and Technology program are provided to boost research on standards, measures, and structure of information and on the behavioral aspects of information transfer. These areas are strategically important to the evolving field of information science because future technological advances depend on a sophisticated understanding of the nature of information itself and of human ability to interact with massive systems of information storage.

DECISION PACKAGES

Scientific, Technological, and International Affairs

OBJECTIVES:

- Promote a more cost-effective U.S. scientific effort by exchanging research information with foreign counterparts, sharing costs, and sharing access to rare or unique research facilities, resources, and expertise, in bilateral programs, joint commissions, informal regional programs, and broad multi-national programs.

- Increase scientific cooperation with Western Europe and with other countries of the industrialized world.

- Undertake programs with developing countries which (i) focus on their scientific problems of priority interest, (ii) contribute to the building of their science and engineering capabilities, and (iii) contribute to their development objectives.

- Improve the science content of international science activities entered into by the U.S. Government as components of foreign policy initiatives.

- Support long-range studies on the relationships between S&T and the economy and quality of life, the processes by which technological innovation occurs, the role of S&T in improving energy, environment and resource policies, and technology and risk assessments.

- Analyze and integrate available information and data to improve the availability of federal decision makers to assess the effectiveness of alternative S&T policies and programs.

- Assist the OSTP, OMB, Congress and other agencies through the support of selected studies and analyses, and through preparation of the legislatively mandated Annual Science and Technology Report and Five-Year Science and Technology Outlook.

- Maintain the present resource data base and develop periodic comprehensive national overviews of R&D funding and of the supply and utilization of scientific and technological personnel by conducting, analyzing, and integrating the results of more than 20 surveys and studies.

- Develop information on S&T resource characteristics and dynamics, including output measures of S&T, and publish these combined results in the NSB Science Indicators Report.

- Increase sophisticated analysis of the science resources data base in order to realize greater returns from the NSF investment in carefully maintaining the data base.

- Increase understanding of the properties and structure of information and information transfer.

- Contribute to the store of scientific and technical knowledge which can be applied in the design of information systems.

Mr. TRAXLER. We spent a great deal of money on this activity.

Dr. AVERCH. Not relative to its importance in the economy.

Mr. TRAXLER. We are talking about spending $25–30 million a year.

Dr. AVERCH. You are talking about two to three percent of the NSF budget.

CROSS-DIRECTORATE PROGRAM

Mr. TRAXLER. Let's turn to the new cross directorate programs tab which is displayed on page H–1. You are requesting $51.9 million for this activity—an increase of roughly 100 percent or $26.4 million above the current plan for 1980. It would appear that in the budget exercise last fall OMB gave you some additional funds and that you put it in this new cross directorate program activity. I would now suspect that since OMB is about ready to take some money away—and I know you may have current information on this——

Dr. ATKINSON. We have brought Mr. Boland up to date; the information is tentative.

Mr. TRAXLER. Yes. Would you bring me up to date on this exercise?

Dr. PIMENTEL. I can recapitulate briefly. It is true that some of the intiatives appear in the Cross-Directorate program; if NSF sustains a large budget cut, the initiatives will be susceptible to such a cut.

Dr. ATKINSON. An example is the special facilities line item in the budget.

A big part of that line item is a new effort in the Foundation for the renovation of research laboratories.

Last year, HEW Secretary Califano argued for improved laboratory facilities. This year, through the budget process, the initiative was given to the National Science Foundation.

Mr. TRAXLER. But this activity is new so it doesn't have a large constituency yet.

Dr. ATKINSON. We didn't quite see it that way.

INDUSTRY/UNIVERSITY COOPERATIVE RESEARCH PROGRAM

Mr. TRAXLER. Let's turn to page H–2 which describes the Industry/University Cooperative Research Program. You are apparently placing a very high priority on this activity. Why is that?

Dr. ATKINSON. The program emphasis results from the Domestic Policy Review on industrial innovation. A key concern of that review is the establishment of close links between industry and the university science community.

This funding is designed to ensure cooperative research efforts between industry and universities where the joint research would also help to build relationships between industry and university scientists. This is the component for which we received support.

Mr. TRAXLER. Is it just basic research?

Dr. ATKINSON. Some applied work can be done under this program, but, we think of it as basic research with an added requirement: a cooperative relationship between a university and an industry laboratory.

The universities are enthusiastic about the program because their graduate students are moving not into university positions but into industry; the program gives the university scientist and university graduate student a closer tie to the industrial research world. The industrial world has the benefit of seeing the latest work being done in the university and of working cooperatively with university scientists.

NSF has been funding this effort for several years, exciting projects have been done, and we are reestablishing links that previously existed between universities and industry.

The program could be susceptible to budget cutting, but we wouldn't want to eliminate it.

Mr. TRAXLER. Your justifications indicate that the budget request in 1980 from 1979 was reduced by about 30 percent or $1.4 million.

Dr. ATKINSON. I believe ceilings and constraints were placed on some programs. That is true?

Dr. SANDERSON. That was perhaps part of it but also in both fiscal years 1979 and 1980, the current plan is higher than the budget request. The same thing occurred in 1979. We started off the program not anticipating the high degree of interest and support it would receive from the research community.

REPROGRAMMINGS

Mr. TRAXLER. You have asked for two reprogrammings for this program in 1980—the first last December and the second one is currently before us in the amount of about $1.4 million. Of course we haven't made a decision on the second reprogramming.

Since you only asked for $4 million for this activity, I cannot understand why with only three months of the fiscal year behind you, you began to do a flip-flop here. Where is the pressure coming from for this money?

Dr. ATKINSON. The first reprogramming was based on what we judged to be the remarkable flow of quality proposals. The second reprogramming resulted from the Domestic Policy Review. We knew we would have a large increase in fiscal year 1981, and we sought to develop a smooth transition in funding from fiscal year 1980 to fiscal year 1981.

Mr. TRAXLER. One of the things we are concerned about is the rapid expansion of the program we are going to see an inability to manage it properly? With this dramatic increase, is it possible that industry will back away when they know and the Federal government will assume the dominant basic research support role.

Dr. ATKINSON. We have worried a great deal about the management. I personally have been involved in the selection of the manager and the development of guidelines for the program.

In answer to your second question, we require applicants to certify that these are new projects—projects that would not have been conducted in the current research budget of the industry.

Dr. SANDERSON. One of the more interesting things Dr. Pimental and I have been participating in is an effort with the chemical industry. The chemical industry has become quite concerned about the decline in communications with the university research community. They have made strong commitments, thanks to this

program, to provide additional funds on top of what they would normally have provided in order to be more responsive to this opportunity to work with the university research community.

Mr. TRAXLER. Frankly, the funding level in this program suggests that the priority it enjoys was not in your own budget but someone else's. Is there any truth to that?

Dr. ATKINSON. The program has a high priority in the Domestic Policy Review. In that sense, it has added money to NSF's budget because the President decided he should pursue this program.

We would not argue that the program should replace basic research programs, but we would want a core of activity even at the expense of the university research programs.

Mr. TRAXLER. If the Committee does not reauthorize your second reprogramming, what would you do with that activity?

Dr. ATKINSON. It is programmed out of the basic research area; the funds would still be directed at this industry-university cooperative effort. I would not want the second reprogramming if the program would grow only at the cost-of-living rate or less.

Mr. TRAXLER. Even if you are subject to revisions this week or next week?

Dr. ATKINSON. Yes. The funding comes out of the basic research programs. It would still go to universities in this program but cooperative research would be required.

Mr. TRAXLER. Mrs. Boggs. Feel free to interrupt at any point.

Mrs. BOGGS. Thank you, Mr. Traxler.

SPECIAL FACILITIES IMPROVEMENT PROGRAM

Mr. TRAXLER. On page H–5, you are requesting $20,250,000 an increase of $12,150,000 for Special Facilities and Instrumentation. Is this a new program and if so, tell us why it is necessary to start a brand new program?

Dr. PIMENTEL. The Facilities Improvement Program was initially proposed by Mr. Califano in HEW because over the past decade none of the Federal agencies has mounted any significant programs of facilities improvement at universities—specifically research facilities.

The proposal for this program was concentrated on fundamental research, and consequently NSF was considered the proper place to lodge such a program. The funding, $14.25 million, indicates that it is only a beginning on a significant accumulated need.

We would use this funding for modernizing and improving existing research facilities to handle the modern, sophisticated instrumentation that is now being used in research. If this program gets under way, it is likely to require additional funding in future years.

Mr. TRAXLER. How much other instrumentation and facility money is available?

Dr. ATKINSON. This is not instrumentation money. And it is not for new buildings but, for renovation of laboratories.

Dr. PIMENTEL. Safety precautions, ventilation and similar items. Another of the ross-directorate programs, one expressly directed at research instrumentation but limited to two- and four-year colleges, is being continued at the $3 million level.

Mr. TRAXLER. Mrs. Boggs?

SCIENCE EDUCATION PROGRAMS

Mrs. BOGGS. The excitement about the program that NSF had initiated in the junior high schools was that the appetite of the young people would be so whetted that they would begin to demand better laboratory conditions, better instrumentation and better environmental conditions within the laboratories themselves.

I am just distressed there are no funds in HEW that can match the kind of new learning and new techniques that these young people could pick up if they were able to be a part of the NSF program.

Dr. ATKINSON. You will have an able representative in the Department of Education in the person of Dr. Rutherford. He is to be the Assistant Secretary for Educational Research and Improvement in the new department.

Mrs. BOGGS. Mr. Chairman, as you know, we have a television series that will be geared to the young people who are a little more mature with the hope that young people will become interested in science.

There is not much point in training the teachers and having the show to excite these interests unless we have the facilities in the schools to carry through on this.

I would hope to see through a coordinated and cooperative effort, some progress being made next year in this area.

Dr. RUTHERFORD. It is not only lack of facilities but also instrumentation. There was a time when the Office of Education provided apparatus for the high schools. They no longer do that.

The television show seems to be working. It has already the second highest children's audience next to Sesame Street.

Mrs. BOGGS. Pardon a personal reference, but my granddaughter who is nine has become not only more interested in science but in mathematics as a result of the show.

As you well know, I feel very strongly that the only way we are going to get more young women into positions in the scientific field is by making opportunities available to them early enough so that they will choose science as a career.

Dr. PIMENTEL. You are certainly right; the need for equipment in the junior high schools is going to be very great. There is no chance the NSF could meet it. With so many junior high schools the program must be a Department of Education activity.

Mrs. BOGGS. If I may add this one thought: with the decrease in the school population we are beginning to see a trend toward better utilization of high school facilities. They are now beginning to use a four-year high school system, instead of three years, in order to more efficiently use the physical facilities of the high schools.

Dr. PIMENTEL. We might bridge the gap a bit.

Mrs. BOGGS. Yes.

Mr. TRAXLER. After all this conversation, if the President reduces your budget request, is this an area that will be impacted severely?

Dr. ATKINSON. Yes. Facilities improvement is one of the items.

PROGRAM DEVELOPMENT AND MANAGEMENT

Mr. TRAXLER. Turn to Program Development and Management on page I-1. You are requesting a limitation of $60,800,000 and 1,293 positions for fiscal year 1981. This is an increase of $236,238 over 1980 when $2,547,762 in carryover funds and $84,000 transferred to the Department of Education are considered.

You are requesting an additional 19 positions above fiscal year 1980?

SENIOR EXECUTIVE SERVICE POSITIONS

Last year's detailed schedule of permanent positions indicated 137 Excepted Executive (EE) positions in fiscal year 1980. This year's detailed schedule of permanent positions shows twelve EE positions and 129 Senior Executive Service (SES) positions in both 1980 and 1981.

How did you determine which EE positions would be converted to the Senior Executive Service? Why were not all EE positions converted to the Senior Executive Service?

Mr. UBOIS. All the grades were reviewed first within the National Science Foundation and then negotiated with the Office of Personnel Management with regard to the total number of positions that we would have within SES and as to their special character and so on. On a position-by-position basis OPM reviewed and approved our request for SES positions.

Dr. PIMENTEL. It was a detailed negotiation, position-by-position, with OPM.

Mr. TRAXLER. Why does the total of EE and SES positions for 1980 (141) shown in this year's budget increase over the number of EE positions for 1980 (137) shown in last year's budget?

Mr. UBOIS. Programs come and go and the level of effort and responsibility required for management changes over time. We have adjusted many of those downward, and we have eliminated some in connection with programmatic emphasis and changes.

Mr. TRAXLER. Can you tell us how much is included in your 1981 request for SES bonuses and compare that with fiscal year 1979 bonuses for EE positions?

Mr. UBOIS. There were no bonuses for EE positions in 1979. I think there is something less than $400,000 included in the 1981 request for bonuses.

Mr. TRAXLER. Fine, for the record, provide the amount budgeted for fiscal year 1981.

[The information follows:]

SES BONUSES IN FISCAL YEAR 1981

The amount budgeted for SES bonuses in fiscal year 1981 is $397,000.

SUPERGRADE AND SES POSITIONS FILLED

Mr. TRAXLER. The number of "supergrades" at the Foundation continues to increase. The NSF had 130 in 1977, 131 in 1978, and the budget indicates 141 for 1981. How many "supergrade" positions are currently filled?

Mr. UBOIS. I would have to supply that for the record.

[The information follows:]

SUPERGRADE POSITIONS CURRENTLY FILLED

Currently, 111 SES and 12 non-SES supergrade positions are filled.

COMPETITION FOR SES POSITIONS

Mr. TRAXLER. Do you think that is an unreasonable increase in your supergrade positions?

Mr. UBOIS. We certainly don't think so and we are delighted to say OPM doesn't think so. As you may know, OPM had a limited number of SES positions to distribute government-wide. There was in effect competition among agencies for how many SES positions each agency would be able to have out of that pool. We have to justify on a position-by-position basis all of our SES positions.

Mr. TRAXLER. Do you anticipate further increases for 1982?

Mr. UBOIS. Not at this time.

Mr. TRAXLER. That was a good answer.

STAFFING STUDY

On page I-4 is mention of the Agency staffing study completed last fall. We discussed this briefly last year.

Has the Foundation used this study to shift resources between program directorates?

Dr. PIMENTEL. Yes, sir. Our entire discussion of billet needs with OMB was based on the staffing study. We had listed billets, position-by-position, directly from the staffing study.

Mr. TRAXLER. Do you feel that each of your program directorates is properly and adequately staffed according to the study?

Dr. PIMENTEL. Our staffing study identified a need for 31 additional billets in FY 1981.

We were permitted an increase of 19 billets. I would say that any difference between FY 1980 and FY 1981 represents additional need. The President's initiatives added very significant programs to NSF activities, and we diverted to new activities some of the billets assigned to us.

Dr. PIMENTEL. We asked for 31 but received 19. That represents the documented need and the new initiatives such as the Ocean Margin Drilling program and the very large expansion of the industry-university cooperative effort caused us to divert 12 of the assigned positions justified by the staffing study to the new programs.

Mr. TRAXLER. In view of your shortage of administrative positions, do you feel you can adequately administer the programs?

Dr. PIMENTEL. We are managing staff carefully to make sure that the quality of NSF's review process is maintained, even though we feel NSF would benefit from those additional billets.

CURRENT STATUS OF POSITIONS

Mr. TRAXLER. Your justifications on page I-1, indicates 1,274 permanent positions in 1980 and 1,293 in 1981. This is an increase of 19 permanent positions. How many positions are currently filled—both permanent and other?

Dr. PIMENTEL. Do you mean of those 19 positions?
Mr. TRAXLER. No; your total permanent positions.
Mr. UBOIS. We have 1,253 people currently on board of the 1,274.
Dr. PIMENTEL. That is an estimate.
Mr. TRAXLER. Those are permanent positions?
Mr. UBOIS. Yes, sir.
Mr. TRAXLER. Do you have any temporary positions?
Mr. UBOIS. Yes, we do.
Dr. PIMENTEL. We will provide the number for the record.
[The information follows:]

NUMBER OF TEMPORARIES

On February 29, 1980, the Foundation had 10 employees on-board in temporary positions. Three employees were working part-time and seven were working full-time. The seven temporary employees working full-time are included in the 1,253 total on-board strength figure.

HIRING FREEZE

Mr. TRAXLER. What would be the effect of a hiring freeze on the National Science Foundation?

Dr. PIMENTEL. Let me assume that the hiring freeze will be like the one we had a year ago in which we were permitted to bring in one for each two who left. We would use the replacements where the pressures are greatest, and we would use temporary positions while we await the number of people required to meet the need in a specific area.

It was difficult last time; it is plain it will be difficult again this time.

But if NSF takes a large budget cut in FY 1981 some of the initiatives will be cut. That would mean the personnel diverted from other programs could be returned—unpleasant but some relief.

PERSONNEL COMPENSATION AND LAPSE RATE

Mr. TRAXLER. What lapse rate is assumed in the funds for both 1980 and 1981? What was the actual lapse rate in 1979 and 1978?

Dr. PIMENTEL. The assumption is 3 percent for the positions carried over from 1979. We assume a 33 percent lapse rate for the 20 new positions, added in FY 1980, 3 percent for the positions that we already have.

Mr. TRAXLER. Did you give me the lapse rate for 1978?

Dr. ATKINSON. That is roughly how we based our percents. It's 5.5 percent.

Mr. TRAXLER. And for 1979?

Dr. ATKINSON. It was 6.5 percent. Because of the hiring freeze it was higher in 1979. Obviously, our 3 percent lapse rate projected for 1980 will be higher if there is a hiring freeze.

Mr. TRAXLER. Again, what is the lapse rate that you are assuming for 1980 and 1981?

Dr. ATKINSON. For permanent positions, 3 percent. But for new positions, as Dr. Pimentel said, 33 percent.

We have a problem with recruitment. We require a national search with national advertising, so we cannot fill those positions

as quickly as we might like, the assumption of 33 percent is about right.

Mr. TRAXLER. In the event that the President reduces your budget, could the number of new positions also be reduced? Is there a correlation between that increase and the funds available for grants?

Dr. PIMENTEL. As I indicated, NSF would need those people in the activities from which they were taken, so there is no immediate correlation.

Mr. TRAXLER. Of your 20 additional positions that you were granted in 1980, how many have been filled?

Mr. UBOIS. Approximately 14 of that 20, sir.

Mr. TRAXLER. Can you provide for the record when they were filled?

[The information follows:]

NEW FY 1980 POSITIONS CURRENTLY FILLED

Currently, 14 of the 20 positions are filled. These positions and dates they were filled are as follows:

	Position Title	Grade	Entry on Duty
1.	Assistant General Counsel	EE-II	2/10/80
2.	Program Assistant	GS-7	10/22/79
3.	Program Officer	EC-13	7/19/79
4.	Secretary	GS-6	7/2/79
5.	Professional Assistant	GS-9	1/28/80
6.	Program Manager	EC-14	8/15/79
7.	Secretary	GS-5	8/27/79
8.	Section Head	ES-4	8/6/79
9.	Section Head	ES-4	7/16/79
10.	Program Assistant	GS-7	8/5/79
11.	Secretary	GS-7	3/16/80
12.	Program Manager	EC-13	11/1/79
13.	Special Assistant	GS-14	2/10/80
14.	Secretary	GS-5	9/17/79

Positions filled prior to October 1, 1979 were in anticipation of the 20 positions being authorized in FY 1980. If the positions had not been authorized, they would have been offset from vacancies of existing lower priority positions.

COMPENSABLE WORKYEARS

Mr. TRAXLER. This year's personnel summary table shows 1,380 staff-years in 1981, an increase of 93 over 1980. Why the large increase in the staff-years in 1981? Your permanent positions only increased by 19.

Dr. PIMENTEL. Repeat the question, please.

Mr. TRAXLER. Your personnel summary table, which we got out of the budget book, shows total number of positions for 1981 at 1,293, and your total compensable staff-years at 1,380, an increase of 93 staff-years over 1980. The question is why the large increase in staff-years in 1981? Permanent positions only increased by 19.

Dr. PIMENTEL. Dr. Wilson is the head of NSF's Office of Planning and Resources Management.

Dr. WILSON. The total includes part time, temporary and consultants as well as full-time permanent staff.

Mr. TRAXLER. What type of work is going to be accomplished with this increase?

Dr. PIMENTEL. Are you talking about the new billets?

Mr. TRAXLER. Your 1,380 staff-years in 1981.

Dr. WILSON. Total staff-years, in addition to full-time permanent, include consultants that we bring in to advise on programs and part-time people we bring in for clerical and secretarial help with the workload during peak periods.

Mr. TRAXLER. Why do you need 93 more staff-years in 1981?

Dr. WILSON. I cannot answer that in detail. I will have to supply that for the record.

Mr. TRAXLER. Fine. Is NSF being controlled by both positions and staff-years? Next year, I understand that all agencies will be controlled by staff-years.

Dr. WILSON. No. It will start in fiscal year 1982.

[The information follows:]

INCREASE IN COMPENSABLE WORKYEARS 1980–81

The 93 increase referred to is the difference in compensable workyears between fiscal year 1980 and 1981 shown in the National Science Foundation's Personnel Summary in the Appendix to the Budget of the U.S. Government—fiscal year 1981.

Compensable workyears are calculated according to instructions contained in OMB Circular No. A–11. They are actual workyears based on fiscal year 1979 payroll records and estimated workyears for fiscal year 1980 and fiscal year 1981 based on the amounts included in the budget for permanent personnel, temporary and part-time employees, student aides, consultant compensation and terminal leave. In calculating the estimated compensable workyears for fiscal year 1980, the $2.5 million carryover of fiscal year 1979 funds which the Foundation was directed to apply to the fiscal year 1980 costs of the October 1979 pay raise was inadvertently omitted. When this amount is included in the calculation, the increase in compensable workyears in fiscal year 1981 is 17 rather than 93. The 17 compensable workyear increase results from the 19 additional positions lapsed for part-year funding and approximately one additional workyear of consultant compensation.

Mr. TRAXLER. Thank you.

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

On page I–2, looking at the middle of the page, the justifications indicate that the Foundation does work for the Office of Science and Technology Policy.

What type of work do you do for the Office of Science and Technology Policy?

Dr. ATKINSON. Dr. Averch is responsible for much of that effort; he can describe it.

Dr. AVERCH. The kinds of studies we do are analytic back-up studies for policy issues that confront Dr. Frank Press and others in the White House. For example, we are currently reviewing the procedures used by agencies to factor in scientific and technological information in the regulatory process.

Some in-house staff work would address that issue. There are also energy questions, but I will give you more examples for the record.

[The information follows:]

NSF POLICY WORK IN SUPPORT OF OSTP STAFF

Some examples of studies and analyses carried out by STIA staff at the request of OSTP are: Interagency Study of Nonfuels Minerals; Domestic Policy Review of Solar Energy; Annual S&T Report, 1978, 1979, 1980; Industrial Innovation Domestic Policy Review; and Five-Year Outlook I, II.

Dr. ATKINSON. This is a Congressional requirement for policy analysis in support of that Office.

Dr. AVERCH. Another good example was the analysis that we helped them do for the President's Domestic Policy Review of Industrial Innovation.

Mr. TRAXLER. We appreciate your breaking down the cost—both in terms of funds and staff-years—associated with this effort for the record. Also, what did the Office of Science and Technology Policy do for NSF in 1978 for $30,000?

[The information follows:]

STIA FINANCIAL AND STAFF SUPPORT TO OSTP

	Cost[1]	Staff effort[2] (person-years)
Fiscal year 1978	[3]$549,411	8
Fiscal year 1979	340,160	9
Fiscal year 1980 (current year estimate)	[3]585,916	9

[1] Includes costs for grants, contracts, and consultant support.
[2] Covers all direct staff time, including supervision, management, and oversight of projects.
[3] Higher level reflects 2-year cycle of "Five-Year Outlook" report.

NSF AWARDS TO FEDERAL AGENCIES

Mr. TRAXLER. I am advised that Mr. Conte may have touched on this subject this morning, but let's proceed with it anyway.

You made 93 grants and/or contracts totalling over $41 million to other Federal agencies in 1979—primarily the Department of Defense. Under what other circumstances does NSF make grants and/or make contracts with other Federal agencies? You can provide that for the record.

[The information follows:]

NSF Guidelines for Support of Research Performed by Other Federal Agencies

National Science Foundation policy guidelines outlining the circumstances under which NSF makes grants and contracts with other Federal agencies are contained in NSF Circular No. 108 (Revision 3), dated March 6, 1979, title "Support of Research, Science Education, and Related Activities Performed by Other Agencies." This Circular is quoted below:

NATIONAL SCIENCE FOUNDATION

Office of the Director
Washington, D.C. 20550

NSF CIRCULAR NO. 108

(Revision No. 3)

ADMINISTRATION AND MANAGEMENT

March 6, 1979

Subject: **Support of Research, Science Education, and Related Activities Performed by Other Agencies**

1. **Purpose.** This Circular establishes general rules to govern the use of NSF funds to support research, education, and other related activities to be performed by other Federal agencies.

2. **Cancellation.** This Circular cancels NSF Circular No. 108 (Revision No. 2) dated October 1, 1977.

3. **Scope.** The term "Federal agency" as used herein refers to all elements of the Federal Government, as well as the Smithsonian Institution, and Federally-funded research centers, such as the Oak Ridge National Laboratory, and others.

4. **Policy.** The Foundation is expressly authorized by its own statutory authority to support research performed by other Federal agencies. (See Section 14(f) of the NSF Act.) The Foundation assumes however, that each agency in pursuit of its own mission, and with due regard for the provisions of Executive Order 10521 relating to the support of basic research, requests appropriations for the support of research appropriate and necessary to that mission. Therefore, it is Foundation policy not to encourage research proposals from other Federal agencies except in pursuit of specific NSF objectives. Other Federal agencies, their employees or facilities contractors are not eligible to compete for NSF support unless a proposed project meets one or more of the exceptions in paragraph 6., below.

5. **Background.** In supporting individual scientific projects, the Foundation seeks to accomplish a variety of objectives in addition to the accomplishment of the specific project. These include the strengthening the research staff of performing organizations, training graduate and undergraduate students; and otherwise providing support to educational and nonprofit or other private organizations in a way which will advance the general progress of scientific research. Generally, these broad objectives are best accomplished if Foundation funds are allocated to the support of scientific research at academic and other nonprofit organizations, or other private organizations as set forth in NSF Circular No. 113, "Participation of Industry in NSF Programs."

6. **Exceptions.**

a. *Scientific Research Projects.* Research projects from Federal agencies that enable NSF to serve more efficiently the research needs of scientists from academic or other institutions may, on occasion, be recommended for support. Such proposals must be presented to the appropriate Assistant Director for prior concurrence before the proposal may be reviewed or considered for possible funding. In order to qualify under this category the proposing agency should demonstrate a substantial interest in the project by agreeing to contribute a significant portion of the total project costs. Preferably this cost sharing commitment should cover the salaries and employee benefits of senior research personnel.

This policy is not intended to bar the occasional action of program directors in the National Science Foundation in conjunction with laboratory chiefs or program directors of other agencies jointly to support other scientific activities, such as research projects, performed by third parties, conferences, and symposia that are of mutual interest. The best method for pooling funds should be determined in each individual case. However, Foundation funds are not to be used to pay for rental or use charge for auditoria, projection facilities, etc., owned and operated by other Federal agencies.

b. *Military Service Academies.* Research proposals submitted on behalf of faculty members of the various military service academies such as the U.S. Military Academy at West Point, the U.S. Coast Guard Academy, the U.S. Naval Postgraduate School, etc. should be accepted and subjected to competitive review and evaluation in the same way as proposals from other academic institutions. However, it is considered inappropriate to include major capital facilities in awards to such institutions.

c. *Joint Appointments.* Scientists conducting research under a joint appointment with a university and a Federal agency, such as a Veterans Administration (VA) Hospital, shall submit their proposals via the

Please include this Circular in NSF Manual No. 16, "Handbook for Program Officers"

university. Support is available only where the investigator is a bona fide faculty member of the university, though part of the salary may be provided by the Government agency.

d. *New Facilities.* When the possible establishment of major new facilities or research capabilities is being considered, either in pursuit of a specific (research) objective of an NSF program or to serve the general instrumentation, observations or logistics needs of U.S. science, full consideration should be given to the use of capabilities or facilities in existing Federal laboratories and Federally-funded research and development centers as well as capabilities that may be available in commercial organizations prior to the creation of new or additional capabilities.

e. *International Travel Awards.* Under certain conditions, staff scientists of other Federal agencies are eligible for international travel awards for attendance at international conferences and visits to laboratories. The conditions under which such support may be offered are described in NSF Circular No. 50, "Support of Foreign Travel through International Travel Support, Project Grants and Fellowships."

f. *National and International Programs.* The Foundation provides funds for research and logistic support activities at other Government agencies as appropriate to the objectives and goals of national, international, or specific research programs from which the support funds are to be derived. For example, the Foundation bears special responsibilities for certain programs such as the United States Antarctic Research Program, the Arctic Research Program and the International Decade of Ocean Exploration. It also plays a central role for a number of international science and technology programs with other countries. Proposals for research from scientists in Government laboratories may be considered for support on an equal basis with university scientists when such support will lead to the accomplishment of program objectives. Furthermore, funds for special services, including logistic support to several of these programs, are provided under memoranda of agreement with various Government agencies.

g. *Science Education Programs.* Provided specific eligibility requirements of particular programs are met, Federal agencies and Federally-funded facilities may be considered in equal competition with all other proposals except that in the case of service academies, (1) awards solely for the benefit of the academy will not be made when derived from their future appropriations, and (2) awards will not be made for service academy functions that are properly allowable to their normal activities and the purposes of their own appropriations.

Richard C. Atkinson

Richard C. Atkinson
Director

Distribution E

Mr. TRAXLER. Do other Federal agencies compete for the awards?

Dr. ATKINSON. Let me detail that for the record. We direct our effort at the university community, but under special conditions we fund work in government laboratories. We will put the list together for the Committee files.

ADVISORY COMMITTEE TRAVEL

Mr. TRAXLER. Last year we discussed the increase requested for personnel costs and travel for the National Science Board, the Advisory Council and other advisory committees and consultants. The increase requested totalled over 130 percent in two years. I note the current 1980 estimate is lower than that requested last year. Still, the 1981 request is 39 percent higher than the 1979 actual cost. Why should this increase 39 percent in two years?

Dr. WILSON. There is continued oversight, particularly with some of the new programs. We use the external scientific community as consultants in the proposal review process as well as oversight.

NSF TRAVEL COSTS

Mr. TRAXLER. Your travel cost is $2,555,696 in 1979. The 1981 justification, on page I-8, indicates $3,145,000 for travel in 1981. That increase is 23 percent in two years.

There is a general effort on the part of the Administration to reduce travel costs. How can you feel justified and comfortable by increasing the travel budget by 23 percent?

Dr. WILSON. One reason is the increased cost of travel, in higher per diem and transportation. More and more of the cities where our program officers visit grantee institutions are becoming high-rate cities. It is required that the program officers pay the actual costs over $50 per day.

Dr. ATKINSON. In fiscal year 1980 there was an 8 percent reduction in actual expenditures from the budget request. We are starting fiscal year 1981 at a somewhat lower base than we would have had in fiscal year 1980 if our original request had been approved.

OFFICE SPACE RENTAL COSTS

Mr. TRAXLER. The table on page I-8, under the Office Space Rental, shows $3,280,508 in 1979, $3,360,000 in 1980 and $3,560,000 in 1981.

Why is the 1979 Office Space Rental cost $70,000 less than planned?

Mr. UBOIS. Those estimates are in response to interactions with the General Services Administration which acts as the landlord negotiating rental prices as best they can with the owners of the private buildings in which we are housed.

They submit to us what must be one of the ugliest acronyms in the Federal goverment, SLUC rates, standard level user charges. In English that means rental charges, and we just respond to the kinds of estimates that they provide for us. We find normally that in fact these estimates are very close to reality, as the budget year becomes the current year.

Mr. TRAXLER. Why does the increase for Office Space Rental go up $200,000 in 1981 but only $80,000 in 1980. Do you have new space?

Mr. UBOIS. No, as I said, the General Services Administration is in negotiations with the landlord. We are in private buildings leased to the Federal government, and we responded to negotiated rates agreed to between GSA and the private landlord.

Dr. Atkinson. We have no new space.

Dr. PIMENTEL. We have been advised by other Congressional committees that we should try to move the science education directorate into closer contact with the other basic research directorates. The science education directorate is housed on Wisconsin Avenue, and the odds are rental charges would be higher if we were able to find space. The higher rental would affect the fiscal year 1981 budget.

STAFFING FOR INSTRUMENTATION PROGRAM

Mr. TRAXLER. On page I-20, under Executive Management, is mention of a new program of instrumentation and research facilities. Tell us a little bit about this new program. What is to be accomplished that has not already been done; how many new positions are involved, and how much money?

Dr. PIMENTEL. We would assign three positions to that activity.

Mr. TRAXLER. And how much money would support that program?

Dr. ATKINSON. It is a $14.25 million program.

Mr. TRAXLER. How does this differ from the support for research facilities and equipment for which $126 million is requested in 1981.

Dr. PIMENTEL. Would you repeat that?

Mr. TRAXLER. How does this new program differ from the support for research facilities and equipment.

Dr. WILSON. That type of activity is spread around throughout all the programs, and those proposals are handled by the regular program officers. Most of the facilities and instrumentation are part of the regular research proposals.

NATIONAL MEDAL OF SCIENCE

Mr. TRAXLER. Also in the same paragraph is mentioned that the costs associated with the presentation of the National Medal of Science is increasing by $3,000 in 1981. Why should costs increase?

Mrs. BOGGS. Is it gold?

Dr. ATKINSON. The medal is gold.

Dr. WILSON. I am not sure whether it is just increased administrative and other costs or whether the committee is meeting twice. This is the selection committee that recommends the medal recipients.

Dr. ATKINSON. Let us supply that for the record.

[The information follows:]

INCREASED COST ASSOCIATED WITH THE PRESENTATION OF THE MEDAL OF SCIENCE

The $3,000 increase requested for FY 1981 will provide sufficient funds for the National Medal of Science Selection Committee to meet twice a year, if required,

two days each meeting. These funds cover the Committe member's travel and per diem expenses to and from Washington and while they are in Washington. The members are not otherwise compensated for their services.

The Committee provides advice and recommendations to the President in the selection of the Medal of Science recipients.

NSF OBLIGATION TRENDS—FISCAL YEARS 1977–1979

Mr. TRAXLER. Also, provide for the record a table for fiscal years 1977, 1978 and 1979, indicating—on a percentage basis—the obligations by month for each account.

Dr. WILSON. Yes.

[The information follows:]

NATIONAL SCIENCE FOUNDATION
PERCENTAGE OF MONTHLY OBLIGATION PATTERNS BY ACCOUNT
FY 1979 - FY 1978 - FY 1977

	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept
Research and Related Activities												
1979	6	4	4	9	10	11	7	9	12	7	14	7
1978	6	9	11	9	8	7	8	5	10	12	9	6
1977	4	6	7	11	7	11	7	9	7	11	15	5
Average Total %	5	7	7	10	8	10	7	8	10	10	12	6
Science Education Activities												
1979	*	*	1	3	3	2	15	5	28	5	15	22
1978	*	1	1	3	4	2	12	5	24	8	17	22
1977	*	*	1	*	4	6	11	14	11	18	24	11
Average Total %	*	1	1	2	4	3	13	8	22	9	18	19
Special Foreign Currency												
1979	28	*	*	*	34	8	8	3	*	*	8	11
1978	*	4	2	2	2	2	*	10	14	6	39	18
1977	2	5	22	7	12	*	12	10	10	7	7	5
Average Total %	9	3	8	3	15	3	6	8	9	5	19	12

* Less than 1%

OFFICE AUTOMATION

Mr. TRAXLER. Last year there was some discussion about this NSF's computer activities and employee productivity. A table was included in the record regarding annual computer costs. Can you bring us up to date on your computer activities, including increases in employee productivity?

Dr. ATKINSON. We are satisfied with that effort, and we will provide it for the record.

[The information follows:]

NSF EMPLOYEE PRODUCTIVITY IMPROVEMENT RESULTING FROM AUTOMATIC DATA PROCESSING

Until FY78 the Foundation's Automatic Data Processing (ADP) support consisted primarily of a Management Information System (MIS) which provided information to the staff in the areas of financial management, grants and contracts, proposal status, personnel statistics, and administrative functions. It was then decided to augment this MIS by the addition of a time-sharing facility for the Foundation staff which would provide them with the ability to utilize the MIS integrated data base in the on-line preparation of correspondence. This effort became known as Office Automation.

Office Automation involved the automated generation of letters to peer reviewers and enabled the Foundation to refine the peer review function considerably. In the past year the project has reached fruition and is now utilized in 90% of the Foundation's Divisions. It has provided the mechanism to increase the number of reviews for each proposal in an efficient and timely manner. In fact, in the past 18 months the average number of reviews has doubled. Daily productivity has increased from 30 to 75 proposal review initiations. Additionally, the flexibility of this automated effort has enabled program managers to reflect their individual styles in correspondence, and this personal touch has been a significant factor in the increased response rate from reviewers.

Independently conducted analyses indicate that Office Automation has been an invaluable asset to the Foundation's productivity. In a period of growth when our budget has developed steadily, and the requirements for a more comprehensive proposal tracking system have increased, our clerical staffing has remained stable because of our automated capabilities. The project continues to evolve. We are now looking at new methods of refinement and anticipate that by next year we will have achieved some major milestones in our effort to reduce the paperwork burden.

Employee productivity was also enhanced by major achievements in our Management Information System. We recently automated the generation of award letters (10,000 per year) and this has reduced the production process substantially. Improvements to our Financial Accounting System have resulted in a significant decrease in the time needed by accountants and accounting technicians in coding expenditures. In the past, they were required to provide detailed coded information; now they submit a minimal number of entries, and the balance of the information is generated by the system. Furthermore, improvements to proposal and award processing have enhanced productivity. For example, program officers formerly monitored each incrementally funded grant in order to ensure that progress reports were received in time to make a decision on further funding. Moreover, proposal information for these grants had to be entered into the data base when incremental funding was provided that year. Now the computer alerts the program officer to the need for renewal action, and automatically produces the proposal information forms and creates the appropriate records on the data base.

Although these developments indicate the general trend towards improved employee productivity, the Foundation does not have the means for assessing the increase in productivity quantitatively.

COMPUTER ACTIVITIES COST

Mr. TRAXLER. How much is the 1981 request for the Foundation's computer activities?

Mr. UBOIS. For data processing equipment we are requesting $830,000 in fiscal year 1981 in contrast to $965,000 for the current year, and $1,847,000 in actual cost in fiscal year 1979.

Mr. TRAXLER. How many personnel are assigned to your computer activities?

Mr. UBOIS. Something on the order of 50. There are about 70 in that total division, but not all of them devoted to data processing.

Dr. ATKINSON. We hired a new director for that division. We conducted a national search, and hired an extraordinarily competent individual.

Mr. TRAXLER. What is the future for the Foundation's computer activities? Will the computer budget soon be reduced to just operating costs or do you see a continuing acquisition of new hardware?

Dr. ATKINSON. We will continue to acquire new hardware, but the cost will be cheaper and cheaper.

Mr. TRAXLER. Update the table found in last year's hearings on annual computer costs for the record.

[The information follows:]

ANNUAL COMPUTER COSTS

FY 76 through FY 81
In Thousands

	FY 76			FY 77			FY 78		
	Requested	Actual	Difference	Requested	Actual	Difference	Requested	Actual	Difference
D.P. RENTALS	900.0	875.3	-24.7	950.0	616.0	-334.0	500.0	1,024.0	524.0
D.P. CONTRACTS									
. Operations & Maintenance	(285.0)	(356.9)	(71.9)	(400.0)	(633.1)	(233.1)	(300.0)	(383.0)	(83.0)
. Software Development	(0)	(0)	(0)	(0)	(0)	(0)	(170.0)	(234.0)	(64.0)
SUBTOTAL	285.0	356.9	71.9	400.0	633.1	233.1	470.0	617.0	147.0
D.P. EQUIPMENT									
. Computer Hardware	(0)	(1,093.5)	(1,093.5)	(0)	(661.9)	(661.9)	(300.0)	(414.7)	(114.7)
. Office Automation	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
SUBTOTAL	-0-	1,093.5	1,093.5	(0)	661.9	661.9	300.0	414.7	114.7
D.P. SUPPLIES	100.0	81.9	-18.1	100.0	121.9	21.9	100.0	96.7	-3.3
TOTAL	1,285.0	2,407.6	1,122.6	1,450.0	2,032.9	582.9	1,370.0	2,152.4	782.4

	FY 79			FY 80			FY 81
	Requested	Actual	Difference	Requested	Current Plan	Difference	Requested
D.P. RENTALS	1,200.0	1,422.4	222.4	1,260.0	1,075.0	-185.0	640.0
D.P. CONTRACTS							
. Operations & Maintenance	(410.0)	(620.7)	(210.7)	(688.0)	(875.0)	(187.0)	(875.0)
. Software Development	(290.0)	(550.0)	(260.0)	(912.0)	(880.8)	(-31.2)	(772.0)
SUBTOTAL	700.0	1,170.7	470.7	1,600.0	1,755.8	155.0	1,647.0
D.P. EQUIPMENT							
. Computer Hardware	(700.0)	(1,103.5)	(403.5)	(700.0)	(700.0)	(0)	(565.0)
. Office Automation	(300.0)	(743.9)	(443.9)	(700.0)	(265.0)	(-435.0)	(265.0)
SUBTOTAL	1,000.0	1,847.4	847.4	1,400.0	965.0	-435.0	830.0
D.P. SUPPLIES	110.0	110.0	(0)	120.0	110.0	-10.0	110.0
TOTAL	3,010.0	4,550.5	1,540.5	4,380.0	3,905.8	-474.2	3,227.0

Appropriation Language Change

Mr. Traxler. The NSF is requesting a number of changes to the appropriation language, some of which have been requested before and denied.

Let's discuss the new proposals. You are requesting language to lease one aircraft with an option to purchase.

What type of an aircraft are you referring to?

Dr. Pimentel. A research aircraft at NCAR, the National Center for Atmospheric Research.

Dr. Atkinson. It is to be used to replace one of two much older aircraft that are not capable of doing the job.

Mr. Traxler. Supply us with a fact sheet on the proposed new NCAR aircraft for the record.

[The information follows:]

60-770 O - 80 - 16

NATIONAL SCIENCE FOUNDATION

FACT SHEET
On The
Proposed New NCAR Aircraft

The National Center for Atmospheric Research (NCAR) is responsible for conducting research in the atmospheric sciences at NCAR and for providing facilities for atmospheric research to both the university community and to NCAR scientists. One of the facilities maintained to support research is the Research Aviation Facility (RAF). The current RAF fleet consists of 2 Queen Air planes, one Sabreliner for high altitude research, and one Electra, a long-range 4 engine aircraft.

In 1977 NCAR convened a small ad hoc group of scientists to review the current capabilities of the RAF and make recommendations for aircraft needs and requirements for research in the decade of the 1980's. The study involved about 70 active scientists from universities, several government laboratories, the private sector, and NCAR.

Their findings were that the existing fleet was inadequate to satisfy the requirements of the atmospheric sciences research community for the future in many areas where the atmosphere plays an important, and in some areas a crucial role, in our national goals and priorities.

The NCAR Queen Airs are too small to carry air motion instrumentation and particle measuring systems simultaneously. They are limited in the electrical power they can provide for instrument operation and are seriously inadequate in their operational capability. The Sabreliner is too fast for particle measurements and is restricted from flight in icing conditions. The Electra is too large and too expensive to operate on single-investigator type projects.

While the RAF fleet was satisfactory for the 1970's, new requirements for research in the 1980's and the availability of new aircraft with increasing capabilities led to the following recommendations:

1) that NCAR upgrade the capability of the Research Aviation Facility by phasing out one Queen Air and replacing it in FY 1980 with a medium weight, twin turboprop airplane with added instrumentation for measurements of cloud physics, cloud dynamics and gas/particle chemistry parameters.

2) that top priority be provided for the acquisition and development of the air motion and sensing systems and the basic data handling system for the new platform such that installation can begin as soon as the new platform is available.

The urgency for acquiring the new aircraft is dictated by several factors: the need for moving ahead on a broad front of atmospheric studies for which this plane will be a key observational component; the need to prepare for a series of experiments and studies of weather and mid-latitude cyclone-anti-cyclone sub-structures which is expected to occur during the 1980's; and the necessity to replace the oldest Queen Air because of age (15 years) and air frame hours (6700) about the time a new plane can be readied.

The specific programs for which the new aircraft is required are:

1) severe storms and mesoscale research such as the Cooperative Convective Precipitation Experiment (CCOPE) planned jointly with the Water and Power Resources Service of the Department of Interior, and the Severe Environmental Storms and Mesoscale Experiment (SESAME) for operation jointly with NOAA, NASA and other Federal agencies;

2) the low level boundary layer-oceanography program for investigating coastal upwelling and air-sea interactions;

3) the acid rain-air chemistry program for measuring and tracing chemical air pollutants with their potential effect on the atmosphere and ecology including the forests and lakes;

4) atmospheric turbulence research with its applications to aircraft structures and mixing of the atmosphere;

5) clouds physics research for its potential ultimate payoff in weather modification applications.

A comparison of the important performance capabilities for atmospheric research is provided in the attached table for the Queen Air vs a twin turboprop type aircraft.

The estimated cost of outright purchase of a twin engine turboprop aircraft possessing the characteristics described in the attached table is approximately $1.5M. Procurement of the same aircraft on a lease/purchase basis over a 5 year period is estimated at $2.3M. An additional $0.5M is required for instrumentation. The FY 1981 NSF budget request includes $0.4M to commence the procurement of this aircraft on a lease/purchase basis.

AIRCRAFT CHARACTERISTICS

	Queen Air (Old)	Twin Turboprop (New)
1) Range, nautical miles (full fuel load with IFR[1] reserve)		
1,000 feet altitude	750 nm	1030 nm
10,000 " "	900	1420
20,000 " "	950	1830
30,000 " "	-	2170
2) Altitude, maximum (feet)	25,000	35,000
3) Endurance (with IFR fuel reserve) hours at optimum altitude	5.7	8.8
4) Cabin volume (cubic feet)	184	305
5) Weights (pounds)		
Maximum for takeoff	8800	14,000
Empty	6200	8,250
Payload (instrumentation)	580	1,650
6) Cruise speed (knots TAS[2])	165	215
7) Electrical power available for research instrumentation (amperes at 28 volts)	240	600

The above comparison does not adequately demonstrate the superiority of the turboprop aircraft in critical areas of operation. For example:

a) With 95°F air temperature on the runway at Denver, a turboprop can take off with a full load of fuel, 3 crew members and 700 pounds of instrumentation and still have 450 feet per minute rate of climb on one engine. A Queen Air by comparison must offload 800 pounds of fuel to maintain a 150 ft/minute rate of climb (the minimum necessary for NCAR safety requirements) thus reducing range to 340 nm and endurance to 2.2 hours.

b) Performance in icing conditions (encountered often in certain types of atmospheric research) indicates even greater superiority for the turboprop with the Queen Air unable to carry out several missions last year over the Rocky Mountains because of inadequate performance at 12-16000 feet altitude in icing conditions.

Although the instrumentation payload for the new aircraft is greater by a factor of three and the range is almost double that of the Queen Air, the fuel consumption per hour is only about 1/3 greater. The reduction in maintenance costs is expected to almost compensate for the increased fuel consumption. Thus a considerable increase in useful work is expected at a slight increase in overall costs of operation.

1. IFR - instrument flight rules
2. TAS - true air speed

Official Reception and Representation Expenses

Mr. Traxler. Why do you want $5,000 for official reception and representation expenses in 1981 where the amount is only $2,500 in 1980.

Dr. Atkinson. No funds from that account will support anything for the NSF staff, including me. Whenever we have foreign visitors, we pay our share, but we have about 20 formal bilateral science agreements with other countries and visitors from all over the world. Frankly, the $5,000 really pinches; we are now in an embarrassing situation.

Dr. Averch, do you want to add anything?

Dr. Averch. We are treated very well when we go overseas, especially to China. When foreign visitors come here, we are unable to reciprocate on the same level. I do know that whenever we have foreign visitors, our own staff members dig into their own pockets to pay for lunches or dinners and many other costs associated with hosting those people.

Mr. Traxler. Last year the Committee did give you what you asked for, in fact you requested that the reception allowance be reduced.

Dr. Averch. Yes, but the rate of activity, especially with China, has gone way up.

Dr. Atkinson. We can provide for the record a list of the functions.

Mr. Traxler. No, spare us.

Mrs. Boggs. As a hostess, I would like to say I think it is a very minimal request.

Mr. Traxler. Advise us for the record how much was spent in 1979 for official receptions and representation expenses.

And how much have you spent in 1980 to date?

Dr. Atkinson. We will provide that for the record.

Mr. Traxler. Thank you.

[The information follows:]

National Science Foundation reception and representation fund expenditures

Fiscal year 1979 (including unused fiscal year 1978 limitation)	$3,514.80
Fiscal year 1980 limitation (to Mar. 19, 1980)	$1,342.72

Trends in Funding Science Education

Mr. Traxler. Turn to Science and Education. In 1981 you are requesting $85.7 million. That is an increase of $7.5 million above the current plan for 1980. There was a stimulating article in the New York Times on January 29th of this year concerning Science and Education. Dr. Zacharias, whom I am sure you are familiar with, has made some rather strong charges in the articles. He says and I quote "the scientists have retreated." In another quote he indicates that, "The Federal government is no source of educational reform; it's just a check-writing operation, and the NSF wants the big amounts for research and peanuts for education."

Frankly, when we look at the levels for science education over the past ten years—it would appear that the author's comment is fairly accurate. Clearly; science education has not kept pace with inflation—and clearly the Science Foundation has not felt that it

was necessary to have science education keep pace with inflation. Could we have your comments on Dr. Zacharias' remarks?

Dr. RUTHERFORD. There are several things happening. It does not have a great deal to do with inflation. At the end of the 1960s there was kind of a sense that developed that the job had been done, that the government had invested in a very interesting and imaginative way in helping the schools to create new kinds of curricula and course materials.

The rationale was the creation of science and engineers, and it appeared to many that that job had been accomplished, so that along with some political difficulties, it resulted in a rapid, over about a three or four year period, reduction of support from what the budget originally had been.

It, as a matter of fact, was cut in half and inflation made it less than that. The trouble was that when a budget gets down, as it did, to such a low point in the early part of the 1970s, it then became very difficult to increase it again because the public rationale didn't seem to be there.

The trouble is, in the 1950s and 1960s the case was wrongly put. It is not sufficient in our kind of society just to produce scientists and engineers. All people have to understand science and also we have to find ways to bring into the enterprise more minorities and others who have in the past been passed over.

So once funding was down there were problems to get it raised again, but the Foundation was then facing the fact that it began to have trouble getting research dollars. The concept, I think perhaps in Congress, perhaps in the Foundation was that those things were competitors for the same dollars.

It's always difficult for education to stand up against things that are more concrete like the need for research money, so there are lots of factors there.

The problem is that science education investment is really buying research, only buying it 20 to 25 years from now, and it has not been looked at like that, so the Foundation's problem and Congress' problem is not to believe that a new Department of Education is going to solve that problem, but to decide whether or not in fact it is important that people understand science and technology, and that women and minorities become involved and whether they think somebody else ought to do it.

Mr. TRAXLER. I will forgo my long speech about the importance of the relationship of the research scientist at the university level in the instruction of the teachers at lower levels—from elementary schools to a college level.

RESOURCE CENTERS

Dr. ATKINSON. Mr. Traxler, we have an excellent example in the resource centers in Atlanta and in New Mexico. University professors and scientists join with high school and grade school teachers in planning curricula, programs, and special activities designed to draw minority students into the sciences.

Dr. RUTHERFORD. Mr. Zacharias is correct in the sense that the scientists are back in the laboratories, not working with school people trying to improve education, but that is not primarily the

fault of the scientist. Where he is wrong is when he refers to the Foundation as a money-pumping exercise. The Science Education Program has very few dollars and is doing very imaginative things with it.

As to the middle school children, we are now investing about 15 percent of our funds at this level. We are doing some first-rate research and beginning to reach the teachers again, but it's the case that the total resources available for such a huge job are far too small.

Dr. ATKINSON. When I recruited Dr. Rutherford for the Foundation, I told him the science education budget would be $120 million. That was the plan put forth by the National Science Board. Three years later, we are still a long way from that $120 million.

Mr. TRAXLER. You request it and OMB denies it?

Dr. ATKINSON. You can see our ZBB effort and the priorities, the cuts in science education have tended to be deeper than elsewhere.

Mr. TRAXLER. Mrs. Boggs?

Mrs. BOGGS. One of the new thrusts is the involvement of business and industry into the programs, and also I notice that you have an outreach program for small businesses.

WOMEN AND MINORITIES IN SCIENCE

So often you will read stories such as I did last weekend about the greater New Orleans metropolitan area where the women were not really trained for the computer sciences, and the various types of scientific training programs that could be opened up to them. They were, therefore, more or less pushed into job categories that were traditionally of female job categories, and were having a very difficult time breaking out of this type of syndrome.

I do think this is something we all have to think about. We have a great initiative this year if it goes through.

I attended the first of the demonstration projects in the President's Rural Initiatives last week in Shreveport, Louisiana, where there are large Federal projects. We are going to try to involve all areas of government along with business, industry, and labor in order to have some of the spin-off benefits from these big projects impact upon the adjacent communities.

I really think if we can present science education with all of its practical applications of productivity and a better quality of life for the people who are affected particularly bringing women and minorities in the main stream, then we will be better able to justify the need for science education to the Congress and to the people.

Dr. ATKINSON. I see the President's study of science and engineering education—the one due July 1—as important to this effort.

Dr. RUTHERFORD. Here is a sense of the dimension of the problem. For fiscal year 1981 we are asking $86 million. A decade before that the science education budget was $86 million. A decade before that it was $84 million. It went up in between and came back down again, so it had a decade when it was up. But $86 million today cannot be compared to 20 years ago. We have the same dollar figure but the job is much larger.

Twenty years ago we just thought we had to find some bright people and make them scientists. Now we know we have to think

more broadly; to reach girls and others underrepresented in science for example.

Mrs. BOGGS. The study of mathematics is no longer required, for instance. I sit on the President's Council of a private university, and I know the difficulties we had with our engineering department. It had gone down so badly that we were faced with having to take speedy action in order to maintain accreditation.

I was very interested in the comment of a young woman involved in a study of the curriculum among the colleges and universities who insisted that mathematics be a major part of the curriculum.

She said everyone should know how to competently feed computers as well as to analyze what they say. Even people who never expect to have any experience with computers need to know about them, just so that they won't be concerned about them. I hope that we can provide more money for science education.

I commend you for your steps in the right direction.

SCIENCE EDUCATION BUDGET

Mr. TRAXLER. You indicated that you had proposed a $120 million science education budget three years ago.

Dr. ATKINSON. That was the Board's recommendation; I don't think we ever got to OMB with that number.

Mr. TRAXLER. What percent would that have been of your 1978 budget?

Dr. ATKINSON. It would have represented 14 percent of the Foundation's budget.

Mr. TRAXLER. How does science education break out in terms of your budget percentage for 1981?

Dr. ATKINSON. Science education would represent 7 percent of the fiscal year 1981 budget.

TEACHER STATISTICS

Mr. TRAXLER. How many science teachers do we have at the middle school level and the high school level?

Dr. RUTHERFORD. I couldn't give you exact figures now, but I can supply them for the record.

[The information follows:]

Statistics on teachers in kindergarten through grade 12

	Numbers of teachers
Grade levels:	
Teachers grades kindergarten to 4	623,200
Teachers grades 5–8	521,500
Teachers grades 9 to 12	1,021,000

NOTE.—Estimates as of 1978.

TURNOVER RATE FOR SCIENCE TEACHERS

Mr. TRAXLER. What is the average career life time for a science teacher?

Dr. RUTHERFORD. It is lengthening. It used to be somewhere around 7 or 8 years, but since the last decade what has been happening is that there have been lay-offs of teachers in the cities

and the younger teachers have moved out of the profession all together and the older teachers have stayed in.

But during the 1960s and part of the 1970s there used to be alternative jobs for science and mathematics teachers, so the turnover was rather rapid.

Mr. TRAXLER. How many inexperienced science teachers do we have coming into our school systems each year?

Dr. RUTHERFORD. In the elementary grades it isn't clear what a science teacher is and whether you include the social science teachers or not. It is probably down to something like a few thousand a year. I could get some data on that for you. It's fairly static, because the schools of education and universities have trimmed back on their programs.

It's very difficult to attract good people into teaching careers in science and mathematics these days.

Dr. PIMENTEL. The problem is not so much numbers but the quality of the readiness to teach science at this junior high school level.

Dr. RUTHERFORD. It's the problem of attracting people into the profession where they see they are not getting support, no laboratories, no equipment, salaries are not that good, so that is the situation.

Mr. YOUNG. It is not just a simple case of new hires. Frequently individuals are transferred from other teaching positions not closely associated with science and mathematics because of the tenure system in many large school systems.

Dr. RUTHERFORD. On a national basis, however, there are a large number of jobs available for science and mathematics teachers at the high school and junior high school level on the books, but they are not being turned out in large numbers, and if they are turned out and are quite good, they are attracted to industry very often.

SCIENCE TEACHER INSTRUCTION

Mr. TRAXLER. On page J-I-18, you state that 12,500 teachers received instruction—what does that mean?

Is that an hour of lecture on a topic in science—or is it something aimed at improving both their teaching skills and subject knowledge?

Dr. RUTHERFORD. These are in the sciences. In some cases it might be a topic like energy that would include physics.

MINORITIES, WOMEN AND PHYSICALLY HANDICAPPED

Mr. TRAXLER. On page J-I-12, we see that the minorities, women, and physically handicapped element is slated for an increase of 61 percent. Is the NSF's entire effort aimed at providing special opportunities for a few exceptional pre-college students to study or conduct research at universities?

Dr. RUTHERFORD. The large increase of about $1 million is for a new program for minority students. It is part of a larger effort involving several agencies to identify bright young minority kids to work with scientists during the summer.

Mr. TRAXLER. What have you done to ensure that these students actually learn some science as opposed to running errands and doing other menial tasks?

Dr. RUTHERFORD. We have had quite a bit of experience in making such arrangements at the Foundation. We have been doing it for over two decades. It's a matter of identifying those scientists at the universities who really care about young people being scientists.

Then one follows up and sees what happens by interviewing the kids. Each university is in charge of seeing that that happens.

Dr. PIMENTEL. There is follow-up.

Dr. RUTHERFORD. The experimental part next summer will be to see if younger kids can be involved in laboratory work. That is something other than a cleaning job.

USE OF CALCULATORS BY STUDENTS

Mr. TRAXLER. On page J-III-3, under the Science, Education, Development and Research Subactivity, there is a statement that a recent five State team of investigators has studied the impact of calculator use by 1,500 elementary students. Apparently, this study suggests that there are no detrimental effects of using calculators. Are you in agreement with the findings in this study?

Dr. RUTHERFORD. Yes, I do. As a matter of fact, I think they have positive effects, if properly used.

The concern is the youngsters will not be able to do the basic functions. The research reveals they learn basic arithmetic very well, and in the hands of a good teacher they learn mathematics.

Mr. TRAXLER. How can a child in elementary school who relies on a calculator ever learn how to add, substract, multiply and divide or do fractions?

Dr. RUTHERFORD. They can, and the added benefit is they can do 20 times as many problems in a given period of time with a hand-held calculator.

Mr. TRAXLER. If his battery goes dead can he add manually?

Dr. RUTHERFORD. No; he gets another one.

Dr. ATKINSON. No one will learn to do a square root again.

DECLINE IN STUDENT'S MATH ABILITY

Mr. TRAXLER. Your next comment involves—improving math problem solving, there is a statement that is somewhat puzzling. You indicate that there is considerable evidence that basic skills in mathematics among Americans have steadily improved over the past thirty years. It was my understanding that all of the scores on tests across the country over the past ten years have shown a significant decline in a student's ability to do math—or for that matter to read—or write—or spell—or whatever. What about that?

Dr. RUTHERFORD. The decline has only been in recent years. Starting in the 1950s and especially in the 1960s there was a very dramatic increase in the SAT scores well above those of the 1940s. In spite of the decline, the average scores are still better than they used to be in the 1940s.

Some of the people who are complaining were themselves educated in the 1940s where the scores were lower. We tend to forget that.

Furthermore, we have now many more youngsters going through school than before. So you have an effect of testing on larger numbers of students and you have a reduction through that.

You have Spanish students in large numbers taking examinations that often are not in bilingual form. That depresses the scores.

There is some real decline. There is a worrisome decline in the last few years in a large number of test scores in a variety of subjects, but it seems not to be among our best students. Their scores seem to be as good as ever.

BUDGET ADJUSTMENTS

Mr. TRAXLER. On page J-IV-4, you indicate that the NSF Authorization Act for 1980 earmarked an amount for "Ethics and Values in the Science and Technology Program," which was in excess of the budget request. You also indicate that since additional funds over the budget request were not appropriated, adjustments were made to be responsive to Congressional intent. Apparently an additional $400,000 was allocated to this program.

Is that reallocation of the $400,000 in accord with the appropriation language which is carried in the appropriation bill?

Dr. RUTHERFORD. Yes, sir; that is to say we used a proportional concept to make such adjustments.

SCIENCE MUSEUMS

Mr. TRAXLER. I notice on page J-IV-7, you are proposing the largest single increase in the directorate for public understanding of science. You are asking for $5 million in 1981, an increase of $1.1 million above the current level and $3.9 million in 1980. The legend on that page indicates that the increase will "permit greatly increased support for the activities of science museums."

We discussed this some last year. Is this truly an area that we should be putting additional funds in?

Dr. RUTHERFORD. I believe so.

Mr. TRAXLER. Shouldn't the National Endowment for the Arts support the bulk of this?

Dr. ATKINSON. A clear policy has been enunciated by the White House in conjunction with the various agencies: the science museums are to be funded through NSF, and the art museums are to be funded through the Endowment.

Mr. BOLAND. I couldn't agree more.

Dr. RUTHERFORD. Our funding is not for maintenance or staff but for the development of new ways of presenting materials to improve the important educational function of museums. So our input is substantive as opposed to management.

Dr. ATKINSON. That is why the Institute of Museum Services has a somewhat difficult role. It supports some science museums, in addition to the art and history museums because the funding is for operating expenses—not new exhibits, or new activities.

ZBB BUDGET

Mr. BOLAND. How does this additional funding rank on your ZZB exercise?

Dr. RUTHERFORD. I should add that in some ways that is difficult because the programs serve a variety of purposes, that is to say, very often our purposes cut across programs so our funding at the early adolescence level, for example, we consider to be the leading item on our agenda, still there is no program by that name.

It is imbedded in a variety of other programs so when we trim back it may be we trim out of a variety of programs rather than cutting that whole.

Mr. BOLAND. All out of this one directorate?

Dr. RUTHERFORD. Yes; so just listing programs does not give an accurate picture of our priorities.

Mr. BOLAND. How can we prioritize these programs?

Dr. RUTHERFORD. We will list them for you but I note it's a little more complex.

[The information follows:]

ASSISTANT DIRECTOR -- SCIENCE EDUCATION

DECISION UNIT OVERVIEW AND DECISION PACKAGE DOCUMENT -- FY 1981 ZBB

LEVEL	SCIENTIFIC PERSONNEL IMPROVEMENT	SCIENCE EDUCATION RESOURCES IMPROVEMENT	SCIENCE EDUCATION DEVELOPMENT AND RESEARCH	SCIENCE AND SOCIETY	TOTAL
MINIMUM LEVEL	$ 31.3	$ 28.1	$ 13.6	$ 7.0	$ 80.0
INCREMENTAL 1	$ 0.9	$ 0.0	$ 1.1	$ 0.0	$ 2.0
	$ 32.2	$ 28.1	$ 14.7	$ 7.0	$ 82.0
INCREMENTAL 2	$ 1.5	$ 0.2	$ 0.3	$ 0.4	$ 2.4
	$ 33.7	$ 28.3	$ 15.0	$ 7.4	$ 84.4
INCREMENTAL 3	$ 1.2	$ 0.2	$ 1.5	$ 0.0	$ 2.9
	$ 34.9	$ 28.5	$ 16.5	$ 7.4	$ 87.3
INCREMENTAL 4	$ 1.0	$ 0.5	$ 0.0	$ 1.0	$ 2.5
	$ 35.9	$ 29.0	$ 16.5	$ 8.4	$ 89.8
PRESIDENT'S TARGET	$ 0.8	$ 0.2	$ 1.0	$ 0.4	$ 2.4
	$ 36.7	$ 29.2	$ 17.5	$ 8.8	$ 92.2
INCREMENTAL 6	$ 0.0	$ 0.0	$ 1.5	$ 1.0	$ 2.5
	$ 36.7	$ 29.2	$ 19.0	$ 9.8	$ 94.7
INCREMENTAL 7	$ 1.7	$ 0.3	$ 1.0	$ 0.0	$ 3.0
	$ 38.4	$ 29.5	$ 20.0	$ 9.8	$ 97.7
NSF REQUEST	$ 0.0	$ 0.8	$ 0.0	$ 0.6	$ 1.4
	$ 38.4	$ 30.3	$ 20.0	$ 10.4	$ 99.1

SCIENCE EDUCATION OVERVIEW--FY 1981 PROGRAM--KEY FEATURES

At the Minimum:

The FY 1981 minimum plan is restricted overall to the FY 1979 level; a reduction of 5.5% below the current (FY 1980) appropriation of $84.7M. To achieve this, the following significant actions must be taken:

- In Scientific Personnel Improvement (SPI) the plan to provide much needed fellowship and traineeship stipend increases is suspended and the pre-college teacher upgrading activities are reduced 21% below the current plan for FY 1980.
- In Science Education Resources Improvement (SERI) the Instructional Scientific Equipment Program is reduced 14% below its FY 1979-80 level.
- The Science Education Development and Research (SEDR) subactivity suffers an overall 10.5% reduction below the current plan, which affects both research into learning of science and the development of new methods and materials for teaching science and mathematics.
- In the Science and Society subactivity the Science for Citizens program is held to its FY 1979 level--a 19% reduction below the current plan.

The impact of these reductions affects graduate students training to provide our Nation with a high quality scientific workforce and the quality of education in our Nation's schools because of reductions in numbers of teachers being exposed to retraining in subject matter and techniques of instruction in science and mathematics. The reductions will also cause a loss of slowly building momentum in those research and development activities so essential to the vitality of the teaching enterprise, and retrenchment in areas where gains have recently been achieved in improving the interface between the scientist and society where the scientist's knowledge and expertise are of such inestimable value in the understandings basic to the policy decisions of today. The losses suffered by the Science Education programs are further magnified if one considers the effects of inflation.

Of the 14 different program elements which comprise the 18 separate activities in the Science Education Decision Unit, only one, Minorities, Women and the Physically Handicapped, is funded at the Minimum Level in an amount higher than the current plan for FY 1980. Of the 18, 12 are either equal to or below their FY 1979 levels; again, not considering the effects of inflation.

Recent Congressional action requires that the Foundation evaluate the Resource Centers for Science and Engineering Program to determine how well the Centers concept is working. This evaluation is in progress and will be completed in December 1979. In order to maintain the present level of emphasis on funding for minority-related science education activities the Science Education Resources Improvement plan includes $2.8M in the Resource Centers for Science and Engineering line. The eventual utilization of these funds will be for targeted minority programs; the specific distribution of these funds by program mechanism will depend upon the outcome of the current evaluation of the Centers concept.

At the President's Target

The major increase dollarwise occurs in the Scientific Personnel Improvement subactivity, $5.4M or a 17.3% increase over the Minimum Level. This permits the Foundation to continue the three-phase plan begun in FY 1979 to increase fellowship and traineeship stipends. It also permits an increase in talent identification and special training for high school students (a $0.7M or 30% increase), increases funds for special research-training projects for undergraduate students to their FY 1979 levels, and provides a modest increase of funds for minority, women and handicapped activities. Two other important increases occur which combat obsolescence in the science teaching force: 1) much-needed, highly-focussed, short-term training opportunities particularly designed for undergraduate faculty in the sciences, mathematics and engineering are increased $1.0M or 33%, and 2) a build-up in the middle-school thrust of the Pre-College Teacher Development activity ($2.6M or 37%), a major concern of this Directorate initiated in FY 1979.

The next largest increase dollarwise ($3.9M or 28.7%) occurs in the Science Education Development and Research subactivity where major emphasis will be given to science education in early adolescence, including support of scientists conducting research on and experimentation with the application of new technologies to science instruction for this age group. This will include a special inter-agency effort to utilize the currently more readily available and lower cost computer for improving instruction in basic math skills. A particular concern at this level will be to assist the user community to learn about and adopt or adapt the results of research in science education to solve their own instructional problems.

The Science and Society subactivity receives the third largest dollar increase ($1.8M) which is the second largest proportionally (25.7%). The Public Understanding of Science Program receives an increase of 25 percent, or $1.0M, which is devoted primarily to support for science museums as a part of the Foundation's concern for improving the informal or out-of-classroom learning environment. These efforts will be particularly addressed to adolescents, minorities and other groups lacking access to adequate information about science and how it affects our lives. Smaller increments will restore the Ethics and Values in Science and Technology and Science for Citizens activities to about their planned FY 1980 levels.

The smallest increase occurs in the Science Education Resources Improvement subactivity. Here, about two-thirds of the $1.1M (3.9%) increase will be devoted to the two small-grants Undergraduate Instructional Improvement programs, Instructional Scientific Equipment and Local Course Improvement, which focus on the efforts of individual science faculty members or small groups of faculty to upgrade and update specific course offerings in 2-year and 4-year colleges and the undergraduate divisions of universities. A modest but important increase of $0.4M in the Information Dissemination for Science Education Program assists teachers, supervisors, curriculum specialists, and other school decision-makers to learn about new, tested instructional materials and techniques and research results which make the instructional task more effective and efficient. Other programs aimed at broader, institution-wide improvement in science offerings remain at their FY 1980 levels or below.

Thus, at the President's Target level, as at the Minimum, the focus is on individuals: improving training opportunities for students and teachers; assisting individual faculty members to improve their course offerings; longer term investment in teams of scientists and science educators in their efforts to learn more about the science learning process and what types of instructional materials and techniques improve it; and provision of better learning experiences for those whose knowledge and understanding of science is derived from such informal sources as museums and the mass media.

At the NSF Request

The NSF Request provides an overall increase of $6.9M (7.5%) over the level of the President's Target. The priorities as stated above generally pertain to this level as well. The emphasis is on combatting obsolescence among those who teach science -- in both how they teach and in what they teach. Both the research and development activities in science education are increased to provide a broader base of up-to-date and scientifically accurate knowledge, instructional techniques, and materials from which to attack problems in education in mathematics and the sciences. Particular emphasis is placed on early adolescence, that critically important stage in one's scholarly development. At this level there is also an increased emphasis on public understanding of science through science museum outreach activities and the coverage of science news in the mass media, and on Public Service Science Centers and other mechanisms to improve citizen participation in the resolution of science-related policy issues.

Objectives (at the President's Target:)

- Encourage and further the basic understanding of science by all citizens through both formal and informal learning by improving the materials used in the learning of science and the methods by which science knowledge is transmitted.

- Improve the subject-matter competence of the teachers of science in schools and colleges with emphasis on the middle grades and on faculty from 2-year and 4-year colleges and the undergraduate components of universities.

- Attract, encourage and motivate minorities, women, the physically handicapped, and persons from low income families to study science in order to improve their scientific literacy and to prepare themselves to undertake careers in scientific research and education, with particular emphasis being placed on improvement of science education in the junior high school grades, because most students--especially minorities and girls--opt out of further study of science beyond this age.

- Assist the research community to develop a strong, cohesive program of basic research into how science and mathematics are learned and how they can be most effectively and efficiently taught (including the application of technology to the learning process) with particular attention being given to learning during the early adolescent years.

- Encourage the design and development of tested instructional materials in science and methods of presentation with particular reference to courses for use in the junior high school grades.

- Broaden efforts aimed at obtaining a higher level of science literacy among our citizens and the access of the citizenry to scientific knowledge and expertise as it impacts their dealing with public issues, including ethical considerations in science and technology.

- Assure a stable flow of the nation's most talented students--including minorities who are underrepresented in the scientific labor force--into graduate level training for science and technology-related careers.

- Identify and encourage talented students of science and develop specialized science learning opportunities of immediate relevance to their interests and to the needs of society.

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- Encourage comprehensive improvements in the science education capabilities of undergraduate institutions as well as to assist institutions in meeting more sharply-focused needs of a smaller scale for the improvement of local courses, including provision of equipment for the improvement of laboratory courses and other instructional demonstrations in science education.

- Improve the flow of minorities into careers in science through the encouragement of predominantly minority institutions to update and strengthen the quality of their science curricula and encourage institutions in minority and low income areas to develop local and regional outreach programs and other activities to encourage, motivate and otherwise assist them to prepare themselves to join the science and technology-related workforce.

Dr. ATKINSON. There is a debate in the science museum community; its leaders are upset because they feel NSF is not supporting the museums at a level comparable to the support provided by the Endowments for the art and history museums. It is a problem that must be resolved.

SCIENCE TV PROGRAM—"3-2-1 CONTACT"

Mr. BOLAND. Just one last question or maybe two. You indicated in the hearing yesterday that the small increase in Science Education for 1981 will probably be a victim of the budget reduction exercise. Will that be your decision or will OMB or the White House make the cut?

Dr. ATKINSON. The decision will be made by OMB. The cuts will be by general level of activity—basic research, applied reseach and science education—and we will not be able to move funds across those categories.

Mr. BOLAND. Is this the program area in which you are funding "3-2-1 Contact," a major new children's television series about science?

Dr. RUTHERFORD. Yes.

Mr. BOLAND. What do you estimate for 1981?

Dr. RUTHERFORD. It is about $1.5 million.

Mr. BOLAND. What amount does the United Technologies Corporation contribute to this program?

Dr. RUTHERFORD. They put in about $2 million.

Mr. BOLAND. How long will the program run?

Dr. RUTHERFORD. It will run through this school term.

Mr. BOLAND. What has the reaction been to the TV series?

Dr. RUTHERFORD. Really better than we anticipated. It looks like about 2½ million children are watching it already. It has had the fastest growth of any program, even Sesame Street at the beginning, and it's already approaching in volume that program.

The feedback from teachers already indicates that they are making a very wide use of it in the schools.

Mr. BOLAND. What has the reaction been to the Friday wrap-up session? As I understand it, the series runs Monday through Friday and there is an evaluation of the program on the last day.

Dr. RUTHERFORD. That is correct.

Mr. BOLAND. I would think that this would be an excellent tool to test the success of the program.

Dr. RUTHERFORD. I haven't seen the studies yet but that is one of the things that is being looked at. My guess is that is the day the teachers choose preferentially to show the program in the school.

Mr. BOLAND. I want to commend the Foundation for their sponsorship of this program. Also the United Technologies Corporation for the part it plays in the development of "3-2-1 Contact." I have seen the program and feel that this will play an important role in the development of the scientists of the future.

Dr. ATKINSON. Mrs. Boggs said something today I hadn't thought about. We have been pressing industry-university cooperation throughout all our programs. This is an example. Maybe we can do more along this line.

U.S.–U.S.S.R. COOPERATIVE RESEARCH PROGRAM

Mr. BOLAND. Let me ask you a question about the U.S.-U.S.S.R. Cooperative Agreement. When Dr. Press was before the Committee I asked, "Do you know whether funds for fiscal year 1980 are still being obligated under that agreement?"

The response was: "I think essentially the rate of expenditure on that has dropped to a halt because of the policy I have described."

Then I went on and asked about a specific program, $600,000 for computer applications in management. I asked: "Are we still obligating funds under that agreement for this particular technology?

The response was: "I would be surprised if any money is being spent in this area at this time because of the deferral of the program."

Dr. ATKINSON. These hearings help to clarify some of these programs. We will be in touch with Dr. Press' office to learn what he had in mind.

Mr. BOLAND. After you discuss the details with Dr. Press, there won't be any chance to obligate additional money at this time.

Dr. ATKINSON. We have obligated only about $120,000 of the $3.2 million.

Mr. BOLAND. But that leaves $3 million left unobligated.

Dr. ATKINSON. That is right. As I said, we will talk with staff on the details.

Dr. AVERCH. I was in communication with OSTP. They are taking a case-by-case look at the various programs in the U.S.-U.S.S.R. cooperative science program. Some will be stopped and some are of such benefit to the United States that the OSTP feels it doesn't want them stopped. The OSTP staff cited the example of magnetohydrodynamics in the Energy Department. This is a case where Soviet research is ahead and we apparently want to continue. But we have a good deal of latitude at the moment because only $120,000 has actually been obligated.

CONCLUSION

Mr. BOLAND. Mrs. Boggs?

Mrs. BOGGS. I don't have any questions, thank you.

Dr. ATKINSON. Mr. Boland, one of the problems is in the deep sea drilling program. We expected a $2.5 million contribution for this year and last year from the U.S.S.R. We may not get that contribution given the recent events.

Mr. BOLAND. I guess you can take book on that.

Mr. Sabo?

Mr. SABO. No questions.

Mr. BOLAND. We have come to the end of a very pleasant couple of days. It is always a pleasure to have you here.

I want to express my appreciation to Dr. Atkinson and the Assistant Directors here for the responses to the difficult questions that have been propounded over the last few days.

It is a pleasure to deal with the Foundation.

This Subcommittee doesn't always give what it desires. I think those in the Foundation realize that. This is a difficult year for those of us who serve in the Congress, a difficult year for the

Administration, for the Foundation, and all the agencies of government.

Having that in mind, we will be looking at this budget closely and make an effort to come up with funding which keeps this Foundation at its high level and in helping it to assist in the objectives and the mission the Foundation has which is a terrifically important one for this Nation in every aspect.

So we are delighted to have you, and we will be open to suggestions when some of the budget review comes up.

Thank you all very much. The National Science Foundation's justifications will be inserted in the record at this point. The Committee stands adjourned.

[The justification follows:]

THE NATIONAL SCIENCE FOUNDATION'S FY 1981 BUDGET DOCUEMENT

FOR THE READER: The NSF Budget Document is subdivided into four parts:

- Budget in Brief
- Summary and Analysis Tables
- Budget Activity Justifications
- Grants and Contracts Awarded Data (Tab A)

I. BUDGET IN BRIEF

This section includes the Director's Statement which reviews the highlights of developments, advances, and achievements in science, and in the Foundation's activities in particular, during the 1970's, and outlines some of the challenges and opportunities for science, today and in the years ahead. It provides a view of the NSF FY 1981 budget in that context.

The Budget in Brief also provides a complete overview of the NSF Budget. It focuses on goals, objectives, rationale for the program balance, increases and decreases, and summary data.

II. SUMMARY AND ANALYSIS TABLES

The Summary and Analysis Tables section includes the NSF appropriation language and provides a complete summary of appropriation and obligation levels, and selected quantitative data.

III. BUDGET ACTIVITIY JUSTIFICATIONS

The budget activity justification section provides detailed explanations of the budget request. The gray tabs in the budget document identify the 11 major budget activities; e.g., Mathematical and Physical Sciences; Astronomical, Atmospheric, Earth, and Ocean Sciences; Science Education; etc. The 11 activities are subdivided into 34 subactivities (white tabs), and these, in turn, are further subdivided into program elements and subelements. For example, the Chemistry subactivity includes several program elements; Structural Chemistry and Thermodynamics, Quantum Chemistry, etc.

The budget is designed so that general summary information is included at the beginning of each budget activity. More detailed information on subactivities, program elements, and program subelements follows each of the budget activity summaries.

IV. GRANTS AND CONTRACTS AWARDED IN FISCAL YEAR 1979 (Tab A)

This section includes data on the number and dollar amount of awards made to institutions in the various states and territories of the U.S. and foreign countries. It provides the latest actual data available for a complete fiscal year.

NATIONAL SCIENCE FOUNDATION

RESEARCH AND RELATED ACTIVITIES
SCIENCE EDUCATION ACTIVITIES AND
SPECIAL FOREIGN CURRENCY PROGRAM
FISCAL YEAR 1981

CONTENTS

NATIONAL SCIENCE FOUNDATION

Director's Statement

We enter this decade with a keen awareness that science has a vital role to play in the years ahead. Our nation's future is closely tied to the strength of our scientific enterprise. In such essential areas as food for the world's growing population, new sources of fuel to replace dwindling oil reserves, the fight against disease, and the assurance of adequate national security, we are profoundly dependent on the new knowledge and technologies that grow out of scientific research. Beyond these fundamental concerns, science must provide the technological development necessary to maintain our economy in the face of increasing competition from abroad and must show us how to protect the life-giving balance of the planet.

The past 10 years have been a time of extraordinary activity in science, with the pace of discovery being described as "explosive" in many fields. In the macro laboratory of outer space, startling discoveries that add to the clues about the origin of the universe have been made. At the micro level, our understanding of the basic building blocks of atomic and molecular structure has advanced rapidly with the aid of new sophisticated tools such as lasers, synchrotron radiation sources, and high-speed computers.

Our grasp of the geophysical history and dynamics of our planet has undergone the greatest revolution since Copernicus with the theory of plate tectonics and its confirmation in the ocean cores of the Deep Sea Drilling Project. This, in turn, has enhanced our understanding of the dynamics of earthquakes and climate, as well as of the formation and location of fossil fuel and mineral deposits on land and under the sea. The deciphering, just ten years ago, of the genetic code for DNA and RNA has led to a ferment of activity in cell biology and immunology. This same decade has witnessed a remarkable expansion in the computer sciences, as pure mathematical theories have been combined with the silicon chip to advance the solid state technology of high-speed computers. Whole new fields of science have emerged, while the boundaries separating others have begun to disappear. Research cutting across disciplinary lines has increased, a reliable sign of vitality in science, and there has been a convergence of the sciences of living and non-living matter.

New basic knowledge today often has quite immediate implications for society. Our understanding of the genetic code has great significance for agriculture and medicine, is making possible previously unimagined industrial technologies, and may even create new energy sources. Private industry is already engaged in the production of synthetic insulin and interferon, using recombinant DNA techniques, and similar techniques are being applied to the study of nitrogen fixation in plants. New knowledge of the earth's crust not only has laid the basis for further work in the continental margins, of great scientific importance, but also has direct and immediate application to the search for oil. Research on the chemistry of the upper atmosphere has made us aware of potential long-term changes in the ozone shield that can have significant consequences

for our health and, ultimately, for life on Earth. With advances in computer and materials sciences, we are now able to install a complete microcomputer on a single chip, a fraction of the size of a thumbnail, while the cost of a chip has remained almost constant. Still further dramatic advances lie ahead with immediate relevance to our productivity and international trade. For example, organic compounds have been prepared with electrical conductivities approaching that of copper.

This drawing together of basic and applied research is not merely fortuitous—rather, it reflects the increasing role of science and technology in all aspects of our daily life and the growing urgency of national problems containing significant scientific components. In any event, it cannot be said that scientific knowledge today consists of dusty reports lying forgotten on a library shelf—too many people are eagerly awaiting the latest developments in fundamental knowledge.

These developments in the seventies have been possible because of the Nation's investment in basic science and in the training of scientists over the past 35 years. An important result of that investment has been the availablility to scientists of a remarkable array of instruments, from laboratory spectrometers to radio and infrared telescopes, from picosecond time measurements to remote sensing satellites, from lasers to synchrotron radiation facilities, from ever-smaller to ever-faster, more powerful computers. On both the macro and micro levels, this instrumentation has given scientists access to new realms of the universe. The seventies have shown us how important this access is to advances in scientific theory and application.

Just as science has been changing dramatically, so has the society in which science operates. The growing complexity and interdependence of our cultural institutions have placed new demands on science and new responsibilities on government. No longer can we say, as was said 100 years ago in the *Washington Post* editorial of January 1, 1880, that "We can count up on the fingers of one hand all misfortunes of national magnitude. Beyond the yellow fever at Memphis and the outbreak among the Indians there has been nothing serious." As science has increased the options for dealing with challenging problems, society has responded by actively reaching for new knowledge, rather than waiting passively for the private sector to develop and use it. The challenge today is to further an active partnership of government, the universities, and industry in supporting research. NSF and the Administration expect to play leading roles.

Thirty-five years ago the Vannevar Bush report, *Science—The Endless Frontier*, laid the groundwork for the post-war cooperation between science and government. It is striking to be reminded again how it foresaw the needs of today. Its stress on the role of science as one member of a team, at the same time recognizing that "without scientific progress no amount of achievement in other directions can insure our health, prosperity, and security as a nation in the modern world," is as valid today as it was when it was written. Its call for the Nation to explore the frontiers of science is as imperative today as ever.

Finally, there have been important developments in the National Science Foundation during the 1970's, and the fiscal year 1981 budget builds on these developments. Despite record inflation in recent years, there has been real growth in the Foundation's

research budget during the 1970's, although this has, unfortunately, been offset in many areas by a decline in basic research support by other Federal agencies. NSF support has played a major role in the dramatic developments mentioned earlier. During the seventies, the search for fundamental knowledge was singled out by each Administration as being increasingly important to the Nation. Most recently, the President's Science and Technology Message of 1979 noted that "most of the great undertakings we face today as a nation have a scientific or technological component."

NSF's applied research effort was formally initiated at the beginning of the decade, building on the Foundation's extensive programs in the physical, biological, and behavioral sciences, and engineering. This marked the beginning of NSF support for applied research in universities and nonprofit organizations and also in industry when the research addressed critical national problems. The new effort stressed interdisciplinary research and cooperation among different types of organizations—university, industry, and State and local government. The inclusion of engineering in a recently-created Engineering and Applied Science Directorate is intended to stimulate still further interaction between basic and applied programs and among different types of research performers, the value of which has proved so important to the vitality of our scientific enterprise.

Other developments of the seventies included increased Foundation support for the social sciences and a recognition that this area of science is coming of age. Congressional amendments to the NSF Act in 1968 made explicit the Foundation's mandate to support the social sciences. Today, NSF is the only agency of the Federal Government with the mission to support basic research in the social sciences and carries almost the entire responsibility for Federal support for this field. The importance of this support is amply demonstrated, for example, by the work of Nobel laureates in economics who have received NSF grants.

A significant growth in international cooperation in science also marked the decade just ended. Bilateral scientific and technical agreements were signed with many countries. The increased exchange of scientific and technical information laid the groundwork for many other types of exchange and communication. The most recent agreement with the People's Republic of China contributed to improved relations with that country. The National Science Foundation has been responsible for implementing over twenty of these agreements on behalf of the U.S. Government.

Science has always been international in nature, as basic knowledge transcends national boundaries. A growing number of larger cooperative undertakings with other nations occurred in the seventies, many of them managed by NSF. This increase in large international undertakings has been due, in part, to the global nature of many scientific efforts, such as studies of the world's oceans and atmosphere, and in part to new developments in instrumentation which enable us to study these phenomena. The International Biological Program, the International Decade of Ocean Exploration, the Deep Sea Drilling Project, and the Global Atmospheric Research Program are some of the significant larger-scale undertakings of the seventies by NSF. In the 1970's, NSF also assumed full responsibility for managing the U.S. Antarctic program, which encompasses a broad range of scientific research in the physical and biological sciences

and involves cooperation with other signatory nations of the Antarctic Treaty. At home, NSF's management of the construction of the Very Large Array radio astronomy facility, initiated in the seventies, extended capabilities for ground-based astronomy. The Foundation continues as lead agency for ground-based astronomy that it supports at several national centers and observatories.

During this decade, as school enrollments declined and the need to implement real growth in the Nation's fundamental research assumed higher priority, funding of NSF science education programs declined relative to the overall budget. Increased attention was directed at research in science education to improve its effectiveness, and, at education for non-scientists, to increase the public's understanding of science. There has been a particular focus on the junior high school level, since this is where general scientific literacy can be increased and where important choices occur on the road to science careers. Special attention has also been given to increasing the participation of women and minorities in science to reduce the significant loss of talent to the Nation from their underrepresentation in science careers. The link between research and teaching in science and the effectiveness of NSF's science education programs over the years played an important part in the decision to transfer only a small portion of the Foundation's education programs to the new Department of Education.

The NSF budget request of $1,148 million for fiscal year 1981 builds on our extensive experience of supporting scientific research and science education in a variety of organizations over the past 30 years. The specific emphases in the 1981 budget reflect many months of deliberation and exchange of views and recommendations on the part of the National Science Board, the Foundation staff, advisory committees, the Office of Science and Technology Policy, and the Office of Management and Budget. Planning for this budget began in earnest almost 20 months ago, at the June 1978 meeting of the National Science Board, and the balancing of priorities has continued down to the last possible moment. Concerns for the Nation's future and for the taxpayer's dollar have weighed heavily in these decisions.

While NSF is not among the largest R&D agencies, the NSF Act places upon it the key responsibility for strengthening the scientific enterprise, nationwide; for fostering the highest calibre of scientists and engineers; and for encouraging the application of science to national concerns. The 1981 budget has been developed with this in mind.

Richard C. Atkinson

Richard C. Atkinson
Director

January 28, 1980

National Science Foundation

Washington, D.C. 20550

FY 1981

Budget in Brief

to the Congress

NEW OBLIGATIONAL AUTHORITY:	
FY 1981 Budget Request	$1,148,000,000
FY 1980 Appropriation (P.L. 96-103)	996,250,000
Proposed Supplemental[1]	840,000
Less Transfer to Department of Education	-6,584,000
FY 1980 New Obligational Authority	990,506,000
Increase in New Obligational Authority FY 1981/FY 1980	157,494,000
PROGRAM LEVEL:	
FY 1981	$1,148,000,000
FY 1980:	
Prior Year Carryover[2]	3,343,893
Proposed Pay Supplemental	840,000
FY 1980 Appropriations	996,250,000
Transfer to Department of Education	-6,584,000
FY 1980 Program Level	993,849,893
Increase in Program Level FY 1981/FY 1980	154,150,107

[1] Provides for increased pay costs of Antarctic logistics support.

[2] Includes $2.5M PD&M carryover earmarked for October 1979 pay raise per House Appropriation Subcommittee guidance.

ABOUT THE NATIONAL SCIENCE FOUNDATION—

The National Science Foundation is the principal Federal agency for the support of basic research across all fields of science and science education at universities and colleges. NSF accounts for about 34 percent of all Federal support for basic research going to academic institutions. In some fields, NSF provides the dominant share of Federal basic research support: more than 69 percent in ground-based astronomy, 60 percent in environmental sciences and over 50 percent in mathematics and engineering.

More than 2,000 colleges, universities, industrial firms, and other institutions and organizations participate in NSF programs. Additionally, over 200 small business firms are involved in NSF supported research, mostly in applied research areas.

NSF is an independent Federal agency. It accomplishes its mission primarily through grants and contracts. It operates no in-house laboratories.

The Foundation was established as an outgrowth of President Franklin D. Roosevelt's desire for a science agency that could contribute to a peacetime economy by enhancing U.S. scientific strength. In 1944, President Roosevelt instructed Dr. Vannevar Bush, then Director of the Office of Scientific Research and Development, to find a way for the Nation to benefit from science in peacetime as it had in wartime and to assure U.S. scientific strength for reasons of national prosperity and security.

Dr. Bush's report, *Science, the Endless Frontier*, led to the establishment of the National Science Foundation. President Harry S Truman signed the NSF Act in 1950. NSF's mission under the Act is to strengthen U.S. science and engineering through the support of basic research and science education programs.

In 1968, the NSF Act was amended to give the agency additional authority to support applied research and to clarify and strengthen the Foundation's responsibilities in science education, international cooperative science, and science policy. NSF is responsible for strengthening science education at all educational levels.

NSF determines the quality of research and science education projects through a system of peer review. More than 30,000 scientists, engineers, and science educators in all parts of the United States participate in the NSF peer review process each year. They provide a yardstick for excellence, giving their views and evaluations of proposed projects. NSF staff members who are experts in science, engineering, or science education make the final decision on awards.

Through contracts with universities or university consortia, NSF supports several national research centers. These include the National Center for Atmospheric Research, Boulder, Colorado; Kitt Peak National Observatory, Tucson, Arizona; Cerro Tololo Inter-American Observatory, Chile; National Radio Astronomy Observatory, Green Bank, West Virginia, Kitt Peak, Arizona, and Socorro, New Mexico; the Sacramento Peak Observatory, Sunspot, New Mexico; and the National Astronomy and Ionosphere Center, Arecibo, Puerto Rico. Major facilities also include the National Scientific Balloon Facility, Palestine, Texas; Cornell Electron Storage Ring and the Submicron Research Facility at Cornell University; and the National Magnet Laboratory at the Massachusetts Institute of Technology, among others.

NSF, by law, consists of the Director and the National Science Board. The National Science Board is the NSF policymaking body and has 25 members, including the Director as an *ex officio* member. The Director and Board members are appointed by the President and confirmed by the Senate for 6-year terms. The terms of the Board members are arranged so that the terms of one-third of the members expire every two years.

The present Chairman of the National Science Board is Dr. Norman Hackerman, President of Rice University. The NSF Director is Dr. Richard C. Atkinson.

The Foundation has about 1,274 employees. The Director, Deputy Director, and four Assistant Directors are appointed by the President and confirmed by the Senate. Three other Assistant Directors are appointed by the NSF Director. More than 30 percent of the NSF staff are experts in the various fields of science, engineering, and science education. About five percent of the staff are scientists serving as "rotators" from academic and other nongovernmental institutions. These rotators work for the Foundation for 1 or 2 years and then return to their home institutions. They help provide a continuous influx of up-to-date information and fresh viewpoints on the needs and opportunities for science and science education.

NSF Responsibilities

- Strengthen basic research in the mathematical, physical, environmental, engineering, biological, social and other sciences.
- Initiate and support applied research at academic and nonprofit institutions and at profit-making and other appropriate organizations.
- Strengthen science education programs at all levels.
- Stimulate international scientific cooperation between U.S. and foreign scientists.
- Increase U.S. research potential through cooperative industry/university research.
- Assist in providing the Nation with highly trained scientists and engineers through a program of fellowships for science and engineering.
- Gather and publish scientific and technical data pertinent to national science policy decisionmaking.
- Manage and fund the U.S. Antarctic Program.
- Recommend and encourage the pursuit of national policies for the promotion of basic research and education in the sciences.

NATIONAL SCIENCE FOUNDATION
FY 1981 BUDGET IN BRIEF

CONTENTS

NATIONAL SCIENCE FOUNDATION
TOTAL DOLLAR SUMMARY
FY 1979 - FY 1981

(Millions of Dollars)

Source	FY 1979 Actual	FY 1980 Budget Request to Congress	FY 1980 Plan Based on Actual Legislation	FY 1981 Budget Request to Congress	Difference FY 1981 Request/ FY 1980 Plan
New Obligational Authority	911.0	1,006.0	[1]990.5	1,148.0	157.5
Carryover	15.9	—0—	[2]3.3	—0—	-3.3
Total	926.9	1,006.0	993.8	1,148.0	154.2

[1]Includes proposed supplemental of $840,000 for increased pay costs of Navy personnel engaged in the U.S. Antarctic Program and excludes $6,584,000 transferred to Department of Education.
[2]Includes $2.5 million carryover earmarked for October 1979 pay raise.

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NATIONAL SCIENCE FOUNDATION
BUDGET SUMMARY

(Millions of Dollars)

Budget Activity	FY 1979 Actual	FY 1980			FY 1981	Differences	
		FY 1980 Program Funded by Congress	Prior Year Funds Carried Over	FY 1980 Current Plan	New Obligational Authority	New Obligational Authority FY 1981/80	Total Program FY 1981/80
Research and Related Activities Appropriation:							
Mathematical and Physical Sciences	$208.9	$226.2	$.2	$226.4	$264.2	$38.0	$37.8
Astronomical, Atmospheric, Earth, and Ocean Sciences	211.6	217.9	—0—	217.9	241.3	23.4	23.4
U.S. Antarctic Program	51.1	55.8	—0—	55.8	63.4	7.6	7.6
Ocean Drilling Programs	11.6	19.5	—0—	19.5	27.3	7.8	7.8
Biological, Behavioral, and Social Sciences	154.7	166.5	—0—	166.5	182.0	15.5	15.5
Engineering and Applied Science	109.9	111.6	.2	111.8	137.0	25.4	25.2
Scientific, Technological, and International Affairs	23.6	26.1	—0—	26.1	28.8	2.7	2.7
Cross Directorate Programs	16.8	25.1	.4	25.5	52.0	26.9	26.5
Program Development and Mangement	54.7	58.1	2.5	60.6	60.8	2.7	.2
Subtotal	$842.9	$906.8	$3.3	$910.1	$1,056.8	$150.0	$146.7
Science Education Activities Appropriation:							
Scientific Personnel Improvement	$33.1	$31.6	—0—	$31.6	$35.2	$3.6	$3.6
Science Education Resources Improvement	28.6	24.0	—0—	24.0	24.2	.2	.2
Science Education Development and Research	12.0	14.9	—0—	14.9	17.5	2.6	2.6
Science and Society	6.3	7.7	—0—	7.7	8.8	1.1	1.1
Subtotal	$80.0	$78.2	—0—	$78.2	$85.7	$7.5	$7.5
Special Foreign Currency Appropriaton	$4.0	$5.5	—0—	$5.5	$5.5	—0—	—0—
Total, NSF	$926.9	$990.5	$3.3	[1]$993.8	$1,148.0	$157.5	$154.2

[1]Includes proposed supplemental of $840,000 for increased pay costs of Navy personnel engaged in the U.S. Antarctic Program and excludes $6,584,000 transferred to the Department of Education.

FY 1981 BUDGET OVERVIEW

Amount Requested

The National Science Foundation's FY 1981 budget request is $1,148 million. The request includes $1,056.8 million for Research and Related Activities, $85.7 million for Science Education, and $5.5 million for Special Foreign Currency. The FY 1981 request is $154.15 million or 15.5 percent above the FY 1980 Current Plan of $993.85 million. The overall increase in basic research is 16.9 percent, which takes into account the U.S. Antarctic Research Program and a major initiative in ocean drilling on the continental margins. This budget allows for real growth in the level of effort of most NSF supported activities and is a fiscally sound response to science needs and opportunities.

Research and Related Activities

Research Perspectives

The National Science Foundation supports research in all areas of science and engineering. The bulk of the Foundation's basic research support is provided through individual research project grants in the Mathematical and Physical Sciences; Biological, Behavioral, and Social Sciences; Astronomical, Atmospheric, Earth, and Ocean Sciences; and the Engineering and Integrated Basic Research Programs in the Engineering and Applied Sciences activity. Together, basic research support in these areas increases from $647.2 million to $737.4 million or 13.9 percent.

Basic research remains the essential cornerstone of U.S. science and its support is the prime mission of NSF. Basic Research is the critical building block for new knowledge. For example, fundamental understanding in materials research, electrical and mechanical engineering, neural biology and processes taking place at the submicron level may combine to create an integrated state of knowledge that can lead to benefits for the handicapped through more sophisticated computerized prosthetic devices. Increasingly, advances in science are interdependent. A breakthrough in a seemingly esoteric area of mathematics or physics can trigger new avenues of research in other areas such as chemistry, biology, and astronomy, and the reverse of this phenomenon is also true.

In FY 1981 the Foundation's basic research effort is designed to keep supporting science at a pace that will continue to give the U.S. a scientific edge among the nations of the world. It involves a new dimension in experimental computer research, accelerated research in mathematics and chemistry, strong support for research on microstructures, and expanded efforts in the neurosciences and on ecosystems and other areas of environmental research. The program also provides for the first major step leading to the construction of new 25-meter diameter millimeter wave telescope for astronomy research.

Overall, basic research in the physical sciences and engineering is setting the pace for the NSF program in FY 1981. Basic research is of extreme importance in providing the fundamental knowledge in mathematics, astronomy, physics and other science areas to strengthen and extend the base of scientific knowledge necessary for future progress. In such areas as computer science, chemistry, and materials research, it also holds promise for advances that can lead to practical applications.

NSF-supported basic research is conducted primarily through universities and other research institutions in every State and through various international cooperative science programs on all continents of the world. Several national research centers supported by NSF are available to outstanding visiting scientists on a competitive basis and provide these scientists with access to some of the Nation's most advanced instruments and facilities.

NSF also provides support for applied research in selected areas where there is good potential for the research results to contribute over the long term to improved technology and productivity, both essential in our national efforts to deal with inflation and to provide more and better jobs for U.S. workers. A significant part of NSF applied research deals with fundamental research aimed at expanding our understanding of phenomena and processes. Consequently, NSF applied research is a step removed from specific field applications, demonstration, and development which are the appropriate responsibility of mission agencies and industry.

Other Budget Highlights

In addition to the increases in various areas of basic research described above, the following special thrusts and emphases deserve particular consideration.

Industry/University Cooperative Research—A special challenge for the U.S. is to utilize fully the research capabilities of industry and universities in activities that can lead to a strengthened, more vigorous U.S. research effort. International competition and the practice of other industrialized nations that combine the resources of industry, universities, and the government in concerted R&D efforts in certain markets have created new challenges for America. This competition demands more cooperative efforts among industry, universities, and government to increase U.S. productivity and improve services. The NSF, in FY 1981, in response to a Presidential directive, is increasing its industry/university cooperative research efforts markedly. These efforts are designed to stimulate the research programs of both industry and universities. They will also help provide appropriate incentives to ensure that there are improved opportunities for university and industry research laboratories to keep American science at the cutting edge of progress, thus giving our industries a technical edge in worldwide competition.

Small Business Research Efforts—NSF is also moving aggressively to strengthen research directed at increasing the opportunities for small businesses to make greater

contributions to the national research effort in FY 1981. The Foundation's program has been augmented by $10 million for this purpose, bringing the total amount for small business participation, primarily in applied research efforts, to approximately $13 million.

Technology Centers—There are a variety of areas which require advances in science and engineering to enhance our technological capabilities. Corrosion prevention and control, high impulse welding and joining, non-destructive testing and various other so called "generic" technologies require further advances to improve substantially our present technology capabilities. In many of these generic areas advances depend on sophisticated understanding of materials, surface corrosion, and heat transfer. The Foundation will establish one or more generic technology centers in FY 1981 as part of a larger Federal effort designed to enhance technology in basic science and engineering. The centers will be jointly funded by industry and government, and substantial public benefits are expected.

Improving University Research Laboratories—The FY 1981 program request includes $14.25 million to upgrade university research laboratories. Many of these laboratories have outdated facilities which limit the research techniques or instrumentation which can be used. This frequently results in less than optimal return on the investment of Federal dollars for support of research. The FY 1981 budget request represents a begining to alleviate this situation. This is planned to be a matching grant program where Federal funds will be matched with an equal amount of non-Federal funds from academic institutions.

Interagency Cooperation and Science Policy—In recent years, the Foundation has substantially expanded its efforts to improve the effectiveness of cooperation with other Federal agencies. This has been accomplished through a variety of mechanisms, including formal and informal interagency coordinating committees and panels. Perhaps the most effective mechanism is the continual, day by day consultation among program officers in the various agencies. There is also a vastly expanded effort to extend cooperation in the field of science education, with a view toward aiding in the establishment of the new Department of Science Education.

NSF also provides important science policy analyses and science manpower studies that are beneficial to the entire scientific community and to various government agencies, the Congress, and the President's Science Adviser.

International Science Activities—Many NSF science activities are international in scope, and international cooperation through science has become increasingly important in the past decade. In FY 1981, the Foundation will establish a promising cooperative research effort with the People's Republic of China. NSF also hopes to increase its cooperative work with the advanced countries of Western Europe. Our experience in the Antarctic for the past 24 years has demonstrated that science can maintain an effective means of interchange and friendly communication even in times of

severe political stress among nations. NSF hopes to continue to conduct a wide range of research support activities that involve the cooperation of many nations in all parts of the world and will continue its effort to enhance U.S. science for the benefit of all peoples.

Ocean Margin Drilling—The FY 1981 budget request includes $10 million, to be matched by the U.S. petroleum industry, to embark on a 10-year Ocean Margin Drilling Program. The scientific results from this program are expected to be as revolutionary in scope as those from the NSF funded Ocean Sediment Coring Program. Further light will be shed on continental drift and the history of the continental margins. Significant new drilling capabilities under the ocean should result from this project. It should also provide knowledge of the geologic framework for passive margins, specifically the U.S. Atlantic margin that contains potential petroleum reserves.

The likely drilling platform is the U.S. Government owned ship, the *Glomar Explorer*. In FY 1981 engineering design and cost estimates for conversion of the *Glomar Explorer* and the advanced deep ocean drilling system, as well as scientific planning, will take place. Results of these efforts will provide the basis for the final "go, no go" decision on the whole project as a joint venture between government and industry.

Science Education—Two NSF Science Education programs, the Minority Institutions Science Improvement program and the Elementary School Science Teacher Training program, are being transferred to the newly established Department of Education. NSF remains a key factor in efforts to strengthen science education at all academic levels. In FY 1981, the Foundation will continue to concentrate efforts at the junior high school level.Experience has shown that large numbers of students, especially minorities and women, drop out of science courses at this level. NSF is determined to tap this potential resource so that minority and women students can have greater opportunities for careers in science and engineering. In addition, the Foundation will continue a range of science education activities designed to stimulate improvements at the graduate and undergraduate level by giving students an opportunity to develop and pursue research and to participate in productive science projects. The Foundation also plans to strengthen its research effort to improve the techniques of science education to make science study more interesting and rewarding.

Special Foreign Currency—NSF has, for several years, undertaken a number of cooperative science programs with nations where the U.S. has local currencies on deposit in amounts declared to be excess to U.S. Government needs by the U.S. Treasury Department. This program has produced beneficial cooperative research efforts with Egypt, India, and Pakistan, and a number of other countries that have given U.S. scientists opportunities for cooperative research otherwise unavailable to them. Excess foreign currencies have also been used effectively in the translation of foreign science journals, text books, and other publications. The use of these excess currencies causes no dollar

drain on the U.S. and provides an opportunity for U.S. science to benefit from the use of currencies generated by the sale of U.S. agriculture commodities overseas.

Cross-Directorate Programs—There are several programs of importance to the support of science by the Foundation that do not fit easily into the existing structure of the Foundation. Typically, these programs cut across disciplinary boundaries. To give visibility to these programs and to define more clearly their purposes and explain their need, NSF has combined these programs in FY 1981 into a new program budget activity entitled Cross-Directorate Programs. These include a variety of activities such as the Industry/University Cooperative Research Program, the 2- and 4-Year College Instrumentation Program, the Experimental Program to Stimulate Competitive Research, Research Initiation in Minority Institutions, and the University Research Facilities Improvement Program. These programs generally require special management and review techniques tailored to particular objectives and requirements. By grouping these programs in the Cross-Directorate Program activity, it is expected that the needs and objectives will be clarified to aid the Congress in its consideration of the NSF budget.

Essential Role of Engineering—A widely recognized problem is the lag between basic research and practical application. NSF is uniquely organized to facilitate this movement from concept toward application. It was recognized from the Foundation's beginning that basic research in engineering as well as the sciences is an essential feature of a totally integrated research effort. In recent years it was further recognized that NSF has a role to play in certain applied research and research applications efforts designed to move research results into application in selected areas of national importance. In FY 1980 the Foundation reorganized to combine its engineering and science applications activities into a single directorate.

Engineering retains its basic research characteristics but is now more closely allied with the applications and applied research activities of NSF to improve the flow of basic research results from concept to use.

Frequently, progress in engineering lies in the acquisition of new knowledge from various science disciplines, especially materials research, chemistry and computer science. The Foundation has taken action to strengthen greatly its engineering and applied research areas in FY 1981 as part of a broader agency effort to expand research in fields that have a high potential for contributing to the eventual solution of problems confronting society in such areas as transportation, energy, environment, new and improved technology, and food and nutrition.

SOME MAJOR RESEARCH QUESTIONS ADDRESSED BY NSF SUPPORTED RESEARCHERS

Basic Research

- Can a model be found to predict laser-induced chemical reactions?
- Can a unified theory be found which describes the strong nuclear force, the electromagnetic force, and the weak force as three related aspects of a single force of nature? Can all the forces in nature be described by a single unified theory?
- What are the taxonomic and biological characteristics of organisms in the endangered tropical forests?
- How can the unprecedented complexity and capacity of Very Large Scale Integrated (VLSI) electronics be controlled and utilized to devise new computer concepts, systems, and applications?
- Is gravitational radiation produced by natural astronomical sources? What are its properties? How can it be detected in the laboratory?
- How can certain chemical bonds, such as between carbon-hydrogen or carbon-carbon, be made more reactive at ordinary temperatures and pressures?
- How do internal interfaces, such as grain boundaries, and micro chemical segregation to interfaces affect the mechanical and physical properties of crystalline solids?
- What are the detailed atomic and molecular structures of amorphous (glassy) solids and how does structure affect the magnetic, electronic, and mechanical behavior, and resistance to chemical attack?
- How do plants and animals interact with the atmosphere to (a) control atmospheric carbon dioxide and (b) respond to acid rain?
- What are the detailed reactions going on deep within the Sun? How are these related to cycles of solar activity? Is the Sun cooling down? What can we learn about the interior of the Sun from studies of its surface conditons?
- Do the Sun's variations affect the magnetosphere, ionosphere, upper atmosphere and, finally, terestrial climate and weather?
- By what mechanisms do brain circuits control body temperature, blood pressure, and heart rate?
- What are the factors that control the formulation, organization and decay of convective severe storms?
- What is the geologic structure of passive oceanic margins (such as the U S. east coast)? Is the geologic picture consistent with the accumulation of petroleum?

- How are earthquakes, volcanic activity and formation of mountain ranges related to plate tectonic processes at active oceanic margins such as western Central and South America?
- What are the geological and geochemical processes that modify sedimentary material to form hydrocarbon and mineral resources?
- What role do the polar regions play in global weather and climate?
- How can "gene-splicing" techniques be used to better understand gene function resulting in improved crop production?
- What are the key relationships between the structure and dynamics of antarctic water masses and the biological processes leading to high productivity?

Science Education

- What learning processes are involved in understanding scientific and mathematical concepts at various educational levels?
- What are the most effective mechanisms for increasing participation of minorities, women, and the handicapped in scientific careers?
- What techniques and approaches can be employed to provide scientific and technical expertise to citizens to increase their ability to make wise choices on technical public policy issues?
- What new instructional materials, educational practices, and research findings are essential for improving science education, especially for the early adolescent?
- How can we most effectively apply technology to the teaching and learning of mathematics and science?
- How can we increase our understanding of the relationship between learning processes and the nature and structure of scientific and mathematical knowledge?

Engineering and Applied Science

- How can techniques of microfabrication be improved and what kinds of new microstructures can be made with these improved techniques?
- What opportunities are there for the use of man-made microstructures such as sensors, transducers, information, processing systems, and microprosthetic systems?
- How can understanding of physical interactions on catalytic surfaces lead to the design of more efficient catalysts for industrial processes, including synthetic fuel production?
- How can the strength of fiber reinforced structural materials, including that of concrete, be improved?

- How can recent developments in computer technology best be applied to automated manufacturing processes, with particular reference to robotics?
- How do national fiscal, monetary and regulatory policies affect the costs and management of programs by State and local governments?
- What new processes and technologies can be developed for improving the efficiency of separation of minerals from low grade ore bodies and the handling of the resulting processing wastes?
- How can the design of structures, dams, and other vital facilities provide effective earthquake protection at acceptable cost, and what are the social factors involved in mitigating earthquake hazards and disasters?

Scientific, Technological, and International Affairs

- What are the economic effects of tax policy on R&D and technological innovation? Of government R&D funding? Of regulations?
- How adequate are the estimates of risks associated with different technologies?
- What is the impact of rising costs on the Nation's R&D activities?
- What are the abilities and limitations of people transferring information to and from physical subsystems such as computer terminals?
- What relationships exist between information and the structure of language?
- How can R&D be better utilized to assist lesser developed countries in pursuing their domestic, social, and economic policy objectives?

SNAPSHOTS OF ITEMS IN THE FY 1981 NSF BUDGET

Mathematical and Physical Sciences

- Research project support in Mathematics, Physics, Chemistry, and Materials ($174.7 million)—Includes increased funding to allow for more adequate project support levels.
- Experimental computer research ($3.7 million)—Provides support for enhancing the experimental computer research capability at universities, including modern computing systems, together with associated development, maintenance, and operating costs.
- Research related to microstructures in Chemistry, Materials Research, and Computer Research ($9.0 million)—Funding for this research increases by $2.0 million above the FY 1980 level of $7.0 million.
- Cornell Electron Storage Ring (CESR) ($7.4 million)—Provides for operations and research costs for the newly converted positron—electron colliding beam facility.
- Research instrumentation and equipment ($42.4 million)—Includes more adequate instrumentation and equipment for research projects, special equipment programs, university laboratories, and major user facilities.
- Materials Research Laboratories ($22.2 million)—Strengthens interdisciplinary research in key areas, permits some upgrading of experimental facilities, and provides more viable support at the smaller laboratories.

Astronomical, Atmospheric, Earth and Ocean Sciences

- Very Large Array (VLA) for Radio Astronomy ($5.2 million)—$4.5 million decrease resulting from completion of funding for VLA fabrication in FY 1980 is partly offset by a $1,850,000 increase in the first year of full VLA operations.
- New 25 meter diameter, millimeter wave telescope ($1.7 million)—This provides support for detailed design and specifications. This action carries with it a commitment to go ahead with the construction of the telescope during FY 1982—FY 1984 at a total cost in current dollars estimated to be approximately $27.0 million.
- Climate Research ($6 million)—Continuation of Climate Dynamics research.
- Coordinated Research and Exploration ($23,600,000). Succeeds the International Decade of Ocean Exploration which ends in FY 1980.
- Earthquake Research ($1.2 million)—Continuation of basic earth sciences research related to the occurrence, location and severity of earthquakes.
- Coastal Research Ships ($3.6 million)—Construction of one 130-140 ft. ship.

- Instrumentation and Equipment ($26.7 million)—Includes $6.6 million for major equipment, including the research ship; and $20.1 million for other research equipment for use on research projects and at national centers.

U.S. Antarctic Program

- Repairs to Aircraft ($2 million)—Includes repairs to a crash-damaged LC-130 aircraft and for modifications to extend the present service life of an older LC-130 aircraft.

Ocean Drilling Programs

- Ocean Margin Drilling Project ($10 million)—These funds together with matching funds from the petroleum industry will take the project up to the point of modifications to the U.S. owned research ship, the *Glomar Explorer*, drilling system procurement, and drilling site selection. This initial effort will provide a basis for the final go, no-go decision for the project as a joint venture between industry and in the government.

Biological, Behavioral and Social Sciences

- Genetic Biology ($10.3 million)—Research support for studies of genetics of plants, gene-splicing in plants and animals, and the transmission and regulation of hereditary material.
- Research Instrumentation ($16.1 million)—This total is included generally as a part of research grants and provides for enhancement of the accessibility and sharing of improved equipment for researchers in the biological, behavioral and social sciences.
- Neurosciences ($17.0 million)—Research support for studies focused on understanding the action, mechanisms and functions of nerve cells and sensory receptors.
- Cognitive Science ($5.6 million)—Research support for studies on the mental representation of knowledge, the development of cognitive capacities, and the acquisition of language, human learning and thought.
- Anthropology ($7.6 million)—Research support for studies centering on tracing the course of human evolution over several million years and to examine the effects of nutritional and demographic factors on societal evolution.
- Ecosystems ($13.0 million)—Support for research addressing critical problems involving ecosystems management such as global carbon dioxide and acid rain.
- Economics, Geography, and Political Science ($15.8 million)—Support of research studies to expand the scientific understanding of the processes underlying the performance of the economy.

Engineering and Applied Science

- Computer Engineering ($2.2 million)—Research efforts in computer vision and applications, as well as robotics, related to productivity enhancement in the U.S.

- Microstructures Engineering ($4.7 million)—Supports the Submicron Resource Facility at Cornell University and provides for resarch on ionbeam-based microfabrication techniques and composite materials systems for electronic devices.
- Earthquake Hazards Mitigation ($19.4 million)—Research on the effectiveness of regulations to achieve given levels of earthquake protection and on the impact of earthquake warning and prediction measures on the socioeconomic environment of the community.
- State Science, Engineering, and Technology ($3.0 million)—Supports efforts designed to build the capacity of states to assess and use scientific and technical information in the public policy development process.
- Small Business Innovation ($13.0 million)—Provides an opportunity and an incentive for small science and technology-based firms to undertake high risk research in connection with research programs that also could have significant benefit to the industrial economy.
- Industrial Technology ($5.2 million)—Supports research on experimental incentives designed to increase the commitment of U.S. industry to research and development and to provide long-term bridges between industry and universities in selected generic technologies.

Scientific, Technological and International Affairs

- West Europe Program ($1.8 million)—Expansion of cooperative research thrust in Western Europe where scientific and technical capabilities in some fields rival or surpass those in the U.S. and where U.S. scientists can most benefit from cooperation.
- Science in Developing Countries ($1.1 million)—Support of research and teaching that relate the application of science and engineering to problems of development in Asia, Africa, Latin American, and the Caribbean.
- Technology Assessment and Risk Analysis ($1.4 million)—Expansion of the risk analysis function to improve methods for evaluating long-term comparative risks and benefits of alternative technologies.
- International Economic Policy ($750,000)—A new focused research and analysis program on issues of international economic policy affecting domestic economic progress and the conduct of foreign relations.
- Postcensal Survey of U.S. Scientists and Engineers ($500,000)—Continued design and planning of a key survey of scientists and engineers to be identified in the 1980 Decennial Census.
- Information Technology ($400,000)—A new program to assess emerging information systems and to design more effective instrumentation for information science research in areas not supported within the private sector.

Cross-Directorate Programs

- Industry/University Cooperative Research ($20.0 million). Strengthens research ties between two major components of the Nation's scientific and technological systems. Research is focused on fundamental scientific or engineering issues of a basic or applied nature.
- Instrumentation and Facilities ($20.25 million). Provides increased support for instrumentation and facilities for 2-year and 4-year colleges; for universities with outmoded graduate-level facilities; and for improving geographic distribution of specialized instrumentation across the Nation.
- U.S./China Cooperation in Basic Sciences ($2.0 million). Provides for cooperation with Chinese scientists in a broad research program in the basic biological, social, mathematical, and physical sciences.
- Decision and Management Sciences ($1.0 million). Increases the scientific base and knowledge leading to the improvement of organizational decisions, management, and operations of public and private enterprises.

Science Education

- Science Education for The Early Adolescent ($14.0 million)—Focuses continued effort at a point of high opportunity—the junior high/middle school years. We need to know more about why many of this age group—particularly minorities and girls—choose not to study science and mathematics beyond this age and thus preclude themselves from possible preparation for future science and technology-related careers.
- Research in Science Education ($6.5 million)—Supports studies to gain knowledge needed to identify and develop the processes by which science is learned and to understand the motivational factors involved in pursuing science as a career. The motivational aspects of learning in the current decade are expected to play an important role in the development of the cadre of scientists of the future.
- Public Understanding of Science ($5.0 million)—Supports efforts to improve the understanding of science by all citizens and to make information available to nonspecialists in order to increase their basic understanding of science and its contribution to the quality of life. The ability of science and technology to contribute to the national welfare depends not only on the inventiveness and technical competence of its practitioners but also on the degree to which its results are understood by citizens and can be assimilated into our social structures and institutions.
- College Science Teaching ($4.0 million)—Provides for subject-matter revitalization of college science teaching. The quality and currentness of college science teaching have been declining as a result of a series of events, among which are: reduced enrollments, declining birth rates, reduced mobility of faculty, changing composition of the student body and changing job market. Because of these factors, the Foundation is proposing to give priority, as a new major thrust in FY 1981, to the updating of the subject-matter competence of college science faculty.

RESEARCH FACILITIES, EQUIPMENT, AND INSTRUMENTATION

The Foundation provides support for a variety of research facilities, major equipment, and other equipment and instrumentation that are essential to the performance of advanced scientific research. NSF support is summarized in the following table and discussed in the paragraphs below.

RESEARCH FACILITIES AND EQUIPMENT
Budget Authority/Obligations in Millions of Dollars

Fiscal Year and Activity	*Land, Buildings, and Fixed Equipment*	*Major Equipment*	*Other Equipment and Instrumentation*	*Total*
FY 1979				
Mathematical and Physical Sciences	—0—	$11.2	$28.0	$39.2
Astronomical, Atmospheric, Earth and Ocean Sciences	4.9	10.9	16.2	32.0
U.S. Antarctic Program	2.5	—0—	5.7	8.2
Biological, Behavioral, and Social Sciences	—0—	—0—	17.1	17.1
Engineering and Applied Science	—0—	0.7	11.3	12.0
Total, FY 1979	7.4	22.8	78.3	108.5
FY 1980				
Mathematical and Physical Sciences	—0—	6.4	30.4	36.8
Astronomical, Atmospheric, Earth and Ocean Sciences	1.7	7.1	17.5	26.3
U.S. Antarctic Program	2.6	1.0	5.0	8.6
Biological, Behavioral, and Social Sciences	—0—	—0—	14.6	14.6
Engineering and Applied Science	—0—	0.5	12.0	12.5
Cross-Directorate Programs	—0—	—0—	5.7	5.7
Total, FY 1980	4.3	15.0	85.2	104.5
FY 1981				
Mathematical and Physical Sciences	—0—	6.5	35.9	42.4
Astronomical, Atmospheric, Earth and Ocean Sciences	0.1	4.8	21.8	26.7
U.S. Antarctic Program	3.2	1.6	4.5	9.3
Ocean Drilling Program	—0—	—0—	1.0	1.0
Biological, Behavioral, and Social Sciences	—0—	—0—	16.1	16.1
Engineering and Applied Science	—0—	0.7	13.1	13.8
Cross-Directorate Programs	14.3	—0—	2.9	17.2
Total, FY 1981	17.6	13.6	95.3	126.5
Difference—FY 1981/FY 1980	13.3	-1.4	10.1	22.0

Definitions

Definitions of the various categories of non-expendable research items supported by NSF are as follows:

- *Land, Buildings, and Fixed Equipment*—Acquisition, construction, rehabilita-

tion, addition to, or improvement of real property assets, such as land, buildings or other structures, and fixed equipment. "Fixed equipment" means equipment that is part of the building, such as elevators, plumbing, lighting and heating systems, air conditioning systems, fire alarm systems, and the like.

NSF normally supports the construction of buildings only at the National Research Centers and in Antarctica but occasionally provides support for buildings needed to house a major equipment item such as an accelerator.

- *Major Equipment*—Applies to a relatively limited number of specific items of specialized R&D equipment, such as accelerators, telescopes, research ships, aircraft, and the like.
- *Other Equipment and Instrumentation*—Includes all R&D equipment *other than* those items specifically categorized as "Major Equipment." To qualify as equipment, an item must cost at least $300 and have a use-life of at least one year.

Detection, measurement and the handling of data are important steps in many research activities. Many fields of science such as chemistry, physics and astronomy are extremely instrument-intensive, and others such as the biosciences are becoming more so. Sophisticated, complex instrumentation is a prerequisite to research on forefront topics.

Facilities, Equipment, and Instrumentation Funding

Support for research facilities and equipment increases from $104.5 million in FY 1980 to $126.5 million in FY 1981 or by 21.1 percent. A substantial part of this increase, $14.25 million, will be used on a one-to-one matching basis to upgrade university laboratories. Support is also provided for special instrumentation and equipment programs, including the 2-year and 4-year College Instrumentation Program ($3.0 million) and the Regional Instrumentation Facilities Program ($3.0 million—$2.8 million for operational costs and $0.2 million for equipment).

BUDGET SUMMARY OF OBLIGATIONS BY ACTIVITY AND SUBACTIVITY SHOWING DOLLAR AND PERCENTAGE CHANGES, FY 1981/FY 1980

(Millions of Dollars)

Activity & Summary	FY 1979	FY 1980 Current Plan	FY 1981 Budget Request	Difference FY 1981/FY 1980 Amount	Difference FY 1981/FY 1980 Percent
RESEARCH & RELATED ACTIVITIES APPROPRIATION					
Mathematical and Physical Sciences					
Mathematical Sciences	22.8	24.9	29.3	4.4	17.7
Computer Research	16.8	18.2	23.3	5.1	28.1
Physics	61.7	63.4	73.5	10.1	16.0
Chemistry	45.2	51.4	59.5	8.1	15.7
Materials Research	62.4	68.5	78.6	10.1	14.7
Subtotal, MPS	208.9	226.4	264.2	37.8	16.7
Astronomical, Atmospheric, Earth and Ocean Sciences					
Astronomical Sciences	59.2	57.0	60.2	3.2	5.7
Atmospheric Sciences	59.1	63.2	71.1	7.9	12.6
Earth Sciences	24.9	25.3	27.9	2.6	10.4
Ocean Sciences	62.4	66.6	76.0	9.4	14.1
Arctic Research	6.0	5.8	6.1	.3	4.6
Subtotal, AAEO	211.6	217.9	241.3	23.4	10.8
U.S. Antarctic Program					
U.S. Antarctic Research Program	7.3	8.0	9.3	1.3	16.2
Operations Support	43.8	47.8	54.1	6.3	13.1
Subtotal, USAP	51.1	55.8	63.4	7.6	13.5
Ocean Drilling Program					
Ocean Sediment Coring Program	10.6	15.9	17.3	1.4	9.0
Ocean Margin Drilling Program	1.0	3.6	10.0	6.4	177.8
Subtotal, ODP	11.6	19.5	27.3	7.8	40.2
Biological, Behavioral, and Social Sciences					
Physiology, Cellular & Molecular Biology	62.3	67.2	74.8	7.6	11.3
Behavioral & Neural Sciences	33.1	35.4	38.7	3.3	9.2
Social & Economic Science	25.4	26.2	27.8	1.6	6.1
Environmental Biology	33.9	37.7	40.7	3.0	8.1
Subtotal, BBS	154.7	166.5	182.0	15.5	9.3
Engineering and Applied Science					
Engineering:					
Electrical, Computer & Systems Engineering	17.0	17.6	22.5	4.9	27.8
Chemical & Process Engineering	13.0	13.9	16.7	2.8	20.0
Civil & Environmental Engineering	8.2	9.3	10.1	.8	8.9
Mechanical Sciences & Engineering	10.7	11.7	13.3	1.6	14.2
Subtotal, Engineering	48.9	52.5	62.6	10.1	19.3
Applied Sciences:					
Applied Research	17.6	17.6	18.7	1.1	6.1
Problem-Focused Research	32.6	28.9	30.5	1.6	5.6
Intergovernmental Science	5.1	5.5	7.0	1.5	27.3
Small Business Innovation and Industrial Technology	5.7	7.3	18.2	10.9	146.9
Subtotal, Applied Science	61.0	59.3	74.4	15.1	25.3
Subtotal, EAS	109.9	111.8	137.0	25.2	22.5

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BUDGET SUMMARY OF OBLIGATIONS BY ACTIVITY AND SUBACTIVITY SHOWING DOLLAR AND PERCENTAGE CHANGES, FY 1981/FY 1980—Continued

(Millions of Dollars)

Activity & Summary	FY 1979	FY 1980 Current Plan	FY 1981 Budget Request	Difference FY 1981/FY 1980 Amount	Difference FY 1981/FY 1980 [1]Percent
Scientific, Technological, and International Affairs					
International Cooperative Science Activities	10.6	12.0	12.9	.9	7.4
Policy Research & Analysis	5.5	5.7	6.8	.9	15.7
Science Resources Studies	3.1	3.2	3.4	.2	6.6
Information Science & Technology	4.4	5.2	5.9	.7	14.5
Subtotal, STIA	23.6	26.1	28.8	2.7	10.5
Cross-Directorate Programs					
Industry/University Cooperative Research	5.4	7.0	20.0	13.0	183.7
Special Facilities & Instrumentation:					
University Research Facilities Improvement	—0—	—0—	14.3	14.3	—0—
2-Year/4-Year College Instrumentation	.6	3.3	3.0	-.3	-9.1
Regional Instrumentation Facilities	5.0	4.8	3.0	-1.8	-37.5
Subtotal, Special Facilities & Instrumentation	5.6	8.1	20.3	12.2	150.0
Cross-Directorate International Programs:					
U.S./U.S.S.R. Cooperative Research Program	3.4	3.2	3.2	—0—	—0—
U.S./China Cooperation in Basic Sciences	—0—	1.0	2.0	1.0	100.0
Subtotal, Cross-Directorate International Programs	3.4	4.2	5.2	1.0	23.8
Other Programs:					
Research Initiation in Minority Institutions	.4	1.0	1.0	—0—	—0—
Experimental Program to Stimulate Competitive Research	.9	3.9	2.7	-1.2	29.9
Post-Doctoral Fellowships	[1.8]	[.9]	[.9]	.9	—0—
Decision and Management Sciences	—0—	—0—	1.0	1.0	—0—
Waterman Award	.1	.1	.1	—0—	—0—
NSF Planning and Evaluation	1.0	1.2	.8	-.4	-36.2
Subtotal, Other Programs	2.4	6.2	6.5	.3	5.3
Subtotal, Cross-Directorate Programs	16.8	25.5	52.0	26.5	103.5
Program Development and Management	54.7	60.6	60.8	.2	.4
Subtotal, Research & Related Activities	842.9	910.1	1,056.8	146.7	16.1
Science Education Activities Appropriation					
Scientific Personnel Improvement	33.1	31.6	35.2	3.6	11.4
Science Education Resources Improvement	28.6	24.0	24.2	.2	.8
Science Education Development & Research	12.0	14.9	17.5	2.6	17.1
Science and Society	6.3	7.7	8.8	1.1	15.0
Subtotal, Science Education Activities	80.0	78.2	85.7	7.5	9.6
Subtotal, Dollar Activities	922.9	988.3	1,142.5	154.2	15.6
Special Foreign Currency Appropriation	4.0	5.5	5.5	—0—	—0—
Total, NSF	926.9	993.8	1,148.0	154.2	15.5

[1]Percentages based on unrounded tabular amounts.
[2]Post-Doctoral Fellowships included in Science Education Activities prior to FY 1981.

MATHEMATICAL AND PHYSICAL SCIENCES

FY 1981 PROGRAM TOTAL $264,200,000

Obligations by Subactivity

Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Mathematical Sciences	$22,782,576	$25,400,000	$24,901,000	$29,300,000	$4,399,000
Computer Research	16,771,026	18,600,000	18,235,000	23,350,000	5,115,000
Physics	61,664,569	64,300,000	63,361,000	73,500,000	10,139,0000
Chemistry	45,230,481	52,935,000	51,414,000	59,500,000	8,086,000
Materials Research	62,416,265	69,000,000	68,501,000	78,550,000	10,049,000
Total	$208,864,917	$230,235,000	$226,412,000	$264,200,000	$37,788,000

Goals and Description

The goal of the Mathematical and Physical Sciences (MPS) activity is to develop a fundamental understanding of the physical laws that govern the world and the universe in which we live. To further this goal, basic research activities are supported in the disciplines of mathematics, computer science, physics, chemistry, and materials. Research results in these fields provide the underlying knowledge for the future technological developments upon which our economic and social well being so intimately depend. They also form much of the intellectual underpinning for engineering and the biological, environmental, and behavioral sciences, as well as provide many of the research instruments and techniques necessary to progress in these fields. More specifically, the Mathematical and Physical Sciences activity strengthens the Nation's research capability by:

- Creating new mathematical knowledge and applying that knowledge to achieve a better understanding of physical, biological, and social phenomena.
- Developing an understanding of the science that underlies computer technology and formulating the principles of design of computer hardware and software systems.
- Advancing knowledge of the fundamental physical laws governing matter and energy with the ultimate goal of achieving a unified, self-consistent explanation of all physical phenomena.
- Stimulating the development of modern chemistry on a broad front, including chemical synthesis, analysis, dynamics, structure, and theory.
- Developing an improved understanding of the fundamental principles, phenomena, and concepts that govern the physical, chemical, and mechanical properties of materials.

With the development of powerful new theoretical concepts, incisive experimental approaches, and sophisticated modern instruments of unprecedented power, resolution, and sensitivity, the MPS disciplines are currently in a period of unusual activity and opportunity. The richness of modern mathematical research, the challenge of complexity in computer science, and progress in understanding the fundamental forces and constituents of matter illustrate the diversity of this opportunity. The revolution in laser-related research, the intense activity in surface science and catalysis research, the power of modern synthetic chemistry, and the unique properties of new amorphous and polymeric materials all suggest the potential to serve the future needs of society as well. Overall, MPS ensures that the most highly qualified investigators across the broad range of disciplines are provided with the resources required to carry out their research, including the necessary instrumentation. To provide these resources MPS utilizes a wide range of support modes, from individual research projects through departmental or university laboratories to regional or national research facilities.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$208,864,917
FY 1980 Program	$226,412,000
FY 1981 Request	$264,200,000
Difference—FY 1981/FY 1980	$37,788,000

The $264.2 million requested for Mathematical and Physical Sciences (MPS) is 16.7 percent above the FY 1980 program level. Even taking into account the anticipated increased costs of performing research, this increase represents significant real growth. NSF has a unique responsibility for ensuring the health and vitality of the Nation's research across each of the component disciplines, although careful consideration is given to trends in research funding by other Federal agencies in determining program requirements. Detailed analysis of these program requirements in connection with long range planning activities has established that overall Federal support for research in the MPS disciplines has eroded to the point where adequate funding is no longer available to provide the most highly qualified investigators with the resources required to carry out their research in an optimum manner.

The FY 1981 Budget Request emphasizes augmented research project support for all disciplines, including provision of modern research instrumentation. In general, this emphasis is directed at achieving real growth in average award size in order to provide more adequate support, including that to young investigators, for graduate students, postdoctoral fellows, equipment, and materials and supplies. At the same time, provision is made for meeting the essential requirements of the university laboratories, such as the Materials Research Laboratories and the Nuclear Science Laboratories, and of major user facilities such as the Cornell Electron Storage Ring, the Synchrotron Radiation Facilities, and the National Magnet Laboratory. These laboratories and facilities represent an effective, and often the only, mode for carrying out

certain types of research. The request also includes a special emphasis on improving the Nation's academic research capability in experimental computer science. Computer research has become primarily a theoretical science in U.S. universities, and the emergence of modern integrated circuit technology presents both the opportunity and the means for making posssible major experimental contributions to this important and growing field. Throughout, the FY 1981 budget request provides for increased flexibility to undertake, on a selective basis, new initiatives particularly suited to MPS capabilities, and to respond more positively to proposals in areas of expanding scientific opportunity.

The distribution of the FY 1981 budget amounts for the five MPS subactivities is based on an extensive analysis of research needs and opportunities. Percentage changes are as follows:

Mathematical Sciences	17.7%
Computer Research	28.1%
Physics	16.0%
Chemistry	15.7%
Materials Researach	14.7%

Explanation of Increases, Decreases, and Continuing Emphases

Research Project Support and Instrumentation—In the Mathematics, Physics, Chemistry, and Materials Research subactivities, research project support is increased by $25.2 million to a total of $174.7 million. Included in that amount is project instrumentation and equipment, as well as Chemistry departmental equipment. Because of the unique requirements of Computer Research, that subactivity is considered separately below.

- Significant real growth in average award size is achieved, particularly in Physics, Chemistry, and Materials Research.
- The postdoctoral program in Mathematics is continued at a level of $0.6 million, and a modest program for young investigators is initiated in Physics at a level of $0.3 million. The young investigator question is addressed in all disciplines, however, primarily by provision of more adequate research support.
- Research related to microstructures in Chemistry and Materials Research is increased by $1.8 million to a total of $7.7 million.
- Emphasis continues in areas of expanding scientific opportunity such as laser-related research, elementary particle and gravitational physics, organometallic chemistry, surface science and catalysis, and unique new materials.
- Within this total, research project instrumentation, including departmental equipment in Chemistry, is increased by $5.0 million to a total of $26.2 million.

University Laboratories—Support for University Laboratories in Physics and Materials Research is increased by $3.9 million to a total of $36.1 million.

- The research capabilities of the intermediate energy electron accelerators at

Illinois and Stanford are enhanced by increasing their support by $0.8 million to a total of $4.6 million.

- Instrumentation and operating support are maintained at the other university nuclear science laboratories by the phase out of one laboratory, a significant reduction in NSF support of another, and an additional increase in funding of $0.3 million to a total of $9.2 million for the remaining laboratories.
- Support for the Materials Research Laboratories is increased by $2.8 million, to a total of $22.2 million. This increase strengthens cooperative research in key areas, permits some upgrading of experimental facilities, including instrumentation, and provides for more viable support levels at the smaller laboratories.

National User Facilities—Support for national user facilities in Mathematics, Physics, Chemistry, and Materials Research is increased by $3.4 million, to a total of $29.9 million.

- Support for a mathematical sciences research institute and/or other alternative modes of conducting mathematics research is increased by $0.8 million to a total of $1.4 million.
- Increases to offset the increased costs of performing research are provided for the newly converted Cornell Electron Storage Ring, the Indiana University Cyclotron Facility, and the Michigan State University Phase I heavy ion accelerator, thus ensuring effective levels of operation.
- An increase of $0.6 million provided for the Institute for Theoretical Physics as it enters its first full year of operation at the planned level of $1.2 million.
- Funding for the synchrotron radiation facilities at Stanford and Wisconsin is held essentially constant as construction activities are completed and increased levels of operation and instrumentation are implemented. Support for half-time dedicated operation of the accelerator at Stanford (SPEAR) continues at a level of $2.0 million.
- A modest increase in the current level of effort at the National Magnet Laboratory is utilized to provide for magnet development and instrumentation.

Computer Research—An increase of $5.1 million is provided for Computer Research, bringing the total support for that subactivity to $23.35 million. This level of support permits significantly increased emphasis on establishing a meaningful experimental computer research capability in U.S. universities.

- Longer range support for experimental computer research is increased by $2.7 million to a total of $3.7 million. Although dependent on the nature and quality of proposals received, it is anticipated that this support will provide for modern computing facilities, together with associated development, maintenance, and operating costs.
- In order to permit effective sharing of resources among dispersed research groups, $0.75 million is provided to develop a nationwide computer research network designed during FY 1980.

- A national competition for awards to young investigators in experimental computer science is initiated at a level of $0.9 million.
- Support for microstructures-related computer research is increased by $0.2 million to a total of $1.3 million.

Research Instrumentation and Equipment—Included above is support for instrumentation and equipment for research projects, special equipment programs, university laboratories, and major user facilities, which is increased by $5.5 million to a total of $42.4 million. Of this amount, some $1.0 million is for non-recurring instrumentation requirements, compared to $3.0 million in FY 1980.

ASTRONOMICAL, ATMOSPHERIC, EARTH, AND OCEAN SCIENCES

FY 1981 PROGRAM TOTAL $241,300,000

Obligations by Subactivity

Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Astronomical Sciences	$59,221,107	$58,550,000	$56,964,000	$60,200,000	$3,236,000
Atmospheric Sciences	59,106,778	65,750,000	63,169,000	71,100,000	7,931,000
Earth Sciences[1]	24,919,404	26,250,000	25,278,000	27,900,000	2,622,000
Ocean Sciences	62,393,725	68,450,000	66,619,000	76,000,000	9,381,000
Arctic Research Program	5,974,000	6,000,000	5,832,000	6,100,000	268,000
Total	$211,615,014	$225,000,000	$217,862,000	$241,300,000	$23,438,000

[1]The Ocean Sediment Coring Program has been moved from the AAEOS Activity to Ocean Drilling Programs, a separate activity.

Goals and Description

The Astronomical, Atmospheric, Earth, and Ocean Sciences Activity supports basic research in selected disciplines that will increase our knowledge of the natural environment on earth and in space. The overall objectives of the various elements comprising the activity are as follows:

- Obtain new knowledge of astronomy and the atmospheric sciences over the entire spectrum of physical phenomena;
- Provide a better understanding of the physical and chemical make-up of the earth and its geological history;
- Obtain further insights into the oceans' composition, structure, behavior, and resources, and examine the effect of human activities on the ocean environment and vice versa;
- Advance knowledge of natural phenomena and processes in the Arctic.

The objectives are pursued through the following subactivities:

Astronomical Sciences: Support of basic research projects and national research facilities is directed at examining the physical principles governing the universe as well as the properties and behavior of its objects. The latter include planets and their atmospheres, our sun, other stars, the Milky Way galaxy, and remote galaxies and quasars.

Atmospheric Sciences: Support is provided for basic research projects and for the National Center for Atmospheric Research to facilitate our understanding of the behavior of the earth's atmosphere.

Earth Sciences: The programs under Earth Sciences are designed to increase our basic knowledge of the solid earth and its evolution. Emphasis is placed on chemical and physical characteristics and processes that produce geologic features including hydrocarbon and ore deposits and events such as earthquakes.

Ocean Sciences: The activities supported are geared to improve understanding of the nature of the ocean, of its influence on human activities, and of society's impact on the marine environment. This is accomplished through Oceanography Project Support, Coordinated Ocean Research and Exploration, and support for oceanographic facilities essential to the research efforts.

Arctic Research Program: Research is supported in the disciplines of geology and geophysics, biology, oceanography, meteorology, glaciology, and upper atmospheric physics. Among the studies underway are those on permafrost, deep ice cores from Greenland, arctic lake and tundra ecosystems, and the resources of the Bering Sea Shelf.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

	Obligations
FY 1979 Actual	$211,615,014
FY 1980 Program	$217,862,000
FY 1981 Request	$241,300,000
Difference—FY 1981/FY 1980	$23,438,000

Major program or project changes in FY 1981 include:

- In Astronomical Sciences a $4,500,000 decrease resulting from completion of funding for Very Large Array fabrication in FY 1980 is largely offset by a $1,850,000 increase for the first year of full VLA operations (total $5,200,000), and detailed design and specifications for a new 25 meter diameter, millimeter wave telescope at $1,700,000. The 25 meter telescope will require an additional $27,000,000 in Fiscal Years 1982-1984.
- An additional $2,826,000 for the astronomy centers will help meet increased operating cost ($1,523,000) and provide instrumentation ($1,303,000). Totals in these categories are operations $30,852,000 and instrumentation $3,228,000.
- An increase of $1,360,000 in Astronomy project support to $19,220,000 will help meet increased costs.
- In Atmospheric Sciences an increase of $4,331,000 in project support to $38,600,000 will expand atmospheric chemical research, climate modeling and cloud physics, continue Global Atmospheric Research Program (GARP) projects and begin data analysis of previous GARP field experiments and an observational program of the Solar Maximum Year. Upgrading of a radar network for upper atmospheric observations and new observing tools to study mesoscale meteorological processes are also included.

- An increase of $3,300,000 to $29,900,000 for the National Center for Atmospheric Research provides for continued support of studies in solar variability, trace gases and aerosols, modeling and convective storm processes, and of aircraft and the Cray-1 computer. Administrative services costs are increased.
- A $300,000 increase to $2,600,000 for the National Scientific Balloon Facility will help continue support services to ongoing programs, renovate the former operations building and begin procurement of equipment for Long Duration Ballooning experiments.
- In Earth Sciences, an increase of $2,622,000 to $27,900,000 will allow for increased emphasis on geologic research on the U.S. continental crust and continued support of the Consortium on Continental Reflection Profiling, lunar sample analysis, research on the nature of earthquakes, modern geological processes, ore-forming fluids and ore deposits, and some instrumentation in geochemistry and geophysics.
- An increase of $3,250,000 to $24,600,000 in Oceanography Project Support will maintain the diversity of current programs, as well as increase emphasis on open-ocean dynamics using new tools such as satellite imagery and chemical tracers, all aspects of recently discovered sea floor hydrothermal vents, paleo-oceanography, and primary productivitiy and food chain processes in the open ocean.
- The Coordinated Ocean Research and Exploration program element increases by $2,850,000 to $23,600,000 includes initiation of projects in ocean acoustic tomography, the impact of rivers on the ocean, and studies of ecosystem production and control mechanisms. This increase will also expand meteorological support for the Sea-Air Exchange project, study of the effect of Western boundary current eddies on the continental shelf and research, particularly chemical, on the hydrothermal circulation of seawater through the oceanic crust.
- A $3,281,000 increase in Oceanographic Facilities and Support to $27,800,000 is necessary to maintain adequate logistics support for the research components of Ocean Sciences. Technician support and ship board equipment are increased along with operations support. The construction/conversion budget includes $3,600,000 for a new coastal research ship to continue the planned upgrading of the academic fleet to increase its efficiency and meet research needs.
- Arctic research increases by $268,000 to $6,100,000 and will continue to provide support for biological research on the Bering Sea Shelf, and geological and geophysical research in Alaska and elsewhere in the arctic.

U.S. ANTARCTIC PROGRAM

FY 1981 PROGRAM TOTAL $63,400,000

Obligations by Subactivity

Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
U.S. Antarctic Research Program	$ 7,281,809	$ 8,000,000	$ 8,000,000	[1]$ 9,300,000	$1,300,000
Operations Support Program	43,809,044	47,000,000	[3]47,840,000	[2]54,100,000	6,260,000
Total	$51,090,853	$55,000,000	$55,840,000	$63,400,000	$7,560,000

[1]These funds will support scientific activities in Antarctica during the October 1981 to March 1982 austral summer field season.
[2]These funds will provide support for the research activities to be conducted in Antarctica during the October 1980 to March 1981 austral summer field season.
[3]Includes $840,000 supplemental appropriation request for FY 1980 costs of October 1, 1979, military pay increase.

Goals and Description

The U.S. Antarctic Program supports national goals to: maintain the Antarctic Treaty, insure that the continent will continue to be used for peaceful purposes only, foster cooperative research to contribute to the solution of regional and worldwide problems, protect the environment, and insure equitable and wise use of living and nonliving resources.

The U.S. scientific research program in Antarctica continues to be the principal expression of national interest and policy. The goal of the U.S. Antarctic Research Program is the scientific investigation of Antarctica and the surrounding oceans. Objectives are to develop an understanding of the role played by the antarctic ice sheets and the antarctic physical, biological, geological, meteorological, atmospheric, chemical and oceanographic processes.

The antarctic area is of further interest to the United States because it:

- Has a major influence on world weather and climate,
- Has the world's richest marine protein resource potential,
- Has other features of unique scientific and practical interest, and
- Provides an excellent environment for international cooperation.

The National Science Foundation has been assigned overall management responsibility for planning, funding, and implementing the national program in Antarctica.

The U.S. Antarctic Research Program subactivity supports a multidisciplinary research program on the Antarctic continent and in the adjacent oceans. The research is conducted at four antarctic stations, from remote temporary field sites, and aboard ships. Remote sensing techniques, using satellites, aircraft, rockets, balloons, and unmanned stations, are used in the conduct of the research. Cooperative research programs with scientists of other nations are commonplace.

The Operations Support Program subactivity provides for the direct support of science activities and the maintenance of an effective U.S. presence in Antarctica.

The National Science Foundation is designated as the single source of funding and management for the U.S. Antarctic Program. The Department of Defense and the Department of Transportation provide operational support as requested by NSF on a cost reimbursable basis. The Foundation also contracts for support services when it is cost effective.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$51,090,853
FY 1980 Program	$55,840,000
FY 1981 Request	$63,400,000
Difference—FY 1981/FY 1980	$7,560,000

The $63,400,000 request for the U.S. Antarctic Program is $7,560,000 more than the FY 1980 program of $55,840,000.

The distribution of the FY 1981 budget amounts between the two budget subactivities and the percentage increases over FY 1980 are as follows:

U.S. Antarctic Research Program $9,300,000, up $1,300,000.
Operation Support Program $54,100,000, up $6,260,000.

The FY 1981 budget highlights are:

- Over one-half of the FY 1981 increase will be absorbed by inflation.
- Interdisciplinary research on the structure and function of the antarctic marine ecosystem will receive emphasis to provide information needed for the wise use and conservation of antarctic marine living resources.
- About forty percent of the operations support increase is for repairs to a crash-damaged LC-130 aircraft and for modifications to extend the present service life of an older LC-130 aircraft.
- The McMurdo Station physical facilities rehabilitation program will be accelerated.

OCEAN DRILLING PROGRAMS

FY 1981 PROGRAM TOTAL $27,300,000

Obligations by Subactivity

Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Deep Sea Drilling Project	$10,624,910	$15,400,000	$15,875,000	$17,300,000	$1,425,000
Ocean Margin Drilling Project:					
Project Planning and Evaluation	1,000,000	2,100,000	3,600,000	—0—	-3,600,000
Initial Implementation Phase	—0—	—0—	—0—	10,000,000	10,000,000
Total	$11,624,910	$17,500,000	$19,475,000	$27,300,000	$7,825,000

Goals and Description

The Ocean Drilling Programs (ODP) are a unique worldwide effort to explore the earth's crust beneath the oceans. An interdisciplinary science program aided by deep-ocean drilling and coring of rocks and sediments is aimed at understanding the detailed composition and behavior of the submerged 75 percent of the earth's surface that is of ever increasing importance to people and countries. These programs are aimed at:

- substantiating and refining the plate tectonics hypothesis that portrays the earth as a dynamic planet on which the distribution of continents and oceans changes continuously over geologic time. This will aid in a better understanding of the cause of violent natural processes, especially the volcanic activity and earthquakes that occur at crustal plate boundaries;
- utilizing detailed sediment records that document the paleoenvironment over many millions of years, and provide opportunities to explain the impact of the changing surface features of our planet on oceanic circulation and corresponding climate changes; and
- establishing the geological framework and studying the specific processes which cause the formation of natural resources and guide their distribution. Resource exploration builds on this scientific base.

The Ocean Drilling Programs activity includes two subactivities, the Deep Sea Drilling Project (DSDP) and the Ocean Margin Drilling Project (OMDP). The National Science Foundation has overall management responsibility for these programs.

The Deep Sea Drilling Project has been supported by NSF since FY 1966 and has been operating since FY 1968. DSDP operations are managed for NSF by the University of California/Scripps Institution of Oceanography (SIO). Under subcontract to SIO

the drilling ship *Glomar Challenger* is operated by its owner Global Marine Inc. for DSDP. The scientific program for DSDP is guided by the Joint Oceanographic Institutions Inc. and their scientific advisory structure, the Joint Oceanographic Institutions for Deep Earth Sampling, which includes foreign members. The Deep Sea Drilling Project is now in the International Phase of Ocean Drilling to which five foreign countries, France, Germany, Japan, the U.K. and the U.S.S.R., each contribute $1,250,000 annually. DSDP/*Challenger* operations have been carried out in almost all of the world's oceans. Major contributions of DSDP are the first reconnaisance of the makeup of the earth's crust beneath the oceans and the most convincing research results to date in support of the plate tectonics hypothesis. Present NSF plans call for support of *Challenger* operations through FY 1981.

The Ocean Margin Drilling Project is a logical extension of DSDP. OMDP will attack the most important unresolved problems in the plate tectonics hypothesis as well as problems that have emerged from 11 years of Deep Sea Drilling Project efforts. The essential difference between OMDP and DSDP will be the transition from a general reconnaisance performed by DSDP to a problem-focused approach in OMDP. The major new initiative of OMDP will be an extensive investigation of the ocean margins. The passive margins with their thick sediment cover (e.g. the U.S. east coast) represent a major frontier for geologic exploration. Besides its great scientific importance, work on the deeply submerged ocean margins will constitute the first major effort to establish the geologic framework for determining the natural resource potential of these areas. The drilling system required for the ocean margin project greatly exceeds the capacity of the DSDP ship *Challenger*. The government-owned *Glomar Explorer* has been identified as an excellent candidate for the advanced drilling technology platform for OMDP.

In order to initiate the Ocean Margin Drilling Project a new approach has been taken. The U.S. petroleum industry has been invited to become a major partner and contributor in this project. Government/industry negotiations have proceeded to the point that a sufficient number of petroleum companies have indicated their willingness to participate and contribute during FY 1981. In that year engineering design and cost estimates for *Explorer* conversion, and the advanced deep-ocean drilling system as well as scientific program planning will proceed. Results of these efforts will provide the basis for a final go, no-go decision later in FY 1981 on the whole project as a joint venture.

Foreign participation in the Ocean Margin Drilling Program similar to the DSDP/International Phase of Ocean Drilling (IPOD) is a possibility. One country has already expressed interest in negotiating participation in OMDP. Other U.S. agencies, especially the U.S. Geological Survey and the Department of Energy may participate in OMDP according to their particular missions and interest. .

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$11,624,910
FY 1980 Program	$19,475,000
FY 1981 Request	$27,300,000
Difference—FY 1981/FY 1980	$7,825,000

The $27,300,000 requested for the Ocean Drilling Programs is 40.2 percent more than the FY 1980 program of $19,475,000.

The distribution of the FY 1981 NSF funds budgeted between the two budget subactivities follows:

- Deep Sea Drilling Project/International Phase of Ocean Drilling is up $1,425,000 to $17,300,000.
- Ocean Margin Drilling Project is up $6,400,000 to $10,000,000.

The Deep Sea Drilling Project increase in NSF funding of $1,425,000 is necessary to cover increased costs for fuel, personnel and supplies and related expenses. The balance of the overall increase of $2,000,000 in DSDP is covered by increased foreign contributions.

The $6,400,000 increase in the Ocean Margin Drilling Project is needed to proceed from the OMDP planning and evaluation phase to project implementation. The $10,000,000 NSF budget for OMDP will be matched by industry contributions. This initial phase of implementation will take the project up to the point of modifications to *Explorer*, drilling system procurement, and drilling site selection, and will provide a basis for the final go, no-go decision for the project as a joint venture.

BIOLOGICAL, BEHAVIORAL, AND SOCIAL SCIENCES

FY 1981 PROGRAM TOTAL $182,000,000

Obligations by Subactivity

Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Physiology, Cellular and Molecular Biology	$62,292,455	$69,500,000	$67,218,000	$74,800,000	$7,582,000
Behavioral and Neural Sciences	33,073,342	36,900,000	35,443,000	38,700,000	3,257,000
Social and Economic Science	25,386,044	26,900,000	26,206,000	27,800,000	1,594,000
Environmental Biology	33,952,783	38,950,000	37,664,000	40,700,000	3,036,000
Total	$154,704,624	$172,250,000	$166,531,000	$182,000,000	$15,469,000

Goals and Description

The goal of the Biological, Behavioral, and Social Sciences (BBS) Activity is to expand knowledge and understanding of biological and social phenomena. The range of research supported includes acquiring rigorous physical and chemical information on the fundamental molecules of living organisms, the systems level interrelationships of organisms and their environment, the complex learning and behavior patterns of human beings, and the interactions of social, economic and cultural organizations and institutions.

Specific major objectives are to identify and fund research that will advance understanding of the:

- Molecular basis of structure and function in cells, organs, organ systems, and whole organisms;
- Interrelationships in terrestrial and freshwater ecosystems and key evolutionary relationships among the many species of plants, animals, and microorganisms;
- Biological, psychological, and cultural factors that underlie behavior; and
- Structure and function of economic and social institutions, and changes that impact on individuals and groups of the societal conditions they experience.

Over the long term, we expect the results of this fundamental research effort to contribute new ideas, options and opportunities for wisely utilizing the biological environment, maximizing human development potential, enhancing the quality of life, maintaining economic and social stability with progress, and increasing productivity.

The aims are ambitious, but to the extent that most national and international problems relate to people, their institutions and their interaction with the environment, the gain in understanding from this research can be invaluable.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$154,704,624
FY 1980 Program	$166,531,000
FY 1981 Request	$182,000,000
Difference—FY 1981/FY 1980	$15,469,000

The Foundation's FY 1981 budget request for Biological, Behavioral, and Social Sciences (BBS) is $182,000,000, an increase of $15,469,000 (or 9.3 percent) over the FY 1980 level of $166,531,000. This increase will support the base of science in the program subactivities that follow and provide for selected new research opportunities. Important, but currently less promising, lines of inquiry will be reduced in order to fund the new research opportunities.

The distribution of FY 1981 budget requests for the four BBS program subactivities is based on a thorough review of research needs and opportunities and consideration of the research supported by other agencies. The percentage increases are as follows:

Physiology, Cellular and Molecular Biology	11.3%
Behavioral and Neural Sciences	9.2%
Social and Economic Science	6.1%
Environmental Biology	8.1%

Explanation of Increases:

- $7,582,000 increase, for a total of $74,800,000 for Physiology, Cellular & Molecular Biology including increases for:
  - — studies of cell-cell interactions to increase our understanding of self recognition of cells in development and differentiation, and hormones and their receptors;
  - — procurement of instrumentation and development of new instrumentation;
  - — studies of membrane structure and function including pathways and movements of substances through membranes; and
  - — research on the structure and function of macromolecules especially on the mechanism of heredity in the context of gene structure and functioning, biosynthesis of macromolecules, and the regulation of enzyme activity.
- $3,257,000 increase, for a total of $38,700,000 for Behavioral and Neural Sciences, including increases for:
  - — studies of biochemical and hormonal mechanisms underlying behavior; and
  - — anthropological research seeking human origins.

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- $1,594,000 increase, for a total of $27,800,000, for Social and Economic Science, including increases for:
  - — additional studies of economic instability, inflation and employment, both domestic and international; and
  - — studies of allocation processes, decision rules, management behavior, and dispute resolution particularly in organizations such as large firms, government bureaucracies and other complex organizations.
- $3,036,000 increase, for a total of $40,700,000, for Environmental Biology including increases for:
  - — research on various aspects of the ecology of crop and forest pests, acid rain, global carbon dioxide, and other pressing ecological problems; and
  - — projects in long-term ecological research and maintenance of field research capability at representative sites.

ENGINEERING AND APPLIED SCIENCE

FY 1981 PROGRAM TOTAL $137,000,000

Obligations by Subactivity

Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Electrical, Computer, & Systems Engineering	$17,020,988	$18,160,000	$17,606,000	$22,500,000	$4,894,000
Chemical & Process Engineering	12,975,094	14,320,000	13,880,000	16,650,000	2,770,000
Civil & Environmental Engineering	8,151,770	9,630,000	9,300,000	10,125,000	825,000
Mechanical Sciences & Engineering	10,708,730	11,990,000	11,665,000	13,325,000	1,660,000
Applied Research	*17,608,213	*18,200,000	*17,628,409	*18,700,000	*1,071,591
Problem-Focused Research	*32,538,834	*30,400,000	*28,885,000	*30,500,000	*1,615,000
Intergovernmental Programs	5,131,539	5,000,000	5,500,000	7,000,000	1,500,000
Small Business Innovation & Industrial Technology	5,724,816	6,000,000	7,370,000	18,200,000	10,830,000
Total**	$109,859,984	$113,700,000	$111,834,409	$137,000,000	$25,165,591

*Does not include approximately $2.2 million (FY 1979) and $2.0 million (FY 1980 and FY 1981) in Applied Research and $1.4 million (FY 1979) and $1.0 million (FY 1980 and FY 1981) in Problem Focused Research for small business solicitations. These funds are now included and displayed in the Small Business and Industrial Technology subactivity.

**Does not include $0.9 million in FY 1979, $2.7 million in FY 1980 Budget Request, $3.85 million in FY 1980 Current Plan, and $2.7 million in FY 1981 for the Experimental Program to Stimulate Competitive Research, which is an EAS effort but displayed for budgetary purposes in the Cross-Directorate program.

Goals and Description

The Foundation's Engineering and Applied Science (EAS) Activity seeks to strengthen the Nation's engineering and applied science research base and enhance the links between fundamental research and applications in addressing selected national goals. This is accomplished by identifying and supporting basic research across a broad spectrum of the engineering sciences, applied research, and related activities that have the highest potential for contributing to the understanding and resolution of significant societal problems.

The specific objectives of EAS are to:

- Advance basic knowledge of fundamental engineering principles that might be applied to the analysis and design of a large variety of manmade systems;
- Strengthen the academic engineering research base in order to address the need for more basic research underlying industrial technology and for more graduating engineers working at the forefront of research.
- Stimulate the application of fundamental scientific and engineering knowledge to the solution of significant problems in the public and private sectors, and

shorten the time between scientific discoveries and their application for societal use;

- Focus U.S. scientific and technological capabilities on selected problems of national significance where NSF can make a unique contribution, such as earthquake hazards mitigation, human nutrition, and others;
- Increase fundamental scientific knowledge in selected problem areas where additional knowledge can contribute to their long-term solution;
- Provide mechanisms to increase the effectiveness of the public and private sectors in appropriately utilizing science and technology;
- Facilitate the integration of scientific and technical resources into the activities of State and local governments;
- Explore new ways to improve cooperation between universities and industry in research and industrial innovation; and
- Draw upon the research capabilities of the Nation's small businesses, with a view towards moving the most promising research along the continuum to commercialization as soon as possible.

On July 1, 1979, the National Science Foundation formed the Engineering and Applied Science Directorate by combining the Engineering activities within the Foundation with the Applied Science and Research Applications Directorate. Many activities between the two were highly complementary. By combining these organizations, NSF is now better able to:

- Strengthen the engineering programs of the Foundation by giving them a single, more visible place in the NSF organization;
- Enhance NSF's program of applied and problem-focused research by providing a broader base of science and engineering on which to build; and
- Recognize the key role of engineering in the transfer of science into technology by placing the Foundation's major engineering, industry-related, and problem-oriented efforts in one organization.

The EAS budget is organized around eight subactivities: Electrical, Computer, and Systems Engineering; Chemical and Process Engineering; Civil and Environmental Engineering; Mechanical Sciences and Engineering; Applied Research; Problem-Focused Research; Intergovernmental Programs; and Small Business Innovation and Industrial Technology.

Electrical, Computer and Systems Engineering supports, basic and applied research in large scale integrated circuit electronics, integrated optics, optical communications, automation and robotics, and mathematical studies of complex interactions in the manmade world.

Chemical and Process Engineering emphasizes research on: the basic mechanisms of catalysis and various chemical and biochemical processes, and the methods of putting the resulting knowledge into industrial applications; general theories of mass

transfer and separation processes, including the characterization and processing of fine particles; and the efficient recovery and use of resources that feed important industrial processes.

Civil and Environmental Engineering focuses on: activities in which the earth's surface itself is involved (such as foundations and dams); the science of designing structures in such a way as to give the most efficient and economical service in response to given demands; and studies of the flow of above- and below-ground water, utilizing principles of engineering, biology, and chemistry to protect and improve the physical environment.

Mechanical Sciences and Engineering addresses problems in: the transfer of heat, a major carrier of power; solid mechanics, which emphasizes the problems of machines under high stress and strain; fluid mechanics, which looks at lubrication, questions of turbulence, and other areas connected with fluid flow; and mechanical systems, which involves the synthesis of all these elements into an appropriate "design."

Applied Research seeks to accelerate the rate of technological innovation growing out of significant advances in selected fields of science and engineering. The program supports unsolicited proposals as well as research in certain coherent areas; the latter involving the selective support of interrelated applied research projects having a high probability of providing a broad knowledge base for major technological innovations or for contributing to the solution of significant public policy issues.

Problem-Focused Research concentrates research on critical societal problems where it is clear that such research is essential for dealing effectively with the problems. Currently, four program areas are supported: Earthquake Hazards Mitigation; Alternative Biological Sources of Materials; Science and Technology to Aid the Handicapped; and Human Nutrition. The subactivity also supports efforts in: Problem Analysis, which examines a wide range of potential research topics and problem areas for use in selecting research directions; and Integrated Basic Research, which provides additional support to basic research topics related to problem areas of existing or emerging major importance.

Intergovernmental Programs supports research that attempts to facilitate the integration of scientific and technical resources into the activities of State and local governments. Efforts are directed not only at individual jurisdictions but also those encompassing statewide, regional, and national networks.

Small Business Innovation and Industrial Technology seeks to: develop selected incentives that the Federal government may use to increase R&D investment in the private sector, with particular emphasis on the role of small business in such activities; and combine the scientific and technological resources of universities and industries in cooperative efforts designed to accelerate industrial innovation and enhance productivity.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The proposed FY 1981 increase of $25,165,591, which will raise the EAS program from $111,834,409 to $137,000,000 in FY 1981, would incorporate the following increases:

- Electrical, Computer, and Systems Engineering by $4,894,000, from $17,606,000 in FY 1980 to $22,500,000 in FY 1981, primarily for a sharply-focused effort in microstructures and computer engineering research. Such an effort will address research in areas where the U.S. has recently been lagging in comparison to foreign countries, and also direct research towards a field which has high potential for productivity improvement and industrial innovation.
- Chemical and Process Engineering by $2,770 ,000, from $13,880,000 to $16,650,000, for efforts particularly in engineering energetics, with an emphasis on upgrading facilities for plasma chemistry and arc technology. Another thrust is in thermodynamics and mass transfer, with support for research in novel and energy-efficient separation processes.
- Civil and Environmental Engineering by $825,000, bringing that program from $9,300,000 to $10,125,000. Emphasis will be on research in structural mechanics, particularly as directed towards probabilistic design methods and optimization techniques on structures subjected to off-shore, wind, and earthquake environments.
- Mechanical Sciences and Engineering by $1,660,000, from $11,665,000 to $13,325,000. Concentration will be on mechanical systems research with emphasis on control theories as applied to manufacturing processes, which provide the foundation for later research in improved manufacturing methods and robotics.
- Applied Research by $1,071,591, raising the program from $17,628,409 to $18,700,000. Such an increase will allow for a new research thrust to examine the impact on the economy of a transition from heavily-regulated to less-regulated industries and services, and also to expand work in areas of manufacturing processes and materials handling.
- Problem-Focused Research by $1,615,000, from $28,885,000 to $30,500,000, principally for expanded efforts in earthquake hazards mitigation.
- Intergovernmental Programs by $1,500,000, from $5,500,000 to $7,000,000, to be applied entirely to the State Science, Engineering, and Technology Program and that program's efforts to implement capacity-building programs in State and local governments to access scientific and technological information.
- Small Business Innovation and Industrial Technology by $10,830,000, from $7,370,000 to $18,200,000, to accommodate significantly heightened efforts in support of small business research and university-industry cooperative research centers, both of which were keystones in the President's Industrial Innovation Initiative announced last fall.

Percentage changes between FY 1981 and the FY 1980 Current Plan for the sub-activities are as follows:

Electrical, Computer, & Systems Engineering	28%
Chemical & Process Engineering	20%
Civil and Environmental Engineering	9%
Mechanical Sciences & Engineering	14%
Applied Research	6%
Problem Focused Research	6%
Intergovernmental Programs	27%
Small Business Innovation & Industrial Technology	147%

SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS

FY 1981 PROGRAM TOTAL $28,850,000

Obligations by Subactivity

Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
International Cooperative Scientific Activities*	$10,603,513	$10,515,000	$12,014,000	$12,900,000	$886,000
Policy Research and Analysis	5,459,033	5,800,000	5,749,000	6,650,000	901,000
Science Resources Studies	3,071,607	3,200,000	3,188,000	3,400,000	212,000
Information Science and Technology	4,428,155	5,200,000	5,152,000	5,900,000	748,000
Total*	$23,562,308	$24,715,000	$26,103,000	$28,850,000	$2,747,000

*Excludes activities under the U.S.-U.S.S.R. Agreement on Cooperation in the Fields of Science and Technology which are presented separately in the Cross Directorate Program Budget.

Goals and Description

Science and technology are national and international resources. Domestically the scientific and technological enterprise of the United States yields new knowledge and practices which improve the quality of life and lead to new products, processes, and services. Abroad, science and technology are increasingly seen as a means to economic growth and social development. Efficient, effective, and timely international exchange of scientific information also contributes to U.S. international objectives. Science and technology more and more affect governing institutions, the industrial and academic sectors, and the role of individual citizens. Consequently, there is greater concern about science and technology policy and funding of the networks linking science and technology (S&T) to society at large.

The goal of the Scientific, Technological, and International Affairs (STIA) program activity is to promote the understanding and effective functioning of the Nation's scientific and technological enterprise. STIA supports activities designed to provide information and systematic analysis of the Nation's S&T enterprise, and to enhance domestic and international exchange of S&T information.

Each program subactivity contributes to attaining the overall STIA goal in a specific way. The Policy Research and Analysis subactivity pinpoints critical S&T policy issues through extramural and intramural research and examines the impact and effectiveness of alternative Federal policies for science and technology. Thus it contributes to the knowledge base for policy formulation. The Science Resources Studies subactivity

develops comprehensive descriptions of the Nation's available human and financial resources for scientific and technological activities. Together, these two subactivities carry out most of the monitoring and policy research and analysis activities of STIA.

The remaining two subactivities are concerned with the improvement of S&T information exchange. International Cooperative Science programs benefit the U.S. scientific effort by gaining knowledge about scientific activities or resources in other countries and by promoting mutually beneficial cost and facility sharing. At the same time, these programs help the United States to implement foreign policy objectives which have S&T content. The Information Science and Technology subactivity supports basic and applied research leading to timely and resourceful use of information especially by the science and technology enterprise.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$23,562,308
FY 1980 Program	$26,103,000
FY 1981 Request	$28,850,000
Difference FY 1981/1980	$2,747,000

The FY 1981 budget request for STIA, $28,850,000, exceeds the FY 1980 Current Plan by 10.5 percent, or $2,747,000. Through internal adjustments and no growth restrictions in some ongoing programs, this small increase nonetheless maintains the three international cooperative science thrusts of FY 1980 and permits other strategically planned activities in each of the four subactivities. Percentage increases in the subactivities follow:

International Cooperative Scientific Activites	7.4%
Policy Research and Analysis	15.7%
Science Resources Studies	6.6%
Information Science and Technology	14.5%

Program increases are described below:

International Cooperative Scientific Activities. Ongoing programs and exchanges, including the thrusts initiated in 1980, are maintained, although they continue to face dollar value pressures overseas. The requested $886,000 increase will:

- Expand the cooperative research thrust in Western Europe where scientific and technical capabilities in some fields rival or surpass those in the U.S. and where U.S. scientists can benefit most from cooperation ($286,000), for a total program of $1,800,000.
- Cover significantly increased dues and operating costs associated with U.S. participation in international scientific organizations ($500,000; total program, $4,100,000).

- Enable approximately one hundred more U.S. scientists and engineers to participate in major international conferences ($100,000; total program, $800,000).

Policy Research and Analysis

- An increase of $750,000 initiates a new research and analysis program in international economic policy that will build upon current work focusing on international technology transfer.
- An increase of $151,000 permits additional risk analysis activities to improve methods for evaluating long-term comparative risks and benefits of alternative technologies.

Science Resources Studies. Completion of several large studies funded in FY 1980 and an increase of $212,000 permits:

- A key survey of U.S. scientists and engineers identified by the 1980 Decennial Census. This continues a thrust begun in FY 1979 which has planned, sequential phases running through 1984. The data obtained will serve as a base for the Federal Government's statistical information on the adequacy, distribution, and characteristics of the Nation's S&T personnel.
- Support of two special projects designed to update the Nation's information and data concerning small R&D firm's industrial activity and the R&D of independent nonprofit institutions.

Information Science and Technology

- An increase of $748,000 allows growth in three program elements: support of research on information transfer and related human behavior aspects ($400,000); investigations of the information economy ($148,000); and research on new and promising information technology ($200,000).

CROSS-DIRECTORATE PROGRAMS

FY 1981 PROGRAM TOTAL $51,950,000

Obligations by Subactivity

Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Industry/University Cooperative Research	$5,445,929	$4,000,000	$7,050,000	$20,000,000	$12,950,000
Special Facilities and Instrumentation Programs	5,606,302	5,800,000	8,100,000	20,250,000	12,150,000
Cross-Directorate International Programs	3,387,484	3,200,000	4,200,000	5,200,000	1,000,000
Other Programs	2,423,171	4,300,000	6,175,348	6,500,000	324,652
Total	$16,862,886	$17,300,000	$25,525,348	$51,950,000	$26,424,652

Goals and Description

The Cross-Directorate Programs Activity is new in the FY 1981 budget. The Foundation has grouped in this budget activity, for presentation purposes, a number of programs with special characteristics and goals. These programs mainly provide funds for purposes not related to any single field of science but to several scientific fields generally supported by the NSF. In some cases, these programs receive and review proposals in many areas aimed toward a specific objective other than advancing a particular field of science. One program, for example, provides equipment to researchers at small colleges and another experiments with building research linkage between academia and industry. Both programs support projects in many fields of science.

Some of the goals of individual programs included in the Cross-Directorate Program Activity are to:

- Encourage greater cooperation in research between universities and industry.
- Provide support for research equipment and improved research facilities to colleges and universities that have programs in the sciences and engineering.
- Maintain research cooperation between the U.S. and the U.S.S.R. and broaden opportunities between the U.S. and China.
- Help predominantly minority colleges and universities establish active research programs on their campuses thereby encouraging capable scientists at these institutions to compete for research support from all appropriate sources.

- Improve the quality of science by stimulating and increasing the competitiveness of scientists for Federal research support in States that are now relatively less able to compete successfully.
- Provide postdoctoral opportunities for recent doctoral graduates to pursue full-time basic research that enhances their ability to make significant contributions to the scientific world.
- Provide support for research in decision and management sciences aimed at the improvement of decision making in the public and private sectors.
- Continue support of efforts to plan and evaluate Foundation programs on the basis of established needs, goals, and objectives.

PROGRAM DEVELOPMENT AND MANAGEMENT

FY 1981 Program Total $60,800,000

Obligations by Subactivity

Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Mathematical and Physical Sciences	$4,154,420	$5,242,000	$4,755,000	$4,822,000	$67,000
Astronomical, Atmospheric, Earth and Ocean Sciences	4,911,017	5,538,000	5,787,000	5,987,000	200,000
Biological, Behavioral and Social Sciences	3,643,141	4,592,000	4,798,000	4,864,000	66,000
Science Education Programs	3,543,920	3,825,500	3,820,000	3,820,000	—0—
Engineering and Applied Science	5,151,927	5,463,500	5,864,000	5,964,000	100,000
Scientific, Technological and International Affairs	6,396,024	6,497,000	6,718,000	6,761,000	43,000
Executive Management	6,389,967	7,926,000	7,458,000	7,631,000	173,000
Central Support Services and Administration	20,575,474	20,516,000	21,363,762	20,951,000	-412,762
Total	$54,765,898	$59,600,000	[2,3]$60,563,762	$60,800,000	$236,238
Full Time Permanent Positions[1]	1,260	1,280	[4]1,274	1,293	19

[1] Includes 12 reimbursible positions.
[2] Includes $2,547,762 FY 1979 PDM carryover funds.
[3] Excludes $84,000 transferred to Department of Education.
[4] Excludes 6 positions transferred to Department of Education.

Organization and Objectives

The goal of the Program Development Activity and Management is to achieve the most effective management of the National Science Foundation. Major objectives of this activity are to:

- operate a system of impartial evaluation and selection of proposals to ensure support of research and science education projects on the basis of scientific merit;
- provide a sufficient staff of well-trained and highly qualified scientists, educators, administrators, and support personnel;
- supply support services to provide staff an environment conducive to effective program and management operations;
- ensure proper accountability and oversight of Federal funds through effective management policies, procedures, and techniques;
- maintain an in-house capability for high quality analysis of science and technology policy;

- identify issues and develop long-range plans for effective and responsive NSF programs; and
- obtain oversight by outside experts and in-house staff to ensure vitality and responsiveness of NSF programs.

NSF is organized into six program directorates, an administration directorate, and six staff offices reporting to the Director. Within this structure, the six program directorates operate and manage the major discrete parts of the Foundation's efforts in science research.

Three of the directorates, each composed of related groups of scientific disciplines, strongly represent basic research programs in the top management level. These directorates are Mathematical and Physical Sciences; Astronomical, Atmospheric, Earth, and Ocean Sciences; and Biological, Behavioral, and Social Sciences.

The other directorates manage research in applied science and engineering; science education; and a consolidation of international science programs, science information activities, science resources studies, and science policy analysis. These directorates are Engineering and Applied Science, Science Education, and Scientific, Technological, and International Affairs.

The staff offices reporting to the Director are Planning and Resources Management, Equal Employment Opportunity, Government and Public Programs, General Counsel, Small Business Research and Development, and Audit and Oversight.

In addition to managing and operating science research programs through grants and contracts, the NSF staff conducts in-house efforts related to:

- studies of science resources, including scientific manpower;
- evaluation of science policy issues and alternatives in support of the National Science Board and the Office of Science and Technology Policy;
- coordination of national and international scientific activities;
- planning and management of a complex logistic support for the U.S. Antarctic Research Program;
- planning and managing the expanded ocean drilling programs; and
- a science liaison staff maintained at Tokyo, Japan, to assist coordination of science programs involving Far Eastern countries.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The FY 1981 estimate of $60,800,000 for Program Development and Management is an increase of $236,238 over the estimate for FY 1980.

A total staff of 1,293 positions is planned for FY 1981, an increase of 19 positions. Six of the new positions were identified for support of basic and applied research efforts by the NSF staffing study completed in the fall of 1979. Eight are needed in connection with the expanded program of ocean drilling. Of the remaining five positions,

three are allocated to the expanded program for research facilities, one to the small business research program, and one for the Five-Year Outlook in Science report authorized by the Science and Technology Policy Act of 1976.

FY 1981 increases and decreases are:

- An increase of $456,000 for permanent personnel compensation for salary costs of the additional 19 positions. This initial funding is approximately two-thirds of the annual cost of these positions and the balance will be annualized in FY 1982;
- An increase of $25,000 for consultant compensation to fund about 250 more consultant days performed by outside experts to provide oversight and advice concerning NSF programs;
- An additional $63,000 for personnel benefits as the employer's contributions to retirement and insurance for the additional 19 positions and for increased costs of benefit payments for the existing staff.
- A total increase of $146,000 is provided for travel. This item covers additional site visits for monitoring and oversight of program awards by existing staff, and 19 new employees, advisory committees, and consultants for new programs
- An increase of $50,000 for transportation of things for household moves of new employees.
- A net decrease of $235,000 in rents and communications, resulting from an increase of $200,000 in space rental rates assessed to NSF by the General Services Administration and a decrease of $435,000 in rental costs for data processing equipment previously leased but now purchased.
- An increase of $50,000 for printing and reproduction due to increased costs of paper, printing supplies, and printing by the Government Printing Office and private contractors.
- A decrease of $108,762 in administrative services contracts previously budgeted for software development.
- A net decrease of $210,000 resulting from reduced purchases of special purpose equipment and computer hardware.

SCIENCE EDUCATION

FY 1981 PROGRAM TOTAL $85,700,000

Obligations by Subactivity

Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Scientific Personnel Improvement	$33,071,847	$32,900,000	[1]$31,600,000	$35,200,000	$3,600,000
Science Education Resources Improvement	28,605,592	29,100,000	[2]24,000,000	24,200,000	200,000
Science Education Development & Research	12,014,423	15,300,000	14,950,000	17,500,000	2,550,000
Science & Society	6,287,455	7,400,000	7,650,000	8,800,000	1,150,000
Total	$79,979,417	$84,700,000	[1,2]$78,200,000	$85,700,000	$7,500,000

[1]Includes $1.0M to be obligated by the Pre-College Teacher Development in Science Program in January 1980 for summer projects for teachers in Grades K-4, but excludes $1.5M for academic year projects scheduled for obligation after April 1, 1980, the date for establishment of the Department of Education. This latter amount will at that time be transferred to the new Department.
[2]Excludes $5.0M which is being transferred to the Department of Education as of April 1, 1980.

Goals and Description

The National Science Foundation Act of 1950 (P.L. 81-507, as amended) directs the Foundation to "...initiate and support...programs to strengthen...science education programs at all levels..." From this mission flow two continuing goals for the Science Education Program in FY 1981:

- To help all citizens increase their basic understanding of science and its contributions to the quality of life; and
- To assure a stable flow of the most talented students into careers in the sciences, with particular reference to increasing the participation of minorities and women.

To implement these goals the Science Education staff, working closely with the Congress, the National Science Board and the scientific community, has developed a balanced and carefully integrated set of program mechanisms. The objectives of these programs are to:

- Support research on how science and mathematics are learned and development of more effective instructional techniques and materials for use at all levels of education;
- Provide high quality training in science for specially selected students in programs ranging from the junior high school through the graduate levels;
- Provide for subject-matter revitalization of both pre-college teachers of science and undergraduate science faculty;

- Assist in the improvement of undergraduate science instruction at 2-year and 4-year colleges and universities; and
- Improve the public's understanding of science and how it affects their daily lives thus increasing the ability of citizens to participate knowledgeably in the resolution of science-related public policy issues.

In pursuing these objectives the Foundation will place special emphasis on four priority thrusts. Two of the four thrusts were initiated in FY 1979. The first of these is the improvement of science education for the early adolescent. This entails focussing continued effort at a point of high opportunity, the junior high/middle school years. What we know about this age group tells us that many choose not to study science and mathematics beyond this age and that this is particularly true of minorities and girls. We need to know more about why this phenomenon occurs at this age level and what needs to be done to alter the situation so that these students have a broadened understanding of science and that they do not preclude themselves from possible preparation for future science and technology-related careers.

The second of the thrusts initiated in FY 1979 is that of improved access of under represented minorities and women to careers in science and engineering. The matter of career access, while related to the early adolescence thrust, is of sufficient importance to continue to set this subject forward as a particular science education concern.

The third priority thrust, initiated in FY 1980, relates to out-of-classroom or informal science learning experiences. This is an important factor in the general development of the public's understanding of science, and is of great importance in interesting and motivating children to study science. Elementary school enrollments are shrinking drastically. Yet within this reduced school enrollment are the scientists who will be entering the scientific labor force at the turn of the century. With a smaller pool to draw from, science must command a greater proportion of talented young students to assure an adequate labor force two decades hence. The motivational aspects of informal, out-of-classroom science learning in the current decade is expected to play an important role in the development of the cadre of scientists of the future.

This year a fourth priority thrust is added to the above continuing concerns—revitalization of college science teaching. For the past several years, higher education (undergraduate institutions in particular) has been affected by a series of events which have, in a cumulative way, affected the quality and currentness of college teaching of science. Declining student enrollments due primarily to birthrate changes have affected faculty mobility and reduced the need for new faculty. This, in conjunction with tenure, has brought about a consequent aging of faculty. In addition, the changing character of the student body and changing patterns in the job market have made the content of many course offerings obsolete. Because of these factors the Foundation is proposing to give priority, as a new major thrust for FY 1981, to the updating of the subject-matter competence of college science faculty.

The program structure necessary to achieve this plan is already in place. It consists

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of four program subactivities, which are administrative groupings of program elements having similar objectives. They are:

Scientific Personnel Improvement—Programs in this subactivity are designed to improve subject-matter competence of pre-college and college science teachers and students; and to identify and encourage the talented, particularly minorities, women and the physically handicapped, to participate more fully in the study of the sciences, mathematics and engineering.

Science Education Resources Improvement—This group of programs is designed to bring about the improvement of instruction in the sciences in schools, 2-year and 4-year colleges, and universities and provide validated knowledge concerning effective instructional strategies and research results in education in the sciences for use by decisionmakers in science education.

Science Education Development and Research—These two programs support scientists and practitioners who are trying to advance our basic knowledge of how the concepts, processes and skills of science are learned and encourage the development of new, more effective materials and methods of instruction, without which the improvement of science education cannot proceed in an orderly fashion.

Science and Society—The programs in this subactivity seek to bring about greater general understanding of science and technology, the connections between them, and the human value implications of both for contemporary life.

Within this program structure the Foundation plans to implement its four priority thrusts. In the accomplishment of this, the strategy initiated in FY 1979 will be continued. This strategy requires that, wherever appropriate in the several science education program mechanisms, special efforts will be made to allocate regular program resources to the furtherance of these priority thrusts. The importance of these priorities in the achievement of the two major goals stated above demands that they be incorporated into each applicable program rather than being isolated as separate or discrete functions.

In addition to these priority concerns, the Foundation's traditional concerns for the support of those students having the greatest talent for study and research in science and for improving the quality of science instruction in junior/community colleges and in 4-year colleges will be continued in FY 1981. The effectiveness of our Nation's leaders—scientists and non-scientist—is directly dependent upon the quality of instruction provided in our institutions of higher eduction.

FY 1981 Budget Highlights and Explantion of Increases and Decreases

Obligations

FY 1979 Actual	$79,979,417
FY 1980 Program	$78,200,000
FY 1981 Request	$85,700,000
Difference—FY 1981/FY 1980	$7,500,000

The amount requested for the FY 1981 Science Education Program Activity is $85,700,000. This represents a 9.6 percent increase over the adjusted Current Plan for FY 1980, $78,200,000.

Given the adjustments in the Science Education Current Plan caused by the transfers to the Department of Education, the percent change between FY 1980 and FY 1981 for the four Science Education Subactivities are:

Scientific Personnel Improvement	11.4%
Science Education Resources Improvement	0.8%
Science Education Development & Research	17.1%
Science and Society	15.0%

Program areas increased in FY 1981 include:

- $425,000 for Graduate Fellowships and Traineeships to provide for increased stipend support.
- $820,000 for Student-Oriented Programs to increase support for special education opportunities in science for middle-school and high school students and for Undergraduate Research Participation.
- $1,011,000 to increase support for improvement of undergraduate instruction in science through the upgrading of subject-matter backgrounds of science faculty.
- $1,359,000 to increase support for minority high school students and for women to increase the access of these underrepresented groups in the scientific and technological labor force.
- $522,000 for improving undergraduate instruction in science through Local Course Improvement.
- $404,000 for Information Dissemination in Science Education to increase the support of activities designed to bring to education decisionmakers information about new instructional materials and techniques and the results of research into the learning of science which can be utilized to improve education in science, including a new emphasis on the dissemination of information on instruction in science in 2- and 4-year colleges.
- $523,000 to increase the Research in Science Education Program for developing new knowlege about the processes by which science is learned and the motivational factors involved in pursuing science as a career.
- $2,035,000 for Development in Science Education to create new instructional materials and techniques primarily to be applied to the furtherance of the Foundation's four Science Education priority thrusts—improvement of educational opportunities for early adolescents, career access for minorities, and women, informal out-of-classroom instructional materials and systems, and the quality of science teaching in higher education.
- $1,080,000 to increase utilization of museums and similar community resources in improving the public's understanding of science and its role in their daily lives.

Programs or projects reduced or eliminated:

- Postdoctoral Fellowships have been transferred to the Cross-Directorate Program section of this budget document.

- The Student-Originated Studies Program has been combined with the Undergraduate Research Participation Program with no loss of support for the group served, undergraduate students.
- The Minority Institutions Science Improvement Program is transferred pursuant to P.L. 96-88, the Department of Education Organization Act of 1979, as well as that portion of the Pre-College Teacher Development in Science Program which involved primary grade (K-4) teachers.
- $448,000 decrease in the Comprehensive Assistance to Undergraduate Science Education Program and a $286,000 decrease in the Instructional Scientific Equipment Program. These decreases are more than offset by increases in other programs which focus directly on the improvement of undergraduate science education.

Thus, the highlight of the FY 1981 Science Education Program activity is its emphasis on increasing those resources allocated to the support of a broad spectrum of activities which will:

- Improve the science instruction of early adolescents, and in particular minorities and girls, to equip them better to appreciate how science affects their daily lives and motivate them to continue the study of science so as not to preclude possible career choices in science and technology;
- Improve study and research opportunities for minorities and women and identify the social, psychological and instructional barriers which these groups face in pursuing careers in science; and, further, to explore and develop the means to alleviate those barriers;
- Increase the number and kind of informal out-of-classroom learning experiences in science, particularly for children, to improve their understanding of science and technology as it touches their lives and to encourage them to delve deeper into the study of science for their personal edfication and possible career utilization; and
- Increase opportunities for college science faculty to upgrade their science backgrounds and to make their course offerings more effective and relevant to the scientific manpower requirements of the future.

In implementing these emphases the Science Education Program will focus on individuals by: 1) identifying talented students at the junior high through graduate school levels and providing special opportunities for extending their education in science; 2) supporting faculty members who wish to update their science subject-matter competencies and improve the quality and relevance of the courses they teach; 3) seeking out and supporting the most talented of those working in the area of science education research and development; and 4) bringing to all citizens an understanding of science through use of the informal education mechanisms with which they interact on a day-to-day basis.

SPECIAL FOREIGN CURRENCY

FY 1981 PROGRAM TOTAL $5,500,000

Obligations by Subactivity

Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Research & Related Activities	$3,836,241	$4,900,000	$4,903,374	$4,400,000	$-503,374
Science Information	165,000	1,100,000	600,000	1,100,000	500,000
Total	$4,001,241	$6,000,000	$5,503,374	$5,500,000	$-3,374

Goals and Description

The National Science Foundation supports science activities in Egypt, India and Pakistan utilizing U.S.-owned foreign currencies designated by the Department of the Treasury as excess to the requirements of the U.S. Government. In this way the National Science Foundation is able to support scientific activities of benefit to the United States and participating foreign countries without exporting dollars. The objectives of the overall activity are pursued chiefly through grants for research and related activities and contracts for the translation into English of technical literature from foreign languages. This activity supports:

- Participation by U.S. scientists and institutions in international cooperative science projects.
- Translations of scientific and technical literature.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$4,001,241
FY 1980 Program	$5,503,374
FY 1981 Request	$5,500,000
Difference—FY 1981/FY 1980	$-3,374

The $5,500,000 requested for the Special Foreign Currency Program Activities is slightly less than the FY 1980 program of $5,503,374.

Percentage Changes in Subactivities

Research and Related Activities	-10%
Science Information	83%

In FY 1981, the Special Foreign Currency Program activities will provide excess currencies in the following dollar equivalents:

- Research and related activites in India and Pakistan ($4,200,000). This total will provide support for new and continuing cooperative research activities and travel for U.S. scientists to attend important scientific meetings abroad.
- Support of cooperative research activities in Egypt ($200,000). This amount representing a reduction of $500,000 from the FY 1980 level, is due to the depletion of SFC reserves in Egypt. Funds will be used to complete existing projects.
- Translations into English from foreign language scientific publications by contractors in India and Pakistan ($1,100,000); an increase of $500,000 to restore the overall program to the annual level of previous years. This is consistent with the recent White House initiatives on innovation highlighting enhancement of the transfer of information from other countries.

EXPLANATION OF PRIOR YEAR CARRYOVERS

In addition to the FY 1980 appropriation, there is $3,343,893 in unobligated funds carried forward from prior years' appropriations, composed of the following:

- *No-Year Funds Carried Forward into FY 1980 ($629,348)*—Prior to FY 1974, NSF appropriations were made on a no-year basis and unobligated balances are available until expended. As a result of closing out expired accounts and reconciling NSF and university records, $629,348 of previously obligated funds were deobligated during FY 1979 but too late to be incorporated into FY 1979 program plans. These funds are being carried into FY 1980 and will be used for basic research in the Mathematical and Physical Sciences ($236,000) and for the Cross-Directorate program of NSF Planning and Evaluation ($393,348).
- *Program Development and Management ($2,547,762)*—An unobligated carryover balance was generated in FY 1979 due to stringent controls imposed by NSF on PD&M funds in response to the Congressional recommendation by the Chairman of the Appropriation Subcommittee on HUD-Independent Agencies that a minimum of $2,500,000 should be carried forward into FY 1980 and applied to cover pay cost requirements resulting from the FY 1979 pay raise legislation.
- *FY 1979 Carryover ($163,409)*—This balance represents one fiftieth of one percent of the FY 1979 Research and Related Activities Appropriation, excluding PD&M. These funds will be used to provide partial support for orderly close-out of projects in the Chemical Threats Program in the Applied Science section of the Engineering and Applied Science Activity. This allocation is within the Congressional limitation of the FY 1979 funds appropriated for the Applied Science and Research Applications (ASRA).
- *Special Foreign Currency Carryover ($3,374)*—These funds will be reallocated in FY 1980 to the Special Foreign Currency Program.

NATIONAL SCIENCE FOUNDATION
SUMMARY AND ANALYSIS TABLES

CONTENTS

ERRATA
APPENDIX TO THE BUDGET OF THE UNITED STATES GOVERNMENT FY 1981

The Program and Financing Schedule included in the FY 1981 Budget Appendix for the NSF Research and Related Activities Appropriation does not reflect final decisions on the FY 1981 budget authority approved by the Office of Management and Budget. Following is a comparison of the total of $1,056,800,000 for this appropriation by program activity:

	Budget Appendix	*Approved By OMB*
Mathematical and Physical Sciences	$264,700,000	$264,200,000
Astronomical, Atmospheric, Earth and Ocean Sciences	240,900,000	241,300,000
U.S. Antarctic Program	63,400,000	63,400,000
Ocean Drilling Programs	29,600,000	27,300,000
Biological, Behavioral and Social Sciences	181,100,000	182,000,000
Engineering and Applied Science	134,500,000	137,000,000
Scientific, Technological, and International Affairs	28,100,000	28,850,000
Cross-Directorate Programs	54,700,000	51,950,000
Program Development and Management	60,700,000	60,800,000

NATIONAL SCIENCE FOUNDATION

RESEARCH AND RELATED ACTIVITIES

For necessary expenses in carrying out the purposes of the National Science Foundation Act of 1950, as amended (42 U.S.C. 1861-1875), title IX of the National Defense Education Act of 1958 (42 U.S.C. 1876-1879), and the Act to establish a National Medal of Science (42 U.S.C. 1880-1881); services as authorized by 5 U.S.C. 3109; maintenance and operation of aircraft and purchase of flight services for research support; hire of passenger motor vehicles; not to exceed $2,500 for official reception and representation expenses; not to exceed $58,100,000 for program development and management; uniforms or allowances therefor, as authorized by law (5 U.S.C. 5901-5902); rental of conference rooms in the District of Columbia; and reimbursement of the General Services Administration for security guard services; $906,050,000, to remain available until September 30, 1981: *Provided*, That not more than $60,900,000 shall be available for Applied Science and Research Applications: *Provided further*, That receipts for scientific support services and materials furnished by the National Research Centers and other National Science Foundation supported research facilities may be credited to this appropriation; *Provided further*, That to the extent that the amount appropriated is less than the total amount authorized to be appropriated for included program activities, all amounts, including floors and ceilings, specified in the authorizing Act for those program activities or their subactivities shall be reduced proportionally: *Provided further*, That if an institution of higher education receiving funds hereunder determines after affording notice and opportunity for hearing to an individual attending, or employed by, such institution, that such individual has, after the date of enactment of this Act, willfully refused to obey a lawful regulation or order of such institution and that such refusal was of a serious nature and contributed to the disruption of the administration of such institution, then the institution shall deny any further payment to, or for the benefit of, such individual. (Department of Housing and Urban Development - Independent Agencies Appropriation Act, 1980; additional authorizing legislation to be proposed.)

lease of one aircraft with option to purchase; $5,000

$60,800,000

$1,056,800,000, to remain available until expended:

SCIENCE EDUCATION ACTIVITIES

For necessary expenses in carrying out science education programs and activities pursuant to the purposes of the National Science Foundation Act of 1950, as amended (42 U.S.C. 1861-1875), including award of graduate fellowships, services as authorized by 5 U.S.C. 3109, and rental of conference rooms in the District of Columbia, [$84,700,000] *Provided*, That to the extent that the amount of this appropriation is less than the total amount authorized to be appropriated for included program activities, all amounts, including floors and ceilings, specified in the authorizing Act for those program activities or their subactivities shall be reduced proportionally. $85,700,000 to remain available until expended:

(Department of Housing and Urban Development - Independent Agencies Appropriation Act, 1980; additional authorizing legislation to be proposed.)

SCIENTIFIC ACTIVITIES [OVERSEAS] (SPECIAL FOREIGN CURRENCY PROGRAM)

For payments in foreign currencies which the Treasury Department determines to be excess to the normal requirements of the United States, for scientific activities, as authorized by law, $5,500,000, to remain available until [September 30, 1981] expended: *Provided*, That this appropriation shall be available in addition to other appropriations to the National Science Foundation, for payments in the foregoing currencies. (Department of Housing and Urban Development - Independent Agencies Appropriatior Act, 1980; additional authorizing legislation to be proposed.)

NATIONAL SCIENCE FOUNDATION

SUMMARY OF FY 1981 BUDGET BY APPROPRIATION AND PROGRAM

	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Research and Related Activities Appropriation					
Mathematical and Physical Sciences	$208,864,917	$230,235,000	$226,412,000	$264,200,000	$37,788,000
Astronomical, Atmospheric, Earth and Ocean Sciences	211,615,014	225,000,000	217,862,000	241,300,000	23,438,000
U.S. Antarctic Program	51,090,853	55,000,000	55,840,000	63,400,000	7,560,000
Ocean Drilling Programs	11,624,910	17,500,000	19,475,000	27,300,000	7,825,000
Biological, Behavioral and Social Sciences	154,704,624	172,250,000	166,531,000	182,000,000	15,469,000
Engineering and Applied Science	109,859,984	113,700,000	111,834,409	137,000,000	25,165,591
Scientific, Technological and International Affairs	23,562,308	24,715,000	26,103,000	28,850,000	2,747,000
Cross-Directorate Programs	16,862,886	17,300,000	25,525,348	51,950,000	26,424,652
Program Development and Management	54,765,898	59,600,000	60,563,762	60,800,000	236,238
Subtotal, Obligations	842,951,394	915,300,000	910,146,519	1,056,800,000	146,653,481
Funding Reconciliation					
Unobligated Balance Brought Forward	-16,845,930	—0—	-3,340,519	—0—	3,340,519
Unobligated Balance Carried Forward	3,340,519	—0—	—0—	—0—	—0—
Adjustments to Prior Year Accounts	-3,759,671	—0—	—0—	—0—	—0—
Unobligated Balance Lapsing	1,313,688	—0—	—0—	—0—	—0—
Research and Related Activities Appropriation	827,000,000	915,300,000	906,806,000	1,056,800,000	149,994,000
Science Education Activities Appropriation					
Scientific Personnel Improvement	33,071,847	32,900,000	31,600,000	35,200,000	3,600,000
Science Education Resources Improvement	28,605,692	29,100,000	24,000,000	24,200,000	200,000
Science Education Development and Research	12,014,423	15,300,000	14,950,000	17,500,000	2,550,000
Science and Society	6,287,455	7,400,000	7,650,000	8,800,000	1,150,000
Subtotal, Obligations	79,979,417	84,700,000	78,200,000	85,700,000	7,500,000
Funding Reconciliation					
Unobligated Balance Brought Forward	-8,671	—0—	—0—	—0—	—0—
Unobligated Balance Lapsing	29,254	—0—	—0—	—0—	—0—
Science Education Activities Appropriation	80,000,000	84,700,000	78,200,000	85,700,000	7,500,000
Special Foreign Currency Appropriation					
Obligations	4,001,241	6,000,000	5,503,374	5,500,000	-3,374
Funding Reconciliation					
Unobligated Balance Brought Forward	-5,532	—0—	-3,374	—0—	3,374
Unobligated Balance Carried Forward	3,374	—0—	—0—	—0—	—0—
Adjustment to Prior Year Accounts	698	—0—	—0—	—0—	—0—
Unobligated Balance Lapsing	219	—0—	—0—	—0—	—0—
Special Foreign Currency Appropriation	4,000,000	6,000,000	5,500,000	5,500,000	—0—
Total, NSF Appropriations	911,000,000	1,006,000,000	990,506,000	1,148,000,000	157,494,000

NATIONAL SCIENCE FOUNDATION

RESEARCH AND RELATED ACTIVITIES APPROPRIATION

ANALYSIS OF CHANGES IN OBLIGATED LEVELS

FY 1979—FY 1981

	Obligations
RESEARCH AND RELATED ACTIVITIES	
FY 1979 Obligated Level	$842,951,394
FY 1980	
Increases:	
Mathematical and Physical Sciences	17,547,083
Astronomical, Atmospheric, Earth and Ocean Sciences	6,246,986
U.S. Antarctic Program	4,749,147
Ocean Drilling Programs	7,850,090
Biological, Behavioral and Social Sciences	11,828,376
Engineering and Applied Science	1,974,425
Scientific, Technological and International Affairs	2,540,692
Cross-Directorate Programs	8,662,462
Program Development and Management	5,797,864
Subtotal	67,195,125
FY 1980 Obligated Level	910,146,519
FY 1981	
Increases:	
Mathematical and Physical Sciences	37,788,000
Astronomical, Atmospheric, Earth and Ocean Sciences	23,438,000
U.S. Antarctic Program	7,560,000
Ocean Drilling Programs	7,825,000
Biological, Behavioral and Social Sciences	15,469,000
Engineering and Applied Science	25,165,591
Scientific, Technological and International Affairs	2,747,000
Cross-Directorate Programs	28,424,652
Program Development and Management	236,238
Subtotal	146,653,481
TOTAL, FY 1981 Obligated Level	1,056,800,000

NATIONAL SCIENCE FOUNDATION

SCIENCE EDUCATION ACTIVITIES APPROPRIATION

ANALYSIS OF CHANGES IN OBLIGATED LEVELS

FY 1979—FY 1981

	Obligations
SCIENCE EDUCATION ACTIVITIES	
FY 1979 Obligated Level	$79,979,417
FY 1980	
Decreases:	
Scientific Personnel Improvement	-1,471,847
Science Education Resources Improvement	-4,605,692
Subtotal	-6,077,539
Increases:	
Science Education Development and Research	2,935,577
Science and Society	1,362,545
Subtotal	4,298,122
FY 1980 Obligated Level	78,200,000
FY 1981	
Increases:	
Scientific Personnel Improvement	3,600,000
Science Education Resources Improvement	200,000
Science Education Development and Research	2,550,000
Science and Society	1,150,000
Subtotal	7,500,000
TOTAL FY 1981 Obligated Level	85,700,000

NATIONAL SCIENCE FOUNDATION

SPECIAL FOREIGN CURRENCY APPROPRIATION

ANALYSIS OF CHANGES IN OBLIGATED LEVELS

FY 1979—FY 1981

	Obligations
SPECIAL FOREIGN CURRENCY	
FY 1979 Obligated Level	$4,001,241
FY 1980	
Increases:	
Research and Related Activities	1,067,133
Science Information	435,000
Subtotal	1,502,133
FY 1980 Obligated Level	5,503,374
FY 1981	
Decrease:	
Research and Related Activities	-503,374
Increase:	
Science Information	500,000
Subtotal	-3,374
Total FY 1981 Obligated Level	5,500,000

NATIONAL SCIENCE FOUNDATION

PERCENTAGE DISTRIBUTION OF TOTAL OBLIGATIONS

	Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*
Research and Related Activities				
Mathematical and Physical Sciences	22.6	22.9	22.8	23.0
Astronomical, Atmospheric, Earth and Ocean Sciences	22.8	22.4	21.9	21.0
U.S. Antarctic Program	5.5	5.5	5.6	5.5
Ocean Drilling Programs	1.3	1.7	2.0	2.4
Biological, Behavioral and Social Sciences	16.7	17.1	16.8	15.9
Engineering and Applied Science	11.9	11.3	11.2	11.9
Scientific, Technological and International Affairs	2.5	2.5	2.6	2.5
Cross-Directorate Programs	1.8	1.7	2.6	4.5
Program Development and Management	5.9	5.9	6.1	5.3
Subtotal, Research and Related Activities	91.0	91.0	91.6	92.0
Science Education Activities				
Scientific Personnel Improvement	3.5	3.3	3.2	3.1
Science Education Resources Improvement	3.1	2.9	2.4	2.1
Science Education Development and Research	1.3	1.5	1.5	1.5
Science and Society	.7	.7	.7	.8
Subtotal, Science Education Activities	8.6	8.4	7.8	7.5
Special Foreign Currency	.4	.6	.6	.5
Total, NSF	100.0	100.0	100.0	100.0

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NATIONAL SCIENCE FOUNDATION
SUMMARY OF OBLIGATIONS BY MAJOR OBJECT CLASSIFICATION

Object	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Research and Related Activities					
Personnel Compensation	$34,705,430	$37,310,000	$39,600,000	$40,081,000	$481,000
Personnel Benefits	3,054,852	3,560,000	3,494,000	3,557,000	63,000
Transportation of Persons	2,555,696	3,235,000	2,999,000	3,145,000	146,000
Travel and Transportation of Things	207,159	300,000	250,000	300,000	50,000
Rents and Communications	7,011,182	7,585,000	6,900,000	6,665,000	-235,000
Printing and Reproduction	430,334	500,000	550,000	600,000	50,000
Other Contractual Services:					
Program Contracts	172,612,624	186,000,000	186,000,000	218,000,000	32,000,000
Program Development and Management Contract Services	3,666,963	4,515,000	4,485,762	4,377,000	-108,762
Supplies and Materials	651,564	620,000	710,000	710,000	—0—
Equipment	2,478,014	1,950,000	1,550,000	1,340,000	-210,000
Grants, Subsidies and Contributions:					
Program Grants	615,572,872	669,700,000	663,582,757	778,000,000	114,417,243
Program Development and Management Grants	4,704	25,000	25,000	25,000	—0—
Subtotal, Research and Related Activities	842,951,394	915,300,000	910,146,519	1,056,800,000	146,653,481
Science Education Activities					
Program Contracts	2,313,914	2,450,000	2,500,000	2,500,000	—0—
Program Grants	77,665,503	82,250,000	75,700,000	83,200,000	7,500,000
Subtotal, Science Education Activities	79,979,417	84,700,000	78,200,000	85,700,000	7,500,000
Special Foreign Currency					
Travel and Transportation of Persons	130,040	300,000	276,000	300,000	24,000
Program Contracts	368,114	1,200,000	600,000	1,100,000	500,000
Program Grants	3,503,087	4,500,000	4,627,374	4,100,000	-527,374
Subtotal, Special Foreign Currency	4,001,241	6,000,000	5,503,374	5,500,000	-3,374
Total, NSF	$926,932,052	$1,006,000,000	$993,849,893	$1,148,000,000	$154,150,107

SUMMARY BUDGET INFORMATION AND SELECTED QUANTITATIVE DATA FY 1979-FY 1981

The following tables summarize the National Science Foundation's FY 1979 through FY 1981 budgets by appropriation title and program and include selected quantitative data indicating level of funding, number of grants, and average cost per grant, for the respective years.

A. Summary of Funding Level By Activity

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Research and Related Activities					
Mathematical and Physical Sciences	$208,864,917	$230,235,000	$226,412,000	$264,200,000	$37,788,000
Astronomical, Atmospheric, Earth and Ocean Sciences	211,615,014	225,000,000	217,862,000	241,300,000	23,438,000
U.S. Antarctic Program	51,090,853	55,000,000	55,840,000	63,400,000	7,560,000
Ocean Drilling Programs	11,624,910	17,500,000	19,475,000	27,300,000	7,825,000
Biological, Behavioral, and Social Sciences	154,704,624	172,250,000	166,531,000	182,000,000	15,469,000
Engineering and Applied Science	109,859,984	113,700,000	111,834,409	137,000,000	25,165,591
Scientific, Technological, and International Affairs	23,562,308	24,715,000	26,103,000	28,850,000	2,747,000
Cross-Directorate Programs	16,862,886	17,300,000	25,525,348	51,950,000	26,424,652
Program Development and Management	54,765,898	59,600,000	60,563,762	60,800,000	236,238
Subtotal, Obligations	842,951,394	915,300,000	910,146,519	1,056,800,000	146,653,481
Unobligated Balances and Other Adjustments	-15,951,394	—0—	-3,340,519	—0—	3,340,519
Research and Related Activities Appropriation	827,000,000	915,300,000	906,806,000	1,056,800,000	149,994,000
Science Education Activities					
Scientific Personnel Improvement	33,071,847	32,900,000	31,600,000	35,200,000	3,600,000
Science Education Resources Improvement	28,605,692	29,100,000	24,000,000	24,200,000	200,000
Science Education Development and Research	12,014,423	15,300,000	14,950,000	17,500,000	2,550,000
Science and Society	6,287,455	7,400,000	7,650,000	8,800,000	1,150,000
Subtotal, Obligations	79,979,417	84,700,000	78,200,000	85,700,000	7,500,000
Unobligated Balances and Other Adjustments	20,583	—0—	—0—	—0—	—0—
Science Education Activities Appropriation	80,000,000	84,700,000	78,200,000	85,700,000	7,500,000
Special Foreign Currency (Obligations)	4,001,241	6,000,000	5,503,374	5,500,000	-3,374
Unobligated Balances and Other Adjustments	-1,241	—0—	-3,374	—0—	3,374
Special Foreign Currency Program Appropriation	4,000,000	6,000,000	5,500,000	5,500,000	—0—
TOTAL NSF APPROPRIATIONS	911,000,000	1,006,000,000	990,506,000	1,148,000,000	157,494,000

Level of Funding by Program, Number of Grants, and Average Cost Per Grant

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Research and Related Activities					
B. Mathematical and Physical Sciences					
I. Mathematical Sciences					
Level of Funding:					
a. Classical Analysis	$2,867,401	$3,335,000	$3,441,000	$3,970,000	$529,000
b. Modern Analysis	2,967,722	3,625,000	3,416,000	3,940,000	524,000
c. Topology, Geometry, and Foundations	5,259,397	5,030,000	4,886,000	5,580,000	694,000
d. Algebra and Number Theory	3,845,942	4,280,000	4,411,000	5,030,000	619,000
e. Applied Mathematics	3,377,809	4,035,000	3,731,000	4,300,000	569,000
f. Statistics and Probability	2,659,376	2,985,000	2,716,000	3,130,000	414,000
g. Special Projects	1,804,929	2,100,000	2,300,000	3,350,000	1,050,000
Subtotal	22,782,576	25,400,000	24,901,000	29,300,000	4,399,000
Number of Awards	885	903	883	891	8
Average $ Per Award	$25,743	$28,128	$28,200	$32,884	$4,684
II. Computer Research					
Level of Funding:					
a. Theoretical Computer Science	2,703,669	2,700,000	2,700,000	2,900,000	200,000
b. Software Systems	2,726,891	3,300,000	3,100,000	3,300,000	200,000
c. Software Engineering	2,459,089	2,900,000	2,700,000	2,900,000	200,000
d. Intelligent Systems	3,289,726	3,300,000	3,200,000	3,400,000	200,000
e. Computer Systems Design	2,907,265	3,300,000	3,135,000	3,350,000	215,000
f. Special Projects	2,684,386	3,100,000	3,400,000	7,500,000	4,100,000
Subtotal	16,771,026	18,600,000	18,235,000	23,350,000	5,115,000
Number of Awards	263	275	267	278	11
Average $ Per Award	$63,768	$67,636	$68,295	$83,992	$15,697
III. Physics					
Level of Funding:					
a. Elementary Particle Physics	22,910,745	23,300,000	22,761,000	26,200,000	3,439,000
b. Intermediate Energy Physics	10,634,998	11,400,000	11,100,000	12,600,000	1,500,000
c. Nuclear Physics	11,557,125	12,300,000	11,800,000	13,500,000	1,700,000
d. Atomic, Molecular, and Plasma Physics	6,727,459	7,200,000	7,100,000	8,300,000	1,200,000
e. Theoretical Physics	7,008,067	7,300,000	7,400,000	9,000,000	1,600,000
f. Gravitational Physics	2,826,175	2,800,000	3,200,000	3,900,000	700,000
Subtotal	61,664,569	64,300,000	63,361,000	73,500,000	10,139,000
Number of Awards	379	336	355	375	20
Average $ Per Award	$162,703	$191,369	$178,481	$196,000	$17,519
IV. Chemistry					
Level of Funding:					
a. Structural Chemistry and Thermodynamics	9,438,647	10,452,000	10,658,000	12,370,000	1,712,000
b. Quantum Chemistry	7,398,196	8,544,000	8,318,000	9,587,000	1,269,000
c. Chemical Dynamics	8,470,000	10,145,000	9,929,000	11,501,000	1,572,000
d. Chemical Analysis	5,139,690	6,100,000	5,783,000	6,653,000	870,000
e. Synthetic Inorganic and Organometaalic Chemistry	5,157,618	6,248,000	5,808,000	6,682,000	874,000
f. Synthetic Organic and Natural Products Chemistry	5,559,330	6,205,000	6,158,000	7,137,000	979,000
g. Chemical Instrumentation	4,067,000	5,241,000	4,760,000	5,570,000	810,000
Subtotal	45,230,481	52,935,000	51,414,000	59,500,000	8,086,000
Number of Awards	905	937	900	900	—0—
Average $ Per Award	$49,978	$56,494	$57,127	$66,111	$8,984

Level of Funding by Program, Number of Grants, and Average Cost Per Grant—Continued

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
V. Materials Research					
Level of Funding:					
a. Solid State Physics	$7,631,289	$8,100,000	$8,140,000	$9,550,000	$1,410,000
b. Solid State Chemistry	4,342,550	4,650,000	4,680,000	5,550,000	870,000
c. Low Temperature Physics	4,336,721	4,700,000	4,630,000	5,400,000	770,000
d. Condensed Matter Theory	4,174,219	4,600,000	4,600,000	5,465,000	865,000
e. Metallurgy	6,434,276	7,100,000	7,050,000	8,300,000	1,250,000
f. Ceramics	3,326,970	3,600,000	3,600,000	4,200,000	600,000
g. Polymers	3,836,000	4,100,000	4,140,000	4,900,000	760,000
h. Materials Research Laboratories	18,130,000	19,600,000	19,351,000	22,180,000	2,829,000
i. National Magnet Laboratory	3,800,000	4,250,000	4,025,000	4,575,000	550,000
j. Synchrotron Radiation	6,004,300	8,000,000	7,885,000	8,000,000	115,000
k. Small Angle Neutron Scattering	399,940	300,000	400,000	430,000	30,000
Subtotal	$62,416,265	$69,000,000	$68,501,000	$78,550,000	$10,049,000
Number of Awards	710	710	730	760	30
Average $ Per Award	$87,910	$97,183	$93,837	$103,355	$9,518
TOTAL, MATHEMATICAL AND PHYSICAL SCIENCES					
Level of Funding	$208,864,917	$230,235,000	$226,412,000	$264,200,000	$37,788,000
Number of Awards	3,142	3,161	3,135	3,204	69
Average $ Per Award	$66,475	$72,836	$72,221	$82,459	$10,238
C. Astronomical, Atmospheric, Earth and Ocean Sciences					
I. Astronomical Sciences					
a. Astronomy Project Support					
Level of Funding:					
1. Solar System Astronomy	1,024,275	1,400,000	1,350,000	1,420,000	70,000
2. Stars & Stellar Evolution	3,568,700	3,900,000	3,950,000	4,230,000	280,000
3. Stellar Systems & Motions	1,127,296	1,350,000	1,260,000	1,320,000	60,000
4. Galactic & Extragalactic Astronomy	5,541,813	5,650,000	5,900,000	6,330,000	430,000
5. Astronomical Instrumentation & Development	5,030,102	6,050,000	5,300,000	5,820,000	520,000
6. Radio Spectrum Management	49,468	100,000	100,000	100,000	—0—
Subtotal	16,341,654	18,450,000	17,860,000	19,220,000	1,360,000
Number of Awards	248	240	252	243	-9
Average $ Per Award	$65,894	$76,875	$70,870	$79,090	$8,220
b. National Astronomy & Ionosphere Center					
Level of Funding:					
1. Scientific Research Support	4,847,998	5,163,000	5,093,000	5,605,000	512,000
2. Construction of Buildings and Research Facilities	77,000	87,000	127,000	65,000	-62,000
Subtotal	4,924,998	5,250,000	5,220,000	5,670,000	450,000
3. Less NASA Facilities Operation Support	-300,000	-300,000	-300,000	-300,000	—0—
Subtotal	4,624,998	4,950,000	4,920,000	5,370,000	450,000
c. Kitt Peak National Observatory					
Level of Funding:					
1. Scientific Research Support	9,511,455	10,395,000	10,358,000	11,283,000	925,000
2. Construction of Buildings & Research Facilities	—0—	—0—	—0—	—0—	—0—
Subtotal	9,511,455	10,395,000	10,358,000	11,283,000	925,000
3. Management Fee	190,000	205,000	212,000	217,000	5,000
Subtotal	9,701,455	10,600,000	10,570,000	11,500,000	930,000

Level of Funding by Program, Number of Grants, and Average Cost Per Grant—Continued

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
d. Cerro Tololo Inter-American Observatory					
Level of Funding:					
1. Scientific Research Support	$4,268,000	$4,707,000	$4,765,000	$5,048,000	$283,000
2. Construction of Buildings & Research Facilities	—0—	50,000	—0—	50,000	50,000
Subtotal	4,268,000	4,757,000	4,765,000	5,098,000	333,000
3. Management Fee	82,000	93,000	95,000	102,000	7,000
Subtotal	4,350,000	4,850,000	4,860,000	5,200,000	340,000
e. National Radio Astronomy Observatory					
Level of Funding:					
1. Scientific Research Support	10,790,000	12,470,000	12,362,000	15,025,000	2,663,000
2. Construction of Buildings and Research Facilities	11,703,000	5,300,000	4,500,000	1,700,000	-2,800,000
Subtotal	22,493,000	17,770,000	16,862,000	16,725,000	-137,000
3. Management Fee	210,000	220,000	220,000	235,000	15,000
Subtotal	22,703,000	17,990,000	17,082,000	16,960,000	-122,000
f. Sacramento Peak Observatory					
Level of Funding:					
1. Scientific Research Support	1,787,000	1,995,000	1,954,000	2,249,000	295,000
2. Construction	—0—	—0—	—0—	—0—	—0—
Subtotal	1,787,000	1,995,000	1,954,000	2,249,000	295,000
3. Management Fee	38,000	40,000	43,000	46,000	3,000
Subtotal	1,825,000	2,035,000	1,997,000	2,295,000	298,000
4. Less DOD Facilities Operating Support	-325,000	-325,000	-325,000	-345,000	-20,000
Subtotal	1,500,000	1,710,000	1,672,000	1,950,000	278,000
Subtotal, Astronomical Sciences	59,221,107	58,550,000	56,964,000	60,200,000	3,236,000
II. Atmospheric Sciences					
a. Atmospheric Sciences Project Support					
Level of Funding:					
1. Aeronomy	4,838,445	5,950,000	5,700,000	6,500,000	800,000
2. Atmospheric Chemistry	3,081,933	4,700,000	3,700,000	4,800,000	1,100,000
3. Climate Dynamics	4,739,932	5,600,000	5,200,000	6,000,000	800,000
4. Experimental Meteorology	2,200,044	2,500,000	2,500,000	3,300,000	800,000
5. Global Atmospheric Research Program	5,661,194	6,000,000	5,600,000	5,600,000	—0—
6. Meteorology	6,610,230	6,400,000	6,469,000	6,900,000	431,000
7. Solar Terrestrial Research	4,845,000	5,100,000	5,100,000	5,500,000	400,000
Subtotal	31,976,778	36,250,000	34,269,000	38,600,000	4,331,000
Number of Awards	475	504	487	535	48
Average $ Per Award	$67,320	$71,925	$70,368	$72,100	$1,732
b. National Center for Atmospheric Research					
Level of Funding:					
1. Atmospheric Analysis and Prediction	2,433,300	2,253,000	2,419,000	2,504,000	85,000
2. Atmospheric Quality	1,418,000	1,736,000	1,630,000	1,741,000	111,000
3. Convective Storms	2,169,000	1,946,000	1,915,000	2,542,000	627,000
4. Advanced Study Program	802,100	686,000	855,000	863,000	8,000
5. High Altitude Observatory	2,202,000	2,195,000	2,343,000	2,565,000	222,000
6. Facilities Operation and Development	10,581,000	12,054,000	11,325,000	12,962,000	1,637,000
7. Administration and Support Services	5,119,600	5,545,000	5,578,000	6,188,000	610,000

Level of Funding by Program, Number of Grants, and Average Cost Per Grant—Continued

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
8. Management Fee	$535,000	$535,000	$535,000	$535,000	0
Subtotal	25,260,000	26,950,000	26,600,000	29,900,000	$3,300,000
c. National Scientific Balloon Facility					
Level of Funding:					
1. National Scientific Balloon Facility	1,870,000	2,470,000	2,270,000	2,600,000	330,000
2. Construction	—0—	80,000	30,000	—0—	-30,000
Subtotal	1,870,000	2,550,000	2,300,000	2,600,000	300,000
Subtotal, Atmospheric Sciences	59,106,778	65,750,000	63,169,000	71,100,000	7,931,000
III. Earth Sciences					
Level of Funding:					
a. Geology	4,634,308	5,050,000	5,050,000	5,650,000	600,000
b. Geophysics	9,857,574	10,350,000	10,040,000	11,000,000	960,000
c. Geochemistry	10,427,522	10,850,000	6,138,000	6,700,000	562,000
d. Petrology	—0—	—0—	4,050,000	4,550,000	500,000
Subtotal, Earth Sciences	24,919,404	26,250,000	25,278,000	27,900,000	2,622,000
Number of Awards	503	516	495	525	30
Average $ Per Award	$49,542	$50,872	$51,067	$53,143	$2,076
IV. Ocean Sciences					
a. Oceanography Project Support					
Level of Funding:					
1. Physical Oceanography	3,793,000	4,250,000	4,150,000	4,650,000	500,000
2. Marine Chemistry	3,506,980	4,000,000	3,850,000	4,350,000	500,000
3. Submarine Geology and Geophysics	7,182,756	7,750,000	7,550,000	8,450,000	900,000
4. Biological Oceanography	5,254,000	5,850,000	5,800,000	7,150,000	1,350,000
Subtotal	19,736,736	21,850,000	21,350,000	24,600,000	3,250,000
Number of Awards	362	357	375	400	25
Average $ Per Award	$54,521	$61,204	$56,933	$61,500	$4,567
b. Coordinated Ocean Research and Exploration					
Level of Funding:					
1. Ocean Dynamics (Environmental Forecasting)	6,778,307	7,200,000	9,500,000	10,500,000	1,000,000
2. Ocean Chemical Processes (Environmental Quality)	5,151,569	6,250,000	4,650,000	6,100,000	1,450,000
3. Seafloor Processes (Seabed Assessment)	4,691,823	5,050,000	4,400,000	5,400,000	1,000,000
4. Living Resources	2,548,600	2,300,000	1,600,000	1,000,000	-600,000
5. General Support	286,318	600,000	600,000	600,000	0
Subtotal	19,456,617	21,400,000	20,750,000	23,600,000	2,850,000
Number of Awards	240	248	250	265	15
Average $ Per Award	$81,069	$86,290	$83,000	$89,000	$6,000
c. Oceanographic Facilities and Support					
Level of Funding:					
1. Operations	18,905,909	20,250,000	19,719,000	22,200,000	2,481,000
2. Ship Construction and Conversion	3,109,626	3,100,000	3,100,000	3,600,000	500,000
3. Shipboarding Equipment & Other Shared Facilities	1,184,837	1,850,000	1,700,000	2,000,000	300,000
Subtotal	23,200,372	25,200,000	24,519,000	27,800,000	3,281,000
Number of Awards	60	75	80	80	0
Average $ Per Award	$386,673	$336,000	$306,488	$347,500	$41,012
Subtotal, Ocean Sciences					
Level of Funding	$62,393,725	$68,450,000	$66,619,000	$76,000,000	$9,381,000
Number of Awards	662	680	705	745	40
Average $ Per Award	$94,250	$100,662	$94,495	$102,000	$7,505

Level of Funding by Program, Number of Grants, and Average Cost Per Grant—Continued

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
V. Arctic Research Program					
Level of Funding:					
a. Atmospheric Sciences	$626,161	$600,000	$600,000	$600,000	—0—
b. Biological Sciences	1,630,780	1,700,000	1,700,000	1,800,000	$100,000
c. Earth Sciences	906,841	900,000	900,000	900,000	—0—
d. Glaciology	1,783,690	1,700,000	1,800,000	1,800,000	—0—
e. Oceanography	897,131	900,000	900,000	1,000,000	100,000
f. Information & Advisory Services	129,417	200,000	132,000	200,000	68,000
Subtotal	5,974,000	6,000,000	5,832,000	6,100,000	268,000
Number of Awards	87	80	76	79	3
Average $ Per Award	$68,700	$75,000	$76,700	$77,200	$500
TOTAL, ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES					
Level of Funding	$211,615,014	$225,000,000	$217,862,000	$241,300,000	$23,438,000
D. U.S. Antarctic Program					
I. U.S. Antarctic Research Program					
Level of Funding:					
a. Atmospheric Sciences	1,960,653	2,000,000	2,000,000	2,300,000	300,000
b. Biological Sciences	1,402,877	2,200,000	2,200,000	2,500,000	300,000
c. Earth Sciences	1,394,214	1,400,000	1,400,000	1,600,000	200,000
d. Glaciology	853,657	900,000	900,000	1,100,000	200,000
e. Oceanography	1,019,225	1,000,000	1,000,000	1,200,000	200,000
f. Information and Advisory Services	651,383	500,000	500,000	600,000	100,000
Subtotal	7,281,809	8,000,000	8,000,000	9,300,000	1,300,000
Number of Awards	140	150	150	170	20
Average $ Per Award	$52,013	$53,300	$53,300	$54,700	$1,400
II. Operations Support Program					
Level of Funding:					
a. Direct Science Support	7,573,545	8,398,000	8,398,000	9,533,000	1,135,000
b. Base Level Support	28,013,006	29,992,000	30,832,000	35,238,000	4,406,000
c. Major Construction and Procurement	8,222,493	8,610,000	8,610,000	9,329,000	719,000
Subtotal	43,809,044	47,000,000	47,840,000	54,100,000	6,260,000
TOTAL, U.S. ANTARCTIC PROGRAM					
Level of Funding	$51,090,853	$55,000,000	$55,840,000	$63,400,000	$7,560,000
E. Ocean Drilling Programs					
I. Deep Sea Drilling Program					
Level of Funding:					
a. Deep Sea Drilling Project, International Phase of Ocean Drilling	18,624,910	21,400,000	21,400,000	23,400,000	2,000,000
b. Less Foreign Contributions	-8,000,000	-6,000,000	-5,525,000	-6,100,000	-575,000
Subtotal	10,624,910	15,400,000	15,875,000	17,300,000	1,425,000
II. Ocean Margin Drilling Project					
Level of Funding:					
a. Project Planning and Evaluation	1,000,000	2,100,000	3,600,000	—0—	-3,600,000
b. Initial Implementation Phase	—0—	—0—	—0—	10,000,000	10,000,000
Subtotal	1,000,000	2,100,000	3,600,000	10,000,000	6,400,000
TOTAL, OCEAN DRILLING PROGRAMS					
Level of Funding	$11,624,910	$17,500,000	$19,475,000	$27,300,000	$7,825,000

Level of Funding by Program, Number of Grants, and Average Cost Per Grant—Continued

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
F. Biological, Behavioral and Social Sciences					
I. Physiology, Cellular and Molecular Biology					
Level of Funding:					
Molecular & Genetic Biosciences					
a. Biochemistry	$8,673,010	$9,330,000	$9,100,000	$10,000,000	$900,000
b. Biophysics	9,441,367	10,205,000	9,918,000	10,900,000	982,000
c. Genetic Biology	8,453,135	9,420,000	9,300,000	10,300,000	1,000,000
d. Metabolic Biology	8,646,437	9,686,000	9,200,000	10,100,000	900,000
Subtotal	35,213,949	38,641,000	37,518,000	41,300,000	3,782,000
Cellular & Physiological Biosciences					
a. Cell Biology	6,300,000	7,689,000	7,500,000	8,700,000	1,200,000
b. Developmental Biology	9,039,188	9,840,000	9,600,000	10,800,000	1,200,000
c. Regulatory Biology	8,600,000	9,330,000	9,100,000	10,100,000	1,000,000
Subtotal	23,939,188	26,859,000	26,200,000	29,600,000	3,400,000
Biological Instrumentation					
a. Biological Instrumentation	3,139,318	4,000,000	3,500,000	3,900,000	400,000
Subtotal	62,292,455	69,500,000	67,218,000	74,800,000	7,582,000
Number of Awards	1,344	1,365	1,305	1,270	-35
Average $ Per Award	$46,350	$50,900	$51,500	$58,900	$7,400
II. Behavioral and Neural Sciences					
Level of Funding:					
a. Neurobiology	8,207,118	9,000,000	8,843,000	9,550,000	707,000
b. Sensory Physiology and Perception	6,313,045	7,100,000	6,800,000	7,450,000	650,000
Subtotal	14,520,162	16,100,000	15,643,000	17,000,000	1,357,000
Cognitive Science					
a. Linguistics	2,474,512	2,600,000	2,600,000	2,800,000	200,000
b. Memory and Cognitive Processes	2,528,292	2,600,000	2,600,000	2,800,000	200,000
Subtotal	5,002,804	5,200,000	5,200,000	5,600,000	400,000
Behavioral Science					
a. Psychobiology	4,105,049	4,200,000	4,600,000	5,000,000	400,000
b. Social and Developmental Psychology	3,320,618	4,000,000	3,300,000	3,500,000	200,000
Subtotal	7,425,667	8,200,000	7,900,000	8,500,000	600,000
Anthropological Science					
a. Anthropological Science	6,124,708	7,400,000	6,700,000	7,600,000	900,000
Subtotal	33,073,342	36,900,000	35,443,000	38,700,000	3,257,000
Number of Awards	783	855	753	740	-13
Average $ Per Award	$42,240	$43,200	$47,100	$52,300	$5,200
III. Social and Economic Science					
Level of Funding:					
Economics, Geography and Political Science					
a. Economics, Geography and Political Science	14,524,147	15,300,000	15,002,000	15,800,000	798,000
Social Measurement and Analysis					
a. Social Measurement and Analysis	10,861,897	11,600,000	11,204,000	12,000,000	796,000
Subtotal	25,386,044	26,900,000	26,206,000	27,800,000	1,594,000
Number of Awards	460	385	480	500	20
Average $ Per Award	$55,190	$69,900	$54,600	$55,600	$1,000

Level of Funding by Program, Number of Grants, and Average Cost Per Grant—Continued

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
IV. Environmental Biology					
Level of Funding:					
a. Ecology	$4,942,244	$5,600,000	$5,222,800	$5,500,000	$277,200
b. Ecosystem Studies	11,663,199	12,750,000	12,372,800	13,000,000	627,200
c. Systematic Biology	7,550,847	8,100,000	7,922,800	8,400,000	477,200
d. Biological Research Resources	4,698,561	7,200,000	6,922,800	8,100,000	1,177,200
e. Population Biology and Physiological Ecology	5,100,132	5,300,000	5,222,800	5,700,000	477,200
Subtotal	33,952,783	38,950,000	37,664,000	40,700,000	3,036,000
Number of Awards	685	690	695	715	20
Average $ per Award	$49,570	$56,400	$54,200	$56,900	$2,700
TOTAL, BIOLOGICAL, BEHAVIORAL AND SOCIAL SCIENCES					
Level of Funding	$154,704,624	$172,250,000	$166,531,000	$182,000,000	$15,469,000
Number of Awards	3,272	3,295	3,233	3,225	-8
Average $ Per Award	$47,280	$52,200	$51,500	$56,400	$4,900
G. Engineering and Applied Science					
I. Electrical, Computer & Systems Engineering					
Level of Funding:					
a. Automation, Bioengineering and Sensing Systems	3,528,154	3,545,000	3,360,000	4,150,000	790,000
b. Electrical and Optical Communications	3,286,256	2,950,000	3,438,000	4,100,000	662,000
c. Computer Engineering	647,267	1,200,000	1,000,000	2,150,000	1,150,000
d. Quantum Electronics, Waves and Beams	3,454,729	3,610,000	3,210,000	3,700,000	490,000
e. Solid-State and Microsturctures Engineering	2,878,748	3,350,000	3,360,000	4,600,000	1,240,000
f. Systems Theory and Operations Research	3,225,834	3,505,000	3,238,000	3,800,000	562,000
Subtotal	17,020,988	18,160,000	17,606,000	22,500,000	4,894,000
Number of Awards	340	363	330	410	80
Average $ Per Award	$50,061	$50,000	$53,351	$54,878	$1,527
II. Chemical and Process Engineering					
Level of Funding:					
a. Kinetics, Catalysis and Reaction Engineering	$1,835,320	2,468,000	2,520,000	2,960,000	440,000
b. Chemical and Biochemical Systems	2,330,150	2,352,000	2,400,000	2,750,000	350,000
c. Engineering Energetics	2,785,382	2,860,000	2,500,000	3,260,000	760,000
d. Thermodynamics and Mass Transfer	3,586,591	4,050,000	3,680,000	4,440,000	760,000
e. Particulate and Multiphase Processes	2,437,651	2,590,000	2,780,000	3,240,000	460,000
Subtotal	12,975,094	14,320,000	13,880,000	16,650,000	2,770,000
Number of Awards	277	305	283	310	27
Average $ Per Award	$46,841	$47,000	$49,045	$53,709	$4,664
III. Civil and Environmental Engineering					
Level of Funding:					
a. Geotechnical Engineering	2,418,993	2,800,000	2,200,000	2,400,000	200,000
b. Structural Mechanics	1,959,000	2,390,000	2,300,000	2,700,000	400,000
c. Water Resources and Environmental Engineering	3,773,777	4,440,000	4,800,000	5,025,000	225,000
Subtotal	8,151,770	9,630,000	9,300,000	10,125,000	825,000
Number of Awards	132	178	140	145	5
Average $ Per Award	$61,756	$54,000	$66,429	$69,828	$3,399

Level of Funding by Program, Number of Grants, and Average Cost Per Grant—Continued

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
IV. Mechanical Sciences and Engineering					
Level of Funding:					
a. Fluid Mechanics	$3,573,306	$3,955,000	$3,800,000	$4,100,000	$300,000
b. Heat Transfer	3,294,694	3,770,000	3,600,000	3,900,000	300,000
c. Solid Mechanics	2,840,730	3,065,000	3,065,000	3,325,000	260,000
d. Mechanical Systems	1,000,000	1,200,000	1,200,000	2,000,000	800,000
Subtotal	10,708,730	11,990,000	11,665,000	13,325,000	1,660,000
Number of Awards	194	240	205	220	15
Average $ Per Award	$55,200	$50,000	$56,902	$60,568	$3,666
V. Applied Research					
Level of Funding:					
a. Applied Social and Behavioral Sciences	8,324,353	8,900,000	8,545,000	9,040,000	495,000
b. Applied Physical, Mathematical, and Biological Sciences and Engineering	9,283,860	9,300,000	9,083,409	9,660,000	576,591
Subtotal	17,608,213	18,200,000	17,628,409	18,700,000	1,071,591
Number of Awards	153	153	190	190	—0—
Average $ Per Award	$115,086	$118,950	$92,781	$98,421	$5,640
VI. Problem-Focused Research					
Level of Funding:					
a. Earthquake Hazards Mitigation	16,473,344	17,900,000	17,900,000	19,400,000	1,500,000
b. Chemical Threats to Man and the Environment	3,152,998	—0—	—0—	—0—	—0—
c. Alternative Biological Sources of Materials	4,132,858	3,900,000	2,936,000	2,900,000	-36,000
d. Community Water Management	724,517	—0—	—0—	—0—	—0—
e. Science and Technology to Aid the Handicapped	1,329,672	1,600,000	2,100,000	2,100,000	—0—
f. Human Nutrition	993,031	1,000,000	989,000	1,100,000	111,000
g. Integrated Basic Research	4,781,731	5,000,000	4,460,000	4,500,000	40,000
h. Problem Analysis	950,683	1,000,000	500,000	500,000	—0—
Subtotal	32,538,834	30,400,000	28,885,000	30,500,000	1,615,000
Number of Awards	432	336	350	340	-10
Average $ Per Award	$75,300	$90,476	$82,500	$89,700	$7,200
VII. Intergovernmental Programs					
Level of Funding:					
a. Local Government	2,641,699	2,850,000	2,400,000	2,400,000	—0—
b. State Government	2,128,069	1,800,000	1,360,000	1,360,000	—0—
c. Science and Technology Resources	361,771	350,000	240,000	240,000	—0—
d. State Science, Engineering, and Technology	—0—	—0—	1,500,000	3,000,000	1,500,000
Subtotal	5,131,539	5,000,000	5,500,000	7,000,000	1,500,000
Number of Awards	75	73	73	89	16
Average $ Per Award	$68,421	$68,493	$75,342	$78,652	$3,310
VIII. Small Business Innovation and Industrial Technology					
Level of Funding:					
a. Small Business Innovation	3,686,589	3,000,000	3,000,000	13,000,000	10,000,000
b. Industrial Technology	2,038,227	3,000,000	2,570,000	5,200,000	2,630,000
c. Appropriate Technology	—0—	—0—	1,800,000	—0—	-1,800,000
Subtotal	5,724,816	6,000,000	7,370,000	18,200,000	10,830,000
Number of Awards	81	95	140	240	100
Average $ Per Awards	$70,677	$63,100	$52,643	$75,833	$23,190

Level of Funding by Program, Number of Grants, and Average Cost Per Grant—Continued

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
TOTAL, ENGINEERING AND APPLIED SCIENCES					
Level of Funding	$109,859,984	$113,700,000	$111,834,409	$137,000,000	$25,165,591
Number of Awards	1,684	1,743	1,711	1,944	233
Average $ Per Award	$65,238	$65,232	$65,362	$70,473	$5,111
H. Scientific, Technological and International Affairs					
I. International Cooperative Scientific Activities					
Level of Funding:					
a. Cooperative Science	6,683,359	6,115,000	7,814,000	7,900,000	286,000
b. Scientific Organizations and Resources	2,946,854	3,700,000	3,700,000	4,200,000	500,000
c. U.N. Conference on Science and Technology for Development	388,936	—0—	—0—	—0—	—0—
d. International Travel	584,364	700,000	700,000	800,000	100,000
Subtotal	10,603,513	10,515,000	12,014,000	12,900,000	886,000
Number of Awards	529	480	572	608	36
Average $ Per Award	$20,044	$21,900	$21,000	$21,200	$200
II. Policy Research and Analysis					
Level of Funding:					
a. Socioeconomic Effects of S&T	1,112,225	1,500,000	1,400,000	1,400,000	—0—
b. International Economic Policy	—0—	—0—	—0—	750,000	750,000
c. Innovation Processes and their Management	1,392,414	1,400,000	1,400,000	1,400,000	—0—
d. Environment, Energy, and Resources	1,087,467	900,000	1,100,000	1,100,000	—0—
e. Technology Assessment	1,452,112	1,300,000	1,249,000	1,400,000	151,000
f. Special Reports and Projects	414,815	700,000	600,000	600,000	—0—
Subtotal	5,459,033	5,800,000	5,749,000	6,650,000	901,000
Number of Awards	137	89	100	103	3
Average $ Per Awards	$39,847	$65,169	$57,490	$64,563	$7,073
III. Science Resources Studies					
Level of Funding:					
a. S&T Personnel	1,909,404	1,775,000	1,688,000	1,700,000	12,000
b. Funding of S&T	588,900	1,025,000	1,000,000	1,100,000	100,000
c. Modeling and Special S&T Indicators	573,303	400,000	500,000	600,000	100,000
Subtotal	3,071,607	3,200,000	3,188,000	3,400,000	212,000
Number of Awards	52	60	48	48	—0—
Average $ Per Award	$59,069	$53,333	$66,417	$70,833	$4,416
IV. Information Science and Technology					
Level of Funding:					
a. Standards & Measures	1,004,576	1,125,000	1,100,000	1,100,000	—0—
b. Structure of Information	1,028,637	1,650,000	1,500,000	1,500,000	—0—
c. Behavioral Aspects of Information Transfer	1,049,942	1,300,000	1,200,000	1,600,000	400,000
d. Infometrics	1,345,000	1,125,000	1,152,000	1,300,000	148,000
e. Information Technology	—0—	—0—	200,000	400,000	200,000
Subtotal	4,428,155	5,200,000	5,152,000	5,900,000	748,000
Number of Awards	40	61	43	46	3
Average $ Per Award	$110,704	$85,246	$119,814	$128,261	$8,447
TOTAL, SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS					
Level of Funding	$23,562,308	$24,715,000	$26,103,000	$28,850,000	$2,747,000

Level of Funding by Program, Number of Grants, and Average Cost Per Grant—Continued

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
I. Cross-Directorate Programs					
I. Industry/University Cooperative Research					
Level of Funding	$5,445,929	$4,000,000	$7,050,000	$20,000,000	$12,950,000
II. Special Facilities and Instrumentation Programs					
Level of Funding:					
a. University Research Facilities Improvement	—0—	—0—	—0—	14,250,000	14,250,000
b. College Instrumentation	606,302	1,000,000	3,300,000	3,000,000	-300,000
c. Regional Instrumentation Facilities	5,000,000	4,800,000	4,800,000	3,000,000	-1,800,000
Subtotal	5,606,302	5,800,000	8,100,000	20,250,000	12,150,000
III. Cross-Directorate International Programs					
Level of Funding:					
a. US/USSR Cooperative Research Program	3,387,484	3,200,000	3,200,000	3,200,000	—0—
b. US/China Cooperation in Basic Research	—0—	—0—	1,000,000	2,000,000	1,000,000
Subtotal	3,387,484	3,200,000	4,200,000	5,200,000	1,000,000
IV. Other Programs					
Level of Funding:					
a. Research Initiation in Minority Institutions	425,944	1,000,000	1,000,000	1,000,000	—0—
b. Experimental Program to Stimulate Competitive Research	875,310	2,700,000	3,850,000	2,700,000	-1,150,000
c. Postdoctoral Fellowships	*(1,774,251)	*(900,000)	*(900,000)	900,000	900,000
d. Decision and Management Sciences	—0—	—0—	—0—	1,000,000	1,000,000
e. Waterman Award	150,000	**(150,000)	150,000	150,000	—0—
f. NSF Planning and Evaluation	971,917	600,000	1,175,348	750,000	-425,348
Subtotal	2,423,171	4,300,000	6,175,348	6,500,000	324,652
TOTAL, CROSS-DIRECTORATE PROGRAMS					
Level of Funding	$16,862,886	$17,300,000	$25,525,348	$51,950,000	$26,424,652
J. Program Development and Management					
Level of Funding	$54,765,898	$59,600,000	$60,563,762	$60,800,000	$236,238
Full-Time Permanent Positions	1,260	1,280	1,274	1,293	19
Positions—End of Year	1,262	1,280	1,274	1,293	19
Subtotal, Research and Related Activities	$842,951,394	$915,300,000	$910,146,519	$1,056,800,000	$146,653,481
Unobligated Balances, Deferrals and Other Adjustments	-15,951,394	—0—	-3,340,519	—0—	3,340,519
Research and Related Activities Appropriation	$827,000,000	$915,300,000	$906,806,000	$1,056,800,000	$149,994,000
K. Science Education Activities					
I. Scientific Personnel Improvement					
a. Fellowships and Traineeships					
Level of Funding:					
1. Graduate Fellowships	11,405,576	10,800,000	10,900,000	11,800,000	900,000

*Post-Doctoral Fellowships included in Science Education Activities prior to FY 1981.
**Funding for Waterman Award for FY 1980 was included in the budget request for the research directorates.

Level of Funding by Program, Number of Grants, and Average Cost Per Grant—Continued

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
2. Minority Institution Graduate Fellowships and Traineeships	$2,082,327	$2,000,000	$2,175,000	$2,600,000	$425,000
3. Postdoctoral Fellowships	1,774,251	900,000	900,000	—0—	-900,000
Subtotal	15,262,154	13,700,000	13,975,000	14,400,000	425,000
Number of Awards	1,744	1,670	1,650	1,560	-90
Average $ Per Award	$8,751	$8,200	$8,470	$9,230	$760
b. Minorities, Women and the Physically Handicapped in Science					
Level of Funding	2,361,832	2,000,000	2,240,000	3,600,000	1,360,000
Number of Awards	81	60	75	120	45
Average $ Per Award	$29,158	$33,300	$29,900	$30,000	$100
c. Student-Oriented Programs					
Level of Funding:					
1. Student Science Training	2,481,787	2,300,000	2,291,000	3,000,000	709,000
2. Student-Originated Studies	977,209	900,000	897,000	—0—	-897,000
3. Undergraduate Research Participation	1,958,629	2,000,000	1,992,000	3,000,000	1,008,000
Subtotal	5,417,635	5,200,000	5,180,000	6,000,000	820,000
Number of Awards	319	350	300	330	30
Average $ Per Award	$16,983	$14,900	$17,266	$18,181	$915
d. Faculty Improvement					
Level of Funding:					
1. Pre-College Teacher Development	6,996,074	9,000,000	7,216,000	7,200,000	-16,000
2. Science Faculty Programs	3,034,152	3,000,000	2,989,000	4,000,000	1,011,000
Subtotal	10,030,226	12,000,000	10,205,000	11,200,000	995,000
Number of Awards	387	460	380	380	—0—
Average $ Per Award	$25,918	$26,100	$26,860	$29,470	$2,610
Subtotal, Scientific Personnel Improvement	33,071,847	32,900,000	31,600,000	35,200,000	3,600,000
II. Science Education Resources Improvement					
a. Comprehensive Assistance to Undergraduate Science Education					
Level of Funding	13,518,541	13,500,000	13,441,000	13,000,000	-441,000
Number of Awards	72	73	69	65	-4
Average $ Per Award	$187,800	$184,900	$194,800	$200,000	$5,200
b. Undergraduate Instructional Improvement					
Level of Funding:					
1. Local Course Improvement	2,954,529	3,000,000	2,988,000	3,500,000	512,000
2. Instructional Scientific Equipment	3,448,037	3,500,000	3,486,000	3,200,000	-286,000
Subtotal	6,402,566	6,500,000	6,474,000	6,700,000	226,000
Number of Awards	435	495	495	450	-45
Average $ Per Award	$14,719	$13,100	$13,100	$14,900	$1,800
c. Minority Institutions, Science Improvement					
Level of Funding	4,909,749	3,000,000	—0—	—0—	—0—
d. Resource Centers for Science and Engineering					
Level of Funding	2,743,871	2,800,000	2,789,000	2,800,000	11,000
Number of Awards	1	1	1	1	—0—
Average $ Per Award	$2,743,871	$2,800,000	$2,789,000	$2,800,000	$11,000

Level of Funding by Program, Number of Grants, and Average Cost Per Grant—Continued

Activity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
e. Information Dissemination					
Level of Funding	$1,030,965	$1,300,000	$1,296,000	$1,700,000	$404,000
Number of Awards	36	50	50	63	13
Average $ Per Award	$28,640	$26,000	$25,920	$27,000	$1,080
Subtotal, Science Education Resources Improvement	28,605,692	29,100,000	24,000,000	24,200,000	200,000
III. Science Education Development and Research					
a. Development in Science Education					
Level of Funding	8,184,741	9,000,000	8,965,000	11,000,000	2,035,000
Number of Awards	53	117	60	75	15
Average $ Per Award	$154,429	$76,900	$149,400	$146,700	$-2,700
b. Research in Science Education					
Level of Funding	3,829,682	6,300,000	5,985,000	6,500,000	515,000
Number of Awards	40	48	60	62	2
Average $ Per Award	$95,742	$131,300	$99,750	$104,800	$5,050
Subtotal, Science Education Development and Research	12,014,423	15,300,000	14,950,000	17,500,000	2,550,000
IV. Science and Society					
a. Public Understanding of Science					
Level of Funding	3,435,088	4,000,000	3,900,000	5,000,000	1,100,000
Number of Awards	30	30	30	35	5
Average $ Per Award	$114,503	$133,300	$130,000	$142,857	$12,857
b. Ethics and Values in Science Technology					
Level of Funding	1,259,144	1,300,000	1,693,000	1,700,000	7,000
Number of Awards	23	20	53	53	—0—
Average $ Per Award	$54,745	$65,000	$32,000	$32,000	—0—
c. Science for Citizens					
Level of Funding	1,593,223	2,100,000	2,057,000	2,100,000	43,000
Number of Awards	52	78	56	48	-8
Average $ Per Award	$30,639	$26,900	$36,700	$43,800	$7,100
Subtotal, Science and Society	6,287,455	7,400,000	7,650,000	8,800,000	1,150,000
Subtotal, Science Education Activities	$79,979,417	$84,700,000	$78,200,000	$85,700,000	$7,500,000
Unobligated Balances, Deferrals and Other Adjustments	20,583	—0—	—0—	—0—	—0—
Science Education Activities Appropriation	$80,000,000	$84,700,000	$78,200,000	$85,700,000	$7,500,000
L. Special Foreign Currency Program					
Level of Funding:					
I. Research & Related Activities	3,836,241	4,900,000	4,903,374	4,400,000	-503,374
II. Science Information	165,000	1,100,000	600,000	1,100,000	500,000
Subtotal, Special Foreign Currency Program	$4,001,241	$6,000,000	$5,503,374	$5,500,000	$-3,374
Unobligated Balances and Other Adjustments	-1,241	—0—	-3,374	—0—	3,374
Special Foreign Currency Program Appropriation	4,000,000	6,000,000	5,500,000	5,500,000	—0—
Number of Awards	161	261	263	253	-10
Average $ Per Award	$24,852	$23,000	$20,925	$21,700	$775
TOTAL NSF APPROPRIATIONS	$911,000,000	$1,006,000,000	$990,506,000	$1,148,000,000	$157,494,000

MATHEMATICAL AND PHYSICAL SCIENCES

PROGRAM ACTIVITY SUMMARY

FY 1981 PROGRAM TOTAL $264,200,000

Obligations by Subactivity

Page	Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
A-I	Mathematical Sciences	$22,782,576	$25,400,000	$24,901,000	$29,300,000	$4,399,000
A-II	Computer Research	16,771,026	18,600,000	18,235,000	23,350,000	5,115,000
A-III	Physics	61,664,569	64,300,000	63,361,000	73,500,000	10,139,0000
A-IV	Chemistry	45,230,481	52,935,000	51,414,000	59,500,000	8,086,000
A-V	Materials Research	62,416,265	69,000,000	68,501,000	78,550,000	10,049,000
	Total	$208,864,917	$230,235,000	$226,412,000	$264,200,000	$37,788,000

Goals and Description

The goal of the Mathematical and Physical Sciences (MPS) activity is to develop a fundamental understanding of the physical laws that govern the world and the universe in which we live. To further this goal, basic research activities are supported in the disciplines of mathematics, computer science, physics, chemistry, and materials. Research results in these fields provide the underlying knowledge for the future technological developments upon which our economic and social well being so intimately depend. They also form much of the intellectual underpinning for engineering and the biological, environmental, and behavioral sciences, as well as provide many of the research instruments and techniques necessary to progress in these fields. More specifically, the Mathematical and Physical Sciences activity strengthens the Nation's research capability by:

- Creating new mathematical knowledge and applying that knowledge to achieve a better understanding of physical, biological, and social phenomena.
- Developing an understanding of the science that underlies computer technology and formulating the principles of design of computer hardware and software systems.
- Advancing knowledge of the fundamental physical laws governing matter and energy with the ultimate goal of achieving a unified, self-consistent explanation of all physical phenomena.
- Stimulating the development of modern chemistry on a broad front, including chemical synthesis, analysis, dynamics, structure, and theory.

- Developing an improved understanding of the fundamental principles, phenomena, and concepts that govern the physical, chemical, and mechanical properties of materials.

With the development of powerful new theoretical concepts, incisive experimental approaches, and sophisticated modern instruments of unprecedented power, resolution, and sensitivity, the MPS disciplines are currently in a period of unusual activity and opportunity. The richness of modern mathematical research, the challenge of complexity in computer science, and progress in understanding the fundamental forces and constituents of matter illustrate the diversity of this opportunity. The revolution in laser-related research, the intense activity in surface science and catalysis research, the power of modern synthetic chemistry, and the unique properties of new amorphous and polymeric materials all suggest the potential to serve the future needs of society as well. Overall, MPS ensures that the most highly qualified investigators across the broad range of disciplines are provided with the resources required to carry out their research, including the necessary instrumentation. To provide these resources MPS utilizes a wide range of support modes, from individual research projects through departmental or university laboratories to regional or national research facilities.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The Regional Instrumentation Facilities and the Industry-University Cooperative Research programs no longer appear as line items in the MPS FY 1980 Budget Request and Current Plan, but are incorporated elsewhere under Cross-Directorate programs. Similarly, components of other Cross-Directorate programs, formerly included in the budgets of individual MPS subactivities, have been deleted from those budgets and incorporated in the budgets of the corresponding Cross-Directorate programs.

The FY 1980 Current Plan of $226.41 million is $3.83 million below the FY 1980 Budget Request of $230.24 million, as a result of Congressional action and the expansion of selected Cross Directorate programs. The relatively small decrease for Materials Research, compared to the FY 1980 Request, results from the transfer of funds from other MPS subactivities to Materials Research. This transfer of funds, together with additional support for materials-related research in the Cross-Directorate programs, is in response to Congressional recommendations. Taking into account the anticipated increase in costs of performing research, the FY 1980 Current Plan corresponds at best to the FY 1979 level of effort in all MPS subactivities except Chemistry, where there is modest real growth. The lower increase in Physics, compared to FY 1979, results from the transfer of the Michigan State University Phase II heavy ion accelerator construction responsibility to the Department of Energy.

The FY 1980 Current Plan includes $36.8 million for instrumentation and equipment, a decrease of $4.8 million below the FY 1980 Request. This reduction results from partial completion of the Cornell Electron Storage Ring conversion, completion of the Michigan State University Phase I Heavy Ion Facility, and construction of the

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synchrotron radiation facilities at Stanford and Wisconsin during FY 1979. In FY 1980 the resulting $4.8 million is applied to increased operations and research costs at these facilities.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$208,864,917
FY 1980 Program	$226,412,000
FY 1981 Request	$264,200,000
Difference—FY 1981/FY 1980	$37,788,000

The $264.2 million requested for Mathematical and Physical Sciences (MPS) is 16.7 percent above the FY 1980 program level. Even taking into account the anticipated increased costs of performing research, this increase represents significant real growth. NSF has a unique responsibility for ensuring the health and vitality of the Nation's research across each of the component disciplines, although careful consideration is given to trends in research funding by other Federal agencies in determining program requirements. Detailed analysis of these program requirements in connection with long range planning activities has established that overall Federal support for research in the MPS disciplines has eroded to the point where adequate funding is no longer available to provide the most highly qualified investigators with the resources required to carry out their research in an optimum manner.

The FY 1981 Budget Request emphasizes augmented research project support for all disciplines, including provision of modern research instrumentation. In general, this emphasis is directed at achieving real growth in average award size in order to provide more adequate support, including that to young investigators, for graduate students, postdoctoral fellows, equipment, and materials and supplies. At the same time, provision is made for meeting the essential requirements of the university laboratories, such as the Materials Research Laboratories and the Nuclear Science Laboratories, and of major user facilities such as the Cornell Electron Storage Ring, the Synchrotron Radiation Facilities, and the National Magnet Laboratory. These laboratories and facilities represent an effective, and often the only, mode for carrying out certain types of research. The request also includes a special emphasis on improving the Nation's academic research capability in experimental computer science. Computer research has become primarily a theoretical science in U.S. universities, and the emergence of modern integrated circuit technology presents both the opportunity and the means for making posssible major experimental contributions to this important and growing field. Throughout, the FY 1981 budget request provides for increased flexibility to undertake, on a selective basis, new initiatives particularly suited to MPS capabilities, and to respond more positively to proposals in areas of expanding scientific opportunity.

The distribution of the FY 1981 budget amounts for the five MPS subactivities is based on an extensive analysis of research needs and opportunities. Percentage changes are as follows:

Mathematical Sciences	17.7%
Computer Research	28.1%
Physics	16.9%
Chemistry	15.7%
Materials Researach	14.7%

Explanation of Increases, Decreases, and Continuing Emphases

Research Project Support and Instrumentation—In the Mathematics, Physics, Chemistry, and Materials Research subactivities, research project support is increased by $25.2 million to a total of $174.7 million. Included in that amount is project instrumentation and equipment, as well as Chemistry departmental equipment. Because of the unique requirements of Computer Research, that subactivity is considered separately below.

- Significant real growth in average award size is achieved, particularly in Physics, Chemistry, and Materials Research.
- The postdoctoral program in Mathematics is continued at a level of $0.6 million, and a modest program for young investigators is initiated in Physics at a level of $0.3 million. The young investigator question is addressed in all disciplines, however, primarily by provision of more adequate research support.
- Research related to microstructures in Chemistry and Materials Research is increased by $1.8 million to a total of $7.7 million.
- Emphasis continues in areas of expanding scientific opportunity such as laser-related research, elementary particle and gravitational physics, organometallic chemistry, surface science and catalysis, and unique new materials.
- Within this total, research project instrumentation, including departmental equipment in Chemistry, is increased by $5.0 million to a total of $26.2 million.

University Laboratories—Support for University Laboratories in Physics and Materials Research is increased by $3.9 million to a total of $36.1 million.

- The research capabilities of the intermediate energy electron accelerators at Illinois and Stanford are enhanced by increasing their support by $0.8 million to a total of $4.6 million.
- Instrumentation and operating support are maintained at the other university nuclear science laboratories by the phase out of one laboratory, a significant reduction in NSF support of another, and an additional increase in funding of $0.3 million to a total of $9.2 million for the remaining laboratories.
- Support for the Materials Research Laboratories is increased by $2.8 million, to a total of $22.2 million. This increase strengthens cooperative research in

key areas, permits some upgrading of experimental facilities, including instrumentation, and provides for more viable support levels at the smaller laboratories.

National User Facilities—Support for national user facilities in Mathematics, Physics, Chemistry, and Materials Research is increased by $3.4 million, to a total of $29.9 million.

- Support for a mathematical sciences research institute and/or other alternative modes of conducting mathematics research is increased by $0.8 million to a total of $1.4 million.
- Increases to offset the increased costs of performing research are provided for the newly converted Cornell Electron Storage Ring, the Indiana University Cyclotron Facility, and the Michigan State University Phase I heavy ion accelerator, thus ensuring effective levels of operation.
- An increase of $0.6 million provided for the Institute for Theoretical Physics as it enters its first full year of operation at the planned level of $1.2 million.
- Funding for the synchrotron radiation facilities at Stanford and Wisconsin is held essentially constant as construction activities are completed and increased levels of operation and instrumentation are implemented. Support for half-time dedicated operation of the accelerator at Stanford (SPEAR) continues at a level of $2.0 million.
- A modest increase in the current level of effort at the National Magnet Laboratory is utilized to provide for magnet development and instrumentation.

Computer Research—An increase of $5.1 million is provided for Computer Research, bringing the total support for that subactivity to $23.35 million. This level of support permits significantly increased emphasis on establishing a meaningful experimental computer research capability in U.S. universities.

- Longer range support for experimental computer research is increased by $2.7 million to a total of $3.7 million. Although dependent on the nature and quality of proposals received, it is anticipated that this support will provide for modern computing facilities, together with associated development, maintenance, and operating costs.
- In order to permit effective sharing of resources among dispersed research groups, $0.75 million is provided to develop a nationwide computer research network designed during FY 1980.
- A national competition for awards to young investigators in experimental computer science is initiated at a level of $0.9 million.
- Support for microstructures-related computer research is increased by $0.2 million to a total of $1.3 million.

Research Instrumentation and Equipment—Included above is support for instrumentation and equipment for research projects, special equipment programs, university

laboratories, and major user facilities, which is increased by $5.5 million to a total of $42.4 million. Of this amount, some $1.0 million is for non-recurring instrumentation requirements, compared to $3.0 million in FY 1980.

Coordination and Relationship to Other Efforts

Mathematics—Since NSF accounts for 90-95 percent of all Federal support for core mathematics, the Foundation has a unique responsibility in this area. It is estimated that NSF support of applied mathematics and statistics is about 50 percent of the total Federal effort. Coordination of the Federal effort is accomplished through an interagency group called ICEMAP (Interagency Committee for Extramural Mathematics Programs), which meets once a year to exchange lists of grants and budget data. Also, informal telephone and personal contacts are made on a continuous basis.

Computer Research—NSF provides 50-80 percent of support for basic research in various areas of computer science and thus bears primary responsibility for such support. Interagency coordination is effected by an informal coordinating committee, by exchange of proposal and action lists and by person-to-person contacts. Particularly close coordination is maintained with DOD, DOE, NASA, and NIH in the new initiative to provide increased long-range support for experimental computer science.

Physics—NSF provides one-third of the support for university groups performing experiments in the elementary particle physics field, one-quarter of the national support for nuclear physics, including three-fifths of the university-based support, one-quarter of the national program in basic atomic physics, and 95 percent of the support for ground-based experimental and theoretical gravitational physics. Coordination with other government agencies is achieved through the High Energy Physics Advisory Panel, the joint NSF/DOE Nuclear Science Advisory Committee, and Interagency Committees on Atomic and Molecular Physics and on Plasma Physics.

Chemistry—NSF plays a pivotal role, providing 45-50 percent of the Federal support of basic research in Chemistry in American colleges and universities. Coordination is accomplished through the Federal Interagency Chemistry Representatives Group, and the Interagency Coordinating Group in Laser Development and Applications.

Materials Research—Approximately 55 percent of all Federal support for basic materials research at academic institutions is provided by NSF. Interagency coordination occurs at several administrative levels which include the Committee on Materials of the Federal Coordinating Council for Science, Engineering and Technology, the Department of Defense Apportionment Reviews and informal program reviews. NSF has been instrumental in establishing and operating the Interagency Materials Group.

Changes in Budget Structure

The Engineering subactivity was transferred from the Mathematical and Physical Sciences, and Engineering (MPE) activity into the new Engineering and Applied

Science activity in accordance with NSF reorganization effective on July 1, 1979. The remaining five MPE subactivities were renamed the Mathematical and Physical Sciences activity.

The Regional Instrumentation Facilities and Industry-University Cooperative Research Programs, which were line items in the MPE Budget Request for Fy 1980, have been included in the FY 1981 Budget Request for Cross Directorate Programs. Similarly, these portions of other Cross Directorate Programs, formerly contained within the budgets of individual MPE subactivities, have been transferred to this category in the FY 1981 Budget Request.

In order to maintain consistency and to permit realistic comparison with the FY 1981 Budget Request, the FY 1979 and FY 1980 budgets for MPS have been adjusted to reflect the new FY 1981 budget structure.

Evaluation and Oversight

The major project-by-project evaluation effort made in MPS is the proposal review process, which involves evaluation of previous research or progress made under a grant when renewed support from NSF is requested. Since the intellectual importance or long term benefit from a given basic research effort may not be not discernible until long after the work is completed, this "evaluation" often reflects only the estimated quality of the expected research results.

Site visits by NSF staff and by teams of consultants provide an important element of evaluation and oversight in certain science areas.

Most of the external evaluation and oversight activities in MPS are carried out by formally constituted advisory committees for each of the five discipline-oriented subactivities. These committees are comprised of from twelve to thirty-six members who normally serve for three 1-year terms arranged so that approximately one-third of the membership changes each year. Although the details of evaluation vary somewhat between subactivities, each committee normally meets one or more times, usually for two days, each fiscal year. One or more programs in each subactivity are selected for particularly detailed examination at specific meetings, either by the full committee or by a suitably constituted subcommittee. For such detailed examination the committee or subcommittee is augmented by consultants especially qualified in the scientific area being evaluated. The advisory committees also have overall advisory responsibility for the collective activities of the respective subcommittees.

Following each meeting, the committee or subcommittee prepares a written report, which is provided to the Assistant Director for MPS and to the Director of NSF.

MATHEMATICAL SCIENCES SUBACTIVITY $29,300,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Classical Analysis	$2,867,401	$3,335,000	$3,441,000	$3,970,000	$529,000
Modern Analysis	2,967,722	3,625,000	3,416,000	3,940,000	524,000
Topology, Geometry, and Foundations	5,259,397	5,030,000	4,886,000	5,580,000	694,000
Algebra and Number Theory	3,845,942	4,280,000	4,411,000	5,030,000	619,000
Applied Mathematics	3,377,809	4,035,000	3,731,000	4,300,000	569,000
Statistics and Probability	2,659,376	2,995,000	2,716,000	3,130,000	414,000
Special Projects	1,804,929	2,100,000	2,300,000	3,350,000	1,050,000
Total	$22,782,576	$25,400,000	$24,901,000	$29,300,000	$4,399,000

Objectives and Description

The objectives of the Mathematical Sciences research program are to:

- create new mathematical knowledge and
- apply mathematical knowledge to the better understanding of phenomena of the physical, biological, and social milieus of mankind.

The first of these objectives is achieved by the creation of new mathematical structures and techniques and the analysis and study of relations which exist between them. The second objective is achieved by translating phenomena of the physical, engineering, biological, environmental, and social sciences into mathematical problems, and then, by the application fo existing, or the creation of new mathematics, finding soutions of the mathematical problems so formulated.

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Mathematics is characterized by its universality, the power of its abstractions, and its use as a tool in all of the sciences. Mathematics has made major contributions to the advancement of the physical sciences and engineering in this century. In the past few decades it has also become an essential tool for biological and social scientists.

Mathematics created with a motivation which lies within mathematical theory itself is called core mathematics. Mathematics consciously created or used as a tool for understanding various aspects of nature is called applied mathematics. This means that there is a continuous use of known mathematics and a simultaneous creation of

new mathematics as the mathematical sciences are used to solve problems in the other sciences. The effects are mutually beneficial. Mathematics serves as a language and tool for the other sciences, and the problems presented by the other sciences stimulate the creation of new mathematical ideas and techniques.

This use of mathematics by physics, engineering, chemistry, and astronomy has made possible their development into quantitative sciences, and one may therefore say that the mathematical sciences constitute an indispensable undergirding of science. The length of time from the creation of a mathematical concept until it finds use in another science and from this to the use of that science by a societal structure can be quite long. This lack of immediate relevance and uncertainty as to ultimate relevance tends to limit public enthusiasm regarding the importance of mathematics.

The result is that research in the mathematical sciences in the U.S. has been and continues to be heavily concentrated in academic institutions, where it has traditionally been conducted as an adjunct to teaching. Approximately eighty percent of the recipients of the Ph.D. in the mathematical sciences take academic positions. Most of the remainder take positions in the Federal Government or in a relatively few large industrial organizations.

Major Research Questions

A number of major mathematics research questions involve the following areas:

- *Quantum Scattering Theory*. This represents one of the basic subareas of mathematical physics. The goal is a rigorous mathematical understanding of scattering phenomena, especially involving multiparticle systems. There have been important recent developments in the area of geometric methods, in inverse scattering problems, and in long range scattering. A particularly healthy trend involves fruitful cross-fertilization with molecular dynamicists and calculational atomic theorists thus far mainly through questions involving resonances.
- *Nonlinear Partial Differential Equations*. The theory of nonlinear partial differential equations is currently occupying the attention of many outstanding mathematicians. Several particularly exciting new thrusts now evident are the result of studies concerning nonlinear waves and convex hypersurfaces with given curvatures.
- *Nonlinear System Theory*. An important problem in mathematical control theory is to determine when a system may be modified by feedback to obtain desired performance. For linear systems this problem is well understood, the results having been developed in the past decade. A major research question is the generalization of the known linear results to nonlinear systems coupling, noninteracting control, and stabilization. The resolution of this problem has important practical implications, since all real systems are nonlinear; the mathematical problem is of considerable inherent interest since it draws upon algebraic and differential geometry and makes substantial connections with recent results in quantum mechanics and nonlinear wave theory.

- *Explanation of the Structure of 3- and 4-Dimensional Manifolds.* While major results have recently been obtained for the higher dimensional manifolds, 3- and 4-dimensional manifolds have proven astonishingly resistant to analysis. The presence of this gap may indicate some fundamental lack of understanding of topological structures, and its removal is thus of prime importance. New methods appear to be called for. In this connection very recent work concerning the existence of hyperbolic structures on manifolds offers great promise.
- *Relationship of Analytic and Algebraic Theories and Structures to Number* Theory. There have always been surprising connections between number theory and other, seemingly unrelated, areas of mathematics. These connections, such as those involving complex analysis and number theory, studied by Riemann in the middle of the last century, have had profound implications, both within number theory and in subareas previously thought to be disparate from number theory. Among the deepest and most exciting research efforts currently being undertaken is a variation on this theme which involves applications of harmonic analysis, representation theory, algebraic groups, and other mathematical theories and structures to very important and long-standing problems in number theory.
- *Methods of Using Modern Computer Technology in Data Analysis.* Mainly because of an increase in computer speed, some statistical techniques which require large amounts of computation are becoming practical, and investigations are now underway on man-machine interactive ways for finding patterns in multidimensional data.

Significant Recent Achievements

Surfaces of Minimal Area and Hyperbolic Structures on Manifolds

W. H. Meeks and S. T. Yau of Stanford University have shown, among other related results, that if C is a very mildly restricted simple closed curve in 3-dimensional Euclidean space, then any disk of least area whose boundary is C has no intersections with itself. The restrictions guarantee, for example, that the curve C is not knotted. Besides solving a famous problem dating from the 1930's when Jesse Douglas proved the existence of possibly self-intersecting, minimal area disks spanning such curves C, for which he received one of the first two Fields Medals in 1936, the solution of Meeks and Yau lends itself to a number of interesting generalizations to 3-dimensional manifolds. In particular, a new proof is provided for the classical Dehn's lemma and sphere theorem for 3-dimensional manifolds, for which the late Christos Papakyriakopoulos received the Veblen prize of the American Mathematical Society in the late 1950's.

Even more significant is the way in which these results can be combined with very recent work of William Thurston of Princeton University, winner of the 1979 Waterman Award for his work on the theory of foliations and his more recent work showing the existence of a certain kind of non-Euclidean geometric structure. Com-

bining the results of Meeks and Yau, the results of Thurston on hyperbolic structures, and an argument due to Cameron M. Gordon of the University of Texas at Austin, yields an affirmative answer to the celebrated Smith Conjecture, first formulated by Paul A. Smith of Columbia University in the 1940's. Smith proved that if a certain type of transformation of the 3-dimensional sphere left a set of points fixed, then these points form a simple closed curve. He conjectured that the curve in question could never be knotted. It has taken more than 30 years to vindicate Smith's intuition. The methods involved are powerful and hold great promise for future development in mathematics.

Spectral Geometry

What is known succinctly as spectral geometry is a hybrid area, involving geometry and partial differential equations, which relates properties of geometric manifolds to properties of invariant differential operators they support. Typical of the results in this area, and indicative of the appeal it has for pure mathematicians and applied mathematicians alike, is a recent result of the Englishman, W. K. Hayman, for which a new proof and somewhat stronger result have now been given by Robert Osserman of Stanford University. In essence, the result is that for a drumhead without holes but of otherwise arbitrary shape to produce a deep note, it is necessary that it include a sufficiently large circular area. Osserman derives explicit bounds on the radius of the circular drum included and also generalizes the result to drums with holes.

New Results on Robustness

The assumptions underlying statistical models are, as would be expected, seldom, if ever, completely satisfied in the real world: data are contaminated by human error, random noise, and round-off error. Also, the models used are not, in general, exact. This fact has motivated research on the concept of robust estimation; robustness being a qualitative property meaning that a statistical procedure is well behaved or insensitive to small changes in the structure of the assumed model. There are several precise mathematical definitions of robustness. Using one of these, P. W. Millar of the University of California at Berkeley has recently proved that certain estimators and tests based on minimum distance technique, a generalization of least squares, are robust. This result represents a theoretical explanation of the insensitivity to small changes in the model of a number of commonly used estimators, and therefore increases the confidence that can be placed on estimates thus obtained.

Reaction—Diffusion Equations

The development of complex spatial patterns in media capable of both reacting and diffusing has interested scientists since Turing in 1952 demonstrated the role this phenomenon may play in morphogenesis. More recently, much attention has been focused on reaction-diffusion processes and on the partial differential equations that mathematically model them because of their application to the understanding of such diverse phenomena as galactic structures, chemical reactions, combustion processes,

and population dynamics. Particular interest has been centered on a chemical reaction, associated with the names of the Russian scientists Belovsov, Zaikin, and Zhabotinskii (1971).

The past five years have seen considerable achievements by several investigators in the understanding of the behavior of such phenomena through the use of appropriate mathematical models. R. Aris of the University of Minnesota has effectively exploited such models to study chemical catalysis; P. Fife of the University of Arizona to explain biomathematical phenomena; and I. Prigogine and G. Nicolis of the University of Bruxelles in the area of self-organization in nonequilibrium systems.

A significant amount of the mathematical work on these problems has dealt with models that exhibit spontaneous, self-excited, spatially homogeneous solutions. Very recently, a number of investigators (N. Koppell and L. Howard of MIT; D. Cohen, J. Neu, and R. Rosales of Cal Tech, A. Friedman of Northwestern, and J. Greenberg of SUNY at Buffalo) have succeeded in showing that such systems also support spatially inhomogeneous solutions that exhibit target patterns and rotating spiral waves.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan is $499,000 less than the FY 1980 Budget Request of $25,400,000. In general, the same pattern of increases over FY 1979 levels is maintained as in the original request. The increase of $200,000 in the Current Plan for the Special Projects element reflects the planned start up of modes of support alternative to the standard research grant.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$22,782,576
FY 1980 Program	$24,901,000
FY 1981 Request	$29,300,000
Difference—FY 1981/FY 1980	$4,399,000

The $29.3 million requested for the Mathematical Sciences is $4.399 million more than the FY 1980 Current Plan. This increase will allow the following changes in the Mathematical Sciences program:

- The basic research project support program will be expanded by $3.349 million to a total of $25.95 million, allowing both the support of a larger number of investigators and a slight increase in the support of each investigator, and
- An increase of $1.05 million to a total of $3.35 million in Special Projects for programs and management techniques to foster the increasingly fruitful interactions among mathematicians and different mathematical subfields. These include working sessions of different sizes and durations, institutionally-designated postdoctoral fellowship support, and a possible mathematical sciences research institute.

Near the beginning of FY 1980, the budget structure for Mathematical Sciences was changed by removing Statistics from Applied Mathematics and Statistics, Probability from Modern Analysis and Probability, and forming a new Statistics and Probability program.

Percentage increases among the various Mathematical Sciences program elements are:

Classical Analysis	15.4%
Modern Analysis	15.3%
Topology, Geometry, and Foundations	14.2%
Algebra and Number Theory	14.0%
Applied Mathematics	15.3%
Statistics and Probability	15.2%
Special Projects	45.8%

Coordination and Relation to Other Efforts

Research in the mathematical sciences is supported by NSF, the Department of Defense, the National Institutes of Health (essentially only in applied mathematics or biostatistics), the Department of Energy, and to a small extent, NASA and a few other agencies.

It is important that there be effective communication and coordination between these agencies and NSF. Such coordination among the various groups supporting research in the mathematical sciences at Federal agencies is achieved through an informal interagency committee called ICEMAP (Interagency Committee for Extramural Mathematics Programs) which meets approximately once a year. Extensive day to day contact between program officers at the various agencies is maintained by telephone and by personal visits. Conferences and workshops are sometimes supported jointly by NSF and one or more of these agencies. Since NSF provides partial support (about 7 percent) of the Army's Mathematics Research Center at the University of Wisconsin, contact between the Army Research Office and the NSF is continual and close. NSF staff members attend meetings of the Army Mathematics Steering committee, as well as conferences supported by this organization.

Since the mid-sixties, the Department of Defense agencies have gradually adopted a more restrictive philosophy regarding the relevance of core mathematics to their needs, with the result that by 1970 virtually no core mathematics was being supported by the Office of Naval Research, the Army Research Office, or the Air Force Office of Scientific Research. This situation continues to exist, leaving NSF as essentially the sole Federal supporter of core mathematics research. Foundation support of applied mathematics involves research of a more general methodological character than the more problem-oriented research by other agencies.

Classical Analysis Program Element $3,970,000

Objectives and Description

The purview of the classical analysis program consists of those subdisciplines of mathematics which deal first with analysis—that is, areas in which limiting processes are fundamental to the language and to the phenomena one is attempting to describe. In addition, the program concentrates on those areas with antecedents in natural philosophy, such as the study of differential equations and complex variables. Other subjects of current interest are those which arose by evolution from the more traditional theories. These include several complex variables, analytic spaces and Riemann surfaces, and approximation theory. Classical analysis provides a rigorous framework in which many problems involving the application of mathematics may be formulated. These applications in turn have always provided a wealth of challenging problems.

The objectives of this program element are to:

- Investigate properties and behavior of solutions of ordinary and partial differential equations;
- Better understand the relationships between analysis and geometry, in particular, the relations betwen solutions of partial differential equations and geometric properties of surfaces and manifolds; and
- Study phenomena arising in the analysis of harmonic and holomorphic functions of one and several variables.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Continued support will be provided for research in the theory of ordinary and partial differential equations, harmonic analysis, the theory of one and several complex variables, the theory of approximation, and the study of the properties of differential equations on manifolds. Nonlinear partial differential equations and several complex variables are the two most rapidly expanding areas of this program. The $529,000 increase, from $3,441,000 in FY 1980 to $3,970,000 in FY 1981, will be reflected in support of these directions.

Modern Analysis Program Element $3,940,000

Objectives and Description

Modern Analysis is that area of the mathematical sciences dealing, for the most part, with functions and families of functions, developed mainly in the twentieth century. By considering families of functions and endowing them with algebraic and topological structures, one creates a function space. Research in this area of mathematical sciences has led to the introduction to powerful tools which can be used in applied mathematics; in studies of the solutions of differential equations; in the quantum field theory of physics; and as models for generalized quantum mechanical systems.

The subfields of Modern Analysis include functional analysis, harmonic analysis, linear topological spaces, operator theory, topological dynamics, ergodic theory, mathematical physics, and measure theory.

The objectives of the program are to:

- Deepen understanding of the mathematical foundation arising from the abstraction of the natural concepts of other sciences;
- Observe the effects on the objects natural to classical analysis due to the imposition of algebraic and topological structures; and
- Reapply results from abstraction to the basic science from which it came.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The FY 1981 increase of $524,000 from $3,416,000 to a total of $3,940,000, will allow the program to show real growth over its FY 1980 level of effort.

Topology, Geometry, and Foundations Program Element $5,580,000

Objectives and Description

Topology is a modern offspring of geometry, closely related to it and yet so distinguished by one characteristic that it has come to be regarded as a major field of mathematics. In geometry, the notion of distance plays an important role. This is not so in topology. Topology is concerned with those properties of geometric objects which are

unaltered by a relative displacement of their parts, such as stretching, twisting, or compressing without cutting or tearing. This is a very severe requirement. One might surmise that few geometric properties would meet it and that those that did would be very basic indeed. This is the case and accounts both for the importance of topology and for its abstract character. Topology, in conjunction with algebra or analysis, has contributed substantially to other areas of mathematics and other sciences, including the development of basic results in dynamical astronomy and important results on the qualitative nature of electrostatic fields and flow of fluids.

Present day research in geometry consists principally of the application of the tools of classical analysis to the description of properties of curves and surfaces. Research of the type supported in this program has traditionally been the most useful to the physical sciences and engineering,and recently this usefulness has been expanding to other areas of scientific endeavor.

Much of the research in geometry is interdisciplinary in that it consists of the application of geometry to the elucidation of problems in analysis or vice versa. Similarly, the tools of algebra are used extensively in the study of curves and surfaces to a greater extent than formerly.

The Foundation of Mathematics subelement is concerned with logical processes and with the reduction of logical thought to the manipulation of symbols. The reduction of mathematical reasoning to mechanical manipulation of symbols according to definite rules prepared the way for the creation of the electronic digital computer. Moreover, two mathematicians, Turing and von Neumann, steeped in mathematical logic, are counted as the most important figures in the development of modern computers. The interplay between logicians and computer scientists continues. Logicians are interested in whether certain problems can be solved by algorithms. Computer scientists are interested in the same question as it relates to computing time and the nature of the algorithm.

The Foundations of Mathematics subelement is the smallest in the mathematics program, but the quality of the research being done is extremely high. Perhaps the most dominant areas of research in the Foundations of Mathematics are model theory and recursion theory. The former is of particular current interest because of its applications in other science fields.

The objectives of this program are to:

- Describe and understand properties of geometric structures and abstract manifolds;
- Discover new algebraic techniques for determining geometric structure and simplify those techniques which now exist;
- Understand the foundations of set theory, cardinal and ordinal number theory, and related areas of mathematics; and
- Answer questions of decidability concerning various algebraic structures.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

It is expected that the proposed increase of $694,000 for this program, from $4,686,000 in FY 1980 to $5,580,000 in FY 1981, will more than offset the increased costs of performing research. Consequently, the number of projects funded is expected to increase.

Within this increase, the vigor of spectral geometry, topological classification of singularities, model theoretic studies in algebra, and novel geometric methods in topology of manifolds will be recognized.

Algebra and Number Theory Program Element $5,030,000

Objectives and Description

Algebra is one of the oldest and most important branches of mathematics. The problem of solving algebraic equations has always been an important one, both practically and intellectually, and was the central motivating force for research in algebra for centuries. In the early 19th century, attempts to solve algebraic equations led to new concepts such as groups, rings, and fields. It may be said that the modern study of algebra is basically concerned with entitites such as these, which may be collectively called algebraic structures. Group theory has long been central to research in algebra, and much recent research in group theory has been in the theory of finite groups. Number theory has also been the subject of added research interest because of several important recent discoveries. Recent years have seen many of the techniques and results of algebra being used in other fields of mathematics to carry on research. As a result there is now an extremely active and important area known as algebraic geometry supported under the Algebra problem, in which the techniques of algebra are brought to bear on the problems of geometry.

The objectives of the Algebra program are to:

- Increase our understanding of the topology and geometry of surfaces describable by algebraic equations and analogous situations in higher dimensions;
- Obtain a deeper understanding of algebraic sets and special transformations of these sets;
- Determine the structure of all finite groups;
- Continue the progress on answering certain long-standing questions and conjectures in the theory of numbers;
- Explore further the increasingly important areas of discrete mathematics and combinatorial theory; and

- Construct and exploit new algebraic techniques for applications to questions arising not only in other areas of mathematics but also in other sciences.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The $619,000 increase proposed for FY 1981 from $4,411,000 in FY 1980 to $5,030,000 in FY 1981, will allow for a real increase in the level of effort in this program.

The widespread interest in finite groups will continue, and recent advances dealing with properties of certain structures of polynomials are expected to spur research in commutative algebra and algebraic geometry. Number theory is in a very fruitful period at this time, and the same is true of ring theory. The renaissance in combinatorial theory which started a decade or so ago is attracting more and more able researchers. Continued emphasis will be given to all these areas in FY 1981.

Applied Mathematics Program Element $4,300,000

Objectives and Description

The pervasive use of mathematical abstractions for the description of phenomena in astronomy, physics, chemistry, engineering, and technology has during the past three decades extended to the biomedical and social sciences and to the development of methodologies for the management, control, and optimal allocation of resources within complex systems. This trend has been and continues to be shaped by the availability of very fast computers with large memories that permit the organization, reorganization, and performance of sophisticated mathematical operations on very large numerical data structures. This capability has made possible the analysis of sophisticated physical phenomena and of the very complex phenomena from the biological and economic sciences.

By its own nature this is a very diverse program. Its largest research area is centered on the proper mathematical description of problems which arise in the physical sciences and engineering: solid and fluid mechanics, wave propagation, bifurcation, and galactic phenomena. A second component of the program is devoted to the mathematical formulation of problems that arise in the biomedical sciences, as in population dynamics, ecological structures, epidemiology, and genetics. Another significant research area deals with methodologies of control, optimization, and optimal allocation of resources, including problems in mathematical economics. A fourth component of the program is centered on the development of numerical methods and programming techniques for the proper and efficient use of digital computers on mathematical models and for the implementation of optimization schemes.

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The objectives of this program are to:

- Express, in mathematical language, phenomena that occur in the physical and social environment, and manipulate these expressions in order to deduce mathematical consequences of significance and usefulness in the real world;
- Devise, when appropriate, novel mathematical structures for the above purpose; and
- Develop techniques and methodologies for the proper implementation of mathematical models on digital computers.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $569,000 from $3,731,000 to a total of $4,300,000 in the Applied Mathematics program will support greater efforts of research on rection-diffusion equations, numerical methods for partial differential equations, and mathematical methodologies for the control, optimization, and optimal allocation of resources.

Statistics and Probability Program Element $3,130,000

Objectives and Description

Probability theory deals with mathematical models for a diverse collection of physical phenomena which involve chance or incomplete information. A few examples of such phenomena are: sampling to obtain information about a population from a subpopulation, traffic flow, communication in the presence of noise, games of chance such as bridge and poker, waiting lines at service facilities, and the search for lost or hidden objects.

One can study the properties of any probability model but those models which must closely approximate the real physical situation usually receive the most attention. Some mathematical questions arise from the physical phenomenon being modeled. Others are natural to mathematicians, but they too may lead to knowledge of the behavior of the original physical phenomenon.

The dividing line between statistics and probability is quite fuzzy. Statistics is basically concerned with obtaining information from data—in particular with obtaining information about a large collection of data from a smaller subcollection or information about a large number of events from the observation of a limited number of such events. Statistics involves the application of probability models and probabilistic techniques to situations involving data. There are applications of statistics in medicine, agriculture, insurance, sociological and demographic studies, industrial production, market research, and essentially all experimental work in engineering and the sciences.

The objectives of this program element are to:

- Develop mathematical models for phenomena which involve chance or incomplete information, use probabilistic and other mathematical methods to obtain the mathematical consequences of these models, and apply the results to the real world;and
- Devise new statistical procedures, some for entirely new situations and some which are better than old procedures because a new model better fits the actual physical phenomenon, because the new procedure more efficiently uses data, or because the new procedure uses modern high speed computational techniques to advantage.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The FY 1981 increase of $414,000, from $2,716,000 to a total of $3,130,000, for Statistics and Probability will allow increased support for the use of computers in statistical research on large dimensional data base problems as well as increased emphasis on robust estimation techniques, infinite interacting particle systems, and limit theorems under some conditions of dependence.

Special Projects Program Element $3,350,000

Objectives and Description

The Special Projects program has been established to accommodate proposals which cut across more than one field of mathematics or which present administrative aspects markedly different from those of the research project type. Briefly, the program supports projects that are supportive of research activity as well as research activity itself which does not fit well into one of the subdisciplinary programs.

The principal types of projects considered by this program element are:

- Research seminars, institutes, and workshops in all areas of the mathematical sciences;
- Research conferences and symposia which are discipline-wide in nature, as well as those having to do with highly specialized topics;
- A program of regional conferences designed to stimulate research in various areas of the country deficient in research competence in a specific field of the mathematical sciences. At each such conference ten lectures are given by a world renowned authority on the conference topic. Lectures in core mathematics

are published by the American Mathematical Society and those in applied mathematics by the Society for Industrial and Applied Mathematics;

- *Postdoctoral research fellowships.* A small program of such fellowships was conducted on an experimental basis in Fiscal Years 1979 and 1980 for mathematical scientists who have not had their doctorate more than four years. Fifteen (15) fellowships were funded in Fiscal Year 1979 and thirty (30) in Fiscal Year 1980. The program will be continued in Fiscal Year 1981 at the 1980 level, still on an experimental basis.
- Programs and techniques designed to foster the increasingly fruitful interactions among different mathematical subfields. These include working sessions of different sizes and durations, special years, institutionally-designated postdoctoral support, or a possible mathematical sciences research institute. The aim of all of these programs is to bring researchers together in order to facilitate comparing of ideas, results, and techniques from various mathematics subfields, and thereby mutually enriching mathematical research.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The proposed increase of $1,050,000 for this element, from $2,300,000 in FY 1980 to $3,350,000 in FY 1981, will provide: (1) an increase of $800,000 in modes of support of research in addition to research project support, working sessions of different sizes and duration, institutionally-designated postdoctoral fellowship support, or a possible research institute and (2) a slight increase in both the ongoing program of support for research conferences and the regional conference program. All of these increases are in keeping with the aim of bringing mathematical scientists together to foster interactions fruitful for the increased production of high quality research.

QUANTITATIVE PROGRAM DATA
MATHEMATICAL SCIENCES SUBACTIVITY

Proposals and Awards

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
No. Proposals Received*	1,879	1,900	1,950
No. Awards**	885	883	891
Dollars Proposed (Total)	$162,717,000	$95,000,000	$100,000,000
Dollars Proposed (Annual Rate)	90,539,000	54,150,000	56,100,000
Dollars Awarded (Total)	22,782,576	24,901,000	29,300,000
Dollars Awarded (Annual Rate)	17,525,058	19,154,615	22,538,461
Average $ per Award	25,743	28,200	32,884
Average Award Duration (Years)	1.3	1.3	1.3

*Includes proposals for committed renewals, etc.
**Includes awards for committed renewals, supplements, etc.

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	98.0	98.0	98.0
Industry	—0—	—0—	—0—
Federal Agencies	—0—	—0—	—0—
Other	2.0	2.0	2.0

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Senior Scientists			
Faculty*			
No. years supported	324	333	371
Amount of faculty support**	$9,809,333	$10,700,000	$12,350,000
Postdoctoral Associates			
No. of years supported	35	50	70
Amount of postdoctoral support	$549,782	$900,000	$1,300,000
Graduate Students			
No. supported per award-year	271	275	312
Amount of graduate student support	$977,372	$1,050,000	$1,250,000
Other Personnel Costs***	2,045,875	2,175,000	2,500,000
Land, Buildings, and Fixed Equipment	—0—	—0—	—0—
Major Equipment	—0—	—0—	—0—
Other Equipment	29,739	75,000	150,000
Other Costs	2,483,300	2,600,000	3,050,000
Indirect Costs	6,887,175	7,401,000	8,700,000
Total	$22,782,576	$24,902,000	$29,300,000

*Includes faculty associates and other professionals.
**Distributed among 1,299 individuals.
***Includes fringe benefits.

COMPUTER RESEARCH SUBACTIVITY $23,350,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Theoretical Computer Science	$2,703,569	$2,700,000	$2,700,000	$2,900,000	$200,000
Software Systems	2,726,891	3,300,000	3,100,000	3,300,000	200,000
Software Engineering	2,459,089	2,900,000	2,700,000	2,900,000	200,000
Intelligent Systems	3,289,726	3,300,000	3,200,000	3,400,000	200,000
Computer Systems Design	2,907,265	3,300,000	3,135,000	3,350,000	215,000
Special Projects	2,684,386	3,100,000	3,400,000	7,500,000	4,100,000
Total	$16,771,026	$18,600,000	$18,235,000	$23,350,000	$5,115,000

Objectives and Description

The Foundation's Computer Research program supports basic research in computer science. The objectives of the program are to:

- Develop, through research, an understanding of the science which underlies computer technology;
- Discover and formulate principles of design of computer hardware and software systems;
- Stimulate new areas of computer science research which are potentially important for society;
- Encourage collaboration of computer scientists with researchers in other fields.

Sophisticated computer technology has been one of our most important national resources, contributing significantly to both the conduct of research and the efficient functioning of society. The magnitude of basic research being done in computer science by industry is relatively small; it is concentrated in selected areas and draws heavily upon academic research results. Furthermore, industry draws extensively upon departments of computer science to provide trained personnel. Academic research, in turn, depends largely upon the Federal Government. Within the Federal Government, the Foundation's Computer Research program is the only program which focuses primarily on the support of basic research in computer science in academic institutions.

As the field of computer science was developing from the late 1950's through the early 1970's, NSF provided support for computing facilities in colleges and universities. Much experimental resarch was conducted on those facilities but they are no longer either available or suitable for modern research. Thus, academic computer research has become mainly a theoretical activity except at those few institutions that receive extensive ARPA support.

Experimental computer science requires research computing facilities and associated maintenance personnel permitting the design, construction, and evaluation of

research prototype information processing systems. These facilities consist of hardware and software. The hardware is purchased from a variety of manufacturers at a variety of sizes and prices. Often it is then modified by laboratory personnel. The software, a major focus in experimental computer science, is usually designed and built by the researchers themselves and it is here that many experimental questions are answered. Finally, as the working prototype is put through its paces, another set of research questions about its performance and reliability are answered.

To carry out research of this type long term support which provides, in addition to equipment, funds for development, maintenance, operating costs, and personnel is needed. Building and maintaining an effective experimental capability will permit colleges and universities to contribute more effectively to fundamental knowledge in this important field, attract needed numbers of high quality researchers and advanced students to academic careers, and provide improved training of both Masters and Ph.D. level personnel so urgently required by industry.

Thirty-six percent of doctoral level computer scientists are employed by universities, seven percent by government, and fifty-four percent by business/industry. Few of those who enter industry go into basic research. Most enter design, development, or supervisory roles.

The proposed FY 1981 budget provides $23.35 million for program support. $16.4 million of this will be used to provide regular research project support. A total of $1.6 million will be used for instrumentation for computer systems research, providing small instruments needed at institutions conducting research in modern computer systems. In addition, a total of $3.7 million will be used for the longer range support of experimental research by providing for larger equipment, operating costs and system development and maintenance costs. Approximately $0.75 million will be used to develop a nationwide computer-based communication network which will increase the effectiveness of individual research groups and help smaller computer science departments remain in the mainstream of research. Finally, approximately $0.9 million will be used for initiating a competitive program of awards for young experimental computer scientists who are just beginning their research careers and need sustained, long term support to accomplish the extensive systems development which is prerequisite to creative experimental research.

Computer research is a new and expanding field. Many of the Nation's best students are being attracted by the intellectual challenges and career opportunities that this field offers. It stimulates a sophisticated industry which contributes greatly to the Nation's economy. The Foundation's investment in basic computer research will help assure that this country's commanding lead in computer technology is maintained.

Major Research Questions

A number of major questions in computer research involve the areas given below.

- The development of micron and submicron sized electronics relaxes many of the traditional design constraints on computer architecture and makes it feasible

from a cost and project management standpoint for universities to experiment with computer design for the first time since the early 1950's. A new look at problems previously thought solved as well as research on new problems is needed.

- New electronics technology favors parallel or concurrent computer systems. This, in turn, favors new approaches to problem solving and new algorithms to carry out computations. A thorough reexamination of heretofore intractable problems, as well as reformulation of classical problems to gain new perspective, will pay big dividends in understanding and problem solving ability.
- The last several years have seen the rapid emergence of promising new work in the area of large data bases. A variety of new structures and retrieval techniques are being explored which will make existing computer applications more effective and are necessary for the new large data-oriented systems of the future.
- Efforts to devise proofs of program correctness, while partially successful, encounter complications that make widespread application questionable. Nevertheless, these efforts have characterized some of the situations in which proof is difficult. One possible resolution is the discovery of equivalence preserving transformations that can remove the difficulty.

Significant Recent Achievements

- H. T. Kung of Carnegie-Mellon University has developed a theoretical model for systems of Very Large Scale Integration (VLSI) chips. Called a "systolic system," this approach provides a solid mathematical foundation for the design of special purpose VLSI chip modules.
- There have been major advances in relating parallel processing to determinism in models of computer systems. Dr. Walter Savitch of the University of California-San Diego has shown that deterministic parallel computer systems are more powerful than non-deterministic serial systems, thus allowing the computation of new limits on computing capability.
- Michael Harrison of the University of California-Berkeley, Walter Ruzzo at the University of Washington, and Jeffrey Ullman at Stanford University have shown that there is no way to prove that unauthorized access to a computer system can be completely prevented. Absolute security might be achieved (although it is unlikely) but we could never know that it has been. The question is undecidable.
- The representation of truly realistic synthetic images is a significant problem in computer animation, computer graphics research, and computer modeling. Results find their way into such diverse applications as flight simulators and the presentation in real time of a display of an internal body organ based on X-ray data. The generation of realistic synthetic images involves hundreds of thousands of display points requiring large amounts of computer memory and computational capability. C. Csuri of Ohio State University has developed an algorithmic

approach to the modelling of such complex images which allows considerably simpler representations and more accurate real time displays.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

Both the FY 1980 Budget Request and the FY 1980 Current Plan reflect transfer of activities to the new Cross-Directorate Programs activity. The total resulting reduction is $600,000.

There are two additional aspects to the changes between the Budget Request and the Current Plan. First, the overall support level is reduced, which reduces our ability to pursue the societal impact research of the Special Projects program as vigorously as planned.

Second, the initiation of longer range support for experimental research is given highest priority. This will be beneficial to experimental research supported by all of the program elements and is reflected as a priority adjustment in each of them. $1,000,000 is planned for this purpose and appears in the Special Projects current plan. Other components of the Special Projects program element and other program elements except Theoretical Computer Science have been reduced to provide this sum.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$16,771,026
FY 1980 Program	$18,235,000
FY 1981 Request	$23,350,000
Difference—FY 1981/FY 1980	$5,115,000

The proposed $5,115,000 increase, from $18,235,000 to a total of $23,350,000 will be used as follows:

- $1,015,000 will be used to offset partially the increased cost of performing research Expected inflation will still produce a decrease in effective support, however.
- $500,000 is added to the Special Projects program element to offset partially the cost of initiating the nationwide computer-based communications network (CSNET).
- $3,600,000 will be added to the Special Projects program element to increase support for experimental computer science research to a total of $4.6 million. $3.7 million of the $4.6 million will be used for longer range support of experimental research and $0.9 million for a national competition for the support of young investigators in experimental computer science.

Several emphases are included within the individual program elements; namely,

- Approximately $1,250,000 total in Computer System Design, Software Systems Science and Theoretical Computer Science for microsystem architecture and modelling. Included are the theory of Very Large Scale Integration (VLSI) model-

ling, microsystem architecture, and design methodology for VLSI systems. With the advent of Very Large Scale Integration, the process of designing computer systems on a single chip has become too complex to rely entirely on manual approaches. Automation of all or parts of this process is needed to cope with the complexity. Support will be provided for projects aimed at studying the VLSI design process.

- Approximately $1,600,000 for equipment awards. In FY 1979, 23 awards totaling $1,597,817 were made. A like amount is planned for FY 1980. These grants support research equipment which is shared by more than one research project. Instrumentation included in regular research project awards is maintained at the FY 1980 level of $400,000.

Percentage increases among the various Computer Science program elements are:

Theoretical Computer Science	7.4%
Software Systems	6.5%
Software Engineering	7.4%
Intelligent Systems	6.3%
Computer Systems Design	6.9%
Special Projects	120.6%

Coordination and Relationship to Other Efforts

NSF is the agency with primary responsibility for basic research in the computer area; other Federal programs support similar research ancillary to their prime mission. Interagency liaison is effected by an informal coordination committee, by exchange of proposal and action lists, and by person to person contact among program staffs. Specifically:

- In Theoretical Computer Science, NSF provides approximately 80 percent of the Federal support. Coordination is principally with the Department of Defense (DOD) and the Department of Energy (DOE).
- In Software Systems Science, NSF provides approximately 50 percent of the Federal support. Coordination is primarily with DOD agencies.
- In Software Engineering, NSF provides almost all of the support for basic research except in numerical analysis where the figure is closer to 20 percent. Liaison is especially close with DOE, but also includes NASA and all of the DOD agencies.
- In Intelligent Systems, the Advanced Research Projects Agency (ARPA) of DOD is the principal source of Federal support. NSF coordinates its support with DOD, NIH and NASA to provide continuity for key areas of research which do not meet current program requirements of mission agencies.
- In Computer Systems Design, NSF provides about 60 percent of the support for basic research. Other principal sources are NASA, DOE and DOD agencies.

- The longer range support for experimental computer science research is a new initiative begun in FY 1980. Increasing the level of activity in experimental computer science research at the universities has been identified as the highest priority at this time in this young scientific discipline. This effort is closely coordinated with DOD, DOE, NASA and NIH. Support for experimental research provided by DOD at three or four institutions is much greater than that available to any other institution.

The programs in Computer Research are also coordinated closely with industry. The Computer Science Advisory Subcommittee includes one or more representatives of industry on a rotating basis and approximately 20 percent of mail reviewers solicited to evaluate proposals are industrial scientists. In addition, members of the NSF staff visit industrial laboratories to learn about industrial research activity.

Theoretical Computer Science Program Element $2,900,000

Objectives and Description

The objective of this program element is to increase our understanding of the theory of computation, theory of formal languages, analysis of algorithms, and other topics concerned with the theoretical foundations of computer science.

The advent of computers has given mankind analytical tools of unprecedented power, but at the same time, opened new questions which must be answered in order to understand the use of these tools. How can the methods of solving problems be expressed most effectively? What computing procedures are most efficient? What limitations are inherent in the nature of information and problems which limit man's ability to get solutions at reasonable cost or in reasonable time? Theoretical Computer Science research provides support to study these and related questions to provide the theoretical basis for the science underlying computations.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

An increase of $200,000 will partially offset the increased cost of performing research in those projects which are being continued, including areas such as highly parallel algorithms for solving computational problems and the theoretical limits on the speed of computation of key problems.

Software Systems Science Program Element $3,300,000

Objectives and Description

The objective of this program element is to explore the conceptual basis for the specification of future software systems. This includes advanced programming languages and optimizing compilers, the analysis of program structure to support verification and proof of correctness of programs. It also involves the discovery of new and improved algorithms.

Research is conducted on high order data structures and their applicable operators to discover, analyze and classify transformations applied to high order structures, to understand the organization of systems in which a unit can be subject to concurrent multiple access, and to explore methods for the improved analysis of procedures and algorithms.

Continuing rapid changes in computer technology imply that the ultimate limitation in the utility of computing systems is likely to be in man's ability to specify the problems for which a solution is desired and to define and validate software systems that can carry out a solution. The Software Systems Science program attempts to develop a basic understanding of such limiting factors.

FY 1981 Budget Highlights and Explanation of Incrases and Decreases

An increase of $200,000 will partially offset the increased cost of performing research in those projects which are being continued including the mathematical analysis of the semantics of programming languages and the design of expressive programming languages for concurrent systems.

Software Engineering Program Element $2,900,000

Objectives and Description

The objective of this program element is to increase our fundamental understanding of the structure of computer software and the software design process, especially in the areas of numerical methods, verification, testing, portability, reliability and human interfacing to numeric and nonnumeric software systems. Current areas of emphasis include program validation and testing through the use of software tools and studies of human factors in software design and utilization. The development of prototypes or experimental implementations is an integral part of the research program.

Computer software systems are among the most complex systems built by man. Yet they are the least understood. The results of this research program should play a major

role in increasing our understanding of how to design, produce and maintain computer software.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

An increase of $200,000 will partially offset the increased cost of performing research in those projects which are being continued including research on developing software tools for writing and debugging programs and the analysis of robustness and portability of software.

Intelligent Systems Program Element $3,400,000

Objectives and Description

The objective of this program element is to increase our ability to employ computers in assisting the human intellect in complex problem situations.

This program element is directed toward research on computer-based systems which have some of the characteristics of intelligence. Relevant areas include pattern recognition, pattern generation, knowledge representation, problem solving, theorem proving and others which relate to the automatic analysis and handling of complex tasks. One key for this research is to learn how to take better advantage of the computer's speed to assist the human being's breadth and depth of perception and understanding; learning how to make computers and computer programs more flexible and adaptable to changing requirements; and extending the reach of computer analysis to situations which cannot be fully prescribed in advance.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

An increase of $200,000 will partially offset the increased costs of doing research in those projects which are continued. Areas to be continued will include work on knowledge based systems to assist with the analysis of chemical or crystal structures, the design of complex experiments in genetics and other complex decision tasks.

Computer Systems Design Program Element $3,350,000

Objectives and Description

The objective of this program element is to increase our knowledge and understanding of computer systems—their organization, performance characteristics, and ability to operate correctly in the face of malfunction of some of their components.

For several years there have been major advances in integrated circuit technology. Increases in the density of logic on a chip and reduction of costs continue to occur. These two trends portray future computer systems ranging from single microcomputers imbedded in home appliances to a large number of interconnected microprocessors. Computer systems design research is focused on gaining new understanding of the organization of computer systems so that future computer systems will be more effective.

With this trend in technology, computers are being used more and more in situations where failure could have catastrophic consequences. Fault-tolerance research focuses on gaining a better understanding of how to design computer systems which will operate correctly even in the face of failure of some of their parts.

Many computer systems include a very poor user interface. Graphical displays are a much more user-oriented approach to this interface. High quality displays consume substantial computation capability and often cannot be done in real time as needed by the human user. Research on computer graphics is aimed at the study of alternate hardware configurations and software algorithms with the hope that the new knowledge generated will provide a basis for much improved human/computer interface.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

An increase of $215,000 will partially offset the increased cost of performing research in those projects which are being continued including work on the architecture of highly parallel computing systems and the use of computers to assist the process of designing Very Large Scale Integrated (VLSI) chips.

Special Projects Program Element $7,500,000

Objectives and Description

Since computer science is a new and rapidly growing field of research, its areas of most intense activity tend to shift in response to the solution of old problems and the opportunities offered by new technology and new concepts of application. The structure of the Computer Research program changes to reflect these shifts. The objectives of the Special Projects program are to encourage and nurture new areas of investigation and to develop new modes of support that fit the changing needs and structure of computer science research.

This program element has several components including:

- Support of research facilities for experimental computer science;
- Development of a nationwide computer based network to enhance the national capability for computer science research, as contrasted to simple remote usage of computers;

- Awards for young experimental computer scientists;
- Science research project support in selected areas:
  - — privacy and security of data bases and computer systems;
  - — organization of very large data bases;
  - — design and limitations of computer models of complex systems;
  - — impact of computers on society.
- Workshops and special studies.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The Special Projects program element is being expanded by $4,100,000, from $3.4 million in FY 1980 to $7.5 million in FY 1981, $3.6 million of the increase will be used to introduce a strong emphasis on experimental computer science research and $500,000 to develop a nationwide computer science research network. Other activities in the Special Projects program element will be reduced by approximately $250,000 to provide a total of $750,000 needed by the Computer Science Network.

The specific use of Special Projects funds will be as follows:

- Support for research facilities for experimental computer science is increased by $2,700,000 to a total of $3,700,000.

  Increasing experimental computer science research activity in the universities is the most important objective for the computer science section at the present time. Because of a lack of adequate experimental facilities, academic computer research has become primarily a theoretical activity except at those few institutions which receive extensive ARPA support. At the same time, new technology has opened new opportunities for innovation and created intense commercial interest in integrated computer and communication systems. The U.S. has a competitive edge in the design and construction of such systems, due in part to earlier NSF support of campus computer facilities for research. To make best use of this advantage, we must pursue research in integrated computer systems vigorously through a combination of theoretical and experimental approaches. Strengthened experimental research programs at the universities are essential both to explore new ideas and to assure the continuous supply of trained talent required by industry. The $3,700,000 included in the FY 1981 Budget Request for this purpose represents an initial step in a continuing effort to upgrade the experimental computer research capability of U.S. universities.
- Initiation of awards for young experimental computer scientists at a level of $900,000.

  Young computer scientists who wish to engage in experimental research must invest years of intense effort in systems development as part of the research

process. Heavy teaching loads make this difficult to accomplish and the work itself is not publishable in scholarly journals or easily measured by academic standards. These factors discourage experimental research scientists at the critical period in their lives when they are establishing their research programs. As a result, creative scientists often retreat into theoretical research which offers better prospects of meeting academic promotion criteria or go into industry where challenging professional opportunities are readily available.

To help alleviate this trend, awards containing several years support will be made available for young experimental computer scientists. These awards will provide the time and opportunity needed by the recipients to establish productive experimental research programs.

- Support for development of a Computer Science Network (CSNET), is increased by $650,000 to a total of $750,000.

  Over the past decade, experience has been gained with the use of computer networks to enhance research. DOD and DOE, using ARPANET; NIH, using SUMEX; and NSF, using THEORYNET and the Symbolic Processing Net, have all clearly demonstrated the amplifying effect of computer networking on the effectiveness of interacting researchers. During the same period, networking technology has been developed to the stage that it is now practical to extend these benefits to larger communities of scientists. The national community of research computer scientists is keenly interested because of the benefits some members of that community have already experienced from existing networks and is a natural group to organize and implement a major extension. A project, (CSNET) is being planned to organize, design, and implement a network which could connect computer science research groups in universities, industry, and government. Design of CSNET will begin in FY 1980 and development will begin in FY 1981 with an NSF contribution of $0.75 million. It is expected that the support for the network will remain at this level during a 2-year development period and then taper off over the following 3 years as it becomes a self-supporting operation.

  Success with this project would provide the following benefits:

  — nationwide sharing of software and hardware systems;
  — nationwide collaboration of scientists on research projects;
  — enhanced university/industry interaction;
  — greater equality of research opportunity at all institutions.

- Science research project support, workshops and studies are reduced by $150,000 to a total of $2,150,000.

  This is a substantial effective reduction in this component of the special projects program element. Reductions will be made particularly in studying the impact

of computer technology on society, an activity which should be conducted by the offices and agencies concerned with policy formulation, and in the study of computer modeling.

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QUANTITATIVE PROGRAM DATA
COMPUTER RESEARCH SUBACTIVITY

Proposals and Awards

	Actual FY 1978	Estimate FY 1980	Estimate FY 1981
No. Proposals Received*	569	570	600
No. Awards**	263	265	270
Dollars Proposed (Total)	$89,992,000	$75,000,000	$80,000,000
Dollars Proposed (Annual Rate)	40,486,000	43,400,000	46,272,000
Dollars Awarded (Total)	16,771,026	18,235,000	23,350,000
Dollars Awarded (Annual Rate)	11,979,304	12,310,714	13,028,571
Average $ per Award	63,768	68,150	86,500
Average Award Duration (Years)	1.4	1.4	1.4

*Includes proposals for committed renewals, etc.
**Includes awards for committed renewals, supplements, etc.

Large Grants

	Actual FY 1978	Estimate FY 1980	Estimate FY 1981
No. Proposals Received	—0—	10	20
No. Awards	—0—	2	9
Dollars Proposed (Total)	—0—	$40,000,000	$80,000,000
Dollars Proposed (Annual Rate)	—0—	8,000,000	16,000,000
Dollars Awarded (Total)	—0—	1,000,000	4,450,000
Dollars Awarded (Annual Rate)	—0—	1,000,000	4,450,000
Average $ per Award	—0—	500,000	500,000
Average Award Duration (Years)	—0—	1.0	1.0

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1978	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	95.0	95.0	95.0
Industry	—0—	—0—	—0—
Federal Agencies	—0—	—0—	—0—
Other	5.0	5.0	5.0

Personnel and Other Factors

	Actual FY 1978	Estimate FY 1980	Estimate FY 1981
Senior Scientists			
Faculty*	106	110	130
No. Years Supported**	$3,003,690	$3,300,000	$4,300,000
Amount of Faculty Support			
Postdoctoral Associates	16	17	19
No. Years Supported	$249,888	$285,000	$400,000
Amount of Postdoctoral Support			
Graduate Students	336	340	350
No. Supported Per Award-Year	$2,693,426	$2,750,000	$3,350,000
Amount of Graduate Student Support	2,172,692	2,200,000	2,850,000
Other Personnel Costs***	—0—	—0—	—0—
Land, Buildings, and Fixed Equipment	—0—	500,000	2,000,000
Major Equipment (More than $200,000)	1,979,817	2,300,000	2,200,000
Other Equipment	1,844,812	1,900,000	2,150,000
Other Costs	4,826,701	5,000,000	6,100,000
Indirect Costs	$16,771,026	$18,235,000	$23,350,000
Total			

*Includes faculty associates and other professionals.
**Distributed among 404 individuals.
***Includes fringe benefits.

PHYSICS PROGRAM SUBACTIVITY $73,500,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Elementary Particle Physics	$22,910,745	$23,300,000	$22,761,000	26,200,000	$3,439,000
Intermediate Energy Physics	10,634,998	11,400,000	11,100,000	12,600,000	1,500,000
Nuclear Physics	11,557,125	12,300,000	11,800,000	13,500,000	1,700,000
Atomic, Molecular, and Plasma Physics	6,727,459	7,200,000	7,100,000	8,300,000	1,200,000
Theoretical Physics	7,008,067	7,300,000	7,400,000	9,000,000	1,600,000
Gravitational Physics	2,826,175	2,800,000	3,200,000	3,900,000	700,000
Total	$61,664,569	$64,300,000	$63,361,000	$73,500,000	$10,139,000

Objectives and Description

The objective of the Physics research program is to advance knowledge of the fundamental laws governing matter and energy. Physics is concerned with the existence, structure and interactions of various forms of matter and energy and with the basic forces which cause the observed phenomena. Hints are emerging that a few unified theories may be able to describe phenomena hitherto considered separately, such as the strong, weak, electromagnetic and gravitational forces. The realm of investigation ranges from the submicroscopic worlds of elementary particles (quarks and leptons), nuclei, atoms and molecules, to macroscopic aggregations of gases and plasmas, even extending to the cosmological scale with clusters of galaxies and black holes. The ultimate goal is to unify the understanding of all physical phenomena into one self consistent explanation.

These studies are pursued by a combination of sophisticated laboratory experiments and theoretical interpretations. The program provides support in each of the various areas for: accelerator laboratories in nuclear, intermediate energy and elementary particle physics; university research groups in all areas of physics using centralized laboratory facilities; small-scale university laboratory experiments; and theoretical interpretation, exploration and prediction. Four program elements, Elementary Particle Physics, Intermediate Energy Physics, Nuclear Physics, and Atomic, Molecular, and Plasma Physics support experimental investigations. The Theoretical Physics program element provides for studies of the theoretical framework within which the experiments are interpreted. The Gravitational Physics program element supports both theory and experiments to examine the effects of gravitational phenomena.

The results of basic research in Physics form the bedrock of our understanding of Nature and our Universe, and provide for the analysis of complex problems in other physical sciences, in the life sciences, in engineering, and in environmental sciences. These results also provide an underpinning for applications to technology and national problems, e.g., energy, nuclear medicine, energy storage, etc. Instrumentation devel-

oped originally for physics experiments frequently yields standard tools in other research fields and in industry.

Major Research Questions

- Can a unified theory be found which describes the strong nuclear force, the electromagnetic force, and the weak force as three related aspects of a single force of nature? Can all the forces in nature be described by a single unified theory?
- What are the detailed properties of states involving charm or bottom quarks? Do top quarks exist and, if so, can experimental evidence be found for their existence?
- How, using the nucleus as a laboratory, can the properties of the weak force be elucidated? How can the general symmetry and conservation laws be tested?
- How can the presence of particles other than neutrons and protons (hyperons, mesons, quarks, etc.) in the nucleus be determined? What are the effects of these on the nucleus, and, conversely, how does this nuclear environment affect them?
- What is the spatial distribution of charge and matter within the nucleus? How does it change when the nucleus is highly excited or in high spin states? What happens to a nucleus under extreme conditions of temperature, density and unusual composition?
- Can a non-neutral plasma (for example, one consisting only of electrons) be brought to such a low temperature that it turns into a liquid and then to a crystal?
- How closely identical (except for properties such as the sign of the electric charge) are particles and their corresponding anti-particles?
- Is gravitational radiation produced by natural astronomical sources? What are its properties (polarization, velocity, amplitude, frequency spectrum)? How can it be detected in the laboratory?

Significant Recent Achievements

- *1979 Nobel Prizes in Physics.* Since 1975, the Theoretical Physics Program has been supporting Sheldon Glashow and Steven Weinberg, whose triumph in understanding the weak force was recently crowned by a Nobel Prize shared with Abdus Salam of Trieste and London. The Program also supports a significant amount of research by others along the lines pioneered by Glashow, Salam, and Weinberg.
- *CESR Begins Operation.* The 8 GeV X 8 GeV Cornell Electron Storage Ring (CESR) has been brought into successful operation earlier than projected and below the previously estimated cost. Initial operation of the facility has already yielded valuable information on the upsilon particles discovered only two years ago.

- *Charmed Quark Studies at SPEAR.* NSF-supported groups from Stanford, California Institute of Technology, and Princeton, together with their colleagues from the Stanford Linear Accelerator Center and Harvard, have assembled a large geodesic of sodium iodide crystals (the "Crystal ball") for use in experiments at the Stanford Positron-Electron Asymmetrical Ring (SPEAR), the positron-electron colliding beam facility at the Stanford Linear Accelerator Center (SLAC). This detector, with its very high resolution in measuring energies of electromagnetic showers, has been highly successful in studying the spectroscopy of states involving charm quarks. The experiment showed that the previously reported singlet's state does not exist and that the new state possesses both energy and decay properties in good agreement with theory.
- *Pion-Nucleus Interactions.* Neutrons produced at small scattering angles by 144 Mev protons colliding with nuclei have been investigated at the Indiana University Cyclotron Facility. This process in light nuclei is dominated by exchange of a single pion which can be understood theoretically by treating the nucleus as an elementary particle. This procedure, together with the current theory of weak interactions and information from inelastic electron scattering, predicts the magnitude of the pion-nucleus interaction strength and its dependence upon the momentum transferred. Agreement is remarkable between theory and experiment for Lithium 6 and Carbon 12 nuclei.
- *Radiocarbon Dating.* The ultrasensitive isotope detector technique employed at the University of Rochester MP tandem Van de Graaff accelerator has now been used to date with radiocarbon a frozen wooly mammoth calf discovered two years ago in Siberia and is presently being used to measure Chlorine 36 in ground water and samples of antarctic meteorites. The Chlorine 36 measurements can be used along with hydrological data to date ground water in a million year time scale. The meteorite measurements have established terrestrial changes ranging from 0.1 to 0.7 million years and have provided information on the pre-terrestrial history.
- *Increased Sensitivity of Gravitational Wave Detectors.* An ingenious new transducer design has been created by an NSF-supported group at the University of Maryland to improve the conversion of very small mechanical oscillations into electrical signals. This will lead to significant advances in sensitivity of resonant bar gravitational radiation detectors.
- *Rydberg Atoms.* The latest developments in lasers make it possible to raise atoms to specific highly excited states. Such Rydberg atoms have unusual properties, because the outermost electron is orders of magnitude more distant from the nucleus than in the ground (unexcited) state and is thus very loosely coupled to the rest of the atom. Certain atomic effects are then more easily studied. Recent work includes the evaluation of relativistic effects in atomic hydrogen and measurements of fundamental atomic constants to a new accuracy.
- *Plasma Diagnostics.* New diagnostics have made it possible to explore the detailed structure of energetic plasmas without disruption or modification. Light

scattered or emitted by the plasma carries important information on the local density and velocity distribution of the plasma particles and on the local electromagnetic fields inside the plasma. Thus, a more exacting comparison with the theory of such plasmas, which is now possible, has so far confirmed the theoretical models.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

Both the FY 1980 Budget Request and the FY 1980 Current Plan reflect transfer of activities to the new Cross-Directorate Programs activity. The total resulting reductions to each are $0.7 million. The remaining difference between the revised FY 1980 Budget Request of $64.3 million and the FY 1980 Current Plan of $63.4 million is the result of Congressional action and directives. All areas except Theoretical Physics and Gravitational Physics are reduced to accommodate the lower overall total. Elementary Particle Physics is reduced $0.5 million, eliminating some planned increases in instrumentation for large experiments at major facilities. Within the reduced total for the area, support for the Cornell Electron Storage Ring (CESR) will be increased from $6.3 million, as estimated in the FY 1980 Request, to $6.7 million because the conversion to colliding beam operation was accomplished ahead of schedule, bringing increased usage of the facility and associated increased power costs. Intermediate Energy Physics and Nuclear Physics are reduced $0.3 million and $0.5 million respectively, curtailing planned support of $2.3 million for the Michigan State University (Phase I) cyclotron by $0.4 million, deemphasizing research on collective acceleration of heavy ions by $0.2 million, and reducing planned increases to the base programs by $0.2 million. Atomic, Molecular, and Plasma Physics is reduced by $0.1 million restricting efforts to improve instrumentation in this area. Theoretical Physics is at about the planned level, with $7.4 million. Gravitational Physics is increased $0.4 million above the earlier estimate of $2.8 million because of the high degree of scientific enthusiasm generated by new concepts for experiments to test relativity and new instrumentation being developed to detect gravitational radiation.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$61,664,569
FY 1980 Program	$63,361,000
FY 1981 Request	$73,500,000
Difference—FY 1981/FY 1980	$10,139,000

A summary of the planned changes in funding of various areas between the FY 1980 Current Plan and the FY 1981 Request is as follows:

- In Elementary Particle Physics, the planned increase of $3.4 million, from $22,761,000 in FY 1980 to $26,200,000 in FY 1981, will be distributed $0.7 million to Cornell Electron Storage Ring (CESR), bringing the total to $7.4 million for the

newly converted positron-electron colliding beam facility, and $2.7 million to restore the vitality of university-based user groups by providing instrumentation and technical support which was restricted during the CESR conversion.

- In Intermediate Energy Physics, the increase of $1.5 million will be used primarily to enhance the capabilities of electron accelerators at Stanford and Illinois, bringing the estimated total for these two projects to $4.6 million in FY 1981. The Indiana University Cyclotron Facility will receive a cost-of-living increase of $0.4 million to a total of $4.2 million. Support of user groups will be enhanced by reprogramming of funds from other projects in this area. The NSF supported accelerator laboratories are under continuous review, the outcome of which may result in curtailment of the support of one intermediate energy nuclear laboratory.
- In Nuclear Physics, an increase of $1.7 million will allow some enhancement of operations at MSU (Phase I), ($0.2 million) to $2.1 million, increased instrumentation and operating support at nuclear physics laboratories ($1.1 million) to $9.2 million, and additional support to smaller experiments in this area ($0.4 million). One laboratory, supported at $0.5 million in FY 1980, is being phased out and the funds are being redirected to support of the remainder.
- In Atomic, Molecular, and Plasma Physics, the $1.2 million increase to $8.3 million in FY 1981 will allow slight expansion of the level of effort.
- In Theoretical Physics, the $1.6 million increase will provide constant level of effort for the base program, and a small expansion for new thrusts. It also provides a $0.5 million increase to the Institute for Theoretical Physics as it enters its first full year of operation at its planned level of $0.9 million from the Physics subactivity and $0.3 million from the Materials Research subactivity.
- In Gravitational Physics, continued growth to this field will be provided with a $0.7 million increase, primarily for experimental projects, as scientific enthusiasm for this field continues strong.
- Instrumentation is an essential component of all areas of experimental physics. It is a continuing need which must be responded to in competition with other needs of the research groups, such as needs for technical support; needs for start-up funds for new investigators; needs for special areas of emphasis, e.g., Gravitational Physics; and on-going needs of the research programs.

The percentage changes between FY 1980 Current Plan and the FY 1981 Request are:

Elementary Particle Physics	15.1%
Intermediate Energy Physics	13.5%
Nuclear Physics	14.4%
Atomic, Molecular, and Plasma Physics	16.9%
Theoretical Physics	21.6%
Gravitational Physics	21.9%

Coordination With and Relationship to Other Efforts

The National Science Foundation provides almost one-half of the total federal support to universities for physics research. The role of NSF and the need for and mechanism of coordination varies with the nature of the field. Subfields requiring large and/or centralized facilities such as accelerators require more careful planning than those areas where individuals work primarily in their own laboratories or offices. Program officers in each field are in frequent communication with their counterparts in other agencies and, when appropriate, work with interagency or advisory committees for coordination and planning. The NSF Advisory Committee for Physics advises and performs oversight reviews on the NSF support of physics. Other agency personnel are invited to participate in the reviews which occur on a regular cycle about once every three years for each program. Special reviews are carried out as needed, including joint studies with other agencies as appropriate.

Although NSF provides only about 8 percent of the total support for elementary particle physics in this country, it funds nearly one-third of the university groups performing experiments in this field. Since the bulk of the work of the NSF-supported university user groups is conducted at major national installations operated with Department of Energy (DOE) support, close liaison is maintained between the two Federal agencies as well as with the laboratories at which the research is conducted. Common access to program decisions and frequent routine discussions and meetings between NSF and DOE staff provide for close coordination of activities. Also NSF staff members participate in meetings of DOE's High Energy Physics Advisory Panel and attend meetings of laboratory program advisory committees where proposed experiments are reviewed.

NSF provides about three-fifths of the total support to universities in nuclear science, the remainder being provided by DOE. NSF provides about 20 percent of the total Federal support for this area, with DOE providing national facilities which are used by NSF-supported groups. Coordination is accomplished by regular meetings, interagency committees on nuclear science, and through the joint NSF/DOE Nuclear Science Advisory Committee. Starting in FY 1980, the NSF and the DOE are sharing responsibility for development of a national facility for heavy-ion research at Michigan State University. NSF will continue in support of the operation and research program using a 500 MeV superconducting cyclotron (Phase I) while the DOE will undertake construction of an 800 MeV superconducting cyclotron (Phase II) to be injected by the beam from the Phase I cyclotron. Upon completion of Phase II construction, it is expected that the entire facility, including Phase II, will be operated with NSF support.

NSF supports about one-quarter of the national university program in basic atomic physics and about one-tenth in basic plasma physics. The other two principals are the Department of Defense (DOD) and DOE. Interagency committees on atomic and molecular physics and on plasma physics are the principal vehicles for coordination, in addition to direct staff contacts.

NSF supports about 40 percent of university basic research in theoretical physics. Coordination is achieved in the course of periodic meetings, including those described above for the experimental programs, and by staff contacts as appropriate.

National support for ground based experimental and theoretical gravitational physics research is heavily concentrated at NSF (Physics 85 percent, Astronomy 9 percent) with NASA playing a small role (6 percent). Effective coordination within NSF and between these agencies is provided by staff discussions.

Elementary Particle Physics $26,200,000

Objectives and Description

The Elementary Particle Physics Program has as its goals the understanding of the ultimate structure of microscopic matter and the laws of force which govern its behavior. In recent years, giant strides in understanding have been achieved through the experimental discoveries of new states of matter giving evidence of new types of quarks, heavy leptons and now, gluons, the particle believed to be responsible for binding the quarks together into the better known particles such as the proton, neutron, and pi meson. Further evidence has been produced which indicates the validity of some of the unification theories such as that of Glashow, Salam, and Weinberg which express the equations for the weak and the electromagnetic forces in a unified form.

These discoveries and associated theoretical understanding generate the next set of questions which require investigation. Included among these are the following:

- Can the strong force be combined with the weak and electromagnetic forces into a single theory; what experimental evidence will bear upon this point?
- How many different types of quarks and leptons exist; what are their properties and what are their relative relationships to one another?
- Is there an intermediate vector boson which mediates the weak interactions?
- What are the properties of gluons, and is it possible to calculate their interactions with quarks?

It has also recently become clear that the knowledge of elementary particle phenomena not only describes the microscopic structure of matter but also the microscopic universe and its early evolution.

The research involves experimental investigations of interactions of elementary particles using particle beams at accelerators as well as cosmic rays. These frontier experiments generally need novel and sophisticated instrumentation which also provides a strong push in developing new technology. The research is done primarily by university user groups, conducting experiments at major accelerator centers, such as Stanford Linear Accelerator Center (SLAC) and the Positron-Electron Project (PEP), Fermi National Accelerator Laboratory (FNAL), Brookhaven National Laboratory (BNL) and Cornell Electron Storage Ring (CESR). The first three laboratories are supported by the Department of Energy and the CESR facility is supported by the National Science Foundation.

To achieve the goals of the program, new thrusts into higher energy regimes utilizing new, unique facilities just beginning operation will be emphasized. CESR, the 8 GeV X 8 GeV electron-positron storage ring, and PEP, the 18 GeV X 18 GeV electron-positron facility, will be particularly important. These facilities are well suited to the study of bottom and top quarks, gluons, and heavy leptons. In addition, active user groups performing experiments at conventional, fixed target facilities such as those supported by the Department of Energy at Fermilab and Brookhaven will be maintained to study processes not measurable at the electron rings.

Finally cosmic rays will be used to study processes at energies not yet achieved in the laboratory.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $3,439,000, from $22,761,000 in FY 1980 to $26,200,000 in FY 1981, requested will be distributed as follows:

- During the past three years, heavy emphasis was given to preparing for experiments at the electron storage rings at Cornell and SLAC. To accommodate to these needs, it was necessary to reduce the base users program and to require a postponement in required improved instrumentation. In FY 1981 strong attention will be given to restoring the vitality of that element of the program. The increase of $2.7 million to a total of $18.8 million in the base users program will be used primarily to provide instrumentation which increases efficiency and capability in acquiring and processing data. This will be achieved through the acquisition of fast minicomputers and the development of data links to central computers. The remaining funds in the increase will be used to protect groups against erosion of capabilities due to inflation.
- An active research program at CESR will be continued. An increase of $0.7 million to a total of $7.4 million will be provided in anticipation of higher power costs and other items.

Intermediate Energy Physics Program Element $12,600,000

Objectives and Description

The primary objective of the Intermediate Energy Physics program is the investigation of nuclear matter with the unique experimental capabilities provided by high resolution proton beams in the energy range above 100 MeV, secondary fluxes of neutrons, mesons, and muons, and high-duty-factor and high-resolution beams of electrons in the 50-500 MeV range, along with their associated photon fluxes.

This energy range is particularly important for probing with high precision the fundamental nucleon-nucleon and meson-nucleon interactions that comprise the nuclear force. Other main objectives include the understanding of reaction mechanisms between the various probing particles and complex nuclei and the testing of symmetry principles and conservation laws in physics.

The NSF supports the operation of intermediate energy accelerator facilities at a few universities and also supports resident faculty and staff to further develop the experimental facilities and to exploit them in nuclear research. This includes capabilities for research with proton beams in the 100-200 MeV energy range. The Indiana University Cyclotron Facility is specially oriented toward support of a very broad and active group of outside users, some supported by NSF, and some by DOE. Superconducting linear electron accelerators which utilize beam recirculation to substantially increase the energy have been built with NSF support and are beginning operation at Stanford University and the University of Illinois.

A significant number of scientists engaged in intermediate energy research are resident faculty at universities which do not possess appropriate accelerator facilities. Support for these scientists to conduct research as users allows them to make vital contributions to the field by traveling to the specific national facility, whether funded by NSF or DOE, suited to their special research interests. In addition to research carried on at Indiana, Illinois, and Stanford, user groups supported by NSF are active in diverse areas of research at DOE's Los Alamos Meson Physics Facility, and others are exploiting the special features available at other DOE labs: the MIT-Bates Electron Accelerator, the Brookhaven Alternating Gradient Synchrotron, and Fermilab. An NSF-supported group is pioneering intermediate energy research at the Stanford Linear Accelerator. A few groups are now carrying out part of their research activities at international facilities in Switzerland, Canada, and France.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The Indiana University Cyclotron Facility will be increased by $0.4 million to $4.2 million in order to maintain a constant level of effort at this national facility. Design studies for new instrumentation will be included.

The high duty factor superconducting electron accelerators located at the University of Illinois and Stanford University will be reaching their design specifications allowing a shift in emphasis to the nuclear physics research unique to these facilities. In particular, high precision investigations of the correlations between final state particles should reveal finer details of nuclear structure. Magnetic excitations of nuclear energy levels will now be observable. This research will require incremental funding of about $0.8 million to bring the total for the two facilties to about $4.6 million.

Support of user groups at the major intermediate energy facilities will continue with an increase in emphasis on the electron facilities and incremental funding of $0.7 million will be required for new groups and equipment.

Research and development of collective accelerators, which sweep heavy ions along with an electron pulse injected into a gas-filled drift tube, will be deemphasized with a net reduction of $0.2 million.

Other areas of the program will be contracted by about $0.2 million compared with FY 1980.

Nuclear Physics Program Element $13,500,000

Objectives and Description

A primary objective of the Nuclear Physics program is a better understanding of the way collections of nucleons mutually interact through the strong force to form nuclei. These interactions involve two, three, and many nucleon interactions. Other objectives are to understand the nature of the weak force, the strong force, and their relationship to each other and to the electromagnetic force. Of increasing importance are studies of the macroscopic dynamic effects observed in very high velocity collisions of nuclei. Inner shell electron phenomena, forces and fields within solids, and nuclear reactions relevant to problems in astrophysics and nucleogenesis are important continuing areas of emphasis.

Facilities for the research supported by the Nuclear Physics program are located mainly at universities and presently consist of low energy cyclotrons and electrostatic accelerators, with auxiliary equipment tailored to the research interests of those using a particular facility. The variation in auxiliary equipment provides a diversity of capability such that most areas of nuclear physics can be pursued. In general, several alternative approaches to the solution of a given research problem are possible. To maintain these diverse capabilities, new equipment will be provided to existing laboratories as it becomes available and the need is demonstrated. New facilities with new capabilities will also be supported to keep the research at the frontier of nuclear science. Nuclear interaction between heavy ions is one area at the frontier. Accordingly, support for the enhancement of the capabilities of existing facilities to provide better heavy-ion beams is an important aspect of the program. In addition, the program supports design and development of new types of accelerators in order to provide ions in qualitatively new realms of energy and mass.

Nuclear Physics has had a pronounced influence on other sciences and on technology. As recent examples, accelerated beams of boron, nitrogen and fluorine have been used to study depth of penetration of hydrogen and helium in reactor vessels. Very accurate isotope dating techniques have been developed for application to archeology, geochemistry and other areas of science and technology.

In some of these efforts, and in pure research work as well, there has been considerable Industry/University cooperation. For example, the dating techniques mentioned above were developed jointly by physicists from the University of Rochester,

the University of Toronto, and General Ionex Corporation and much of the work on interactions between charged particles and solids was carried out in a joint program involving Rutgers University and the Bell Telephone Laboratories. Other such cooperative projects are planned.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

A major thrust in the Nuclear Physics program is in the development and exploitation of new capabilities for research into heavy-ion physics. At Michigan State University, an increase of $0.2 million to a total of $2.1 million is planned to support research at the newly-completed (Phase I) 500 MeV heavy-ion cyclotron. This will support the in-house research program on Phase I and will provide equipment and manpower to make the facility accessible to outside users as well as to the resident staff. The installation of a post accelerator at the State University of New York at Stony Brook will proceed as planned at $1.2 million, an increase of $0.2 million over FY 1980.

Support of university low energy nuclear physics laboratories will continue to allow investigation of the many different aspects of nuclear structure and other topics which can be addressed by versatile low energy Van de Graaffs and cyclotrons. One university laboratory, supported at $0.5 million in FY 1980, will be phased out, with the funds being reprogrammed into the remaining laboratories. Total support to these laboratories will be enhanced by $0.9 million to an estimated $8.0 million with emphasis on instrumentation and increased technical support at the stronger laboratories.

Support for user groups working away from their home institutions, for other individual research projects, and for new investigators will be increased by $0.4 million to a total of $2.2 million.

Atomic, Molecular, and Plasma Physics Program Element $8,300,000

Objectives and Description

The primary goal of this program is to develop greater understanding of the way in which matter at the atomic and molecular level interacts with its surroundings, and the way in which charged particles collectively respond to stimuli produced by collisions, radiation, or electromagnetic fields. The program is closely coupled to investigations which enlarge our knowledge of the basic properties of matter through tests of current theory.

The revolutionary development of new lasers has generated a similar revolution in experimental atomic physics. One can now obtain high concentrations of atoms and molecules in well-defined excited states. Thus, a specific current objective of the program is to support investigations of laser-induced excited-state interactions. Be-

cause of their weak binding, excited state systems frequently interact much more strongly with external fields than normal atoms, thus providing an enhanced view of these interactions. Such studies promise to open new dimensions in allied fields such as laser-induced chemistry. Another challenging area which is rapidly expanding is in accelerator-based atomic physics in which fast particles excite the innermost electrons of the atom.

Plasmas of new and unique properties are being investigated. We are extending our knowledge of basic plasma interactions to new compositions of matter such as the electron gas or solid in which collisions between plasma constituents become less and less important. New diagnostic techniques are yielding new and important information in a non-perturbing fashion. The program continues studies leading to precision measurements of fundamental atomic constants while also stimulating research in emerging fields of atomic, molecular, and plasma physics.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Funding in FY 1981 will be increased by $1.2 million from $7.1 million to a total of $8.3 million. Continuing pressures on the program result from the need to provide modern, state-of-the-art equipment to a rapidly developing area of Physics and the need to stimulate new and/or speculative research. The planned increase will partially alleviate the rising costs and increasing sophistication of the ongoing activities, provide some funds for the purchase of research equipment that had been delayed, and will assist in the maintenance of existing equipment. New areas of atomic physics not included in the present program are emerging—such as accelerator-based atomic physics and the expansion of chemical physics resulting from the widespread use of lasers. These are generating large pressures on the program for support of new and exciting projects.

Theoretical Physics Program Element $9,000,000

Objectives and Description

The objective of this program element is to promote the theoretical understanding of the basic physical laws governing the behavior of matter and of the way in which these laws determine the properties of all physical systems, from nuclei to stars.

The theoretical physicist formulates hypotheses and models to explain what is observed. The hypotheses are then used to predict the results of new experiments, which will test whether the theory represents a correct understanding of nature. Thus, the theorist not only interprets the clues which nature provided in the past but also plays an important role in suggesting new directions for research aimed at uncovering new clues.

The program supports individuals and groups of theorists primarily studying elementary particle, nuclear, and atomic physics and an Institute for Theoretical Physics.

The Institute is located at the University of California, Santa Barbara, and began operation in September 1979. It is a five-year experiment, attempting to facilitate an effective attack on inter-subfield problems in theoretical physics.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The program will continue to support the most talented researchers in each major area of theoretical physics. Special emphasis will continue to be placed on elementary particle theory, which has proved exceptionally fruitful recently, and on nuclear theory, which will be focused on the nuclear phenomena revealed by major new experimental facilities. Of the $1.6 million increase requested, $0.5 million will be for the Institute for Theoretical Physics, bringing the total from Physics to $0.9 million. (The Materials Research program will provide the additional $0.3 million required for full-scale Institute operation.) The remaining $1.1 million of the increase requested will strengthen project support for theoretical physics. This will improve the flexibility to pursue new ideas in all areas, provide increased opportunities for theorists to exploit the recent breakthroughs in particle theory, and permit interactions among theorists to be more adequately fostered. These interactions are centrally important to progress in theoretical physics.

Gravitational Physics Program Element $3,900,000

Objectives and Description

The objective of the Gravitational Physics program element is to develop our understanding of the role played by gravity in nature. At the cosmological level, this program explores aspects of the explosive creation of the Universe, its present dynamical evolution, and its ultimate fate. On the astronomical scale, basic studies of strong gravitational fields are intimately related to the observed properties of incompletely understood objects such as X-ray sources, quasars and black holes. In the laboratory, exceedingly sensitive experiments look for the fine details of weak gravitational fields to check theoretical predictions. At the microscopic scale of distances, theorists seek to unify the gravitational interaction with quantum mechanics and particle theory.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Development of gravitational wave receivers will continue. Emphasis in narrowband (resonant bar) devices will shift from assembly of cryogenic systems to the development and production of low noise transducers and amplifiers operating at the theoretical limits of sensitivity ($0.2 million increase). Prototype studies of wideband

(laser interferometer) gravitational radiation detectors will expand ($0.1 million increase). Other experimental studies of Newtonian and post-Newtonian gravitation, cosmology, and the foundations of General Relativity will continue at approximately the same level of effort ($0.2 million increase).

Theoretical research will expand modestly to allow new young scientists to enter the field ($0.2 million increase). Researchers will study intense gravitational fields, relativistic astrophysics, and quantum gravitation. The connections between classical gravitation and elementary particle theory will be stressed.

QUANTITATIVE PROGRAM DATA
PHYSICS SUBACTIVITY

Proposals and Awards Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of Proposals Received*	547	550	600
Number of Awards**	349	355	375
Dollars Proposed (Total)	$148,000,000	$155,000,000	$175,000,000
Dollars Proposed (Annual Rate)	95,000,000	100,000,0000	115,000,000
Dollars Awarded (Total)	61,664,569	63,361,000	73,500,000
Dollars Awarded (Annual Rate)	61,600,000	63,361,000	73,500,000
Average Dollar Per Award	162,703	178,000	196,000
Average Award Duration	12 mo.	12 mo.	12 mo.

*Includes proposals for committed renewals, supplements, etc.
**Includes awards for committed renewals, supplements, etc.

Discrete Items

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Colliding Beam Laboratory	$8,000,000	$6,700,000	$7,400,000
Cyclotron Laboratories	7,800,000	7,000,000	6,800,000
Van de Graaff Laboratories	6,600,000	7,700,000	8,700,000
Electron Accelerator Laboratories	3,100,000	3,800,000	4,600,000
Institute for Theoretical Physics	400,000	400,000	900,000

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges			
Discrete Items	42.0%	40.4%	38.7%
Other Project Awards	56.8%	58.4%	60.1%
Industry	0.2%	0.2%	0.2%
Other	1.0%	1.0%	1.0%

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Senior Scientists			
Faculty*			
Number of work-years supported	150	140	150
Amount of faculty support	$4,760,000	$4,900,000	$5,700,000
Postdoctoral Associates:			
Number of years supported	340	330	350
Amount of postdoctoral support	$5,330,000	$5,500,000	$6,300,000
Graduate Students			
Number supported per award-year	640	620	650
Amount of graduate student support	$3,600,000	$3,700,000	$4,200,000
Other Personnel Costs	10,210,000	10,500,000	12,000,000
Other Direct Costs	23,614,569	23,961,000	28,300,000
Indirect Costs	$14,150,000	$14,800,000	$17,000,000
Total	$61,664,569	$63,361,000	$73,500,000

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Instrumentation

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Land, Buildings, and Fixed Equipment	—0—	—0—	—0—
Major Equipment	$7,700,000	$3,300,000	$2,800,000
Other Equipment and Instrumentation	$9,100,000	$9,200,000	$11,400,000

CHEMISTRY PROGRAM SUBACTIVITY $59,500,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Structural Chemistry and Thermodynamics	$9,438,647	$10,452,000	$10,658,000	$12,370,000	$1,712,000
Quantum Chemistry	7,398,196	8,544,000	8,318,000	9,587,000	1,269,000
Chemical Dynamics	8,470,000	10,145,000	9,929,000	11,501,000	1,572,000
Chemical Analysis	5,139,690	6,100,000	5,783,000	6,653,000	870,000
Synthetic Inorganic and Organometallic Chemistry	5,157,618	6,248,000	5,808,000	6,682,000	874,000
Synthetic Organic and Natural Products Chemistry	5,559,330	6,205,000	6,158,000	7,137,000	979,000
Chemical Instrumentation	4,067,000	5,241,000	4,760,000	5,570,000	810,000
Total	$45,230,481	$52,935,000	$51,414,000	$59,500,000	$8,086,000

Objectives and Description

The Foundation's objective in supporting basic research in chemistry is to stimulate development of chemistry on a broad front, including chemical synthesis, analysis, dynamics and structure.

Chemistry is in a period of unusual discovery and excitement, a period perhaps unparalleled in the history of the field. On the horizon, there are opportunities for new insights into chemical phenomena at a level of detail never before possible. Gaining these insights will make the chemistry of the future even more useful than that of the past, both as it influences other sciences and as it impacts areas such as energy, agriculture and health.

Several factors account for the accelerated pace of discovery, but none more clearly than instrumentation. Instruments are a window on the interactions of atoms and molecules, which is the level of most fundamental importance for understanding chemistry. Over the years chemists' demands for increasingly incisive measurements have produced a constant progression of new instruments. Very recently, however, improvements have occurred at an unprecedented rate, due to technological advances in areas such as superconductivity, electronics, and lasers. Now there are instruments to make measurements—and computers to analyze the data—along essentially every dimension of importance to chemistry: time and spatial resolution, selectivity, and sensitivity. Even the fastest chemical processes, such as photosynthesis, can be studied in stop action fashion. And the reactions of individual molecules can be isolated in time and space—and even in particular quantum states—to study intermolecular forces and reveal the laws of chemical bonding.

Advances in theory and chemical synthesis also are occurring rapidly, spurred in part by the instrumentation revolution. Practical applications of theory are increasingly commonplace, due to the power and ubiquity of computers. Rather than an abstract subject for specialists, theory is more and more a tool for general use in chemistry.

Chemical synthesis, which is the ability to modify existing compounds and create new ones with particular molecular structures, lies at the heart of chemistry. Consistent with the other developments occurring in the field, the capabilities in chemical synthesis also have advanced remarkably during the past decade. Synthetic challenges such as the laboratory production of genes, proteins, antibiotics, and vitamins—once thought to be the sole province of nature—are now yielding to the new sophistication of chemical synthesis. As far as one can project, there appear to be limitless opportunities for even greater advances in synthesis in the future.

As a result of these developments the research frontier in chemistry is unusually fertile at this time. Significant discoveries are expected in all subfields of chemistry during the eighties. The goal of the Foundation's chemistry programs, therefore, is to pursue these opportunities across a broad front as aggressively as available resources permit.

Major Research Questions

Modern chemistry involves a spectrum of experimental and theoretical research into the synthesis, structure, and dynamics of molecules. Some representative examples of questions confronting chemists are:

- Why are metal surfaces (heterogeneous catalysis) so much more active than metal complexes (homogeneous catalysis)?
- How can the influence of the microenvironment surrounding molecules be sufficiently understood to be used for enhancing productive reactions and preventing undesirable ones?
- What are the mechanisms and time scale for energy migration within a molecule?
- Can more selective and efficient methods of separation be developed to unravel mixtures as complex as those found in chemical systems of biomedical or environmental importance?
- How can certain chemical bonds, such as between carbon-hydrogen or carbon-carbon, be made more reactive at ordinary temperatures and pressures?
- What new methods of volatilization and ionization of macromolecules could extend the use of mass spectral techniques?
- To what extent can computer modelling of the design and construction of complex molecules be developed into tools for synthesis of new molecules?
- Can alternative chemical paths for nitrogen fixation be found, and can analogous conversions of other abundant materials be catalyzed?
- Can a predictive model to identify new laser-induced chemical reactions be found?
- What critical data on chemical and photochemical reaction intermediates are needed so that lasers can be used for ultrafast analysis of transient species?

Significant Recent Achievements

The following examples are representative of the diversity of basic research in chemistry. They illustrate both the quest for new knowledge at the most fundamental level, as well as the practical potential of chemical research.

A New Catalyst for Fuel Cells

The concept of fuel cells has been around for more than a century. They were used successfully in manned space flights and are presently being developed to provide electrical power for apartment houses. Fuel cells convert chemical energy into electricity by the "combustion" of a fuel on an electrode surface. A fuel cell is essentially a battery in which reactants (fuels) are continuously supplied to the electrodes and the products are continually removed. However, most electrochemical reactions, which lie at the heart of fuel cell technology, are not effective without a catalyst. This is particularly true for oxygen. A major advance in efforts to produce a better, cheaper catalyst for oxygen was recently announced by James P. Collman, at Stanford University. The Stanford group has synthesized new compounds, called face-to-face porphyrins, that can be attached to graphite electrodes. Experiments have demonstrated that such electrodes catalyze the reduction of oxygen to water. The demonstration of catalysis took place in the laboratory of Fred Anson at the California Institute of Technology, a co-investigator on the research project. In terms of both current and voltage, the new porphyrin catalysts appear to be more potent than the costly platinum catalysts now being used in most practical fuel cells. This project, which also involves collaboration with chemists at the Hercules Research Center, is partly supported through the Foundation's Industry-University Cooperative Program.

Picosecond Studies of Ultrafast Reactions

The exploration of light-induced processes has made spectacular advances thanks to lasers that can generate light pulses lasting less than a picosecond with powers in the range of ten trillion watts. Consequently, a new field is emerging known as picosecond spectroscopy. Several research groups, with support from the Foundation, are using picosecond spectroscopy to study ultrafast processes. For example, Kenneth B. Eisenthal, of Columbia University, is studying how individual hydrogen atoms within a molecule can sometimes dictate the structure and reactivity of the molecule. An important and very unusual system in which hydrogen plays this role is a compound known as 7-azaindole. This compound exists as a hydrogen-bonded dimer. The phenomenon of hydrogen bonding is critical in most biological reactions. Upon absorption of a single photon by azaindole, two hydrogen atoms shift simultaneously, producing a different structural form. Eisenthal's laboratory has found that this double hydrogen transfer occurs in fewer than 5 picoseconds. These results have generated both theoretical and experimental interest for two reasons: the system involves excited state hydrogen transter; and the dimer of 7-azaindole is similar to the hydrogen-bonded base pairs of DNA. Thus, this dimer could become a model for studying light-induced genetic changes (mutagenesis).

Laboratory Synthesis of Plant Growth Promoter

In the plant kingdom, gibberellic acid is an important compound because it regulates plant growth. It and related gibberellins stimulate cell division and elongation in leaves and stems. They also influence fertilization and dormancy and, when a seed begins to sprout, trigger release of digestive enzymes that open the young plant's food reserves. Gibberellic acid is commercially produced from the Fungus, *Gibberella fujikuroi*. Chemical synthesis of the hormone has been a goal of synthetic organic chemists for almost 20 years, since scientists first determined its structure in the early sixties. Until recently, however, a combination of factors have thwarted all attempts at synthesis. Now, the total synthesis of this plant-growth-promoting substance has been achieved by E. J. Corey and his co-workers at Harvard University. Their total synthesis ends one of the longest quests in synthetic organic chemistry. It also opens new ways to construct slightly altered compounds that will be the key to determining how gibberellic acid performs its many functions. Perhaps equally important, as a by-product of developing synthetic routes to gibberellic acid, many other general-purpose synthetic methods have been discovered by Corey.

Spectroscopy in Supersonic Molecular Beams

A supersonic molecular beam is the term used to describe a gas that is forced under high pressure through a very small nozzle into a high vacuum. As the beam of gas enters the vacuum it expands rapidly. This rapid expansion drastically cools molecules in the beam, but without freezing them out of the gas phase (the effect is analogus to the way air conditioners work). This drastic cooling makes it possible to study molecules having internal temperatures reduced to within less than one degree of absolute zero. Recently, Donald H. Levy's laboratory at the University of Chicago has used this technique to study the intra-molecular energy flow and photochemistry of weakly bound molecules. With the aid of lasers, they have succeeded in depositing energy selectively into a single vibrational state of such a molecule and then measuring the time it takes for this energy to migrate and break the weak bond. They also are able to measure how any excess energy, not used in bond breaking, is distributed in the fragments that are produced in the photochemical reaction. Such knowledge becomes a major building block in improving fundamental understanding of many chemical processes.

Chemical Synthesis of Cockroach Pheromone

Females of the species *Periplaneta americana*, the American cockroach, have long been known to produce an extraordinarily potent pheromone that acts over relatively short distances as a sex excitant. Interest in this material has intensified since its discovery some 25 years ago, resulting in numerous behavioral studies as well as attempts to isolate and identify the active components. Recently, W. Clark Still of Columbia University developed a new synthetic strategy for preparing molecules containing 10 atoms in a ring. This development made possible for the first time the synthesis and structural characterization of the cockroach sex excitant known as peri-

planone B. The new synthetic methods developed by Still constitute an important advance in preparing molecules with complex geometrical arrangements. The successful synthesis also means that the sex excitant can now be prepared in sufficient quantity to permit extensive investigations of its use in pest control.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

Both the FY 1980 Budget Request and the FY 1980 Current Plan reflect transfers of activities to the new Cross-Directorate programs activity. The amount transferred to this activity is $400,000. The FY 1980 Current Plan represents an overall decrease of $1,586,000 below the FY 1980 Budget Request. This decrease was absorbed among each of the Chemistry program elements. In addition, since submission of the FY 1980 Budget, there has been a small enhancement in the Structural Chemistry and Thermodynamics Program in response to exceptionally high quality proposals in this program.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$45,230,481
FY 1980 Program	$51,414,000
FY 1981 Request	$59,500,000
Difference—FY 1981/FY 1980	$8,086,000

The increase of $8,086,000, from $51,414,000 to a total of $59,500,000, will be combined with about $1,600,000 obtained by selective reductions in less competitive research areas, as determined by peer review. The combined amount ($9,686,000) will be used as follows:

- $7,123,000 to provide approximately 16% growth in the average award size. In recent years, most of the Chemistry Division's project grants have fallen below levels needed to pursue basic research efficiently. As a result, real growth in grant sizes is needed to meet the high cost of chemicals and to reach adequate personnel and instrumentation levels on individual projects.
- To increase support for instrumentation serving groups of investigators in chemistry departments by $724,000. The FY 1980 total for departmental instrumentation is $3,946,000.
- To provide an additional $86,000 per year for the National Resource for Computation in Chemistry. In FY 1980 the Foundation is providing $814,0000 for this activity.
- To initiate about 40 new projects ($1,753,000). Young investigators will be principal investigators on many of these new projects. The number of new projects will be approximately equal to the number of projects terminated by selective reductions.

- Instrumentation support included in individual project grants will increase by 15% ($900,000). The level of support for individual project instrumentation in FY 1980 is about $5.9 million. The level proposed for FY 1981 is $6.8 million.
- Included with the new projects will be research in submicron related science ($500,000). New opportunities for chemical research related to submicron science include chemical resists and photochemistry, surface analysis and characterization and ultramicro electrochemistry. Support for this area in FY 1980 is about $2.3 million. A level of $2.8 million is planned for FY 1981.

The enhanced support levels provided in FY 1980 for research related to catalysis and laser chemistry will be maintained in FY 1981.

Percentage changes between the FY 1980 Current Plan and the FY 1981 request for the Chemistry program elements are as follows:

Structural Chemistry and Thermodynamics	16.1%
Quantum Chemistry	15.3%
Chemical Dynamics	15.8%
Chemical Analysis	15.0%
Synthetic Inorganic and Organometallic Chemistry	15.0%
Synthetic Organic and Natural Products Chemistry	15.9%
Chemical Instrumentation	17.0%

Coordination and Relationship to Other Efforts

Individual program directors interact with their counterparts in other agencies and, in addition, the NSF Chemistry Division hosts interagency meetings of administrators who are responsible for funding in chemistry throughout the Federal Government. This group meets twice a year to exchange information, discuss problems and coordinate efforts. The Chemistry Division also participates in an interagency coordinating group in the area of laser development and applications.

Only three Federal agencies support chemical research in colleges and universities in a significant way: Department of Energy, 12%; National Institutes of Health, 26%; and NSF, 48%. Although the Department of Defense supports chemistry, the total is small (8%).

Within these totals, the role of NSF varies by area. NSF supports about 60% of the research in inorganic chemistry, 70% in physical and analytical chemistry, and 20% in organic chemistry. In addition, NSF provides approximately 80% of the total national support for chemical instrumentation. Most of the support for synthetic organic chemistry (80%) is provided by NIH. As a result, the NSF program in synthetic organic chemistry is smaller than one would otherwise expect. The Foundation's Synthetic Organic and Natural Products Chemistry Program is the main source of support of the nonhealth-related areas of organic synthesis.

Since FY 1978, the National Science Foundation and the Department of Energy have jointly supported the National Resource for Computation in Chemistry.

Structural Chemistry and Thermodynamics Program Element $12,370,000

Objectives and Description

The Structural Chemistry and Thermodynamics Program provides support for: the determination and chemical interpretation of molecular shape and composition, using spectroscopic and diffraction methods; the experimental and theoretical study of the bulk properties of matter, using thermodynamic and statistical methods; the investigation of intermolecular interactions in solids and liquids by a variety of techniques, including appropriate scattering methods for the characterization of the structural and dynamical properties of surfaces and interfaces and also their catalytic properties in chemical reactions; the study of small molecular aggregates; and the development of new experimental and theoretical tools related to these. The specific objectives of research in this program are to:

- Characterize the relationships between intermolecular forces and the properties of matter that are determined by large numbers of molecules acting together;
- Determine the energy changes accompanying molecular transformations of either a physical or chemical nature;
- Develop appropriate statistical theories to show how molecular characteristics determine the properties of gases, liquids and solids;
- Determine the properties of surfaces and interfaces, and the nature of phase transformations in single and multicomponent liquid and solid systems;
- Measure and theoretically describe the structural, dynamical and chemical properties of molecular species found at the boundary between a gas and a solid;
- Determine structural parameters for molecules, including transient species and ions; and
- Develop new physical methods for chemical structure determination.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

In addition to funds released by selective reductions in less competitive areas, an increase of $1,712,000 from $10,658,000 in FY 1980 to $12,370,000 in FY 1981, is needed for the following purposes:

- Development and application of laser spectroscopic methods for structural analysis of molecules and chemical reaction intermediates.
- Continued development of laser light scattering, both elastic and inelastic, as a detailed probe of the structural and dynamical character of molecules in solution.

- Characterization of the concentration, structure, and reactivity of species present on transition metal-based catalysts during the course of a reaction.
- Acquisition of new data systems that will automate spectroscopy and diffraction studies and permit previously impossible studies to be conducted.
- Development of laboratory equipment to carry out extended X-ray absorption fine structure measurements.
- Continued growth in experimental and theoretical surface chemistry.

Quantum Chemistry Program Element $9,587,000

Objectives and Description

The Quantum Chemistry Program provides support for the development of chemical theory, including both molecular structure theory and scattering theory; experimental studies of chemical transformation under single collision conditions; studies of the interaction of electromagnetic radiation with atoms and molecules; and experimental studies of energy transfer within and between individual molecules. The specific objectives of the program are to:

- Develop chemical theories to aid in the design and interpretation of experimental studies;
- Improve understanding of chemical reactions through experimental studies of single collisions of atoms and molecules;
- Acquire and interpret data on the interaction of radiation with atoms, molecules, and free radicals; and
- Develop a better understanding of energy transfer and relaxation mechanisms within and between individual molecules.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Support for this program will increase by $1,269,000, from $8,318,000 to $9,587,000 in FY 1981. This increase, combined with selective reductions, is required for expanded activity in the following areas:

- State-to-state chemistry. The application of laser technology to colliding molecular beam studies has made possible the study of chemical reactions at the most fundamental quantum-state level. This new research area is in its infancy and is undergoing significant growth.
- Theoretical chemistry. The application of new laser devices to chemical systems

is placing new demands on theory. New methods and concepts are needed to interpret and design a wide variety of experiments.

- Instrumentation. A new generation of small on-line computers for data acquisition and control is providing the capability needed for many forefront experiments. There is also an increasing demand for laser systems for spectroscopic observations and for studies of energy transfer and relaxation.

Chemical Dynamics Program Element $11,501,000

Objectives and Description

Research in Dynamics involves elucidation of the factors that determine the mechanisms and rates of chemical reactions. These factors include the nature of reactants, the influence of chemical environments and energy sources, and the role of catalytic substances. The principal methodologies of chemical dynamics are the measurement of reaction kinetics and the identification of transient intermediates. Information from kinetic studies, together with knowledge of structures and composition of reactants and products, leads to an understanding of the evolving molecular events that occur in the course of chemical changes.

Ultimately, the goal of chemical dynamics research is to discover general laws that govern chemical reactions and to find correlations that relate molecular structure with reactivity. Specific objectives of this program are to:

- Determine the kinetics of those reactions which will further illuminate the general principles of chemical reactivity;
- Understand the influence of chemical environments, energy sources and catalysts on rates and products of chemical reactions;
- Observe and identify short-lived intermediates in reacting systems and understand their role in producing chemical change;
- Develop correlations and generalizations between molecular structure and reactivity that allow design of catalysts with desirable properties;
- Develop new techniques and instruments to allow the above objectives to be achieved; and
- Provide fundamental rate data of significance to other disciplines such as the atmospheric and life sciences.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Support for the Chemical Dynamics Program in FY 1981 will increase by $1,572,000, $9,929,000 to $11,501,000. This increase, combined with selective reductions in less com-

petitive subfields, will be directed toward accelerating research in the following areas:

- Laser Chemistry, Spectroscopy, and Kinetics. Continuing studies will test whether new chemical reactions distinct from thermal processes can be induced by the rapid influx of energy, and whether symmetry and other rules governing normal chemical reactions apply under these severe reaction conditions. Picosecond lasers will be applied increasingly in time-resolved spectroscopic studies of transient intermediates of chemical reactions, and to determine rates of ultra-fast transformations heretofore not open to scrutiny.
- Catalysis. Solar energy, nitrogen fixation and alternatives to petrochemical synthesis are key areas in which substantial effort should pay dividends. The rational design of effective catalysts depends upon developing predictive principles which relate structure and function. Organometallic and metal cluster compounds, macromolecules such as micelles or membranes, and changes in reaction medium on irradiation with light can promote chemical transformations while avoiding energy- and resource-wasting processes. Research in bioorganic and bioinorganic mechanisms will continue to unravel the complex reaction sequences employed in catalysis by living systems.
- Laboratory determination of rates and mechanisms of environmentally significant chemical reactions. Internal combustion engine emissions, industrial effluents, pesticide contamination/degradation, and atmospheric phenomena such as smog formation, ozone depletion, carbon dioxide accumulation, and acid rain are examples of key environmental problems. Solutions to these and prevention of new problems hinge on understanding the dynamic interaction of multiple and simultaneous chemical reactions in the gas phase, in solutions, and at gas-liquid interfaces. Both the rates of fundamental reactions and the reactivity of transient intermediates are needed; new measurement techniques will facilitate development of such data on time scales and with an accuracy not previously possible.

Chemical Analysis Program Element $6,653,000

Objectives and Description

Chemical analysis deals with the separation, identification and determination of the components, either atomic or molecular, which comprise the complex mixtures found in all states of matter. Chemical analysis is, therefore, an essential tool for the disciplines of chemistry, for other disciplines such as biology, oceanography and materials research, and for technologies such as clinical medicine, metal refining, and food processing, as well as those comprising the chemical industry itself.

The objectives of this program element are to:

- Discover more sensitive, selective, accurate, and precise methods of chemical analysis which are applicable to all states of matter;
- Develop new or improved methods for the analysis of species that exist at surfaces and interfaces;
- Enhance the usefulness of analytical techniques by coupling novel chemistry and advanced instrumentation with computer management of the entire analytical process; and
- Discover comprehensive approaches to the analysis of complex materials such as coal or airborne particulates.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Support for this program will increase by $870,000, from $5,783,000 to $6,653,000. The increase is required for continued support of high quality research projects in the following areas:

- Studies of dynamic and equilibrium methods of analysis capable of determining bulk solution concentrations as well as the concentration of species at a liquid-solid interface and studies of the electrolysis processes related to energy conversion devices.
- Studies of sources for the atomization, ionization or excitation of samples utilizing advanced instrumentation such as lasers, ion microprobes, and high intensity X-radiation with particular attention to submicron analytical methodologies.
- Development of analytical techniques based on new instrumental capabilities that allow the measurement of transient events on the nanosecond and subnanosecond time scale using laser excitation.
- Understanding of the role of chemical interactions at conducting, semiconducting and insulating interfaces that have been chemically modified.
- Research on improved chromatographic methods of separation which are based on novel chemistry and advanced instrumentation as well as new methods used in one-dimensional diffusion.

Synthetic Inorganic and Organometallic Chemistry Program Element $6,682,000

Objectives and Description

The objective of this program is to increase our overall comprehension of chemical reactivity involving metal ion participation. This information will in turn contribute greatly to the basic understanding of catalytic activity extending all the way from industrial processes vital to our economy to biological processes that affect the health of all plant and animal life.

Synthetic inorganic and organometallic chemistry is concerned with the preparation and reactions of chemical compounds composed of metals and nonmetals (such as silicon, chlorine, boron, etc.). Inorganic atoms rarely have the ability to link chemically to other atoms of the same kind to provide extended molecules, as does carbon. However, compounds made from metals do have the ability to act as catalysts for many organic chemical reactions, and they also play an important role in plant and animal nutrition, in medicine, in ecology, and in energy conservation. Catalysts are exceptionally important to the synthetic chemist, because they increase the speed of a reaction and often direct the reaction in a specific way. Industry has an intense interest in catalysis, because in large scale processes catalysts can be used to conserve enormous amounts of energy and minimize disposal or pollution problems. The discovery or design of ideal catalysts is a scientific and technological challenge before the nation and the world—be it in the production of fuels, food substitutes, fertilizers, gasoline, fibers, plastics, or pharmaceuticals. For rational design of ideal catalysts, there must be an understanding of inorganic reactions at a molecular level. This program supports research that will provide this information.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $874,000, from $5,708,000 to $6,682,000 in FY 1981, plus funds provided by selective reductions in less promising areas, will be used for expanded support of research related to the following:

- Metal clusters and catalysis.
- Plant and animal trace element nutrition and nitrogen fixation.
- Heavy metal ion removal in environmental science.
- Research on chemical basis of chemotherapy utilizing metal coordination compounds and metal clusters in the treatment of arthritis, cancer, and a host of specific metal ion deficiency diseases.
- Specialized equipment especially in catalysis-related research.
- Metallic element synthetic chemistry related to materials development and surface science.

Synthetic Organic and Natural Products Chemistry Program Element $7,137,000

Objectives and Description

The ultimate goal of this program is to develop synthetic organic chemistry to the point that any organic compound, whether previously known or not, can be readily prepared from available starting materials. A related objective is to understand completely how molecular structure determines the chemical, physical, and biological properties of a given compound.

To make progress toward these objectives, it is necessary to study known reactions, discover new reactions, and systematize synthetic methodologies. The results of these efforts enable the synthetic organic chemist to start with molecules of one compound, break specific bonds, add new groups of atoms, then adjust the three-dimensional structure of the molecule to give exactly the desired product, all in fast and efficient ways. Attention is also directed toward the characterization and synthesis of natural products (organic compounds isolated from man, animals, and plants) for reasons including the discovery of compounds with interesting and useful properties, the application of new synthetic strategies to known target compounds, and the unambiguous proof of the structure of such compounds. As their synthetic abilities evolve, organic chemists are able to manipulate the structures of increasingly complex compounds that not only are useful but also test the limits of the most fundamental concepts in modern chemistry.

Over the past century, especially the last 30 years, hundreds of different classes of reactions have been discovered and their usefulness evaluated. Over a million organic compounds have been synthesized, represented by such varied types as pharmaceuticals, plastics, synthetic fibers, flavorings and fragrances, preservatives, pesticides, herbicides, fuels, and explosives. Clearly, synthetic organic chemistry has a major impact on our nation's economy and standard of living. Yet, much remains to be done, especially to develop new compounds with beneficial effects.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The funding level of this program will increase by $979,000, from $6,158,000 to $7,137,000. This increase will be used to maintain the overall quality of work supported by this program and to initiate especially promising new projects in synthetic methodologies utilizing starting materials derived from renewable natural resources.

- The chemistry of organic compounds containing phosphorus, sulfur, silicon and boron, and their uses as synthetic reagents.
- Selected nonhealth related projects.
- The synthesis of compounds that test and extend theoretical concepts.

Chemical Instrumentation Program Element $5,570,000

Objectives and Description

Chemistry is an experimental science that is constantly changing and its vitality remains intimately tied to the availability of instruments and equipment for basic research. The objective of the chemical instrumentation program is to assist departments of chemistry in acquiring major items of instrumentation and equipment. The program is managed to avoid unnecessary duplication and to ensure that instrumentation is used in a cost-effective way.

The instrumentation program provides for the following types of support:

- Instrumentation that is essential to the research objectives of a broad range of chemical subfields and a large number of scientists in chemistry departments;
- Instrumentation of crucial importance to the research objectives of two or more members of a chemistry department and of a more restricted technical scope; and
- Instrumentation development requiring construction of new instrumentation or improvement of existing instrumentation which is expected to achieve basic research objectives in chemistry.

This program element also includes support for the National Resource for Computation in Chemistry (NRCC), located at the University of California, Berkeley. NRCC is jointly funded with the Department of Energy in approximately equal amounts.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Support for chemical instrumentation and equipment will be increased by $810,000, from $4,760,000 to a total of $5,570,000 in FY 1981. This is required to continue to supply new departmental instrumentation in the following areas:

- Nuclear magnetic resonance instrumentation for broad departmental use.
- Mass spectrometry instrumentation with multiple-source capability for support of basic research in synthetic and mechanistic chemistry.
- High-speed mini-computers for data acquisition and interpretation in experimental chemistry as well as for computation in theoretical chemistry.
- Lasers in chemical research.

In addition, funding for the National Resource for Computation in Chemistry will be increased by $86,000 above the FY 1980 level of $814,000 to a FY 1981 level of $900,000.

QUANTITATIVE PROGRAM DATA
CHEMISTRY PROJECT SUPPORT PROGRAM SUBACTIVITY

Proposal and Award Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of Proposals Received*	1,447	1,500	1,500
Number of Awards**	905	900	900
Dollars Proposed (Total)	$231,391,000	$259,808,000	$288,201,000
Dollars Proposed (Annual Rate)	92,556,000	103,923,000	115,280,000
Dollars Awarded (Total)	45,230,481	51,414,000	59,500,000
Dollars Awarded (Annual Rate)	43,422,000	43,357,000	57,120,000
Average $ Per Award	49,978	57,127	66,111
Average Award Duration (Months)	12.5	12.5	12.5

Percentage Distribution of Funds by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	97.7	97.5	97.3
Industry	0.5	0.6	0.8
Federal Laboratories	1.5	1.6	1.6
Other	0.3	0.3	0.3

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Senior Scientists, Faculty***			
Number of years supported	126	130	138
Amount of faculty support	$3,888,000	$4,372,000	$5,059,000
Postdoctoral Associates			
Number of years supported	553	576	610
Amount of postdoctoral support	$5,733,000	$6,509,000	$7,513,000
Graduate Students			
Number supported per award-year	1,135	1,183	1,254
Amount of graduate student support	$6,267,000	$7,120,000	$8,227,000
Other personnel costs	1,395,000	1,562,000	1,816,000
Land, Buildings, and Fixed Equipment	—0—	—0—	—0—
Major Equipment (more than $200,000)	—0—	250,000	500,000
Other Equipment	8,686,000	9,617,000	11,007,000
Other Costs****	8,200,000	9,315,000	10,769,000
Indirect Costs	10,436,481	11,855,000	13,709,000
National Resource for Computation in Chemistry*****	625,000	814,000	900,000
Total	$45,230,481	$51,414,000	$59,500,000

*Includes proposals for committed renewals, etc.
**Includes awarded for committed renewals, supplements, etc.
***Includes faculty associates and other professionals.
****Fringe Benefits, expendable equipment, travel, publication costs, computer costs, other direct costs.
*****Split-Funded with DOE. Transfer of Funds to DOE.

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MATERIALS RESEARCH PROGRAM SUBACTIVITY $78,550,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Solid State Physics	$7,631,289	$8,100,000	$8,140,000	$9,550,000	$1,410,000
Solid State Chemistry	4,342,550	4,650,000	4,680,000	5,550,000	870,000
Low Temperature Physics	4,336,721	4,700,000	4,630,000	5,400,000	770,000
Condensed Matter Theory	4,174,219	4,600,000	4,600,000	5,465,000	865,000
Metallurgy	6,434,276	7,100,000	7,050,000	8,300,000	1,250,000
Ceramics	3,326,970	3,600,000	3,600,000	4,200,000	600,000
Polymers	3,836,000	4,100,000	4,140,000	4,900,000	760,000
Materials Research Laboratories	18,130,000	19,600,000	19,351,000	22,180,000	2,829,000
National Magnet Laboratory	3,800,000	4,250,000	4,025,000	4,575,000	550,000
Synchrotron Radiation	6,004,300	8,000,000	7,885,000	8,000,000	115,000
Small Angle Neutron Scattering	399,940	300,000	400,000	430,000	30,000
Total	$62,416,265	$69,000,000	$68,501,000	$78,550,000	$10,099,000

Objectives and Description

Fundamental research supported by NSF's Materials Research Program provides the scientific underpinnings to long-term technological advances in energy-producing systems, in manufacturing, in national defense, in transportation, in environmental matters, and in our ability to compete economically with other nations. Because of the increasing importance of materials to our society, materials research is entering an era of unusual opportunity and need.

The common goal which unites the various materials disciplines is the search for basic understanding of the behavior and properties of materials in terms of the microscopic interactions between the fundamental constitutents (electrons, ions, atoms and molecules) and in terms of their bulk- and micro-chemical composition and structure (defect, crystal and crystal aggregate).

Materials research at the NSF includes the materials-related disciplines of metallurgy, ceramics, polymers, solid state physics, solid state chemistry, low temperature physics, and condensed matter theory, and emphasizes the importance of strong disciplinary research in parallel with strong interdisciplinary approaches. The Materials Research Laboratories, which represent a unique national resource, foster interdisciplinary research on important scientific problems which would not generally be possible through individual grant support.

Practical materials are often extremely complex compared with the model systems traditionally studied by scientists. There is a healthy trend wherein scientifically oriented disciplines are addressing the more complex systems frequently encountered by metallurgists, ceramists and polymer scientists. For example, condensed matter theorists are working with polymer scientists to develop and apply modern statistical mechanics methods to understand the properties of technologically important polymers.

Rapid advances in our understanding of the behavior and properties of materials have been stimulated by sweeping new developments in modern instrumentation. Electron microscopes which allow individual atoms to be seen, synchrotron radiation sources which provide high intensity X-rays, and high resolution surface analytical instruments have enabled materials researchers to probe the structure and micro-composition of condensed matter to a degree not heretofore possible. The support of major user facilities—for high magnetic field research, synchrotron radiation, and small angle neutron scattering—by the Division of Materials Research provides physicists, chemists, materials scientists, biologists and earth scientists with powerful new tools that allow the broad and cost-effective exploration of research opportunities that would not be possible otherwise.

These developments in interdisciplinary research, advances in instrumentation and exciting opportunities for improved understanding in areas such as amorphous solids, microstructures research, surfaces and interfaces, phase transitions, materials synthesis and processing, and corrosion and wear, suggest an unusually fertile future for all facets of materials research.

Major Research Questions

Although sustained progress has been made in understanding the properties and behavior of materials, many questions remain which require the continued efforts of theorists and experimentalists in all sub-fields of materials research. Some examples of important topics being addressed by materials researchers are:

- What parameters determine the behavior of materials near a phase transition, such as the melting temperature or a magnetic critical point?
- What are the basic mechanisms of hydrogen embrittlement of structural alloys? What role does hydrogen play in the fatigue fracture of high strength steels?
- What are the mechanisms of electrical conduction in layered compounds such as intercalated graphite and organic conductors of the polyacetylene type?
- How do internal interfaces, such as grain boundaries, and microchemical segregation to interfaces affect the mechanical and physical properties of crystalline solids?
- What atomic transport processes determine the high temperature corrosion resistance of metals and ceramics?
- What are the detailed atomic and molecular structures of amorphous (glassy) solids and how does structure affect the magnetic, electronic, and mechanical behavior, and resistance to chemical attack?
- How can theoretical methods be used to analyze the complex data produced by newly developed surface analysis and characterization techniques?
- How can the molecular arrangement in polymers be altered to produce materials of exceptional strength?

- How is the occurrence of superconductivity in metals and alloys determined by the normal state properties of these materials?

Significant Recent Achievements

Ion Scattering By Surface Phonons

Recently, D. Miller of the University of California at San Diego has shown that it is now possible to measure individual lattice excitations (phonons) on the surfaces of materials such as lithium fluoride and silver through the use of the new technique of atomic beam scattering. This technique shows a significant advantage over traditional neutron scattering, in that the atomic beam is nonpenetrating and the scattering is therefore very surface sensitive. The measurement of surface excitations is an important development, since it provides detailed information on surface atom interactions.

A Sensitive Nondestructive Evaluation Technique

Small flaws in a solid material may be highly significant in affecting mechanical properties but are exceedingly difficult to detect without destroying the material. Techniques permitting the identification of existing flaws by non-destructive tests are also technologically significant in leading to improved reliability of engineering designs. A study of the feasibility of new techniques has been undertaken by a group at the Stanford University Materials Research Laboratory. The theory of a new type of eddy current probe utilizing a small ferrite sphere resonant at microwave frequencies has been developed by B.A. Auld and N. Riaziat. When the probe is placed near a metal surface its frequency is disturbed. This perturbation of frequency is further changed by the presence of a crack, so that extremely small cracks can be detected. Results obtained gave a sensitivity an order of magnitude better than the conventional probes now available, thus providing a more sensitive nondestructive evaluation technique.

Theoretical Predictions of Phases in Polymers

Novel theoretical approaches based on statistical mechanics have been developed by P. Taylor at Case Western Reserve University. The approaches correctly predict the existence and the relative stability of four crystalline phases in polyvinylidene fluoride (PVF_2). This polymer is of considerable interest because of the piezoelectric and pyroelectric properties of one of the crystal structures. The results will improve process and property control needed for more successful device applications.

Synthesis of a New Optical Material

Within the Cornell University Materials Research Laboratory considerable emphasis has been given to the development of capabilities in crystal preparation, in optical materials synthesis, and in laser techniques. In the latter area, materials exhibiting nonlinear optical properties have been of particular interest. H. Mahr found that urea single crystals, of appropriate size and crystalline perfection, exhibit non-

linear optical properties superior to those of existing device materials. Of particular significance is the extension of efficient doubling and frequency mixing applications in the ultraviolet down to 200 nm, of potential importance in submicron devices. Urea crystals have a high threshold for laser damage, and can be used at room temperature, unlike the best currently available materials which require refrigeration.

A Theory of the Dynamics of Catalytic Processes

Certain chemical reactions on solid surfaces exhibit anomalous oscillatory or turbulent behavior, i.e., either periodic or random fluctuations as a function of time. Recently, H. Suhl and his collaborators at the University of California at San Diego have qualitatively explained this behavior in an elegant and practical application of non-linear theory. The example on which they focused is the oxidation of carbon monoxide on a platinum surface. By solving the set of non-linear differential equations for the various types of reactions which occur during this process, they were able to derive a number of mathematical conditions for the existence of oscillatory and turbulent solutions. These are qualitatively similar to the experimental conditions for this type of behavior. This kind of analysis is important for understanding the dynamics of catalytic processes, of which the oxidation of carbon monoxide is a prime example.

An Advance in Surface Science

Mechanical, thermodynamic, and electrical properties of bulk materials depend on crystal structure as well as grain size and a variety of crystal lattice defects. For surfaces and interfaces, it is likely that defects and the "island" structure—the equivalent of grain structure in the bulk—are equally important in determining materials properties of interest in catalysis; corrosion and oxidation; fabrication of superconducting and submicron devices; fracture; and adhesion. M. Lagally, of the University of Wisconsin at Madison, has modified the method of low energy electron diffraction (LEED) to make possible the first quantitative study of island size distributions for any surface or overlayer. Angular widths of LEED beams diffracted from a fractional monolayer of oxygen on tungsten were measured as a function of coverage and related, through the development of appropriate models, to island size. The demonstration of the feasibility of quantitative measurements of this type has implications for such technologies as molecular beam epitaxy, nucleation and crystal growth, and heterogeneous catalysis.

Applications of X-ray Topography

X-ray diffraction is one of the oldest and most important techniques for examining the structure of materials. However, X-ray crystallographers are still making substantial contributions to further developing and applying diffraction techniques. S. Weissman of Rutgers University, using dislocation-free silicon as a model material, has applied X-ray diffraction techniques to determine strain distributions and gradients in notched crystals deformed elastically. The experimental determination of strain gradients in front of the notch root by the X-ray topographic technique provides a basis for

evaluating the validity of continuum mechanics fracture models. The research is being continued to include studies of elastic strain distributions in electronic devices such as tantalum sputtered onto silicon substrates. These results could impact the electronics industry.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

Direct comparisons between the original FY 1980 Budget Request and the Current Plan are complicated by the establishment of several Cross-Directorate activities which also support materials research related projects. The currently planned funding of such programs totals $1,850,000, the major component being the US-USSR Cooperative Research Program which supports activities in electrometallurgy ($665,000), corrosion ($250,000) and polymers ($150,000). Other materials-related areas include Industry-University Cooperative Research, Regional Instrumentation Facilities, 2-/4-Year College Instrumentation, and Research Initiation in Minority Institutions. The FY 1980 Current Plan represents a net decrease of $501,000 below the revised FY 1980 Budget Request. This decrease is modest compared to that experienced by other subactivities within the Mathematical and Physical Sciences activity, because of the ransfer of funds from these subactivities to Materials Research. This transfer, coupled with materials-related support via the above mentioned Cross-Directorate activities, is in response to a Congressional recommendation to increase the relative support of the Materials Research subactivity. The bulk of the decrease was absorbed by the Materials Research Laboratory, National Magnet Laboratory, and Synchrotron Radiation Programs.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$62,416,265
FY 1980 Program	$68,501,000
FY 1981 Request	$78,550,000
Difference—FY 1981/FY 1980	$10,049,000

The increase of $10,049,000, from $68,501,000 to a total of $78,550,000, will be used as follows:

- Provide an increase of $6,525,000 for growth of scientific research project support in all sub-fields of materials research. The average individual award will be increased, even at the cost of reducing the numbers of investigators supported. Such increases are urgently needed to meet growing research costs, especially in the area of instrumentation.
- The increase of $2,829,000 for the MRLs, in accord with the first priority being given to individual project support, will permit some increase in the level of effort. This will be directed primarily at high risk research programs, increase of support at smaller MRLs, and major instrumentation needs.

- The $550,000 increase for the National Magnet Laboratory will provide for the purchase of badly needed equipment to exploit more fully high magnetic fields. These purchases have been deferred for several years because of inadequate funds.
- Research to provide an underlying science base for microstructures and to use microstructural techniques for the enhancement of materials science will be increased by $1,000,000. Support for microstructure research in FY 1980 is about $3,500,000. The additional $1,000,000 will be apportioned among various program elements in accordance with evolving needs and opportunities.
- Decreased construction costs for the synchrotron radiation facilities essentially will be offset by increased operating costs and instrumentation.
- A decrease in construction costs plus an increase of $30,000 will provide for increased operating costs and some instrumentation for the Small Angle Neutron Scattering Facility at Oak Ridge National Laboratory.

Percentage changes between FY 1981 and the FY 1980 Current Plan for the Materials Research program elements are:

Solid State Physics	17.3%
Solid State Chemistry	18.6%
Low Temperature Physics	16.6%
Condensed Matter Theory	18.8%
Metallurgy	17.7%
Ceramics	16.7%
Polymers	18.4%
Materials Research Laboratories	14.6%
National Magnet Laboratory	13.7%
Synchrotron Radiation	1.5%
Small Angle Neutron Scattering	7.5%

Coordination and Relationship to Other Efforts

Coordination between the materials research activities of the NSF and those of the various other Federal agencies takes many forms. Program directors interact with their peers at other agencies concerning programs and projects of mutual interest. Committees such as the Committee on Materials, and groups such as the Interagency Materials Group meet regularly and provide forums for exchange of information and coordination of programs.

The NSF also cooperates with other agencies in direct support of conferences and workshops of mutual interest. In the area of facilities, the coordination between the NSF and the Department of Energy (DOE) on the development of synchrotron radiation facilities continues. As one example of this coordination, researchers at the Stanford Synchrotron Radiation Laboratory have built an experimental beam line to examine characteristics of the wiggler magnets which will be essential for the success of the forthcoming DOE National Synchrotron Light Source at Brookhaven. Also, close coordination was maintained between NSF and DOE in the recent decision to establish an NSF supported small-angle neutron scattering research capability at Oak Ridge National Laboratory.

NSF contributes over 50% of the Federal support for basic materials research in universities. Only three other agencies, support materials research in universities to a significant extent: DOE, DOD, and to a lesser extent NASA. NSF maintains a broad spectrum of support. Thus NSF plays a unique role in supporting the generic, multi-purpose research which develops the fundamental knowledge base needed to solve future and unanticipated problems.

Solid State Physics Program Element $9,550,000

Objectives and Description

The objective of the Solid State Physics program is to increase the basic understanding of the physical phenomena and processes which underlie the electrical, optical and magnetic properties of solids. Experimental research on metals, semiconductors and insulators in the crystalline state, the amorphous state and in intermediate states of disorder, form the major part of the program. Phenomena under investigation include phase transitions, critical phenomena and non-equilibrium phenomena, as well as electronic, magnetic and lattice structures and their excitations. Important areas of current activity include studies of physical phenomena at surfaces and interfaces; in amorphous and disordered metals; in semiconductors and magnetic systems; in lower dimensional solid state systems; and in photon, electron and neutron scattering from solids. The development of new techniques and new instrumentation is a natural component of these on-going research activities.

Many practical applications (e.g. transistors, solid state lasers, memory devices and solar cells) have arisen from basic research in this area. It is expected that current research in solid state physics will have equally important applications.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $1,410,000, from $8,140,000 to a total of $9,550,000, in FY 1981 will support: developing needs for instrumentation and research support for individual projects utilizing specialized research facilities such as synchrotron radiation, neutron scattering and high magnetic fields; and continued emphasis on amorphous solids, surfaces and interfaces, solid state microstructures and new technique development. Increased participation by joint Industry-University Cooperative research projects is expected in several areas.

Solid State Chemistry Program Element $5,550,000

Objectives and Description

The Solid State Chemistry program supports chemical research on the extended properties of solids (as distinct from those of molecules) and their surfaces. It is concerned with the relationships between structure, chemical reactivity, surface properties, and such physical properties as energy transport, electrical conductivity, and magnetism. Because of advances in physical theory and the availability of instrumentation with singular perceptivity, there are unparalleled opportunities for understanding the properties of complex materials.

The objective of this research is to develop adequate knowledge to permit the design and chemical synthesis of new materials, with some desired set of properties, for emerging science and technology. The availability of such new materials, which are not discovered but which are designed and synthesized, has been crucial for testing theories and for new technologies. The role of solid state chemistry is to bring about the interplay of solid state theory, new experimental methods, model formulation, and chemical synthesis, that leads to these materials.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $870,000 over the FY 1980 level of $4,680,000 to a total of $5,550,000 in FY 1981 will be used to: develop methods for the synthesis of new types of solids, including the so-called one dimensional conductors, liquid crystals and solid ionic conductors; develop and apply atomic resolution techniques for the characterization of complex structures and of exciton transport mechanisms; use picosecond laser techniques, including transient grating and photon echo, to examine exciton dynamics, exciton-phonon interactions, and energy transfer. The existing base for Industry-University Cooperative Research and research related to sub-micron structures is expected to grow.

Low Temperature Physics Program Element $5,400,000

Objectives and Descripton

The objective of the Low Temperature Physics program is to increase basic understanding of phenomena in which the effects of quantum mechanics manifest themselves in macroscopic properties such as superconductivity and superfluidity. Consequently, the experimental programs involve the use of low and/or ultralow temperatures in an essential way. Phenomena studied included phase transitions and critical

point behavior in the isotopes of helium, hydrogen, and other materials, the occurrence and nature of superconductivity among new phases of binary and ternary alloys and compounds, the nonequilibrium superconducing properties of weak-link and Josephson junction devices and the superfluid properties of the isotopes of helium. Particular areas of activity include the study of these and related phenomena as they pertain to systems of reduced dimensionality and crystalline perfection. Basic low temperature research activities have led to several emerging technologies of importance to the Department of Defense and the Department of Energy. Fundamental low temperature research is expected to contribute to future technologies. This connection provides a natural basis for Industry-University Cooperative Research.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The proposed increase of $770,000 from $4,630,000 to a total of $5,400,000 in FY 1981 will support increased emphasis on ultralow-temperature techniques and facilities, new superconducting materials and composite structures and disordered materials at ultralow temperatures. The level of effort in non-equilibrium superconductivity, two-dimensional superconductors and spin-polarized hydrogen will be enhanced.

Condensed Matter Theory Program Element $5,465,000

Objectives and Description

The objective of the Condensed Matter Theory program is to provide the theoretical understanding of the many topics covered by experimental efforts in condensed matter sciences and of the ways in which the structure and composition of materials are related to their many properties and performance. The condensed matter theorists formulate hypotheses and develop models to explain experimental observations, to determine whether their theories give a correct description of experiments, and to suggest new directions or opportunities for further research.

FY 1981 Budget Highlights and Explanation of Increase and Decrease

Support for this program will increase by $865,000 from $4,600,000 to a total of $5,465,000 in FY 1981. This will provide for increased emphasis on phase transitions, non-linear phenomena, surface related spectroscopies, computing equipment, and an increase of $125,000 to a total of $300,000 for condensed matter theory research at the Institute for Theoretical Physics. Some of the increase will be used to fund theory related to problems in polymers, metallurgy and ceramics.

Metallurgy Program Element $8,300,000

Objectives and Description

The Metallurgy program supports a broad spectrum of research ranging from the extraction and refining of ores into primary metals, through the processing of metallic materials with specific properties into useful objects. The goal of such studies is to relate microscopic behavior of metallic materials from the point of view of structure, composition and processing to observed macroscopic properties. Once these relationships are understood, the properties of materials can be controlled and performance predicted. The program has three major sub-areas: chemical metallurgy, physical metallurgy, and mechanical materials processing.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $1,250,000 above the FY 1980 level of $7,050,000, to a total of $8,300,000 in FY 1981 will be used to purchase badly needed instrumentation such as electron microscopes and mechanical testing facilities and to provide expanded research support to take advantage of new opportunities in the sub-areas of surface studies (corrosion, erosion, abrasion and wear), chemical metallurgy, and deformation processing. In addition, some of the increase is expected to be used to fund new Industry/University Cooperative research awards.

Ceramics Program Element $4,200,000

Objectives and Description

The objectives of the Ceramics program are to increase fundamental understanding of ceramic materials and to provide the scientific basis for long term advances in ceramics technology. Research is supported on a variety of ceramic materials, including refractory oxides, nitrides, carbides and other inorganic compounds, glass, semiconductors, graphite and cemented carbides (cermets).

A major goal of ceramic scientists is understanding the properties of these materials in terms of their chemical composition, structure (electronic, defect, crystal, and crystal aggregate), and the environment in which they are used. Synthesis and processing of ceramics includes fundamental studies involving reaction kinetics, thermodynmics and phase equilibria. High temperature corrosion of ceramics in severe environments presents new challenges and opportunities for ceramic scientists.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $600,000 above the FY 1980 level of $3,600,000, to a total of $4,200,000 in FY 1981 will support expanded research activities in high temperature corrosion, ceramic processing and studies of fracture mechanisms of brittle materials, as well as provide funds for the purchase of replacement and new instrumentation at universities. Part of the increase will be used to fund new Industry/University Cooperative Research in ceramic science.

Polymers Program Element $4,900,000

Objectives and Description

The objective of the Polymers program is to increase fundamental understanding of macromolecules, i.e. the giant, long-chain molecules that make up such important materials as fibers, rubber, plastics, proteins, and organic composites. Research is directed to the synthesis of new type of polymeric materials by new methods and through utilization of renewable raw materials; to the investigation of the basic chemical and physical structure of macromolecules; to the study of macromolecules in amorphous and crystalline arrangements and in the dynamics of such systems; to the relation of molecular structure with such bulk properties as strength or electronic conduction; to the nature of surfaces and interfaces in polymers and polymer mixtures; and to the properties of solutions and liquid crystals of polymers. The program also supports theoretical research underlying advances in polymer science.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $760,000 above the FY 1980 level of $4,140,000, to a total of $4,900,000 in FY 1981, will be used primarily to increase the size of existing grants which is abnormally small owing to limited funds in the face of the rapidly growing number of high quality proposals received by the Program. The increase will enhance research on the synthesis of new polymers with enzyme-like properties, on the dynamics of motions in long-chain molecules, on an understanding of molecular behavior in amorphous polymers, and on relating the liquid crystalline arrangements of rigid chains in solution to the exceptional strength of fibers that can be produced from them. Increases in other areas of substantial scientific opportunity, such as the study of polymer-fiber interfaces in composites, energy transport, and polymer-blood interactions cannot be accommodated with the projected funds.

Materials Research Laboratories Program Element $22,180,000

Objectives and Description

The objective of the Materials Research Laboratory (MRL) program is to extend the range of traditional academic project research to include major problems, which often require a diversity of scientific and technical competence and sophiticated facilities to assure progress. In the past such problems, commonly involving multi- or interdisciplinary research efforts and often of major significance in technology, have been studied only in national or industrial laboratories and usually limited to specific technological requirements. Over the last several years, substantial interdisciplinary programs have developed within the MRL's. Thus, the range of problems feasible in academic research has been significantly extended. With MRL support many capable scientists in the academic community are addressing interdisciplinary research problems of national importance.

Thirteen university laboratories are currently supported; Brown, Carnegie-Mellon, Case Western Reserve, Chicago, Cornell, Harvard, Illinois, Massachusetts-Amherst, Massachusetts Institute of Technology, Northwestern, Pennsylvania, Purdue and Stanford. Each of the individual laboratories is locally managed with respect to program planning and implementation. Over the past several years each laboratory has developed three functional elements: (1) interdisciplinary or multidisciplinary programs directed at selected complex materials problems or problem areas, in which several researchers, usually from different disciplines, work cooperatively; (2) central experimental facilities, which usually cannot be developed and operated under the project support mechanism, and which are shared by faculty working on a range of related problems; and (3) "other research", to explore novel, often high risk, concepts and to assist younger faculty in initiating research programs.

Current thrust programs in the MRLs cover most of the broad field of materials research, and include major efforts on surfaces, interfaces and catalysis; materials joining; polymer blends and copolymers; deformation and fracture of materials; phase transitions; amorphous materials and glasses; microstructural materials; novel materials and processes; semiconductors and semiconducting polymers. All of these areas require multidisciplinary expertise and in all of them the MRLs as a group are among the leaders of the field.

The MRL program encourages academic research on major problem areas of potential technological significance. This is indicated by growing incidence of spin-off programs supported by mission-oriented agencies. A good example is the polyacetylene program at the University of Pennsylvania which now receives major support from ARPA and the Army Research Office. The broader education of materials scientists and engineers is a highly significant aspect of the program.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The proposed increase of $2,829,000, from $19,351,000 in FY 1980 to a total of $22,180,000 in FY 1981, represents real growth. At this level, all on-going program commitments will be met, and a modest increase in level of effort will be feasible. This increase will be directed primarily at higher risk areas for which adequate funding had not been available in the past; at increasing the support of the smaller MRL programs to more viable and productive levels; and at the upgrading of experimental facilities, including the provision of instrumentation.

National Magnet Laboratory Program Element $4,575,000

Objectives and Description

The Francis Bitter National Magnet Laboratory (NML) is the only national user facility for high magnetic field research in the U.S. Continued NSF support will be provided for core-funding of three interrelated objectives at the NML: (1) To develop, operate, and maintain the most advanced magnet systems in the world; (2) To provide unique magnetic field facilities for use by visiting scientists; and (3) To carry out in-house basic and applied research utilizing high magnetic fields. The NML experimental facilities and staff support are made available to users without charge on the basis of the scientific merit of their proposed experiments. Users must obtain their own support for their research costs which include materials, specialized equipment and travel.

There is little question that high magnetic fields are and will continue to be an important tool for research in many scientific areas including plasmas, superconductivity, magnetic materials, atomic and molecular physics and chemistry, and biomolecular science. In addition, high fields play an important role in applied areas such as plasma fusion, magnetohydrodynamics (MHD), magnetic separation, and superconducting machinery. The NML is an important national resource for many high technology research programs—particularly in the energy field. One example of this is the ALCATOR project for magnetic confinement of plasmas which was initiated at the NML and is now supported by the DOE fusion effort.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $550,000, from $4,025,000 to a total of $4,575,000, will permit only a minimal increase in the current level of effort. This is expected to be utilized primarily to provide for magnet development and instrumentation.

Synchroton Radiation Program Element $8,000,000

Objectives and Description

The objective of NSF support for the national facilities at Cornell, Stanford, and Wisconsin is to provide synchrotron radiation for experiments concerned with the structure of matter in all fields of science. These sources provide a continuous spectrum reaching into the far ultraviolet and X-ray regions, with high intensity in very short bursts, and a high degree of polarization. The unique properties of such radiation sources facilitate the study of long-standing fundamental questions in many disciplines including condensed matter and surface science, materials science, biology, chemistry and engineering.

The experimental facilities and staff support are available to users without charge. The existing facilities are now saturated. There is a growing user community of more than 800 scientists of whom nearly 20% are from industrial laboratories, 20% from U.S. Government labs, and the rest from U.S. universities.

The synchrotron radiation source at Wisconsin provides users with an intense beam of photons in the ultraviolet through the soft X-ray region, and is used primarily for the study of surface properties. New efforts in photoelectron diffraction and angle-dependent photoemission provide direct measurement of atomic distances and site symmetry for surface atoms. Other thrusts in solid state science, catalysis, absorption and fluorescence by gasses are now possible.

A three-year construction project was initiated in FY 1978 to provide a greatly improved source consisting of a 1.00 GeV electron storage ring (Aladdin) at the Wisconsin Synchrotron Radiation Center. Aladdin will serve nearly three times as many users as before over an extended spectral range and will meet the user demand in the ultraviolet and soft X-ray regions when it becomes operational in the second half of 1980.

A major expansion of the Stanford Synchrotron Radiation Laboratory was initiated in FY 1978 to provide additional beam transport systems and equipment for experiments in the hard X-ray as well as the ultraviolet spectral range. A new experimental building has been constructed. This expansion will provide capability for new types of experiments as well as help to meet the growing demand for use of the Stanford Synchrotron Radiation Laboratory (SSRL) facilities.

A modest number of experimental research stations have been instrumented at Cornell to make use of the very high energy synchrotron radiation generated at the Cornell Electron Storage Ring. The radiation available at the Cornell High Energy Synchrotron Source (CHESS) will make experiments possible that need photon energies greater than 40keV-the limit now available at SSRL. Experiments on CHESS were begun in late 1979.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The FY 1981 budget of $8,000,000 represents an increase of $115,000 over FY 1980 level of $7,885,000. The FY 1980 increment of $2,000,000 for dedicated operations of SPEAR for the SRL will be continued. The remainder of the budget has offsetting increases and decreases due to the completion of construction activities at SSRL and Wisconsin, and the increased level of operations as well as the need for instrumentation to effectively use the newly constructed sources.

Small Angle Neutron Scattering Program Element $430,000

Objectives and Description

The objectives of the Small Angle Neutron Scattering Program are (1) to provide researchers in several disciplines with the ability to obtain data on small angle scattering from materials of interest to them and (2) to develop further the state-of-the-art in small-angle neutron and X-ray scattering research.

The small angle scattering capability at Oak Ridge is available to scientists from all parts of the U.S. NSF and Oak Ridge have developed procedures to ensure that the facility will be managed as a national resource to the benefit of all participating scientists.

Beginning in FY 1978 and continuing in FY 1979, NSF provided for the construction of a beam tube and small angle neutron scattering camera at an existing reactor at the DOE supported Oak Ridge National Laboratory. Construction of the small angle neutron facility was completed in FY 1980 on schedule and within the planned budget; testing and initiation of full-scale operations are scheduled for mid FY 1980.

FY 1981 Highlights and Explanation of Increases and Decreases

The amount of $430,000 is requested for continued support of the small angle neutron scattering program in FY 1981. The increase of $30,000 over the FY 1980 level of $400,000 will be used to help provide the proper level of support for the operation of this unique national user facility. Proper instrumentation and staff are essential to make the facility viable for users.

QUANTITATIVE PROGRAM DATA
MATERIALS RESEARCH PROGRAM SUBACTIVITY

Proposal and Award Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Large Grants:			
Number of Proposals Received*	22	23	24
Number of Awards**	20	20	20
Dollars Proposed (Total)	$39,300,000	$43,200,000	$47,520,000
Dollars Proposed (Annual Rate)	33,000,000	36,300,000	39,930,000
Dollars Awarded (Total)	28,334,000	31,661,000	35,185,000
Dollars Awarded (Annual Rate)	28,334,000	31,661,000	35,185,000
Average $ Per Award	1,416,700	1,583,000	1,759,000
Average Award Duration (Years)	1.00	1.00	1.00
Other Project Awards:			
Number of Proposals Received*	1,120	1,150	1,180
Number of Awards**	690	710	740
Dollars Proposed (Total)	$153,000,000	$170,000,000	$192,000,000
Dollars Proposed (Annual Rate)	81,000,000	90,000,000	102,000,000
Dollars Awarded (Total)	34,081,000	36,800,000	43,415,000
Dollars Awarded (Annual Rate)	31,556,000	34,393,000	40,575,000
Average $ Per Award	49,393	51,830	58,670
Average Award Duration (Years)	1.08	1.07	1.07

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges			
16 MRLs, NML, SSRL & SRC	44.5	43.9	43.2
Other Universities and Colleges	54.0	54.3	54.0
Other Project Awards			
Industry	0.8	1.0	2.0
Federal Agencies	0.5	0.4	0.4
Other	0.2	0.4	0.4

Manpower and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Senior Scientists Faculty***			
Number of years supported	195	200	208
Amount of faculty support	$5,905,000	$6,835,000	$7,865,000
Postdoctoral Associates			
Number of years supported	370	370	375
Amount of postdoctoral support	4,500,000	4,950,000	5,500,000
Graduate Students			
Number supported per award-year	1,240	1,240	1,250
Amount of graduate student support	8,685,000	9,555,000	10,990,000
Other Manpower Costs	4,704,000	5,175,000	5,900,000
Land, Buildings & Fixed Equipment	—0—	—0—	—0—
Major Equipment	3,500,000	2,300,000	1,200,000
Other Equipment	8,200,000	9,200,000	11,200,000
Other Costs	11,722,265	14,046,000	17,031,000
Indirect Costs	15,200,000	16,440,000	18,864,000
Total	$62,416,265	$68,501,000	$78,550,000

* Includes proposals for committed renewals, etc.
** Includes awards for committed renewals, supplements, etc.
*** Includes faculty associates.

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ASTRONOMICAL, ATMOSPHERIC, EARTH, AND OCEAN SCIENCES

PROGRAM ACTIVITY SUMMARY

FY 1981 PROGRAM TOTAL $241,300,000

Obligations by Subactivity

Page	Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
B-I	Astronomical Sciences	$59,221,107	$58,550,000	$56,964,000	$60,200,000	$3,236,000
B-II	Atmospheric Sciences	59,106,778	65,750,000	63,169,000	71,100,000	7,931,000
B-III	Earth Sciences[1]	24,919,404	26,250,000	25,278,000	27,900,000	2,622,000
B-IV	Ocean Sciences	62,393,725	68,450,000	66,619,000	76,000,000	9,381,000
B-V	Arctic Research Program	5,974,000	6,000,000	5,832,000	6,100,000	268,000
	Total	$211,615,014	$225,000,000	$217,862,000	$241,300,000	$23,438,000

[1]The Ocean Sediment Coring Program has been moved from the AAEOS Activity to Ocean Drilling Programs, a separate activity.

Goals and Description

The Astronomical, Atmospheric, Earth, and Ocean Sciences Activity supports basic research in selected disciplines that will increase our knowledge of the natural environment on earth and in space. The overall objectives of the various elements comprising the activity are as follows:

- Obtain new knowledge of astronomy and the atmospheric sciences over the entire spectrum of physical phenomena;
- Provide a better understanding of the physical and chemical make-up of the earth and its geological history;
- Obtain further insights into the oceans' composition, structure, behavior, and resources, and examine the effect of human activities on the ocean environment and vice versa;
- Advance knowledge of natural phenomena and processes in the Arctic.

The objectives are pursued through the following subactivities:

Astronomical Sciences: Support of basic research projects and national research facilities is directed at examining the physical principles governing the universe as well as the properties and behavior of its objects. The latter include planets and their atmospheres, our sun, other stars, the Milky Way galaxy, and remote galaxies and quasars.

Atmospheric Sciences: Support is provided for basic research projects and for the National Center for Atmospheric Research to facilitate our understanding of the behavior of the earth's atmosphere.

Earth Sciences: The programs under Earth Sciences are designed to increase our basic knowledge of the solid earth and its evolution. Emphasis is placed on chemical and physical characteristics and processes that produce geologic features including hydrocarbon and ore deposits and events such as earthquakes.

Ocean Sciences: The activities supported are geared to improve understanding of the nature of the ocean, of its influence on human activities, and of society's impact on the marine environment. This is accomplished through Oceanography Project Support, Coordinated Ocean Research and Exploration, and support for oceanographic facilities essential to the research efforts.

Arctic Research Program: Research is supported in the disciplines of geology and geophysics, biology, oceanography, meteorology, glaciology, and upper atmospheric physics. Among the studies underway are those on permafrost, deep ice cores from Greenland, arctic lake and tundra ecosystems, and the resources of the Bering Sea Shelf.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan is $7,138,000 less than the FY 1980 Budget Request. As a result of Congressional cuts to the budget request, the AAEOS activity was reduced by $1,850,000. Further reductions resulted from reprogramming actions. Funds in the amount of $1,975,000 were added to the new Ocean Drilling Programs activity of which $1,500,000 is to accelerate Ocean Margin Drilling planning and $475,000 offsets changes in timing at foreign contributions. In addition, $3,313,000 was reprogrammed to the new Cross-Directorate Programs activity. This represented the AAEOS share of programs transferred and augmented in the FY 1980 current plan.

After the decrease and reprogramming, a total of $217,862,000 is available for the AAEOS activity. The table below shows the distribution of these funds compared to the FY 1980 Budget Request:

Subactivity	*Budget Request*	*Current Plan*	*Difference*
Astronomical Sciences	$58,550,000	$56,964,000	$-1,586,000
Atmospheric Sciences	65,750,000	63,169,000	-2,581,000
Earth Sciences	26,250,000	25,278,000	-972,000
Ocean Sciences	68,450,000	66,619,000	-1,831,000
Arctic Research Program	6,000,000	5,832,000	-168,000
Total	$225,000,000	$217,862,000	$-7,138,000

The decreases were distributed in a manner intended to reflect identifiable reprogramming actions and minimize impacts on research. The distribution of these cuts is discussed in more detail at the subactivity level.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$211,615,014
FY 1980 Program	$217,862,000
FY 1981 Request	$241,300,000
Difference—FY 1981/FY 1980	$23,438,000

Major program or project changes in FY 1981 include:

- In Astronomical Sciences a $4,500,000 decrease resulting from completion of funding for Very Large Array fabrication in FY 1980 is largely offset by a $1,850,000 increase for the first year of full VLA operations (total $5,200,000), and detailed design and specifications for a new 25 meter diameter, millimeter wave telescope at $1,700,000. The 25 meter telescope will require an additional $27,000,000 in Fiscal Years 1982-1984.
- An additional $2,826,000 for the astronomy centers will help meet increased operating cost ($1,523,000) and provide instrumentation ($1,303,000). Totals in these categories are operations $30,852,000 and instrumentation $3,228,000.
- An increase of $1,360,000 in Astronomy project support to $19,220,000 will help meet increased costs.
- In Atmospheric Sciences an increase of $4,331,000 in project support to $38,600,000 will expand atmospheric chemical research, climate modeling and cloud physics, continue Global Atmospheric Research Program (GARP) projects and begin data analysis of previous GARP field experiments and an observational program of the Solar Maximum Year. Upgrading of a radar network for upper atmospheric observations and new observing tools to study mesoscale meteorological processes are also included.
- An increase of $3,300,000 to $29,900,000 for the National Center for Atmospheric Research provides for continued support of studies in solar variability, trace gases and aerosols, modeling and convective storm processes, and of aircraft and the Cray-1 computer. Administrative services costs are increased.
- A $300,000 increase to $2,600,000 for the National Scientific Balloon Facility will help continue support services to ongoing programs, renovate the former operations building and begin procurement of equipment for Long Duration Ballooning experiments.
- In Earth Sciences, an increase of $2,622,000 to $27,900,000 will allow for increased emphasis on geologic research on the U.S. continental crust and continued support of the Consortium on Continental Reflection Profiling, lunar sample analysis, research on the nature of earthquakes, modern geological processes, ore-forming fluids and ore deposits, and some instrumentation in geochemistry and geophysics.
- An increase of $3,250,000 to $24,600,000 in Oceanography Project Support will maintain the diversity of current programs, as well as increase emphasis on

open-ocean dynamics using new tools such as satellite imagery and chemical tracers, all aspects of recently discovered sea floor hydrothermal vents, paleo-oceanography, and primary productivitiy and food chain processes in the open ocean.

- The Coordinated Ocean Research and Exploration program element increases by $2,850,000 to $23,600,000 includes initiation of projects in ocean acoustic tomography, the impact of rivers on the ocean, and studies of ecosystem production and control mechanisms. This increase will also expand meteorological support for the Sea-Air Exchange project, study of the effect of Western boundary current eddies on the continental shelf and research, particularly chemical, on the hydrothermal circulation of seawater through the oceanic crust.
- A $3,281,000 increase in Oceanographic Facilities and Support to $27,800,000 is necessary to maintain adequate logistics support for the research components of Ocean Sciences. Technician support and ship board equipment are increased along with operations support. The construction/conversion budget includes $3,600,000 for a new coastal research ship to continue the planned upgrading of the academic fleet to increase its efficiency and meet research needs.
- Arctic research increases by $268,000 to $6,100,000 and will continue to provide support for biological research on the Bering Sea Shelf, and geological and geophysical research in Alaska and elsewhere in the arctic.

Coordination and Relationship to Other Efforts

Since coordination is primarily by the five AAEOS research areas, specific coordination mechanisms and relationship to similar federally supported research are discussed at the subactivity level.

Changes in Budget Structure

Atmospheric Sciences: The Global Atmospheric Research Program and Climate Dynamics Program that were shown as separate program elements in FY 1980 are included as subelements in the Atmospheric Sciences Project Support program element. Research supported under these elements has become increasingly similar to other atmospheric science project support and this change reflects that fact.

Earth Sciences: The Ocean Sediment Coring program element has been moved from the AAEOS Activity and redesignated as the Ocean Drilling Programs Activity to increase the visibility of the Ocean Margin Drilling Project. Project Support in the several earth sciences subdisciplines now comprises the full Earth Sciences Subactivity. Within that subactivity a new element, Petrology, displays a portion of the research formerly under Geochemistry that focuses on rocks.

Ocean Sciences: The International Decade of Ocean Exploration comes to an end in FY 1980. Phase out of IDOE projects and new projects of similar scale and in similar research areas will be supported under the new Coordinated Ocean Research and Exploration program element.

Arctic Research: The former Environmental and Resource Related Research program elements have been replaced by the various disciplinary program elements supported, including atmospheric, biological and earth sciences, glaciology and oceanography.

Evaluation and Oversight

Evaluation may be defined as the process by which the value of a plan and the effectiveness of its implementation are determined. It is also the process by which programs, projects and schedules are appraised to determine their worth. Using this latter definition as a guide, evaluation is approached as a regular and continuous process, performed by all elements of the AAEOS Directorate, and involving all members of the professional staff.

Examples of evaluation mechanisms are: site visits, status and program reports, publications, advisory and ad hoc panel reviews, audits, program reviews, committees, and focussed evaluation studies. Evaluation affects policy, plans, programs, and implementation of programs.

The AAEOS Directorate has established advisory committees for each of its five Divisions as part of the Foundation's oversight and evaluation effort.

ASTRONOMICAL SCIENCES PROGRAM SUBACTIVITY $60,200,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Astronomy Project Support	$16,341,654	$18,450,000	$17,860,000	$19,220,000	$1,360,000
Nat. Astronomy & Ionosphere Center	4,624,998	4,950,000	4,920,000	5,370,000	450,000
Kitt Peak National Observatory	9,701,455	10,600,000	10,570,000	11,500,000	930,000
Cerro Tololo Inter-American Observatory	4,350,000	4,850,000	4,860,000	5,200,000	340,000
Nat. Radio Astronomy Observatory	22,703,000	17,990,000	17,082,000	16,960,000	-122,000
Sacramento Peak Observatory	1,500,000	1,710,000	1,672,000	1,950,000	278,000
Total	$59,221,107	$58,550,000	$56,964,000	$60,200,000	$3,236,000

Objectives and Description

The major objectives of the Astronomical Sciences Program are to increase knowledge of:

- The origin, evolution and properties of the solar system. This includes the sun, planets, natural satellites, comets and the interplanetary medium.
- The life cycle of stars. This requires knowledge of the physical processes taking place within a star throughout its life time. Present emphasis is on the formation of protostars and later evolutionary stages of stars (pulsars, black holes, supernovae).
- The dynamics and motions of stellar groups. These groups range in complexity from binary stars to star clusters and galaxies. This research involves the study of stellar positions, motions and distances.
- The composition, formation and evolution of our Milky Way galaxy, the interstellar medium of dust and molecules, other galaxies and quasars. These studies require data acquisition, interpretation and cosmological modelling.

NSF support includes funding for:

- The operation and use of important telescopes at university observatories.
- The development, operation and use of advanced observing facilities at the National Astronomy Centers by staff, visiting scientists and graduate students.
- The reduction and interpretation of data, theoretical modelling, publication of findings, and conferences.
- State of the art technology to design, construct and improve the instruments and telescopes used by astronomers to detect and analyze radiation at wavelengths through the electromagnetic spectrum. Present emphasis is on infrared and millimeter wavelengths, radio interferometry (e.g., the Very Large Array) and extremely sensitive solid state light detectors.

Fundamental scientific laws and theories are regularly subject to test by astronomical observations. Apparent velocities of components of astronomical objects as high as ten times the speed of light have provoked considerable discussion among scientists. The high rates of energy generation by quasars and centers of galaxies may also point to recasting the accepted laws of physics. Discoveries of organic molecules in deep space have provoked revisions in theories of molecular formation and the evolution of life.

While astronomy continues to make major contributions to science, it also yields applications to other human needs. Careful studies of solar activity are essential to understanding changes in the earth's climate. Astronomers are monitoring atmospheric pollutants for comparison with conditions 50 years ago. Magnetic storms on earth, which disturb radio communications, are now predicted by monitoring flares on the sun. Very Long Baseline Interferometry can be used to determine precise latitudes and longitudes. Special computer software first developed for astronomy has application in the polishing of the mirrors needed for the Nation's laser fusion R&D program. And millimeter wave techniques have been used to detect breast cancer.

Astronomy Project Support

The Foundation's Astronomy Project Support program awards grants for research in all topical areas of ground-based astronomy. These include the sun and other bodies of the solar system, the structure and evolution of stars, systems of stars, motions of stars, and the composition and behavior of gas and dust throughout interstellar space. Advanced technology is required to extract information from light and radio waves received from the large variety of distant objects. For this reason, in addition to awards for research, the Astronomy Project Support program funds development and procurement of new instrumentation.

Currently NSF expects to award 162 grants to scientists at about 70 institutions through the Astronomy Project Support program. Research and the development of new techniques will involve about 340 scientists and 190 graduate students. A slightly smaller number of grants will be made in FY 1981. Major U.S. astronomy observatories, including the five NSF supported National Astronomy Centers, will participate in projects supported under this program.

Several observatories operated by universities receive program support. These include: the Five College Radio Astronomy Observatory in Massachusetts—site of the largest millimeter wave antenna in the United States; the Owens Valley Observatory in California—site of a three element radio interferometer; the Hat Creek Observatory in California—site of a two element millimeter wave interferometer; and the Haystack Observatory in Massachusetts—which operates a 120 foot diameter radio telescope as part of the international Very Long Baseline Interferometry network.

National Astronomy Centers

The National Science Foundation is responsible for support of the nation's five National Astronomy Centers. These are the National Astronomy and Ionosphere Center (NAIC), the Kitt Peak National Observatory (KPNO), the Cerro Tololo Inter-

American Observatory (CTIO), the National Radio Astronomy Observatory (NRAO) and the Sacramento Peak Observatory (SPO).

The major purpose of these Centers is to make it possible for astronomers at universities throughout the nation to use the advanced and unique instrumentation required for forefront research. These centers maintain and develop a variety of telescopes, instruments and computing facilities that are among the most advanced in the world for radio, millimeter, infrared, and optical astronomy. Listed below are the kinds of research and managing contractor for each Center.

National Astronomy Center	Type of Research	Location of Major Facilities	Contractor
National Astronomy & Ionosphere Center (NAIC)	Radio and Radar Astronomy and Ionospheric Physics	Arecibo, Puerto Rico	Cornell University (CU)
Kitt Peak National Observatory (KPNO)	Optical and Infrared Astronomy	Kitt Peak, AZ	Association of Universities for Research in Astronomy, Inc. (AURA)
Cerro Tololo Inter-American Observatory (CTIO)	Optical and Infrared Astronomy	Cerro Tololo, Chile	Association of Universities for Research in Astronomy, Inc. (AURA)
National Radio Astronomy Observatory (NRAO)	Radio Astronomy	Green Bank, WV Kitt Peak, AZ Socorro, NM	Associated Universities Inc. (AUI)
Sacramento Peak Observatory (SPO)	Solar Astronomy	Sunspot, NM	Association of Universities for Research in Astronomy, Inc. (AURA)

The National Astronomy and Ionosphere Center maintains a set of unique instruments and facilities that are required in radio and radar astronomy and ionospheric physics. It operates the world's largest single radio/radar telescope—1,000 feet in diameter—in the mountains of Puerto Rico near Arecibo. FY 1981 will be the first full year of operation of a new ionospheric heating facility at NAIC. This instrument will be used for research in energy and electrical changes in the ionosphere.

The Kitt Peak National Observatory is dedicated to research in stellar, solar, and planetary astronomy. Located about 50 miles southwest of Tucson, Arizona, the site is excellent for astronomical observing. Ten stellar telescopes are maintained, including one of the largest operational optical instruments in the world (the four meter diameter Mayall telescope), and the McMath Solar Telescope, the largest solar telescope in the world.

The Cerro Tololo Inter-American Observatory provides access to the skies of the Southern Hemisphere. It is situated in the Andes Mountains approximately 50 miles east of the coastal town of La Serena, Chile. The observatory operates the largest telescope in the Southern Hemisphere, identical to the Mayall 4-meter telescope on Kitt Peak. The observatory also operates seven other telescopes.

The National Radio Astronomy Observatory operates three major radio telescopes

for research in all fields of radio astronomy. A 300-foot telescope and a 140-foot fully steerable telescope are located in Green Bank, West Virginia. A 36-foot millimeter wave telescope is located at Kitt Peak. A fourth new observing facility, the Very Large Array (VLA), on the Plains of San Augustin, near Socorro, New Mexico, will begin its first year of full operation in FY 1981.

The Sacramento Peak Observatory is located 9,200 feet above sea level at Sunspot, New Mexico (near Alamogordo). The principal instrument is the vacuum solar tower telescope; its high resolution images of the sun's surface have not been equaled by any other solar telescope. The observatory also operates the only large coronagraph in the Western Hemisphere. This instrument makes it possible to observe the solar corona regularly, an observation otherwise possible only during a solar eclipse. Four special purpose telescopes are also on the site, and there are four small patrol telescopes which record major solar activity daily.

Significant Recent Achievements

Gravity Waves

Last year three astronomers at the University of Massachusetts announced the first experimental evidence directly supporting the existence of gravitational waves.

Such waves, long hypothesized but never directly observed, are in some ways similar to radio waves, but are based on the forces of gravity rather than on those of electricity and magnetism. The existence of gravity waves is one of the longstanding but heretofore untested predictions of Einstein's general theory of relativity.

The discovery was based on observations over a four-year period of the binary pulsar PSR 1913+16. The pulsar, located some 15,000 light years away from Earth, was observed with the 1000 foot diameter radio antenna operated by the National Astronomy and Ionosphere Center and located near Arecibo, Puerto Rico. Discovered in 1974 by the same research group, it is known to be orbiting another massive object—perhaps another pulsar, or perhaps a black hole—because its repetitive pulses of emission speed up and slow down over a period lasting a little less than eight hours.

Einstein's theory predicts that such a system should emit gravitational waves which slowly extract energy from the orbit, thereby causing the pulsar and its companion to move closer together. As the size of the orbit decreases, the length of time required for the pulsar to complete an orbit also decreases. Without gravity waves the pulsar and its companion would continue orbiting at a nearly constant rate. But if gravity waves are given off the orbital period should decrease at a rate of one ten-thousandth of a second per year. The measured amount is almost precisely this value, or about four ten-thousandths of a second since late 1974. Since it is hardly possible that anything else could be causing precisely this annual change in orbit, these results have been accepted as the first observed evidence that gravity waves exist. This finding will give impetus to experimental work directed to detection of the gravitational waves, as well as to further theoretical studies of the theory of relativity.

The three scientists who performed the research are Joseph Taylor and Lee Fowler of the University of Massachusetts at Amherst and Peter McCulloch who was on leave from the University of Tasmania.

Double Quasar

Quasars are believed to be the most powerful sources of energy in the universe. Recently the first double quasar was identified. The quasar was first detected by Dennis Walsh at the Jodrell Bank Radio Observatory in England. Its approximate position was later determined at the National Radio Astronomy Observatory using its 300 foot diameter antenna. At this time the object appeared to be an ordinary quasar. Then in March 1979, Robert F. Carswell of Cambridge University studied the object with the Kitt Peak National Observatory's 84-inch optical telescope. Detailed observations revealed that the object was in fact two images separated by an angle of 5.7 arc seconds. This finding was later confirmed by R. Weymann and others using the University of Arizona's 90-inch telescope on Kitt Peak and the new Multiple-Mirror Telescope operated by the University of Arizona and Smithsonian Astrophysical Observatory.

Although binary in appearance, the two images may be the result of light from a single quasar being split by what amounts to a gravitational lens. This could be explained by the presence of a supermassive black hole between the quasar and Earth. According to Einstein's general theory of relativity any object with large mass will noticeably deflect light rays passing near its edge. During solar eclipses astronomers can readily confirm that stars near our line of sight to the Sun's edge (limb) appear displaced by this effect. In the case of a quasar, if an extremely massive object were close enough to our line of sight, a more dramatic effect could appear. The light beam from the quasar could be deflected in more than one direction—thus producing a double image. This explanation is supported by spectroscopic data; the twin objects, designated 0957+561A and B, have identical redshifts and nearly identical features. Also, no other twins have been observed among the thousand known quasars.

More recently B. F. Burke, P. E. Greenfield, and D. H. Roberts of the Massachusetts Institute of Technology observed the double quasar's radio wave image. Using the Very Large Array in New Mexico they produced a radio wave map of 0957+561. It is quite common for a quasar or an active galaxy to expell jets of matter into the neighboring region of space. The radio map of 0957+561 revealed a classic case of this kind. However, only one of the two quasars is expelling matter in this fashion. There is no similar activity associated with its twin. Therefore, the radio wave observations indicate that 0957+561 is a genuine double quasar and that perhaps no gravitational lens need be postulated.

For the present there may not be enough evidence to decide whether observers have discovered one quasar and one gravitational lens or two strikingly similar quasars. Future observations of changes in brightness may be required to reach a final interpretation. In any case, at present the double quasar is a unique object.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan for Astronomy is $56,964,000. This is $1,586,000 less than the FY 1980 Budget Request of $58,550,000. This reduction is primarily a response to the reprogramming and congressional cut discussed in the activity summary.

Of the $1,586,000, $700,000 was taken from the Very Large Array (VLA) construction budget. This saving was possible due to an unexpected low bid for the last phase of VLA construction and a liquidation of most of the VLA contingency account. The balance of the reduction was distributed among astronomy project support and the national centers.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$59,221,107
FY 1980 Program	$56,964,000
FY 1981 Request	$60,200,000
Difference—FY 1981/FY 1980	$3,236,000

The $60,200,000 requested for Astronomical Sciences is $3,236,000 more than the FY 1980 Current Plan of $56,964,000. Reduction in VLA fabrication costs (-$4,500,000) is partially offset by increased costs of VLA operation (+$1,850,000) and the design of a new 25 meter millimeter wave telescope (+$1,700,000). This leaves a net increase of $4,186,000 or 9% for Astronomy Project Support and normal operations of the five National Centers.

The percentage changes for the six Astronomy Program Elements are:

Astronomy Project Support	7.6%
National Astronomy and Ionosphere Center	9.1%
Kitt Peak National Observatory	8.8%
Cerro Tololo Inter-American Observatory	7.0%
National Radio Astronomy Observatory	-0.7%
Sacramento Peak Observatory	16.6%

Programs or Projects Increased in FY 1981

$1,523,000 for increased costs of operating the five National Astronomy Centers (excluding the VLA and equipment costs). Total operations costs at the five Centers will be $30,852,000, an increase of 5.1% over FY 1980 operations.

$1,850,000 for expanded operation of the VLA. FY 1981 will be the first complete year of full operation of all 27 antennas of the VLA ($5,200,000).

$1,700,000 for final design drawings and specifications for a new 25 meter diameter millimeter wave telescope at NRAO. This is the start on a project that will require $9,000,000 per year in Fiscal Years 1982, 1983 and 1984.

$1,303,000 for non-expendable research instrumentation and equipment at the National Centers bringing the total to $3,228,000.

The increase in funds for research grants under Astronomy Project Support is $1,360,000 bringing the total to $19,220,000. Increased costs will absorb all of this amount. This increase of 7.6% will not match current inflation rates. Increased emphasis is given to the following projects:

- U.S. participation in (conclusion of the) international Solar Maximum Year ($70,000).
- Theoretical and laboratory astrophysics ($280,000).
- Use of radio astronomy techniques to determine stellar positions ($60,000).
- Increased support observations by university astronomers for non-planetary research using the NASA infrared telescope facility in Hawaii ($160,000).
- More extensive data analysis required for theoretical understanding of obervations ($150,000).
- Data reduction facilities at major user institutions ($340,000).
- Visiting users of the VLA ($120,000).
- Improvements to existing telescopes ($180,000).

Projects or Programs Discontinued or Reduced

The VLA fabrication budget will be reduced to zero in FY 1981. Completion of this project results in a $4,500,000 reduction from FY 1980.

Cost increases will require a reduction in university research equivalent to about five average-sized astronomy grants, and continued tightening of national center operations.

Coordination and Relationship to Other Efforts

The Foundation is the designated lead agency for support of ground-based astronomy in the United States. The Foundation provides over two-thirds of the total Federal support for ground-based astronomy in the form of research grants at universities and contracts for the operation of the National Astronomy Centers. Other major supporting agencies are the National Aeronautics and Space Administration, the Department of Defense, the Smithsonian Institution, and the National Bureau of Standards.

Coordination among agencies is carried out routinely at all levels of management. In addition, meetings are held of the Government Astronomers' Round Table (GART). Members of GART represent NSF, NASA, and other agencies with astronomers in Washington having funding and oversight responsibilities for ground-based and satellite borne astronomy.

NASA and NSF cooperate on several projects. Both agencies are supporting costs of visitor use of the NASA infrared telescope in Hawaii. Both are maintaining close contact on new developments in astronomical solid state light detectors. Satellites such as the International Ultraviolet Explorer are used by many NSF grantees in support of their projects. NSF staff have also helped in planning for the NASA Space Telescope Scientific Institute.

The U.S. Air Force maintains a small scientific staff at SPO for mission related studies of the sun. SPO is also providing telescope components to the USAF on a reimbursable basis for its worldwide Solar Optical Observing Network. NASA and the National Center for Atmospheric Research conduct regular research programs using KPNO and SPO facilities. The KPNO optical shops have been used for special projects by NASA and the Department of Defense.

In early FY 1979 the U.S. Naval Observatory assumed complete funding responsibility for the NRAO 4-element interferometer telescope at Green Bank, West Virginia. It is expected that NRAO staff will continue to operate it for Naval Observatory research programs.

At NAIC, NASA annually funds a radar astronomy program related to its planetary missions.

Astronomy Project Support Program Element $19,220,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Solar System Astronomy	$1,024,275	$1,400,000	$1,350,000	$1,420,000	$70,000
Stars & Stellar Evolution	3,568,700	3,900,000	3,950,000	4,230,000	280,000
Stellar Systems & Motions	1,127,296	1,350,000	1,260,000	1,320,000	60,000
Galactic & Extragalactic Astronomy	5,541,813	5,650,000	5,900,000	6,330,000	430,000
Astronomical Instrumentation & Development	5,030,102	6,050,000	5,300,000	5,820,000	520,000
Radio Spectrum Management	49,468	100,000	100,000	100,000	—0—
Total	$16,341,654	$18,450,000	$17,860,000	$19,220,000	$1,360,000

Objectives and Description

The Foundation's grants program in astronomy is devoted to research on the nature and scope of our solar system and the universe beyond. Solar system studies include the Sun, the planets, natural satellites, comets, and asteroids. Beyond the solar system are numerous other stars, star clusters, and interstellar gas clouds that form our galaxy. Beyond our galaxy are other galaxies and objects such as quasars. Astronomers study the origin, evolution, and interactions of these diverse objects. The regions beyond our planet are a valuable natural laboratory with matter and radiation existing under a wide range of physical conditions not reproducible in any research

laboratory. Unique opportunities exist for crucial tests of fundamental physical theories.

The objectives of grantees supported by the Astronomy Project Support Program subelements are the same as those for the astronomy subactivity as a whole except for those specifically related to the National Centers.

Major Research Questions

- What is the distribution of matter in the universe? Is the universe infinite in extent? Will the observed expansion of the universe continue forever, or will it eventually collapse upon itself?
- What is the mechanism for the production of the immense energy output of quasars and radio galaxies? The distances to many of these objects and the size of the energy producing regions have yet to be determined.
- What is the nature of the evolution of a star that in some cases leads to the formation of a planetary system and in other cases leads to a binary star system that becomes a source of high energy X-rays and gamma rays?
- What is the mechanism for production of interstellar organic molecules? Do they form the building blocks for the evolution of life on planetary bodies?
- In the last stages of a star's life, what determines its ultimate fate? What are the physical conditions in a star as it becomes a supernova? How is a pulsar formed? What are the conditions that lead to the formation of black holes?
- What are the detailed reactions going on deep within our own Sun? How are these related to cycles of solar activity? Is the Sun a variable star? Can we learn something about the interior of the Sun from studies of its surface conditions?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Solar System Astronomy

This subelement is concerned with studies of the Sun, the nine planets and their satellites, the asteroids, and the comets which make up the solar system. These bodies provide us with our prime examples for the study of cosmogony and, although the past two decades have seen the rapid development of space probes for *in situ* measurements, ground based observations still form an indispensible part of the total effort.

Of special interest in this period is that in 1980 and 1981, the Sun (the only star which we can study in great detail) is passing through the maximum phase of its eleven year cycle of activity. An international effort has been organized around this "Solar Maximum Year" (SMY) to observe and analyze solar phenomena by all available techniques. A number of projects have already begun for the SMY under this subelement in FY 1980 and these will, in most cases, be continued and completed in FY 1981. The programs are coordinated with the Solar Terrestrial subelement of the Atmospheric

Sciences subactivity to support ground based solar optical and radio observations in cooperation with the NASA Solar Maximum Mission satellite launched in late 1979.

The increase of $70,000 to a level of $1,420,000 in FY 1981 will provide support for United States astronomers for the international SMY as well as continuing support for solar system projects.

Stars and Stellar Evolution

The life history of a star begins as it condenses out of interstellar gas and dust. Nuclear energy generation takes place in the center, and the star begins to evolve. The rate of evolution depends on the mass of the star. Eventually the star must die—as a white dwarf, a supernova, or a black hole. Research supported by this subelement involves projects to study all aspects of this cycle, as well as the physical properties of various classes of stellar objects. Laboratory data of astrophysical interest is also obtained in order to aid in the interpretation of observational data.

Funding requested for FY 1981 is $4,230,000, an increase of $280,000 over the FY 1980 allocation. This increase will allow for additional support of theory and laboratory astrophysics, areas in which support has lagged in recent years and in which new opportunities exist for significant advances. Increased emphasis will be placed on: support of theoretical and laboratory studies associated with atoms and molecules in space, support for technical personnel needed at university-based observatories, and support for postdoctoral workers and research personnel.

Stellar Systems and Motions

Precise measurements of the positions and motions of stars and stellar systems are needed to determine the structure of our galaxy and the distances to other objects in the universe.

Extrapolations from such measurements of nearby stars and the more distant stellar background allow us to determine where we are located in the Milky Way Galaxy and to calibrate the methods of distance measurement to the limits of the visible universe.

Although such measurements have long been performed only optically, the discovery of radio stars has encouraged the cooperation between optical and radio astronomers to apply the precise measurement techniques of radio astronomy to the determination of positions and coordinate systems. Such improvements provide a better knowledge of the three dimensional structure of the universe on the largest scales and, on the smallest scales, the position and motions of the earth.

The increase of $60,000 to a level of $1,320,000 will support these fundamental studies on the continuing and regular basis needed for such long term projects.

Galactic and Extragalactic Astronomy

The principal objective of this subelement is to obtain increased knowledge of the interstellar medium, interstellar molecules, our own Milky Way, and distant galaxies and quasars.

The FY 1981 budget level of $6,330,000 is $430,000 above the FY 1980 current plans. There will be an increase of $120,000 for users of the completed Very Large Array. There will be increased support of $150,000 for scientists using the new infrared telescope facility in Hawaii. The theoretical support will continue at approximately the same level but there will be a shift of support for different projects. The theoretical research is needed to provide guidance and interpretation of observational data. It is expected that an increase of $160,000 for various projects will be necessary to provide support for more extensive data analysis. The data are now being collected by more sophisticated equipment. Funds for engineers, technicians, and programmers are now necessary.

There will be more emphasis in millimeter and infrared observations. New instrumentation will allow for more precise measurements of stars and other features in external galaxies and quasars.

Astronomical Instrumentation and Development

This program provides support for development and construction of state-of-the-art telescopes as well as auxiliary instrumentation. Advanced detectors, data handling systems and spectral analysis techniques are provided over the entire wavelength range from radio to near ultra-violet. The FY 1981 budget request of $5,820,000 is $520,000 above the FY 1980 current plan. Important progress is expected in many areas. Some of the highlights for FY 1981 are:

- Optical and infrared detector development will be continued at the enhanced level of the FY 1980 plan. Solid state detectors are available and the demand for them to increase existing telescope efficiency will remain high.
- Responsible encouragement of array detector use demands a commitment to provide advanced data examination and reduction facilities at major user instituions. An additional $340,000 will be spent for new starts for these facilities.
- Considerable improvement in methods for increasing the angular resolution capability of ground based instruments is expected. Increased support of these areas will require $180,000.
- Completion of other projects in the program will free funds needed for the increased operating costs of on-going research and a carefully chosen selection of more general new starts in instrumentation.

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QUANTITATIVE PROGRAM DATA
ASTRONOMY PROJECT SUPPORT PROGRAM ELEMENT

Proposal and Award Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	347	350	350
Total Dollar Amount	$52,827,938	$52,000,000	$52,000,000
Awards:			
Number of Awards	248	252	243
Total of Dollar Amount	$16,341,654	$17,860,000	$19,220,000
Average Dollar Per Award	65,894	70,870	79,090
Average Award Duration[1] (Months)	13	13	13

Percentage Distribution of Funds by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	98.2	97.0	97.0
Industry	—0—	—0—	—0—
Federal Laboratories	—0—	—0—	—0—
Other	2.8	3.0	3.0

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of scientists years supported	159	162	157
Cost of scientists supported	3,100,259	3,370,000	3,585,000
Number of graduate students supported	196	196	192
Cost of graduate students supported	1,200,158	1,410,000	1,490,000
Other personnel costs	2,562,946	2,950,000	3,200,000
R&D facilities	—0—	—0—	—0—
Major equipment	—0—	—0—	—0—
Equipment and instrumentation	2,337,900	2,380,000	2,570,000
Research resources	—0—	—0—	—0—
Other Costs[2]	3,331,738	3,600,000	3,890,000
Indirect Costs	3,808,653	4,150,000	4,485,000
Total	$16,341,654	$17,860,000	$19,220,000

[1] Continuing grants involving multi-year commitments are included here as 12-month awards.
[2] Fringe benefits, expendable equipment, travel publication costs, other direct costs.

National Astronomy and Ionosphere Center $5,370,000

Obligations by Program Subelement

Program Subelement	*Actual FY 1979*	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
Scientific Research Support	$4,847,998	$5,163,000	$5,093,000	$5,605,000	$512,000
Construction of Buildings and Research Facilities	77,000	87,000	127,000	65,000	-62,000
Subtotal	$4,924,998	$5,250,000	$5,220,000	$5,670,000	$450,000
Less NASA Facilities Operation Support[1]	-300,000	-300,000	-300,000	-300,000	—0—
Total	$4,624,998	$4,950,000	$4,920,000	$5,370,000	$450,000

[1] NASA provides $300,000 per year for partial operations and maintenance support for the S-Band planetary radar research program at the NAIC.

Objectives and Description

The National Astronomy and Ionosphere Center (NAIC) provides the U.S. scientific community with the world's largest reflecting telescope for research in radio and radar astronomy and atmospheric physics. The 1,000 foot diameter antenna at the Arecibo Observatory is located twelve miles south of the city of Arecibo, Puerto Rico. When used with its associated high power radar transmitters and low noise receivers, it is one of the world's most sensitive research instruments. The facilities of NAIC are available to qualified scientists on a competitive basis.

In addition to the main telescope, the Center's facilities include a smaller remote 100-foot diameter antenna for interferometric research programs and a high-frequency transmitting facility for atmospheric research. Associated with the main telescope is a broad spectrum of observing and data processing equipment including a multitude of receivers, several very powerful radar transmitters, high speed specialized digital equipment for data acquisition and processing, and several powerful computers for system control, data acquisition, and data reduction. Scientific and technical assistance are provided by the resident staff at Arecibo. The Observatory has available to all scientific users temporary living quarters, a dining area, library, offices and shops.

Headquarters for the NAIC is located on the Cornell University campus in Ithaca, New York. The headquarters complex consists of offices for scientific, engineering and administrative personnel and laboratory space for the design and development of receivers, feeds, electronic systems, and special purpose digital devices.

Radio astronomy research programs at Arecibo are devoted to measuring the properties of radio emissions from celestial radio sources—the planets, stars, interstellar gas clouds, pulsars, our own galaxy (the Milky Way), far distant galaxies, and quasars. The objective of these programs is an understanding of the nature of the objects, their structure, sources of energy, evolution, and how they and we fit into the overall nature of our universe.

The Arecibo Observatory research capability in ground-based radar astronomy is unequaled anywhere else. Measurements of the orbital motions of the nearby planets

and their satellites, and determinations of the radar scattering properties of their respective surface layers are a significant part of the radar astronomy research program. The S-Band radar system at Arecibo has sufficient sensitivity to study most major objects within the orbital distance of Saturn (Mercury, Venus, Mars, Jovian satellites, Saturn's rings, major asteroids and comets). For objects beyond Saturn, the round-trip light-travel time exceeds two-and-one-half hours, the tracking limit of the Arecibo telescope.

Research programs in atmospheric physics are devoted to the investigation of the structure, dynamics, and chemistry of the upper atmosphere at altitudes ranging from 6 to 6,000 km. Areas of investigation include the dynamics of the stratosphere, mesosphere, and thermosphere, the dynamical coupling between these regions of the atmosphere, the interaction in the ionosphere of winds, electric currents, the chemical and energy balance of the ionosphere, and the response of the ionospheric plasma to perturbation by electromagnetic radiation at various frequencies and power levels. Coordinated research programs may use a variety of different instruments such as the 430 and 2380 MHz radar systems, airflow instrumentation, a meteor trail radar, a 50 MHz radar and infrasound detector array.

A major new facility for ionospheric research at the Arecibo Observatory began full operation in early 1980. This powerful high frequency transmitter facility is being used for ionospheric heating experiments, the study of nonlinear processes in the ionospheric plasma, and partial reflection and wave interaction measurements of the middle atmosphere. This facility consists of four transmitters, each delivering 200 KW of power over a frequency range of 3 to 11 MHz to an antenna array consisting of 32 elements.

During FY 1979, the facilities at the NAIC—Arecibo Observatory were used by 152 visiting scientists from 54 domestic and foreign research and educational institutions. As a result of improvements made to the Arecibo telescope in recent years, as well as integration of newly developed instrumentation, the demand from the scientific community for the use of the Arecibo facility has increased dramatically. The number of visiting scientists now performing observations has risen to more than ten times that of the number of visitors in the early 1970's. Of the total observing time on the Arecibo telescope available to users, 74% was assigned to visitors. The telescope observing time was divided among the disciplines as follows: radio astronomy, 77%; radar astronomy, 7%; and atmospheric physics, 16%.

The Construction of Building and Research Facilities sub-element provides funds for site improvements and the construction and upgrading of roadways and utilities systems.

Major Research Questions

Major research questions to be explored at the NAIC in FY 1981 include the following:

- What are the physical mechanisms in the extremely distant and highly energetic

objects such as quasars, radio galaxies, and hydrogen rich protoclusters and what is their role in the evolution of the universe?

- What are the physical properties of the clouds of dust and gas in our galaxy and what role do they play in the early and late stages of stellar evolution?
- What are the detailed physical processes involved in the emission of radiation from pulsars?
- What new information about the physical properties of nearby solar system objects such as planets, satellites, asteroids, and comets can be determined with high powered radar techniques?
- What processes are involved in the dynamic phenomena occurring in the Earth's upper atmosphere and what are the effects of the coupling of these phenomena between different levels of the atmosphere?
- What is the detailed pattern of motions in the stratosphere, and how does this effect the transport of contaminants to high altitudes?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Continuing emphasis and planned new thrusts for FY 1981 include:

- Studies to compare neutral hydrogen emissions of galaxies from different clusters, which lead to new fundamental understanding of the role the environment plays in the galactic evolution.
- Studies of the chemistry of the interstellar medium near recently evolved supernovae by observing pre and post shock molecules.
- Studies of solar active regions to determine the nature of intense (several million degrees) emission regions over a wide band of wavelengths.
- Studies of the maser emission mechanisms and other non-thermal radio emissions from normal stars, and their relationship to stellar evolution.
- Studies of the place of origin of pulsar bursts and their relation to current emission theories.
- Studies of the orbital decay of the binary pulsar to measure the gravitational radiation term contained in the General Theory of Relativity.
- Studies of star formations process in the interstellar medium by means of observing highly condensed objects.
- Radar studies of the terrestrial planets that are in view to map topographic features. Fundamental studies, through radar means, of asteroids to determine surface morphology, composition, size, and rotation rates.
- Observations, using the new high frequency transmitter facility, of controlled nonlinear wave plasma interactions that will provide enhanced understanding

of increasing solar radiation effects through the earth's various atmospheric layers.

- Observations of winds in the stratosphere, mesosphere and thermosphere, designed to provide information on the dynamical coupling between these different levels of the atmosphere.

During 1980 staff levels were increased over the previously planned level to accomodate the operation of the heating facility and maintain essential services. This was achieved by reducing all other costs to a minimum and by eliminating a research scientist position. As a result of increased costs devoted to operation and maintenance of the NAIC's Arecibo Observatory and its remote sites, it is planned to delete two full-time positions in 1981. These consist of a visiting graduate student and a research support specialist/technician.

Projected NAIC staffing for 1981 is targeted at 169 full-time people. The total 1981 staff complement consists of 13 scientists, 58 technicians, 6 administrative, and 92 operations and support service personnel. Staff distribution between major segments of NAIC are estimated to be 147 at the Arecibo Observatory, and 22 at the Ithaca, New York headquarters. An additional 6 NAIC staff members will be supported through cost sharing of the S-Band planetary radar program with the National Aeronautics and Space Administration. With regard to equipment and facilities categories, in FY 1981 only minor allocations of available funds are possible, which will allow for minimal upgrading of selected systems.

The amount of NSF support for NAIC (exclusive of NASA funds) in FY 1981 will be $5,370,000, which is $450,000 above the 1980 support level of $4,920,000. This $450,000 will be absorbed by the increased operating and maintenance costs for NAIC activities.

QUANTITATIVE PROGRAM DATA
NATIONAL ASTRONOMY AND IONOSPHERE CENTER

Personnel and Other Factors

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Number of Scientist Years Supported[1]	12	12	12
Cost of Scientists Supported[2]	$382,000	$412,000	$431,000
Number of Graduate Students Supported[3]	5	5	4
Cost of Graduate Students Supported[2]	48,000	51,000	45,000
Other Personnel Costs[4]	$2,160,000	$2,408,000	$2,662,000
Land, Buildings, and Fixed Equipment	77,000	127,000	65,000
Major Equipment	—0—	—0—	—0—
Other Equipment	245,000	185,000	250,000
Research Resources	—0—	—0—	—0—
Other Costs[4]	1,146,000	1,144,000	1,297,000
Indirect Costs	567,000	593,000	620,000
Total[5]	$4,625,000	$4,920,000	$5,370,000

[1] Number of work-years during the program year by full-time, regular scientific staff members of tasks required to accomplish NAIC's mission, exclusive of the Director, NAIC, and the Director and Associate Director, Observatory Operations (Arecibo, Puerto Rico).

[2] Salaries and benefits only.

[3] Graduate students employed by NAIC during the academic year and summer work periods whose activities contribute to the completion of their graduate degree programs.

[4] Includes such items as utilities and communications, supplies and services, lease and maintenance costs and travel.

[5] Less NASA facilities support.

Kitt Peak National Observatory Program Element $11,500,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Scientific Research Support	$9,511,455	$10,395,000	$10,358,000	$11,283,000	$925,000
Construction of Buildings & Research Facilities	—0—	—0—	—0—	—0—	—0—
Subtotal	$9,511,455	$10,395,000	$10,358,000	$11,283,000	$925,000
Management Fee	190,000	205,000	212,000	217,000	5,000
Total	$9,701,455	$10,600,000	$10,570,000	$11,500,000	$930,000

Objectives and Description

Kitt Peak National Observatory (KPNO) is the nation's major center for ground-based optical astronomy. It provides the U.S. scientific community with the large telescopes, auxiliary instrumentation, and support services required for advanced stellar, solar, and planetary astronomy research. KPNO also maintains a schedule of infrared observing, thus extending the usefulness of the observatory's larger telescopes into the daytime hours.

The observatory proper is located on Kitt Peak, a 6,875-foot mountain in the Quinlan Range, 50 miles southwest of Tucson, Arizona. The mountaintop is easily reached by car and a portion of the facilities there, including a visitor's center and museum, are open to the public during the day. Over 100,000 people tour the observatory each year. The KPNO headquarters and laboratories are located in Tucson, adjacent to the University of Arizona.

KPNO operates 14 telescopes, two of which qualify as world-class instruments. These are the 4-meter Mayall reflector, a stellar telescope, and the 1.5-meter McMath solar telescope. The tally also includes the 61/91-centimeter Burrell Schmidt Telescope which the Warner and Swasey Observatory of Case Western Reserve University relocated from Cleveland, Ohio, to Kitt Peak during FY 1979. Starting in February 1980, KPNO will schedule one-half of the telescope's observing time in return for sharing in its operational support. This fast photographic instrument is equipped with full-aperture objective prisms, thus providing KPNO with an outstanding large-scale spectroscopic as well as photometric survey capability.

Over 40 items of major auxiliary instrumentation are available on Kitt Peak for use with the telescopes. These include the spectrographs, photometers, polarimeters, cameras, and image-tube systems necessary for the wide range of investigations carried out by visiting and staff astronomers.

Apart from the small percentage of time (about 5 percent) used to maintain and carry out essential improvements on the telescopes, over 60 percent of the available observing time is reserved for visiting scientists and graduate students. Since the

amount of observing time requested is several times greater than the time available, written research proposals are required for observing time. These are judged on a competitive basis by a scientific evaluation committee advising the KPNO Director. In FY 1979 a total of 433 visiting astronomers including 90 graduate students used the telescopes on Kitt Peak. They came from 100 U.S. institutions and 30 foreign institutions. There were a total of 305 research programs.

The KPNO staff in FY 1981 will total 289 full time equivalents (FTEs) and will be made up of 34 scientific, 21 engineering, 112 technical, 66 administrative and clerical and 56 other support personnel. This is a reduction of 36 FTEs from FY 1980.

In FY 1980, a reorganization of the Kitt Peak activities took place. There are now four major divisions under which the observatory operates. These are:

- *Telescope Operations* which covers all of the activities related to the proper working and maintenance of the telescopes on the mountain.
- *Engineering and Technical Services* which provides engineering and technical support for staff and visitor equipment and research and development in new areas such as detectors and studies of possible designs for next generation telescopes.
- *Administration and Facilities Support* which provides administrative support (including the Director's Office) for KPNO and in some areas for the other AURA observatories and is responsible for operation and maintenance of the KPNO facilities in Tucson. Included are management, business support, purchasing, accounting, personnel, shipping and receiving, utilities and communication, lease and maintenance agreements, printing and reproduction.
- *Scientific Staff Programs.* The scientific staff who are responsible for development of equipment for their own research, and for support of visitors were formerly considered under two separate headings depending on their own scientific speciality, namely, the Solar System Program and the Galactic and Extragalactic Program. The division between these areas has now been abolished and all scientific staff are combined into a single program.

The amounts budgeted for each of these divisions in FY 1981 are as follows:

- Telescope Operations, $2,909,000 (unchanged from FY 1980).
- Engineering and Technical Services, $2,854,000 (unchanged from FY 1980).
- Administration and Facilities Support, $2,052,000 (unchanged from FY 1980).
- Scientific Staff Programs, $2,193,000 (up $160,000 from FY 1980).

In addition to the above, the amount of $1,275,000 has been budgeted for new scientific projects and equipment replacement in FY 1981 (up $675,000 from FY 1980). These include replacement of the mountain computer facilities ($250,000); installation of new computing facilities in Tucson ($250,000); instrumentation improvements on the 4-meter and 2.1-meter telescopes ($320,000 and $106,000, respectively); installation of array detectors on several telescopes and research and development on detec-

tors ($149,000); and continuing study and design efforts on the next generation of telescopes ($200,000).

A four-year program to replace the minicomputers used to control the telescopes was begun in FY 1980 because of costly maintenance problems being encountered with these aging machines. Also, more computing power is required at the telescopes in order to collect and handle data from array detectors and other new instrumentation. The Tucson computing facilities require upgrading for much the same reasons since preliminary reduction of data must be carried out before visitors return to their home institutions.

No projects are planned under the Construction of Buildings and Research Facilities subelement. The Management Fee provides funds for corporate expenses incurred by AURA for the operation and management of Kitt Peak.

Major Research Questions

Research carried out at Kitt Peak, by visiting and staff astronomers, includes investigations of the following problems:

- Is the sun cooling down as some observations suggest?
- What are the element abundances in the old stars in globular clusters?
- How old are the oldest stars in our Galaxy? Are their ages consistent with the age of the Universe?
- Are there large amounts of invisible mass hidden in normal spiral galaxies?
- How can this decade's technological developments be applied to telescope engineering? New ways of using optics, materials, and computers can substantially reduce the costs of moderate to large sized telescopes.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Continuing and planned thrusts in FY 1981 include:

- Support of research that cannot be supported elsewhere—research on the sun and planets; the stars and gas that make up our Galaxy; and the galaxies, quasars, and other tantalizing objects that populate and define the extent of the Universe.
- Replacement of computers on Kitt Peak with modern systems that will enable the use of array detectors and other new instrumentation on the KPNO telescopes.
- Upgrading of the Tucson headquarters computing facility to provide the interactive and batch processing capabilities required to reduce large volumes of array data.

- Development of large format charge-coupled device and charge-injection device detectors in order to combine the advantages of photography and photoelectric photometry in a single image sensor.
- Performing the conceptual and engineering studies required to overcome the cost and technical difficulties involved in constructing optical telescopes up to 25 meters in diameter.

The FY 1981 KPNO program will require a budget of $11,500,000, an increase of $930,000 over the FY 1980 level. The increase is due to increased costs and KPNO's continuing commitment to provide the state of the art equipment required for first-rate astronomical research.

QUANTITATIVE PROGRAM DATA
KITT PEAK NATIONAL OBSERVATORY PROGRAM ELEMENT

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of scientist years supported[1]	32	37	34
Cost of scientists supported[2]	$1,090,443	$1,275,000	$1,299,000
Number of graduate students supported[3]	5	5	5
Cost of graduate students supported[2]	$12,713	$13,000	$14,000
Other personnel costs	5,893,927	6,445,000	6,225,000
Land, buildings and fixed equipment	—0—	—0—	—0—
Major equipment	—0—	—0—	—0—
Other equipment	448,232	431,000	785,000
Research resources	—0—	—0—	—0—
Other costs[4]	2,456,140	2,406,000	3,177,000
Total	$9,701,455	$10,570,000	$11,500,000

[1]The number of years worked during the program year by full-time regular scientific staff members in tasks required to accomplish the center's mission, exclusive of the Director and the Assistant to the Director.

[2]Salaries and benefits only.

[3]Graduate students employed by KPNO during summer work periods whose activities contributed to the completion of their graduate degree programs.

[4]Includes utilities and communications, computer lease and maintenance costs, travel, supplies, and management fee.

Cerro Tololo Inter-American Observatory
Program Element $5,200,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Scientific Research Support	$4,268,000	$4,707,000	$4,765,000	$5,048,000	$283,000
Construction of Buildings & Research Facilities	—0—	50,000	—0—	50,000	50,000
Subtotal	$4,268,000	$4,757,000	$4,765,000	$5,098,000	$333,000
Management Fee	82,000	93,000	95,000	102,000	7,000
Total	$4,350,000	$4,850,000	$4,860,000	$5,200,000	$340,000

Objectives and Description

Cerro Tololo Inter-American Observatory (CTIO) is the southern hemisphere counterpart of Kitt Peak National Observatory. It provides the U.S. scientific community with the large telescopes, advanced instrumentation, and support services required to study celestial objects in the southern skies.

For scientists interested in our Milky Way Galaxy and the nearest galaxies, southern hemisphere observations are essential. Only from the south can one observe with ease the galactic center and the concentration towards it of so many astrophysically important objects such as X-ray sources, planetary nebulae, and globular clusters. At far southern declinations are also found the Magellanic Clouds, nearest-neighbor galaxies to our own, which have well-characterized components that are bright enough to serve as standard candles for determining distances to other galaxies. Even for objects at planetary distances, southern observations are indispensable; various planets culminate at relatively high southern declinations when nearest to us. In spite of the importance of the southern skies, 80 percent of the light-gathering power of the world's optical telescopes has been located for historical reasons in the northern hemisphere.

The experience of 15 years of observing has shown that CTIO's location, 7,250 feet in the Chilean Andes, is one of the best telescope sites in the world. Close to 300 nights per year are useful for observations and between 45 and 90 percent of these have two arc-second or better seeing. (This has long been regarded as the standard of excellence for continental U.S. sites.)

CTIO's major telescope, the 4-meter reflector is the largest in the southern hemisphere. Seven additional CTIO telescopes provide a wide range of observational opportunities to visiting scientists. Extensive auxiliary instrumentation equipped with highly sensitive detectors and operated with television equipment and computer controls make observing very efficient at CTIO. On Tololo mountain, besides the telescopes, are support facilities including laboratories and workshops for the

telescope-maintenance crews, dormitories and a dining room for the visitors and technical supporting staff, a power generating plant, a water pumping-purifying facility, and a warehouse for spare parts for the equipment operated on the mountain.

The CTIO headquarters are located in La Serena, a coastal city 300 miles north of Santiago and 50 miles from Tololo mountain. The complex includes office, a computing center, an engineering facility, machine and vehicle maintenance shops, a scientific library, quarters for visitors, and housing for the resident staff. Visitors use the La Serena facilities for the preparation of observational programs and for the analysis of data obtained at the telescopes. The upgrading and testing of the auxiliary equipment used in the telescopic observations is also carried out in La Serena. CTIO's operations require it to maintain shipping, receiving and liaison offices in Santiago, Chile, and in Tucson, Arizona.

CTIO is operated as a visitor-oriented institution. Over 60 percent of the telescope time is reserved for visiting scientists. In FY 1979, 184 investigators (including 22 graduate students) carried out 148 research programs. Seventy percent of the investigators came to CTIO from U.S. institutions; the rest were mostly from Latin America, Canada, and Western Europe. The research programs were selected from over 300 proposals in an open and competitive manner.

CTIO's major objective in FY 1980 is to continue upgrading the currently available instrumentation in order to increase the efficiency and scientific yield of telescopes. Additional observational opportunities will become available to visitors as the telescopic time required to carry out a program is reduced and as the range of scientific programs that can be carried out is increased.

For FY 1981 CTIO's staff will total 192, which is the same as for FY 1980 and FY 1979. The CTIO staff in FY 1981 in addition to the Director will include 13 scientists, 14 engineers, 51 technicians, 37 administrative employees and 76 other support personnel. CTIO's remote location requires it to employ a resident staff of scientific and engineering specialists capable of maintaining the observatory's advanced instruments.

The Construction of Buildings and Research Facilities Subelement supports the construction, renovation, and expansion of telescope buildings, laboratories and resident staff housing. The only such project for FY 1981 is the addition of one staff residence at CTIO headquarters in La Serena.

Major Research Questions

- The Magellanic Clouds: Based on observation of these nearby galaxies how often do stars undergo explosions and become novae or supernovae? How do the chemical evolutions of the two Clouds differ from each other and from the evolution of the Milky Way?
- The Galactic X-ray Sources: To what extent can optical counterparts of these sources be discovered? What information about the structure of the objects can be provided by simultaneous observations at X-ray and optical wavelengths made, respectively, with satellite and with the CTIO telescopes?

- The Universe at Large: What is the extent and nature of the Universe? (Only in the southern sky is a truly representative sample of extragalactic space out to about 25 megaparsecs observable.)
- Quasar Research: What are the mechanisms by which quasars radiate extraordinary amounts of energy? Since quasars, the most distant observable objects in the universe, are being observed as they were when the universe was young, what clues do they provide about the evolution of the universe?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase in funding from FY 1980 to FY 1981 is $340,000. With this increase, CTIO must cover inflationary cost increases in Chile as well as an increasingly unfavorable dollar-peso exchange rate.

QUANTITATIVE PROGRAM DATA
CERRO TOLOLO INTER-AMERICAN OBSERVATORY PROGRAM ELEMENT

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of scientist years supported[1]	12	13	13
Cost of scientists supported[2]	$388,300	$441,200	$477,000
Other personnel costs	2,326,700	2,571,800	2,808,000
Land, buildings and fixed equipment[3]	—0—	—0—	50,000
Major equipment	—0—	—0—	—0—
Other equipment	350,000	515,000	357,000
Research resources	—0—	—0—	—0—
Other costs[4]	1,285,000	1,332,000	1,508,000
Total	$4,350,000	$4,860,000	$5,200,000

[1]The number of years worked during the program year by full-time, regular scientific staff members in tasks required to accomplish the center's mission, exclusive of Director.

[2]Salaries and benefits only.

[3]Physical facilities, such as land, buildings, and capitalized equipment (whether real of personal property) where the primary purpose is to enlarge or improve the capital plant available for research and development.

[4]Includes utilities and communications, computer lease and maintenance costs, travel, supplies, and management fee.

National Radio Astronomy Observatory Program $16,960,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Scientific Research Support	$10,790,000	$12,470,000	$12,362,000	$15,025,000	$2,663,000
Construction of Buildings and Research Facilities	11,703,000	5,300,000	4,500,000	1,700,000	-2,800,000
Subtotal	$22,493,000	$17,770,000	$16,862,000	$16,725,000	$-137,000
Management Fee	210,000	220,000	220,000	235,000	15,000
Total	$22,703,000	$17,990,000	$17,082,000	$16,960,000	$-122,000

Objectives and Description

The scientific community is supported by the National Radio Astronomy Observatory (NRAO) through its provision of facilities and equipment needed for research in the field of radio astronomy. The Very Large Array (VLA) will be complete and available for full operation by the end of 1980. This powerful new instrument in New Mexico is very much a general-purpose astronomical tool useful for the study of almost every type of celestial object that radiates at centimeter and decimeter wavelengths. Radio emission from solar system objects, galactic sources, quasars and radio galaxies can all be mapped with angular resolution comparable to that of a large optical telescope. In Green Bank, West Virginia, single dish observations have been made by either the 300-foot meridian transit telescope or the 140-foot fully steerable telescope. These telescopes continue to provide highly valued observations over a wide range of centimeter and decimeter wavelengths because of their location in the National Radio Quiet Zone. In this area, harmful radio interference so common elsewhere is minimized by the natural shielding of the mountains, and control over radio transmission activities. An important role of the 140-foot telescope continues to be its use as part of the Very Long Baseline Interferometer (VLBI) network. At the Kitt Peak site, west of Tucson, the 36-foot telescope is used to observe at millimeter wavelengths. Continued development of short wavelength receivers for that telescope have allowed observations producing significant scientific results at wavelengths at which the telescope was not designed to operate.

The observing programs scheduled on the telescopes during calendar year 1978 brought 317 visiting scientists, representing 97 institutions to the NRAO facilities. Of the visitors, 60 were students. While observing pressure on all the instruments is heavy, and proposals greatly exceed available time even on the oldest telescopes, the VLA now has the greatest over-subscription, with a wide range of proposals with high scientific potential from both optical and radio astronomers.

Because of the advancing age of many of the NRAO telescopes, an important part of the program is the design and development of new instrumentation that can maintain the efficiency of the telescope as demands are made to work at ever shorter wave-

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lengths. New radiometers and data processing systems provide capability for astronomers to work at an ever increasing range of frequencies in spite of a world full of radio transmitters. Past design studies have now demonstrated ways that the telescopes' performance can be improved and each year small modifications are made, e.g., to reflector systems or pointing systems to increase the useful life of the facility. Looking to the future, feasibility design work has been completed for a proposed 25-meter millimeter wave telescope that is greatly needed to maintain the preeminent position of the U.S. in millimeter wavelength astronomy.

At the VLA site near Socorro, New Mexico, the installation is progressing on schedule. No problems with either budget or schedule are forseen through to its planned completion in January, 1981. All twenty seven antennas plus one spare are now completed, the last five of these 25 meter diameter dishes wait now only for completion of electronics and the track necessary to move them into location on the array. While working with only a partially completed aperture synthesis array, scientists have demonstrated the ability to produce radio maps equal to the best optical photographs. While during 1979, operation and maintenance manpower constraints limited the number of antennas operating at one time to 17, and operating time to approximately 50 percent of available hours, this will be increased in the coming year. At completion, the southwest and southeast arms of the array will be 13 miles long (presently 10.7 miles are complete), and the north arm will be 11.8 miles long (presently 2 miles are complete).

In January, 1981 a scientific, engineering and support staff of 106 will be required to operate the VLA. As construction of the instrument is completed in the late months of 1980, this will mean a reduction from the level of 132 people in the combined operations and construction areas. Upon completion of the VLA the staff of the NRAO will total 352, a decrease of 25 from the level at the end of 1980.

Major Research Questions

Areas in which it is anticipated that there will be extensive research include:

- Millimeter wavelength observations of the continuum emission from compact radio sources and quasars. In this relatively inaccessible region, the spectral shape, the source variability and its correlation with the better documented optical, infrared, and radio spectral properties will provide valuable insight into the emission and absorption mechanisms found in these sources.
- Continuation of the high resolution radio observations of the inner portions, including the radio jets, of radio galaxies. Such data aids in evaluating the several theories proposed to account for the transport of energy from the active nuclei in these objects.
- VLBI and VLA observations of maser sources in molecular clouds and young star-forming regions. Pinpointing the geometry of these regions will significantly improve our understanding of the earliest stages of star formation.

- Extended solar observations following up the coordinated efforts during the 1980 Solar Maximum Year observations. Fundamental questions dealing with the evolution of magnetic structures above active solar regions and the nature of coronal holes remain to be answered.
- The distribution of molecular species in the interstellar medium and the complex interstellar chemistry associated with regions as diverse as the prestellar cores of dark clouds or the turbulent volumes just behind recently shocked boundaries.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The $15,025,000 requested for Scientific Research Support includes $5,200,000 for operation of the VLA, an increase of $1,850,000 over the preceding year. This increase provides for operations with the completed telescope for 100 percent of the available time. In January, 1981, all 27 antennas, located along the full length of all three arms, will be available.

Operations at Green Bank in support of the 300-foot and 140-foot telescopes will require an increase of $250,000, to a level of $2,980,000. It is expected that the 300-foot antenna will continue to be needed for search and survey observations. Programs are mostly extragalactic observations at distances of over 400 million light years and require the large collecting area of the 300-foot telescope. The 140-foot antenna is used 25% of the time as a VLBI element for observations of quasars, astrometric measurements and geodetic studies. The rest of the time is allocated to single dish observations where spectral lines most often must be studied. Continuing development of maser receivers for the 140-foot telescope increase its efficiency by decreasing the number of receiver changes required to cover the required frequencies.

For the 36-foot telescope approximately three times more good proposals are received than there is time available. While the dish efficiency is very low at short wavelengths, the demands of observing programs have encouraged NRAO to collaborate with the University of Oregon and Queen Mary College, London, to produce a new cooled receiver that will work at the 1-mm, 2-mm, and 3-mm atmospheric windows. Opportunities are now available to observe the higher order transitions of certain light molecules. The operating budget associated with the 36-foot will increase by $86,000 to $1,030,000.

The Technical Support and Development Group, comprised of the computer, engineering and electronic development divisions, will require support in the amount of $2,310,000, an increase of $293,000. Salary increases will require part of the increase, with a new central processing computer planned to use the balance of the increased budget.

General and Administrative activities include the Director's office and the fiscal and business groups. Holding these activities to a minimum feasible level will require an increase of $94,000 to $1,215,000.

The Research Support group at the NRAO will increase by one person. This group maintains the scientific capability of the Observatory and ensures adequate help to visitors in the areas of observing techniques, calibration and data handling, as well providing additional help to the technical groups in the specification and testing of new instruments. The budget for this group will be $1,605,000, an increase of $165,000.

In the area of Non-Expendable equipment to be used for the upgrading of observing facilities, a net decrease of $75,000, to $685,000, will be necessary. This activity enables the NRAO to maintain its facilities at the forefront of the field. The FY 1981 funds will be used for advanced millimeter radiometers, completion of the master upgrading at Green Bank, and continuation of computer and software support of all telescopes.

Management Fee

The management and operation of the NRAO is through Associated Universities, Inc. (AUI) under contract with the NSF. The contract provides for the payment of $235,000 for FY 1981 to cover the corporate expenses related to the administration and operation of the Observatory, an increase of $15,000.

Construction of Building and Research Facilities

The end of 1980 will see the completion of the VLA, which has been the only major construction activity during the past few years. The $1,700,000 in new construction will be for the detailed plans and specifications of a 25 meter diameter, millimeter wavelength telescope to be installed at Mauna Kea, Hawaii. Heavy use of and results from existing millimeter wave telescopes has demonstrated the need for a larger telescope able to observe in the wavelength region between traditional optical and radio domains. This first increment of funding represents a commitment to request additional funds ($9M per year) in FY 1982, 1983, and 1984 to complete this project.

QUANTITATIVE PROGRAM DATA
NATIONAL RADIO ASTRONOMY OBSERVATORY PROGRAM ELEMENT

Manpower and Other Factors

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Number of scientist man-years supported[1]	34	37	38
Cost of scientists supported[2]	$990,000	$1,160,000	$1,283,000
Number of graduate students supported[3]	14	16	16
Cost of graduate student supported	50,000	75,000	75,000
Other manpower costs	5,937,000	6,720,000	8,368,000
Investment costs:			
Ongoing research effort			
Construction	—0—	—0—	1,700,000
Non-expendable equipment[4]	725,000	760,000	1,754,000
VLA Project			
Construction	4,841,000	1,694,000	—0—
Non-expendable equipment[5]	6,063,000	2,123,000	—0—
Project management	623,000	683,000	—0—
Proposed alternatives	—0—	—0—	—0—
Other costs[6]	3,474,000	3,867,000	3,780,000
Total[7]	$22,703,000	$17,082,000	$16,960,000

[1]Number of man-years worked during the program year by the scientific staff members, including those on visiting appointments.

[2]Salaries and benefits only.

[3]This program includes four students employed at NRAO whose activites contribute to the completion of their graduate degree programs, and 12 students who participated in the summer program.

[4]Includes such items as observing equipment, electronic research equipment, electronic test equipment, and facility maintenance equipment.

[5]Includes equipment in the following VLA expenditure categories: antenna system, antenna transporter, antenna services, electronic systems, and computer systems.

[6]Includes operation and maintenance of facilities, building rental, communications and utilities, computer rental, travel and AUI management fee.

[7]Does not include Green Bank Interferometer operations funded by the U.S. Naval Observatory.

Sacramento Peak Observatory $1,950,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Scientific Research Support	$1,787,000	$1,995,000	$1,954,000	$2,249,000	$295,000
Construction	—0—	—0—	—0—	—0—	—0—
Subtotal	$1,787,000	$1,995,000	$1,954,000	$2,249,000	$295,000
Management Fee	38,000	40,000	43,000	46,000	3,000
Total	$1,825,000	$2,035,000	$1,997,000	$2,295,000	$298,000
Less DOD Facilities Operating Support[1]	-325,000	-325,000	-325,000	-345,000	-20,000
Total	$1,500,000	$1,710,000	$1,672,000	$1,950,000	$278,000

[1]Funds provided by the U.S. Air Force (USAF) of the Department of Defense (DOD). The amount for FY 1981 is being negotiated but $345,000 is used for planning purposes.

Objectives and Description

The Sacramento Peak Observatory (SPO) is recognized as one of the world's major solar astronomical facilities. Located at an elevation of 9200 feet on a crest of the Sacramento Mountains in south-central New Mexico, 37 road miles east of the city of Alamogordo, the site provides excellent day-time seeing. The SPO makes available to qualified scientists highly advanced telescopes and instrumentation capable of observing the sun and other astronomical objects in the optical and infrared regions of the spectrum.

The Solar Vacuum Telescope at the SPO, under favorable atmospheric conditions, can observe the sun at an angular resolution unattainable by any other solar telescope, either ground-based or in space. This high resolution capability permits unique research studies of the fine structure of the solar magnetic field, velocity field, and convective processes. With its echelle spectrograph, birefringent filter, detectors, and related data acquisition equipment, the Tower Telescope can obtain unequalled spectral data, simutaneously, at widely separated wavelengths. The observatory's Big Dome complex with a battery of coronagraphs provides an unduplicated capacity for coronal research, including the measurements of coronal magnetic fields. The scientific staff of the observatory supports visitors by helping them to design and execute their approved observing programs efficiently and by developing new instruments and modifying old ones. The resident scientific staff on occasion collaborates with visitors in research programs.

Solar activity will reach a maximum in FY 1980, while the largest solar flares are expected in FY 1981. As a result both visitors and staff will give greater attention to the physics of solar and stellar activity. The launch of the Solar Maximum Mission by NASA in January 1980, will trigger an intensive world-wide study of solar activity, from the ground and from space. The SPO staff anticipates close collaboration with scientists in space solar programs that are funded by the National Aeronautics and

Space Administration (NASA) during FY 1981. SPO staff itself will participate as guest investigators in making observations with NASA's Solar Maximum Mission satellite. Throughout FY 1980 and FY 1981 the Air Force scientific resident staff at SPO will be heavily involved in making flare observations with SPO's equipment and in coordinating these observations with those made with the Solar Optical Observing Network (SOON). Scientists at SPO collaborate extensively with their colleagues at the Kitt Peak National Observatory and the High Altitude Observatory of the National Center for Atmospheric Research through the conduct of research projects of mutual interest and joint participation in topical workshops and seminars.

During FY 1979 and FY 1980, SPO developed instrumentation for detecting and studying the global circulation of the sun. Observations made will aid theorists in developing more realistic physical models of the solar activity cycle.

In FY 1979, 48 visiting investigators from 26 institutions used the SPO facilities. Almost 68% of the available telescope time was assigned to those visitors and resident USAF scientists, whose research proposals received the highest rankings by anonymous external referees. Thirteen students from ten universities were selected from over 30 applicants to work with staff scientists on research projects during the summer. SPO supplies the solar community with important observations that complement solar observations from space, form the basis of solar activity forecasts, and aid investigators in analyzing their data. Daily photographs have been supplied regularly to NASA and to NOAA to aid these agencies in fulfilling their missions. SPO held a summer workshop in July 1979 to focus attention on the leading problems in the physics of solar magnetic fields. Approximately forty scientists and graduate students from around the world participated. The USAF supports a nine-man research team at SPO that conducts studies related to solar terrestrial phenomena. In FY 1979 and 1980 the USAF contributed $325,000 toward the operational costs of SPO.

Major Research Questions

Major research questions being explored at the SPO in FY 1981 include the following:

- What is the physical basis of the sun's magnetic cycle?
- What processes are responsible for the large scale convective and circulatory flows in the solar envelope, and what is the relationship of these motions to the eleven-year cycle of solar activity?
- What are the physical processes involved in the origin and evolution of various forms of transient solar activity such as sunspots, flares, energetic charged-particle streams, and active prominences that extend hundreds of thousands of miles in space?
- What physical mechanisms are responsible for the structure and energy and mass balance of the solar chromosphere and corona and the acceleration of the solar wind which modulates the earth's magnetosphere?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Continuing and planned thrusts in FY 1981 include:

- Expanded observations of the properties of solar flares and other transient phenomena during solar maximum. These studies will be conducted in collaboration with other ground-based observatories as well as spaceborne experiments on the NASA Solar Maximum Mission satellite.
- Measurement and analysis of the global circulation of the sun. Included are pulsations of the whole sun, with periods between 5 and 160 minutes. These pulsations are particularly interesting because they offer a chance to probe the sun's interior.
- Theoretical and observational studies of wave motions of ionized solar gases to improve our understanding of energy transport in the envelope and outer atmosphere of the sun. In particular, the role of the strong magnetic fields in channeling wave energy into the upper atmosphere will be examined.
- Improvements in techniques to sharpen solar images that have been degraded by the earth's atmosphere. If successful, solar physicists will be able to study the properties of small areas of high magnetic fields, as they interact with convection cells. Eighty percent of the sun's magnetic field energy resides in such knots, which are too small to be resolved with conventional ground-based telescopes.
- Continued monitoring of coronal holes to determine their relation to the production of high-speed solar wind streams and interplanetary shock waves and their subsequent effects upon the terrestrial environment.
- Studies of stars which show phenomena similar to those observed on the sun such as flares and magnetic variability.

The projected staff level for FY 1981 is 53.5 Full time equivalent representing an increase of one over the FY 1980 level of 52.5. The increase consists of one scientist. The total Sacramento Peak Observatory staff will consist of the Director, 11 scientists, 1 visiting scientist, 2 support scientists, 22 technicians, and 16.5 operations, maintenance and administrative support personnel.

The NSF budget for SPO increased in FY 1981 by $278,000 to a level of $1,950,000. The increase consists of $295,000 for Scientific Research Support and $3,000 for the AURA Management Fee. The Scientific Research Support increase includes funds for one new operations staff member, an expanded visitor support program, and the increased cost of existing staff and operations and maintenance activities.

QUANTITATIVE PROGRAM DATA
SACRAMENTO PEAK OBSERVATORY

Personnel and Other Factors

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Number of Scientist-Years Supported[1]	10	11	12
Cost of Scientist Supported[2]	$300,000	$350,000	$418,000
Number of Graduate Students Supported[3]	12	10	10
Cost of Graduate Students Supported[2]	27,000	22,000	24,000
Other Personnel Costs	773,000	969,000	1,096,000
Land, Buildings & Fixed Equipment	—0—	—0—	—0—
Major Equipment	—0—	—0—	—0—
Other Equipment	74,000	34,000	82,000
Research Resources	—0—	—0—	—0—
Other Costs[4]	651,000	622,000	675,000
Total[5]	$1,825,000	$1,997,000	$2,295,000

[1] Number of work-years during the program year by full-time regular scientific staff members on tasks required to accomplish SPO's mission, exclusive of the Director of SPO.

[2] Salaries and benefits only.

[3] Students employed by SPO during the academic year and summer work periods whose activities contribute to the completion of their graduate programs.

[4] Includes such items as maintenance, travel, utilities and communications, supplies and services and management fee.

[5] Includes DOD facilities operating support: FY 1979: $325,000; FY 1980: $325,000; FY 1981: $345,000. (FY 1981 DOD support is estimated.)

ATMOSPHERIC SCIENCES PROGRAM SUBACTIVITY $71,100,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Atmospheric Sciences Project Support	$31,976,778	$36,250,000	$34,269,000	$38,600,000	$4,331,000
National Center for Atmospheric Research	25,260,000	26,950,000	26,600,000	29,900,000	3,300,000
National Scientific Balloon Facility	1,870,000	2,550,000	2,300,000	2,600,000	300,000
Total	$59,106,778	$65,750,000	$63,169,000	$71,100,000	$7,931,000

Objectives and Description

The objectives of the Atmospheric Sciences Program Subactivity are to:

- Increase our knowledge of the behavior of the earth's atmosphere from the earth's surface to outer space,
- Provide basic knowledge that can underpin applications by mission agencies, and
- Strengthen research in atmospheric sciences.

The elements that make up this subactivity are research support programs in:

- Aeronomy
- Atmospheric Chemistry
- Climate Dynamics
- Experimental Meteorology
- Global Atmospheric Research Program (GARP)
- Meteorology
- Solar Terrestrial Research

The subactivity also supports the:

- National Center for Atmospheric Research (NCAR); and
- National Scientific Balloon Facility (NSBF)

Atmospheric Sciences is a discipline in which knowledge of physics, chemistry, biology, and other sciences is combined in various ways to improve our understanding of the atmosphere. The research that is supported will, in time, contribute to the solution or alleviation of atmospheric problems such as those associated with pollution from major industries, growing populations, and other societal actions. There also is much to be learned about the origin of droughts and severe storms such as tornadoes and hailstorms, in order to lessen their economic and human impacts.

Research support is provided over a wide range of subjects. Included are studies of the physics, chemistry, and dynamics of the earth's upper and lower atmosphere; the

acquisition of data on physical processes in the troposphere and stratosphere that will aid in understanding the general circulation of the atmosphere and the physical basis of climate; and research on climate processes and variations, as well as research on smaller scale, shorter term phenomena leading to greater knowledge of weather processes. The National Center for Atmospheric Research (NCAR) is a major research complex that is devoted to (1) support of large-scale atmospheric research projects in cooperation with universities and other organizations and (2) the providing and maintenance of large facilities for use by university and NCAR scientists. The National Scientific Balloon Facility (NSBF) provides the necessary support for scientific research requiring *in situ* measurements at high altitudes.

In previous years the budgets for Global Atmospheric Research Program (GARP) and the Climate Dynamics Program were separate Program Elements within the Atmospheric Sciences Program Subactivity. In FY 1980 Atmospheric Sciences was reorganized to bring all university grant programs into one element. The FY 1981 budget reflects this new arrangement. There are no interruptions in funding continuity or budget detail as a result of this change.

In the Atmospheric Sciences Grant Programs the emphasis will be on:

- Observation, analyses and theory during the solar maximum years of 1980 and 1981,
- Particle processes as they determine energy, chemical and radiative balances in the upper atmosphere, ionosphere and magnetosphere,
- Radar measurements of the global dynamics and composition of the atmosphere up to 150 km,
- Atmospheric Chemistry of global cycles of gases including minor constitutents and pollutants in both the upper and lower atmosphere,
- Mesoscale (regions 10 to 100 km in size) Meteorology which encompasses all local weather phenomena e.g., cumulus cloud formation,
- Continued analyses of data from the GARP Atlantic Topical Experiment
- Completion of data processing from the regional Monsoon Experiments (Winter and Summer Monex) and research based on the data,
- Studies of the support of the field program for the GARP Alpine Experiment
- Studies of the natural variability of climate
- Numerical climate modeling for diagnostic studies and applications to societal issues such as the CO^2 increase, and
- Impact studies that will aid in better management of food, energy and water resources.

The National Center for Atmospheric Research and the Balloon Facility programs will emphasize:

- the causes of climatic trends and variability,

- improved understanding of weather processes and weather prediction,
- solar processes—their variability and impact on the interplanetary medium and the terrestrial atmosphere,
- better understanding of severe storms,
- the chemical quality of the atmosphere,
- continued support of stratospheric scientific balloon flights, and
- implementation of the operational phase of Long Duration Ballooning.

Major Research Questions

- How do the sun's variations affect the magnetosphere, ionosphere, upper atmosphere and, finally, terrestrial climate and weather?
- What magnetic, electrical, radiative and chemical interactions occur in the magnetosphere and ionosphere and how do they affect the earth's atmosphere?
- What are the fundamental chemical and radiative properties of the upper atmosphere?
- Are the magnetosphere and lower levels of the atmosphere coupled and, if so, what are the physical mechanisms for such coupling?
- What are the factors that control the formation, organization and decay of convective and severe storms?
- What are the key processes in the formation of precipitation including the role of dynamical-microphysical interactions and electrical charges?
- What are the crucial physical processes that initiate and maintain cyclonic storms of the middle latitudes?
- Which atmospheric processes are sensitive to deliberate or accidential modification by human activities and can these changes be made beneficial to society?
- What processes govern climate, climate change and climate variability and how can the effects of oceans, ice fields, the biosphere, radiation, cloud cover, water vapor, trace gases, and aerosols be modeled successfully?
- How does climate impact human activities and do human activities in turn have an effect upon climate?

Significant Recent Achievements

New Focus on High Latitude Circulation

The global scale circulation of the upper atmosphere displays dramatic weather characteristics superposed on a smooth seasonally varying background pattern driven by solar radiational heating. In response to strong geomagnetic storms, upper atmospheric winds as great as 1,000 miles/hour have been found to surge across the northern U.S. border as far south as Pennsylvania. Observations, disjointed in time and space, have taught us that these "weather" patterns are driven by highly variable heat sources at high latitudes. These heat sources are due primarily to auroral electric fields that drive high-velocity charged particles or plasma flows.

A new capability for measuring these electric fields continuously in time and also spanning the full auroral zone from 60 to 75 degrees North has been accomplished by the addition of a 150 foot diameter fully-steerable antenna to the Millstone Hill radar facility at Westford, Massachusetts. We are now accumulating a much better definition of how auroral electric field patterns are distorted because of increasing levels of solar-driven magnetic disturbances. The next step is to seek the causal relationships linking the observed sub-auroral atmospheric effects to the high latitude phenomena producing them. Eventually, it may be possible to determine if such activity is important to the weather and climate observed at the earth's surface.

Test of Early Warning Tornado Radars

A cooperative national program called Severe Environmental Storms and Mesoscale Experiment (SESAME) sponsored an observational period in April-June 1979 that included the disastrous tornado outbreak of April 10 in Texas and Oklahoma. Using NSF, NOAA, NASA and FAA support, SESAME aims at improving our understanding of severe convective storms and the ultimate application prediction of such storms. New techniques utilizing Doppler radar were tested. Success in this area will significantly reduce death, injuries and property damage. NSF's role is to support both NCAR and university scientists in fundamental research on convective storm processes.

Acid Precipitation Experiments (APEX)

Scientists from the NCAR and seven universities made in-flight sample collections of air, cloud water, and rainwater during 1979 to learn how and where acid rains form. APEX is the first such project to measure the important airborne acids and acid precursors simultaneously in an effort to trace the origins of acid rain and to identify options for its control. In four spring storms in the Northeastern United States 78 percent of the acid in the rain (on the average) was accumulated from the air below the cloud. This implies origins within nearby regions rather than long-range transport by the air above the cloud. APEX is a cooperative program with the Environmental Protection Agency.

Effects of Agricultural Burning on the Atmosphere

Large scale savannah and brushland fires associated with shifting agriculture patterns in South America are a major source of trace gases in the global atmosphere. Agricultural burning is used in the savannahs of east central Brazil, where the residue from harvested crops is burned before new crops are planted. Fire also is used extensively to clear land in the heavily forested Amazon Basin in northern Brazil. During August-September 1979, NCAR and university scientists conducted a program in Brazil to study the effects of biomass burning on the atmosphere. Measurements were made from the NCAR Saberliner aircraft and from the ground. Preliminary results of this experiment indicate that this method of clearing the ground is a major source of atmospheric pollutants, including CO^2 (carbon dioxide) and CO (carbon monoxide). The experiment will be repeated in the summer of 1980 to obtain a more complete understanding of the impact on the atmosphere and of transport mechanisms involved.

Monsoon Experiment (MONEX)—The Field Observation Year

August 1979 saw the end of the year-long observational phase of the Monsoon Experiment, (MONEX). With over 20 nations participating, MONEX is a major international Global Atmospheric Research Program experiment aimed at increased understanding of atmospheric and oceanic processes associated with the monsoon. U.S. field programs, primarily under NSF sponsorship, were supported by 3 research aircraft, 3 research ships, special satellite programs and portable radar, surface, and upper air observations platforms. Approximately 200 U.S. scientists, technicians and support personnel from about 25 universities were involved.

MONEX was staged in two phases: the Winter Phase centered over the South China Sea and the Summer Phase over the northern Indian Ocean, Saudi Arabia and the Bay of Bengal. The monsoon is the most energetic regional circulation in the earth's atmosphere. Because of its tremendous influence on the agriculture, economy, politics and health of a major portion of the world's population, forecasts of the onset and breaks of the monsoon are among the most important recurring weather predictions. Also, because of the size and level of atmospheric energetics, the monsoon circulation affects weather and climate on a global scale. It is anticipated that the research using MONEX data sets will make important advances in atmospheric sciences through a more thorough understanding of monsoon processes and prediction of the time and intensity of monsoons.

New Measurements of the Earth's Energy Budget

As a result of newly developed computer techniques, it is possible now to process vast quantities of solar radiation data observed from geostationary satellites. For the first time, measurements of the earth's radiation budget can be made on a 24 hour basis. Accurate knowledge of the amount of energy that heats the atmosphere and oceans is essential in the construction of numerical models of the earth's climate. These models ultimately will be used to predict future atmospheric states and hence, local weather.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The difference between the Budget Request for the Atmospheric Sciences and the Current Plan is $2,581,000. This decrease reflects reprogramming to the new Cross Directorate Programs activity, to the new Ocean Drilling Programs activity, and the Atmospheric Sciences' share of the budget reductions made by the Congress. The reduction was absorbed to some extent by all programs; however, a larger percentage of the reduction was allocated to the grant programs. This was because the NCAR FY 1980 budget appeared to constrain disproportionately NCAR's research programs. Also, NCAR cannot react easily to major changes late in the allocation cycle because of personnel policies that require a year's notice be given to professional staff.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$59,106,778
FY 1980 Program	$63,169,000
FY 1981 Request	$71,100,000
Difference—FY 1981/FY 1980	$7,931,000

The $71,100,000 requested for Atmospheric Sciences is 12.6 percent or $7,931,000 more than the FY 1980 program.

The distribution of the FY 1981 budget request for the program elements of Atmospheric Sciences gives priority to the following areas:

- Cloud physics and convective storm processes including research that will undergird weather modification activities,
- Determination of the sources and sinks of trace substances in the atmosphere and their chemical, dynamic and energetic roles on the atmosphere and on each other,
- Ocean-atmosphere-ice-land coupling processes that will aid in understanding and modeling the climate system, and
- Continuation of upgrading incoherent scatter radar systems

This results in the following percentage increases:

Atmospheric Sciences Project Support	12.6%
National Center for Atmospheric Research	12.4%
National Scientific Balloon Facility	13.0%

Increases:

- $4,331,000 in Atmospheric Sciences Project Support (total $38,600,000) to:
  - — upgrade an incoherent scatter radar network for upper atmospheric observations,
  - — continue support for expanded atmospheric chemical research generally.
  - — support the basic research component of weather modification projects,

- expand climate modeling and assessment of the impact of climate change and variability on man and his environment,
- support the Alpine Experiment field program,
- begin analyses of first GARP Global Experiment and MONEX data sets,
- study mesoscale meteorological processes using new observing tools,
- support the observational program of the Solar Maximum Year (SMY).

The increase will help restore basic research in areas such as cloud physics that was cut back when the Applied Science and Research Applications (ASRA) Weather Modification program was terminated during FY 1979. The reemphasis of research in weather modification is responsive to increased interest by the scientific community and by Congress. The increase will continue to upgrade and relocate an incoherent scatter radar network in the Americas. The final network will permit an organized research program to evaluate the global scale dynamics as well as the transports of high altitude energy, monemtum and mass. The increase will insure that the atmospheric chemistry program begun in FY 1978 will receive continuing support. The increase will continue to support research necessary for the U.S. Climate Plan. Finally, there will be university support for the SMY.

- $3,300,000 for the National Center for Atmospheric Research (total $29,900,000) to:
  - continue scientific progress in studies of solar variability, trace gases and aerosols, modeling, and convective storm processes;
  - provide ongoing support for facilities such as aircraft and the Cray-1 computer; and
  - increase administrative services.

NCAR's facilities are vital to the university atmospheric sciences community as well as to NCAR scientists. NCAR research, also is vital to the National effort and will be maintained at on-going levels.

- $300,000 for the National Scientific Balloon Facility (total $2,600,000) to:
  - continue support services to ongoing scientific ballooning programs,
  - renovate the former operations building, and
  - begin procurement of communications equipment necessary for an operational long-duration ballooning program (LDB).

    The renovation of the building and the beginning of LDB were deferred in FY 1980.

Decreases:

Although the budget line items do not decrease, there will be changes of emphasis within program areas.

- As the Global Atmospheric Research Program's experiments move into new phases some existing phases are deemphasized. This is the case with the GARP Atlantic Tropical Experiment (GATE) in which analysis activity is decreasing.

Coordination and Relationship to Other Efforts

Atmospheric research support is coordinated through a number of formal and informal mechanisms. The coordinating mechanism for research will be the new Federal Committee for Atmospheric Research which is a part of the Committee on Oceans and Atmosphere (CAO). CAO is a committee of the Federal Coordinating Council on Science, Engineering and Technology. A special CAO panel has been established to develop a National Plan for Weather Modification research and to coordinate Federal activities in weather modification. All aspects of applied research and services are coordinated through the Federal Committee for Meteorological Services and Supporting Research (FCMSSR).

A working group under the structure of FCMSSR coordinates the Global Atmospheric Research Program (GARP). Project offices have been set up for all major GARP experiments, the GARP Atlantic Tropical Experiment and First GARP Global Experiment Project Offices at NOAA's Rockville Maryland, Headquarters and the MONEX Project Office at NCAR in Boulder, Colorado. The U.S. Committee for GARP of the National Academy of Sciences/National Research Council (NAS/NRC) gives advice, helps plan and evaluates the Federal effort in GARP. Internationally, GARP is coordinated by the Joint Organizing Committee which reports directly to the World Meteorological Organization and the International Council of Scientific Unions.

With the passage of P.L. 95-367, the National Climate Program Act, all climate activities within the Federal Government are coordinated by the U.S. Climate Program Office, an interagency office located at NOAA's Rockville Headquarters. P.L. 95-367 provides for OMB, OSTP and Congressional input into the planning of climate activities. A Climate Program Policy Board, chaired by NOAA, is composed of representatives from agencies involved in climate activities. In addition, the NAS/NRC has established a Climate Research Board to help shape the U.S. Climate Program and give advice and critical evaluation to agency climate programs. Internationally, a World Climate Program has been developed that is patterned administratively after GARP, although many UN specialized agencies will be involved.

The increase of carbon dioxide in the atmosphere and its possible effects on global climate have become a major national and international problem. The Department of Energy (DOE) has assumed a lead role in supporting research in this area and in evaluating its impact on society. DOE, NOAA, and NSF staff meet regularly to discuss pending research proposals and are jointly supporting research in this area. NSF has

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an in-house task force on carbon dioxide that coordinates the NSF role and strengthens its coordination with other agencies. International coordination probably will be through the World Climate Program.

Programs at NCAR are closely integrated with other NSF atmospheric science programs. In addition to the coordination mentioned above, NCAR and other NSF atmospheric science programs receive advice from committees of the NAS/NRC such as the Committee on Atmospheric Sciences, the Geophysics Research Board and the Ocean Science Committee. In addition, the Foundation's Atmospheric Sciences Advisory Committee oversees programs, gives advice, and reviews programs.

The network of informal contacts as well as formal *ad hoc* groups is large, thus supplementing formal mechanisms in providing additional information on what other agencies are doing and thinking within the field of atmospheric sciences, both nationally and internationally.

Finally, the University Corporation for Atmospheric Research (UCAR), the corporation that operates NCAR, coordinates university opinions, needs, etc., and acts as a focal point for university atmospheric sciences. Since UCAR is an NSF contractor, it provides close cooperation between NSF and the academic community on atmospheric science policies and plans.

Atmospheric Sciences Project Support Program Element $38,600,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Aeronomy	$4,838,445	$5,950,000	$5,700,000	$6,500,000	$800,000
Atmospheric Chemistry	3,081,933	4,700,000	3,700,000	4,800,000	1,100,000
Climate Dynamics	4,739,932	5,600,000	5,200,000	6,000,000	800,000
Experimental Meteorology	2,200,044	2,500,000	2,500,000	3,300,000	800,000
Global Atmospheric Research Program (GARP)	5,661,194	6,000,000	5,600,000	5,600,000	—0—
Meteorology	6,610,230	6,400,000	6,469,000	6,900,000	431,000
Solar Terrestrial Research	4,845,000	5,100,000	5,100,000	5,500,000	400,000
Total	$31,976,778	$36,250,000	$34,269,000	$38,600,000	$4,331,000

Objectives and Description

The objective of the Foundation's Atmospheric Sciences Project Support is to expand fundamental knowledge of the atmospheres of the earth and other planets, as well as of the sun. This includes:

- developing the scientific bases and tools for understanding the dynamic and physical behavior of climate and weather on all scales.
- developing the scientific bases and tools for understanding the natural global cycles of gases and particulates in the earth's atmosphere,
- improving our understanding of the composition, energetics and particularly the dynamics of the upper atmospheric system, and
- improving our knowledge of the sun and neighboring planets, especially as they relate to our understanding the earth's upper atmosphere and space environment.

Support to achieve these objectives is provided to scientists from a broad range of disciplines through the seven atmospheric sciences grants programs.

The Aeronomy Program supports theoretical and experimental programs directed at understanding the upper atmosphere—its behavior, and the physical processes determining that behavior. This is the region within which fluctuations in charged particle concentrations can disrupt long distance radio communication channels, including satellite channels; auroral currents flow, which can produce power-line surges; studies in the ionospheric plasma laboratory, free of confining wall effects, have extended knowledge of processes of plasmas, a topic of concern to scientists engaged in thermonuclear research; and a great variety of processes are found which are of intrinsic scientific interest as well as of importance in controlling this region of our environment.

The Atmospheric Chemistry Program supports research on aspects of chemistry that are unique because the atmosphere, being fluid, transports large numbers of

minor constituents including aerosols and mixes them in a chemically, radiatively, and dynamically interactive system.

The goal of the Climate Dynamics Program continues to be the development of improved understanding of global climate processes as a basis for predicting climate variations and for assessing their impact on human affairs. To achieve such an understanding will require improved and expanded global observations of present climate variables and increased efforts to describe important physical processes that control climate. Improved climate prediction is a national effort that involves the activities of many Government agencies. Under the National Climate Program, NSF has the responsibility to support research that provides improved understanding of the physical basis for climate, the causes of climate variations and its past history.

The Experimental Meteorology Program supports field-oriented research on the physics and dynamics of the troposphere, including research on both advertent and inadvertent weather modification.

The Global Atmospheric Research Program (GARP) supports research directed at answering fundamental questions such as: how do various atmospheric and oceanic processes interact to change the basic state of the atmosphere? NSF has the responsibility of supporting university and private sector scientific participation in U.S. GARP activities. The program is designed to accomplish the objectives through a combination of field experiments, global observations of the atmosphere and oceans, and numerical modeling research.

The Meteorology Program supports a broad spectrum of research on the physical and dynamical behavior of the lower atmosphere. This program is the cornerstone for tropospheric research as it represents the major single source of support in the nation for research in meteorology.

The Solar-Terrestrial Research Program is composed of four major disciplines that correspond to four physical regions between the sun and the earth. They are: (1) the sun, (2) the interplanetary medium, (3) the magnetosphere and (4) the upper atmosphere. A fifth research topic is that of cosmic rays, that pervade all these regions and, in fact, are used as tracers to investigate solar-terrestrial interactions as manifested by particles and fields. These objectives are met mostly through support of university researchers in relatively small, individual projects. Much of the research is collaborative with other divisions of NSF and other agencies, particularly NASA.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Aeronomy

Laboratory and analytic techniques have advanced to the degree of being used to examine individual specified energy states of atoms. Application of these techniques is needed to define the microscopic processes whereby atmospheric particle species are split apart or ionized, chemically interact, radiate, and exchange energy. FY 1979 and 1980 construction of major facilities with unprecedented capabilities for controlled plasma experiments in the ionosphere have primed the field for renewed experimental

and theoretical effort in fundamental plasma processes relevant to our environment. Research into the properties of the upper atmosphere has led to the recognition of the need to deal with it as a global scale system that is coupled to the stratosphere below and the magnetosphere above. Consequently, a major new phase of research was launched in FY 1980, with the initiation of an upgrading of existing incoherent scatter radars to establish a longitudinal chain by 1982. This chain is the key to an extensive program of research, predominantly by university researchers through individual grants. The shift of emphasis is to studies of the dynamics and global scale transports of energy, momentum, and mass, with special concern for the role of energy deposition at high latitudes. Increased emphasis on coordination is needed for effective research on the upper atmosphere as a global scale system. This is exemplified by work in support of the International Magnetospheric Study; effort on the very poorly understood "middle atmosphere" (20 Kms to 100 Kms), within the framework of the internationally planned Middle Atmosphere Program; and growing emphasis on coordinating planned operations at the longitude-chain of radar stations with European counterpart operations, and closely related NASA satellite operations.

Given the special opportunities outlined above, the FY 1981 $800,000 increment in funding, from $5,700,000 to $6,500,000 will: help restore the university grants program across the broad range of research mentioned above; accommodate limited entry into the international Middle Atmosphere Program with partial response to the new opportunities in atmospheric plasma-process research; and sustain the longitude-chain radar upgrading program to allow the emergence of the required global scale view of the dynamic upper atmosphere.

Atmospheric Chemistry

Because trace constituents enter into hundreds of chemical reactions, some of which are driven by solar energy, atmospheric chemistry cannot be understood as a straight-line sequence of independent chemical steps. Some understanding is possible by computer simulation of the entire interacting system, that requires as input the detailed knowledge of molecular processes along with field observations of trace amounts of key chemical entities. The ultimate goal is to develop a model capable of predicting the future evolution of the atmosphere including its chemistry and the effects of natural and man-made perturbations on it. Experiments on artificially polluted air have been hard to interpret in practical terms because of experimental artifacts and unavoidable assumptions about the chemistry involved. Thus, progress in the chemistry of both clean and polluted air requires a more intensive development of the underlying basic chemical knowledge. The FY 1981 Atmospheric Chemistry budget of $4,800,000 will allow added emphasis on this aspect of the research. It will provide for further studies of sources and sinks of trace gases and airborne particulates; of precipitation chemistry including acid rain; and of the transport and exchange of gases and aerosols between the troposphere and the stratopshere. The increase of $1,100,000 from $3,700,000 will accelerate the entire spectrum of research on tropospheric and stratospheric chemistry.

Climate Dynamics

In FY 1981 Climate Dynamics Program support will be increased by $800,000 to a total of $6,000,000. To document the natural fluctuations of climate on a global scale from historic to modern times, emphasis will be given to the assembly and analysis of data from ground and marine stations, satellite and upper-air soundings, ice cores, and historic data sources. Actual obligations in the assembly and analysis of data in FY 1980 will be near $1,800,000. An increase of $200,000 will bring this area to $2,000,000.

Paleoclimatic data are assembled and analyzed to reconstruct past climates as a means of evaluating the rate, magnitude and frequency of climatic change. Primary sources of paleoclimatic data include tree rings, fossil pollen preserved in lakes and bogs, ice cores and the deep-sea record of fossil plants and animals. FY 1980 funding support will be close to $1,700,000. An increase of $200,000 will bring the level to $1,900,000 in FY 1981. As a result of the success of a new hydraulic piston coring device, FY 1981 emphasis will be placed on the continued analyses of the newly obtained ocean cores.

The Climate Dynamics Program supports the development of a spectrum of climate models, their validation from data sets, and their use as diagnostic tools to isolate important physical mechanisms governing climate. Needs in FY 1980 will be near $1,300,000. Many proposals of high merit are now being received and it is expected that $1,630,000 will be needed for climate modeling in FY 1981. The increase of $330,000 will be used to initiate studies of air-sea interactive modeling.

Various human activities such as the burning of fossil fuels are rapidly approaching a level where they may have some impact on global climate. The natural variability of climate is sufficiently large and the rate of operation of some physical processes sufficiently slow, that, by the time a significant man-made change in a climate variable is observed, changes beyond the danger point could follow, even if corrective action were taken immediately. This program will support research on dynamical mechanisms involved in such changes and the development of simple models for determining the sensitivity of the climate to human activities. Research on questions that deal with the agricultural, ecological, socioeconomic, and political impacts of climate and climate change also will be supported. Funding in FY 1981 is $400,000, an increase of $100,000, with emphasis placed on understanding at regional levels the impact of climate on energy and water resource management.

The Climate Dynamics Program has assumed responsibilities in several areas outside the normal proposal review and award role such as support of pertinent workshops and National Academy of Sciences committees. In FY 1981 these costs are estimated to be $70,000, a decrease of $30,000.

Experimental Meteorology

Major research areas covered in this program are the development of precipitation within cloud systems, the interaction of physical and dynamical processes in cloud systems, cloud interactions with their environment and other clouds to form organized mesoscale systems, the role of mesoscale elements in large-scale cyclones and anticyclones, and possible alteration of cloud processes and the cloud environment, both

deliberate and unintended. The development of new observational tools and advances in computer simulation offer opportunities for improving significantly our understanding of mesoscale, midlatitude weather systems. Strong emphasis is being given to basic studies of cloud processes that will enhance the capability to modify the weather. In FY 1980 the program will support limited U.S. university cooperation in the Precipitation Enhancement Project (PEP) sponsored by the World Meteorological Organization. The preliminary field phase of this international weather modification experiment took place in Spain during the winter-spring of 1979 and 1980.

In FY 1981, the program will increase by $800,000 from $2,500,000 to $3,300,000. A $400,000 increase will be utilized to support university participation in the Cooperative Experiment on Convective Precipitation, a major interagency field experiment in Montana during the summer of 1981. This experiment will focus on the physical processes associated with summer convective precipitation and its modification. Another $150,000 will be used for the U.S. participation in PEP. The remainder of the increase ($250,000) will be used to support a range of research activities to strengthen the physical basis for weather modification.

Global Atmospheric Research Program (GARP)

The Global Atmospheric Research Program budget will be level funded at $5,600,000. The research and analysis phase of the GARP Atlantic Tropical Experiment (GATE) will continue as a high priority item during FY 1981. Some of the major analysis projects will have been completed by FY 1980. Therefore, the planned funding level will be $600,000—a decrease of $630,000 for FY 1981. This reflects the planned phasing out of this effort.

The observational phase of the First GARP Global Experiment (FGGE) was completed in FY 1980. FGGE's main objectives are to develop better models for weather forecasting and to assess the predictability of weather systems. U.S. participation in the field phase was funded mainly by NOAA and NASA. NSF participated in the planning and funding of the experiment to assure that university investigators would have the information needed for their research. In FY 1981 NSF will provide $700,000 for FGGE research, an increase of $70,000 over FY 1980.

In association with FGGE, two regional experiments were conducted that involved the U.S. These were:

1. *MONEX*—The Monsoon Experiment is a major study to increase our understanding of the dynamics and thermodynamics of the atmosphere and the ocean in monsoon regions. Three geographical areas have been identified for this experiment. They are the Arabian Sea, the Bay of Bengal and Indonesia-Malaysia. The field programs of MONEX were successfully carried out in FY 1979 and a substantial part of the processing of the observed data is being completed in FY 1980. MONEX is important scientifically and also has significance for global agriculture, economics and politics. The NSF is responsible for supporting the cost of research, logistics, equipment, and management of U.S. participation in MONEX. In FY 1981 the processing and the large amount of data obtained by U.S.

scientists must be completed and the ongoing research must be supported. A total of $2,600,000 is budgeted for MONEX, increasing that support by $30,000 over FY 1980.

2. *POLEX*—The Polar Experiment is a study of the energy balance of the atmosphere in the polar regions. Major U.S. involvement in POLEX never has developed. In FY 1981 $50,000 will support the necessary Polar Experiment Projects. This amounts to no change from FY 1980.

The latest GARP field effort is the Alpine Experiment. This experiment will explore the effects of the Earth's major mountain barriers on the large-scale circulation of the atmosphere. This international effort will be undertaken through a field program in the Alps during FY 1981. U.S. participation will require $700,000 in FY 1981, an increase of $550,000 over the planning costs of FY 1980.

Fundamental studies of the inherent predictability of the atmosphere and the role and effect of turbulence must be continued in order that the general circulation of the atmosphere can be modelled. These studies will be level funded at $900,000 in FY 1981.

Support of national and international GARP planning through the National Academy of Science will require funding of $50,000 in FY 1981, down $20,000 from FY 1980.

Meteorology Program

The emphasis for the past several years has been on processes and systems directly related to mid-latitude weather. Scales of major interest range from hundreds of kilometers to the molecular. The general objective is to have advances in both dynamical and physical meteorology converge on problems related to local weather systems. New understanding of the behavior of weather on this scale offers a considerably increased potential for additional successful research on these important and often hazardous weather systems.

The new observing tools include Doppler radars that provide information about the internal motions of cloudy air, incoherent scatter radars that can provide data on three-dimensional air motions, and dual wave-length and polarization radars that provide more information on the microphysical structure of clouds. The Meteorology Program is supporting the gathering and analyses of such data together with corresponding modeling efforts. Additional components of research include studies of the boundary layer, microphysics of clouds, electric charge separation and cloud electrification, the dynamics of downdrafts, and tornado-like vortices and the interaction of convective clouds with the environment. The program continues to support research on radiation, the basic fluid dynamics of weather systems, and micrometeorology.

Studies of weather systems are receiving renewed emphasis through cooperative work by several university researchers. This arrangement permits efficient use of resources and has initiated several excellent working relationships with NOAA's National Meteorological Center. The scope of existing grants is relatively broad. Several investigations are addressing the diagnostic characteristics of cyclones and comparing these with the numerical simulation of the same systems using the operational forecast model of the National Weather Service.

In the Meteorology Program, the $431,000 increase from $6,469,000 to $6,900,000 will be used in two ways: (1) to initiate new instrumentation or to promote the exploitation of recently developed devices ($331,000), and (2) to initiate new interpretative research on the electrical properties of thunderstorms, including the lightning discharge process ($100,000).

Solar Terrestrial

Many research grants made in the Solar-Terrestrial Program contribute to international programs. Currently there are three major programs in progress or planned. They are the International Magnetosphere Study (IMS), the Solar Maximum Year (SMY) and the Middle Atmosphere Program. The IMS will continue until 1985 as an analysis/theoretical program using the data collected during 1976-1979. The aim of IMS is to understand how the sun's activity energizes the magnetic field of the earth causing disturbance of the upper atmosphere, e.g., the aurora. The SMY is an observational program aimed at the origins of that solar activity, e.g., solar flare. SMY will last from 1979 to 1982. As a first step, NSF and NASA are jointly funding a Scientific Coordinator to help plan and implement observational efforts of both ground-based and satellite missions. Finally, MAP in 1982 to 1985 will investigate the middle atmosphere from 10 to 100km. Particular areas of ignorance concern the chemistry and dynamics of this region in response to (varying) solar inputs. The three programs form an integrated research plan aimed at thoroughly investigating the sun/atmosphere connection.

FY 1981 research in these areas is currently planned at the $5,500,000 level, an increase of $400,000. This increase will be used in the most active observational program i.e., the SMY.

QUANTITATIVE PROGRAM DATA
ATMOSPHERIC SCIENCES PROJECT PROGRAM ELEMENT

Proposals and Awards

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	587	632	739
Total Dollar Amount	$86,330,311	$92,977,744	$108,783,960
Awards:			
Number of Awards	475	487	539
Total Dollar Amount	$31,976,778	$34,269,000	$38,600,000
Average $ Per Award	67,320	70,368	71,600
Average Award Duration	12	12	12

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	87.1	86.3	86.3
Industry	2.3	3.0	3.0
Federal Laboratories	4.6	4.7	4.7
Other	6.0	6.0	6.0

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of scientist years supported	237	229	246
Cost of scientists supported	$6,436,279	$6,898,430	$7,900,334
Number of graduate students supported	459	492	517
Cost of graduate students supported	$3,817,544	$4,088,590	$4,604,334
Other personnel costs	5,249,560	5,626,600	6,408,334
Land, Buildings, and Fixed Equipment	—0—	—0—	—0—
Major Equipment	—0—	—0—	—0—
Other Equipment	1,998,014	2,110,480	2,320,334
Other Costs[1]	6,511,637	7,006,260	7,542,334
Indirect Costs	7,963,744	8,538,640	9,824,334
Total	$31,976,778	$34,269,000	$38,600,000

[1]Expendable equipment, travel, publication costs, computer costs, other direct and indirect costs.

National Center for Atmospheric Research
Program Element $29,900,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Atmospheric Analysis and Prediction	$2,433,300	$2,253,000	$2,419,000	$2,504,000	$85,000
Atmospheric Quality	1,418,000	1,736,000	1,630,000	1,741,000	111,000
Convective Storms	2,169,000	1,946,000	1,915,000	2,542,000	627,000
Advanced Study Program	802,100	686,000	855,000	863,000	8,000
High Altitude Observatory	2,202,000	2,195,000	2,343,000	2,565,000	222,000
Facilities Operation and Development	10,581,000	12,054,000	11,325,000	12,962,000	1,637,000
Administration and Support Services	5,119,600	5,545,000	5,578,000	6,188,000	610,000
Management Fee	535,000	535,000	535,000	535,000	—0—
Total	$25,260,000	$26,950,000	$26,600,000	$29,900,000	$3,300,000

Objectives and Description

The National Center for Atmospheric Research (NCAR) serves as a focal point for the atmospheric sciences research program of the National Science Foundation. The NCAR effort is conducted in cooperation with scientists in universities, government laboratories and other institutions, and is directed toward obtaining a better understanding of the behavior of the atmosphere. Within this mandate NCAR has two major goals and functions:

- Plan and conduct high quality research on selected atmospheric problems of national and international scope and importance.
- Develop and make available selected quality research facilities and services required by the atmospheric sciences community for effective progress in atmospheric research.

NSF supports NCAR through a cost plus fixed fee contract with the University Corporation for Atmospheric Research, a non-profit corporation of 49 universities with doctoral programs in atmospheric sciences. NCAR's main laboratory is in Boulder, Colorado. The NCAR staff totals about 600 of which 40 percent are scientists and 60 percent are technical, maintenance and administrative personnel.

NCAR's research is focused on obtaining increased understanding of atmospheric processes of importance to society. The fundamental information gained may be expected to lead to improved weather predictions, greater knowledge of climate changes, increased capability for evaluating the possible modification of severe storms, better understanding of air quality and acid rain processes, and added comprehension of the mechanisms involved in solar energy driving the atmospheric heat engine. NCAR also develops and operates major facilities for the atmospheric sciences community—computing, aircraft, radars, etc.

Atmospheric Analysis and Prediction

The goal of this research is to increase fundamental understanding of the physical processes governing geophysical fluid motions and apply this knowledge to predicting the behavior of the atmosphere as coupled to the oceans and continents. Specific research objectives relate to the prediction of weather, and understanding climate trends and their causes. The research strategy is based on a balance of three components—theory, modeling and observations—with strong links between them. Numerical models are being developed to integrate such components, which include many physical processes and interactions. An example is a general circulation model of the atmosphere with its coupling of ocean circulation, the dynamics of sea ice, radiatively important trace gases, and land surface processes to provide a global climate model. Both theory and modeling need testing and validation against the observed behavior of the atmosphere.

The research activities in this program include:

- Mesoscale studies over a range of up to 2,000 km to demonstrate and enhance short range weather predictability.
- Climate studies to improve numerical simulation models.
- Large scale dynamics studies to formulate models of the atmosphere that can describe the significant physical processes.
- Oceanography studies to improve the understanding of the processes in the global ocean circulation and the air-sea interactions, and the relationship of these processes to the atmosphere.

Atmospheric Quality

This group studies the chemical composition of the earth's atmosphere with special emphasis on relatively long-lived constituents and develops photochemical-meteorological models for analyses and interpretation of global observations of atmospheric constituents. It determines the significant chemical, physical and biological mechanisms that maintain or perturb chemical balances within the atmosphere. Important applications of these activities relate to atmospheric pollution, acid rain, and the impact on the ozone layer with its implications for mankind.

The research activities of this group include:

- Acquisition, analysis and interpretation of data from satellite observations including application of global data sets to study the chemistry, physics and dynamics of the upper atmosphere.
- Development of numerical simulation models of the global structure and circulation of the atmosphere to an altitude of 50 miles.
- Obtaining stratosphere-mesosphere observations of the space-time distribution of gases that influence the earth's radiation budget, ozone balance, and dynamics of the stratosphere and mesosphere.
- Obtaining observations through cooperative ecology-oriented projects to explore those substances and processes responsible for acid rain.

- Investigating the exchange of air and its chemical constituents between the stratosphere and troposphere.

Convective Storms

The objective of the NCAR convective storms studies is to gain basic understanding of the dynamical and microphysical processes that produce convective storm precipitation and cause some storms to intensify and become dangerously destructive. Practical long range goals are to improve severe storm forecasting, leading to improved warning services, and to increase the capability for evaluating the possible modification of the storm precipitation processes in beneficial ways. A three month comprehensive field observing program, scheduled for FY 1980, was postponed and will occur during FY 1981. The program is designed to:

- Improve and refine conceptual and quantitative models of how precipitation is formed in various storms with emphasis on the interaction of precipitation particles and air flow;
- Investigate the effects of the environment on storm development and growth; and
- Study the effect of aerosols on precipitation processes, particularly condensation and freezing nuclei.

Advanced Study Program

This activity supports visiting scientists and educational programs designed to enhance long term interactions between NCAR and university scientists and to develop scientific talent in the atmospheric sciences and related areas. A program to study environmental and societal impacts of aspects of the atmosphere also is conducted.

Advanced Study Program activities include the following:

- A postdoctoral fellowship program that provides research appointments at NCAR for recent PhD's;
- A graduate assistant program that supports pre-doctoral and masters candidates; and
- A pilot study that develops a methodology linking social value models with physical science models, concentrating on the air pollution problem in the Denver area.

High Altitude Observatory

The research program of HAO is directed toward improved understanding of solar processes and their influence on the interplanetary medium and the earth's atmosphere, including climate trends and their causes.

HAO activities consist of:

- Studies of solar atmosphere and magnetic fields and the balance of energy and momentum within the photosphere and chromosphere;

- Studies of the solar corona, magnetic fields and solar winds to provide information on what may be an important link between solar variability and the terrestrial environment. The NASA-sponsored HAO solar maximum effort provides a special opportunity to gain comprehensive coverage of the active solar corona;
- Study of interplanetary physics, a critical element in relating solar phenomena to the solar wind and subsequent terrestrial effects; and
- Solar variability studies on the fundamental nature of the sun's output—radiation, magnetic field and particles—over a range of time scales, from weeks and months to thousands of years.

Facilities Operation and Development

One of the two major missions of NCAR as a national center is to provide investigators in universities, NCAR, and other laboratories with facilities support of the quality required for effective progress in the atmospheric sciences. The facilities operated and maintained by NCAR include Computing, Field Observing, Research Aviation, Research Systems, and the Global Atmospheric Measurement Program.

The Computing Facility provides atmospheric researchers with state-of-the-art computer services. Through the CDC 7600, users can perform statistical analyses and process data from large data sets. The Ampex Terabit Memory System provides the atmospheric science community with the means of storing massive quantities of data and finally, the CRAY-1, a powerful high speed fifth generation computer, gives scientists the capabilities of developing and operating large numerical atmospheric models.

The Research Avaiation Facility operates highly instrumented aircraft, provides the necessary ground support, and conducts technical developments to maintain and update these capabilities. The four NSF-owned instrumented research aircraft presently operated are: a four-engine turboprop Electra, a twin-jet Sabreliner and two twin-engine Queen Airs. These aircraft support research activities conducted by university and NCAR scientists (about 2/3 university and 1/3 NCAR) principally in the following areas: atmospheric boundary layer (lowest level of the atmosphere), cloud physics, mesoscale and severe storms, air chemistry and radiation. Demand for aircraft support is expected to continue to exceed present capabilities. Replacement of an aging Queen Air to meet the growing demands of the atmospheric scientific community with a modern aircraft of greater capabilities is necessary. In FY 1981 plans are to lease with option to purchase a twin engine turboprop aircraft as a replacement for the Queen Air.

The Field Observing Facility provides support and instrumentation to obtain measurements needed in experimental meteorological programs, including advanced sensing systems, development of new measurement systems and operational and analytical techniques for optimum use of its facilities. Recently increased recognition of the importance of severe convective storms, winter cyclonic storms, boundary layer processes, and air pollution as coupled to boundary layer turbulence, transport and diffusion have increased the demand for Field Observing Facility services. The facilities

include two Doppler radars and a conventional radar, four rawindsonde systems, an extensive software library and data processing services and the Portable Automated Mesonet, a group of 30 remote, automatic weather observing stations reporting in real time to a central data collection station.

The Research Systems Facility maintains an engineering design capability to develop sensor, communication and data acquisition systems. The major goal of RSF is to develop new instrumentation and data processing systems for use by other NCAR facilities and special national and international programs such as the Global Weather Experiment, Monsoon Experiment, etc.

The Global Atmospheric Measurements Program primary functions are the innovation, development and feasibility demonstration of sophisticated superpressure balloon systems, and of the associated lightweight meteorological sensing systems, and cooperation with the atmospheric scientific community in utilizing these techniques in research endeavors.

These facilities serve NCAR and the university atmospheric research community. In FY 1979, NCAR facilities utilization by university and other non-NCAR users was as follows:

Facility	No. of Institutions	No. of Scientists
Aviation	28	45
Computing	87	305
Field Observing	22	22

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Atmospheric Analysis and Prediction

The increase of $85,000 from $2,419,000 in FY 1980 to $2,504,000 in FY 1981 combined with a decreased requirement of $70,000 for staff terminated during FY 1980 will provide $155,000 required for increased costs.

Atmospheric Quality

The increase of $111,000 from $1,630,000 in FY 1980 to $1,741,000 in FY 1981 combined with a decreased requirement of $60,000 for staff terminated in FY 1980 will provide approximately $60,000 to augment the biogeochemical research effort and $111,000 for increased costs.

Convective Storms

The $627,000 increase from $1,915,000 in FY 1980 to $2,542,000 in FY 1981 will provide $500,000 required to conduct a field program in FY 1981. This field experiment will be conducted in cooperation with university scientists and the Bureau of Reclamation at its High Plains Experiment site in Miles City, Montana. The convective storms field

program will include coordinated measurements using an NCAR instrumented Queen Air aircraft, both doppler and conventional radars, and the portable automated mesonet. The NOAA sailplane also will be used. The remaining $127,000 are required for increased costs.

High Altitude Observatory

The $222,000 increase for the HAO from $2,343,000 in FY 1980 to $2,565,000 in FY 1981 will provide $70,000 for augmenting the solar variability programs. The remaining $152,000 will be required for increased costs.

Advanced Study Program

Funding is increased by $8,000 from $855,000 in FY 1980 to $863,000 in FY 1981. At this funding level the graduate assistant program will be reduced from six in FY 1980 to four in FY 1981. Also the summer colloquium program will not be conducted in FY 1981.

Facilities Operation and Development

The funding increase of $1,637,000 from $11,325,000 in FY 1980 to $12,962,000 in FY 1981 will provide $400,000 for replacing the oldest and now obsolete Queen Air aircraft with a twin engine turbo prop aircraft. The new aircraft will be leased with an option to buy. Development of the Portable Automated Mesonet, PAM II, system and the rapid scan radar will begin in FY 1981 at a cost of $150,000. The operation and development of the facilities can expect an extraordinary increase in costs of $660,000 in the following four areas:

Obligations	
Computer Maintenance	$225,000
Aviation Fuel	$110,000
Computer Supplies	$55,000
Salaries of Programmers & Computer Engineers	$270,000

In addition, the expected ordinary increase in costs in FY 1981 is $800,000, primarily in salary increases. Funding available for this category is only $427,000. This $373,000 shortfall will result in a reduction of services provided to the users of the computer facility, reduction in some development programs, and reduction in aviation facility services.

Administration and Support Services

The increase of $610,000 from $5,578,000 in FY 1980 to $6,188,000 in FY 1981 will be required for replacement of worn out equipment such as a telephone switchboard and library computer terminal, $90,000; repairs to roof of the NCAR Mesa Laboratory, $35,000; increased cost of utilities, $95,000, and increase in other costs, $390,000, particularly salaries.

QUANTITATIVE PROGRAM DATA
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH PROGRAM ELEMENT

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of scientist years supported[1]	264	248	241
Cost of scientific support[2]	$8,247,000	$8,944,000	$9,624,000
Number of graduate students supported[3]	13	13	11
Cost of graduate students	$80,000	$79,000	$75,000
Other personnel costs	7,906,000	7,775,000	8,392,000
Total personnel costs[4]	16,233,000	16,798,000	18,091,000
Investment costs:			
Nonexpendable equipment[5]	2,491,000	2,922,000	3,653,000
Construction	—0—	—0—	—0—
Other costs[6]	6,536,000	6,880,000	8,156,000
Total	$25,260,000	$26,600,000	$29,900,000

[1]The number of years worked during the program by full-time regular staff members in tasks required to accomplish the center's mission, exclusive of Director, and Associate Director.

[2]Salaries and benefits only.

[3]Number of students employed by the center whose activities contribute to the completion of a graduate degree program.

[4]Includes salaries for scientific visitors on NCAR payroll ($806,000 for 37 scientist-years in FY 1979; $857,700 for 36 scientist-years in FY 1980; $943,470 for 36 scientist-years in FY 1981.)

Footnote Distribution

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
[5]Includes:			
Computer lease purchase credits	$1,128,000	$1,193,000	$1,193,000
Program equipment and scientific instrumentation	1,243,000	1,604,000	2,223,000
Purchase of computing hardware	—0—	—0—	—0—
Other equipment	120,000	125,000	237,000
Total	2,491,000	2,922,000	$3,653,000
[6]Includes:			
Computer rental and maintenance	1,730,000	1,656,000	1,987,000
Communications and utilities	601,000	708,000	855,000
Travel and transportation	666,000	616,000	708,000
Supplies and materials	1,419,000	1,588,000	2,007,000
Rental of equipment, buildings and land	457,000	485,000	524,000
Other purchased services	1,128,000	1,294,000	1,540,000
Management fee	535,000	535,000	535,000
Total	$6,536,000	$6,880,000	$8,156,000

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National Scientific Balloon Facility $2,600,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
National Scientific Balloon Facility	$1,870,000	$2,470,000	$2,270,000	$2,600,000	$330,000
Construction	—0—	80,000	30,000	—0—	-30,000
Total	$1,870,000	$2,550,000	$2,300,000	$2,600,000	$300,000

Objectives and Description

The mission of the National Scientific Balloon Facility (NSBF) is to provide the scientific community with the most efficient and reliable balloon operational support possible within the state-of-the-art and to conduct a research and development program to advance that state-of-the-art to meet the growing and changing requirements of the scientific community. NSF supports the NSBF under the same contract as NCAR.

The NSBF is situated at Palestine, Texas and includes a staff of approximately 53 engineers, technicians, and support personnel. It provides balloon launching, tracking, payload recovery, data acquisition and engineering services for scientific observations from balloons. Balloon flights are launched from the NSBF base and from other sites in the U.S. and some foreign countries, i.e., transatlantic flights from Sicily; Southern Hemisphere flights from Australia, New Zealand and some South American countries.

In FY 1979 the NSBF conducted 91 balloon flights, 82 from its base at Palestine, Texas, and 9 from remote locations, in support of a broad spectrum of scientific experiments in cosmic rays, X-rays, infrared astronomy, particles and field in the magnetosphere, and measurements of dynamical atmospheric parameters, trace gases involved in ozone formation and destruction, and condensation nuclei important for aerosol production.

The NSBF is the most advanced balloon facility in the world. Its support is provided to a large number of U.S. investigators whose experiments are funded by U.S. agencies including NSF, NASA, DOD, FAA, and to foreign investigators from several countries. Support is provided through the assembly of payloads, launching of balloons, their tracking and recovery, as well as in the acquisition and processing of data and in the provision of engineering services.

This subelement also includes funding for the U.S. contribution to the cooperative United States-Australian scientific ballooning program in the Southern Hemisphere. This program is supported under the terms of an agreement between the National Science Foundation and the Australian Department of Science.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

In FY 1981 the NSBF is expected to provide support to approximately 80 scientific balloon launches. Replacement of outmoded airborne telemetry and command system which began in FY 1980 will continue in FY 1981.

The funding for this subelement in FY 1981 will be $2,600,000, an increase of $300,000 over FY 1980. The expected increase in costs of operating the facility in FY 1981 is $150,000. The remaining $150,000 will allow partial development and testing of the long duration balloon systems: $80,000; and replacement of one airborne telementry and command system: $70,000.

QUANTITATIVE PROGRAM DATA
NATIONAL SCIENTIFIC BALLOON FACILITY PROGRAM ELEMENT

Personnel and Other Factors

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Number of scientist years supported	7	7	8
Cost of scientists supported	$200,000	$243,700	$268,100
Other personnel costs	827,000	1,054,300	1,159,700
Total personnel costs	1,027,000	1,298,000	1,427,800
Investment costs:			
Long duration non-expendable equipment	25,000	—0—	120,000
Other non-expendable equipment	41,000	115,100	70,000
Construction	—0—	30,000	—0—
[1]Other costs	777,000	856,900	982,200
Total	$1,870,000	$2,300,000	$2,600,000
[1]Includes:			
Communications and utilities	82,000	103,600	124,300
Travel and transportation	36,000	45,000	58,500
Long duration supplies and materials	15,000	—0—	—0—
Other supplies and materials	143,000	338,500	398,700
Rentals of equipment, buildings and land	113,000	30,900	34,000
Long duration purchased services	15,000	—0—	—0—
Other purchased services	373,000	338,900	366,700
Total	$777,000	$856,900	$982,200

EARTH SCIENCES PROGRAM SUBACTIVITY $27,900,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Geology	$4,634,308	$5,050,000	$5,050,000	$5,650,000	$600,000
Geophysics	9,857,574	10,350,000	10,040,000	11,000,000	960,000
Geochemistry[1]	10,427,522	10,850,000	6,138,000	6,700,000	562,000
Petrology[1]	—0—	—0—	4,050,000	4,550,000	500,000
Total	$24,919,404	$26,250,000	$25,278,000	$27,900,000	$2,622,000

[1]The Geochemistry element has been divided to provide increased visibility for a former component, the Petrology element.

Objectives and Description

The objective of NSF's Earth Sciences Program is to increase knowledge of the solid portion of the planet. This goal includes investigating the Earth's evolution from its beginning to the present, its chemical and physical properties, and the processes that operate and have operated on it to produce all the features that we see and use and by which our lives are constrained. Mountains and plains, ore deposits and fertile soils, earthquakes and landslides, are the result of a complex interplay of physical, chemical, and biological processes. To achieve a better understanding of these interrelationships is a key aim of the Foundation's support of research in geology and its related fields.

As human population increases and spreads, it is becoming more and more vulnerable to the effects of natural processes on and within the earth. These processes are not well understood, as is clearly shown by our inability to predict or mitigate natural catastrophes, such as earthquakes and volcanic eruptions, and by the severe damage to ecological systems produced by human activities. Increased basic knowledge of the earth sciences can in time, if well used, prevent loss of life and mitigate damage to property by natural disasters.

Basic geologic data are essential also to the technological society in which we live today. The industrial base of our economy is dependent on the development and wise use of our natural resources. The discovery of new mineral and fuel deposits has become increasingly difficult as the more easily found deposits are consumed. A better understanding of fundamental properties of ores, mineral fuels, and host-rock characteristics can provide a basis for discovery of new economically attractive deposits.

The most important part of the earth to biological organisms, including humans, is the crust on which we live, build our houses, and obtain our resources. Now that the Deep Sea Drilling Project and other research have tested the plate tectonics hypothesis (a revolution in earth sciences), we are in a position to re-examine the continental crust with new understanding. Researchers are embarking on an ambitious new thrust to re-examine the U.S. continental crust and its associated mineral deposits, earthquakes, and geothermal areas. Outstanding examples of this new thrust are a seismic

reflection profiling program (COCORP) to understand the complex structure of the U.S. crust down to the mantle, and a scientific drilling program, sponsored by several agencies to research key portions of that crust that up to now have been inaccessible.

Earth Sciences project support results in over 500 awards from about 900 proposals submitted by scientists, mostly from colleges and universities. Research topics cover a very wide range, from theoretical studies of motions of the earth's core to field observation of how a shoreline erodes, and from the study of earthquakes to the history of life on this planet. In FY 1980 the Petrology element was added to the three traditional elements, Geology, Geochemistry and Geophysics. The new element is derived mostly from the old Geochemistry program.

Significant Recent Achievements

Neodymium-Samarium Used for Dating the Earth's Crust and as Tracers

In the past year there have been remarkable advances in the earth sciences through application of neodymium isotopic variations resulting from the decay of a radioactive samarium isotope and the chemical separation of Sm and Nd in nature. The technical advances over the past decade and a renewed interest and vigor in applying new methods to old problems in the earth sciences have resulted in major steps in solving classical problems and the generation of new and fundamental questions which urgently require answers. This year it has been demonstrated that it is possible to date igneous rocks ranging in age from 100 million years to 4.6 billion years. This class of rocks is one of the key products of melting in the earth's interior and occurs in the ocean basins and on the continents. The ability to date these rocks now permits us to establish the major times of melting in the mantle. The separation of these melts from the mantle leaves a residue with isotopic abundances which give the average age of the earth's crust (3.6 billion years) and the history of the earth's crust. It seems that almost all of the early crust of the earth that formed between 4.6-3.6 billion years ago has been destroyed by remixing back into the earth's mantle at about 3.6 billion years ago. This may explain the absence of much older rocks which have been searched for over the past 25 years.

In addition, the isotopic studies have shown that water from different oceans is readily distinguishable by direct measurement of Nd in the ocean water or in deep sea sediments. This will now permit a study of the flow between oceans today and in the past. Plutonium and Nd behave very similarly geochemically so that using these methods there is now also an opportunity to understand the transport of man-made radioactive plutonium in the environment by studying the transport of naturally occurring Nd, which is non-toxic.

Appalachian Structure

The Consortium for Continental Reflection Profiling (COCORP) conducts a continuing project that uses deep seismic reflections to study the continental crust. This

past year has been one of the most fruitful. A profile across parts of the southeastern United States has given a new and surprising picture of the structure and origin of the Appalachians. The area east of the mountains (the Piedmont) was found to contain an extensive layer of flat-lying sedimentary rocks buried beneath the metamorphic crystalline rocks of the surface and separated from them by a large horizontal thrust fault. The discovery has important implications for the origin and development of most major mountain ranges. It also highlights a region of the United States that may have hitherto unsuspected deposits of oil and gas.

Chemical Composition of the Mantle

The mantle of the earth represents some two-thirds of its mass. It is important, therefore, to understand the chemistry of the mantle in order to understand better its convection and thermal budget which affect the plate motions of the crust, and the melting processes which produce volcanoes. Recently MIT scientists, by working with minute quantities of minerals derived from the mantle, have found that some trace element abundances in common mantle minerals are very different from what was previously suspected. The results contradict current models of mantle melting and will lead to revised, presumably more accurate, calculations of mantle chemistry and melting behavior.

Evolution and Deep Structure of the Michigan Basin

The first sampling of rocks that give information on ancient volcanic and structural activity as much as one billion years ago beneath the Michigan Basin was provided by a cooperative effort involving three oil companies, several universities and support from an NSF grant through the Geology Program. The grant supported taking cores from the bottom of a 5,324 meter hole, drilled for petroleum exploration by the oil companies, and the measurement of a number of physical, magnetic, gravimetric, and geochemical properties in the hole and on the cores. Experiments included the deepest measurements that have been made of ambient stress in the earth's crust. Recently published interpretations of the cooperative studies reveal a probable stage of continental rifting and volcanic activity preceding the subsidence that formed one of the major petroleum-producing basins in North America. The study may prove to be a prototype for future cooperative studies involving academic institutions, government agencies, and industry in order to derive the maximum scientific information from the drilling of deep holes on the continent.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan is $25,278,000 compared to the Budget Request for FY 1980 of $26,250,000, a decrease of $972,000. The Geology Program has been maintained at the requested level because of the new important thrust for research on the U.S. continental crust. The Geochemistry and Petrology subelements have been reduced

by a total of $662,000, and Geophysics by $310,000. The decreases will result in less funding for new scientific instruments, a loss of new growth for the COCORP seismic profiling project and a general reduction in the number of projects supported.

FY 1981 Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$24,919,404
FY 1980 Program	$25,278,000
FY 1981 Request	$27,900,000
Difference—FY 1981/FY 1980	$2,622,000

The $2,622,000 increase over the FY 1980 Current Plan to a total of $27,900,000 in FY 1981 will be largely devoted to inflationary increases in on-going programs. However, specific research areas that will be highlighted in FY 1981 include:

- Research on the basic nature of earthquakes.
- Reflection seismic profiling to study deep crustal structures, and the geology and geochemistry of the U.S. continental crust.
- Support of new instrumentation in geochemistry and geophysics.
- Study of current geological processes.
- Geology, geochemistry, and petrology of ore deposits, especially their relation to crustal plates.
- The nature of ore-forming fluids.
- Geologic research on U.S. continental crust.

Funding for lunar sample analysis will continue at a constant level. (In FY 1979, such funding was $1,200,000).

Major Research Questions:

- Were plate tectonic processes operating prior to the breakup of the supercontinent some 200 million years ago?
- What processes in the core cause the earth's magnetic field?
- What are the limits and constraints of the convection model for the mantle? How deep is convection; how heterogeneous is the mantle?
- How are copper and lead-zinc ores related to subduction zones at active plate margins?
- Is the elastic-rebound theory of earthquakes completely ruled out by recent data?
- What are the differences in the processes forming the lunar crustal rocks and the rocks forming the early crust of the earth?

- When did oxygen first start accumulating in the earth's atmosphere?
- What causes hot spots in the mantle, with their associated volcanoes?
- What are the mechanics of faulting, especially faults that are nearly horizontal and involve the movement of large overthrust plates?
- How do sea-floor hydrothermal processes relate to those of the continental crust, and their associated mineral deposits?

Coordination and Relationships to Other Efforts

NSF's coordination of Earth Sciences with other agencies is partly formal, with program staff participating in interagency committee or discussion groups, such as the Interagency Geophysics Discussion Group or the *ad hoc* Earthquake Committee, and partly informal, by personal contacts. The staff of the Earth Sciences Division has been active in committees that deal with earthquakes, geophysics, continental drilling, mineral deposits, and analysis of lunar samples.

Objectives and Description

Project support in the Earth Sciences is divided into four elements: Geology, Geophysics, Geochemistry, and Petrology.

Geology

The Geology program supports basic research in a broad range of subjects, including structural geology, stratigraphy, paleontology, erosion, sedimentation and glaciology. The program is largely field-oriented, supplemented by laboratory testing. Typical projects range from a search for traces of early life in rocks over 3 billion years old to the study of algai mat accumulations near modern coral reefs; or from a field study of alpine folds to a laboratory simulation of how a brittle rock can be 'aged' without breaking. Increasing attention is being paid to research on mineral deposits and how they fit into the plate tectonic framework.

The increase in the Geology budget of $600,000 to $5,650,000 in FY 1981 will allow increased emphasis on the geology of the continental crust.

Geophysics

The rapidly expanding study of the physics of the planet earth is the domain of NSF's Geophysics program. It covers the sub-fields of seismology, gravity, geodesy, magnetism, earth currents, heat flow, and the behavior of natural materials at high pressures. The research is partly field, partly laboratory-oriented. The advent of plate tectonics has integrated all of the geological sciences; nowhere is this more apparent than in geophysics. Twenty years ago what would have been isolated projects in rock

magnetism or seismic probing of the earth's crust are now linked with each other and with field geology, in the testing of the new model of a working earth and applying of the knowledge gained to practical problems like earthquake prediction. The increase of $960,000 to $11,000,000 in FY 1981 should cover increased costs of continuing research. Earthquake related research increases by $600,000 to $7,200,000.

Geochemistry

The Geochemistry element, as now constituted, is largely laboratory-based and seeks to understand the chemical processes that have formed and are forming the minerals of the earth. Research ranges from laboratory simulation of chemical processes to the study of chemical migration in the environment. The geochemistry of ore-forming fluids and hydrocarbons are an important segment of the program. Many of the studies of geochemists resemble superficially the projects of inorganic chemists who may be investigating the compounds of silicon or carbon. The difference is in the questions being asked, and in the aims of the project. The chemist is interested in a reaction rate or the surface activity of a crystal as a chemical process. The geochemist wants to know how Nature makes his minerals and concentrates or disperses them. The increase of $562,000 to $6,700,000 in FY 1981 should cover increased costs of current program.

Petrology

The Petrology element supports the overall study of rock chemistry, geochronology, lunar studies and field-oriented studies in economic geochemistry and rock evolution. Petrology, the knowledge of rocks, is the link between laboratory chemistry and the field study of granite, basaltic volcanoes, kimberlite diamond pipes, or the ore bodies of lead and zinc sulfides. Because meteorites and lunar rocks can help us understand the early earth and because the processes that form all rocks are of interest to the petrologist, research on meteorites and lunar rocks is included in this program. The increase in the Petrology Program of $500,000 to $4,550,000 in FY 1981 allows no increase in emphasis in this area.

QUANTITATIVE PROGRAM DATA
EARTH SCIENCE PROJECT SUPPORT PROGRAM ELEMENT

Proposal and Award Summary

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Proposals:			
Number of Proposals	795	815	840
Total Dollar Amount	$47,920,000	$51,000,000	$56,000,000
Number of Awards	503	495	525
Total Dollar Amount	$24,919,404	$25,278,000	$27,900,000
Average Dollar Per Award	49,542	51,067	53,143
Average Duration of Award (Months)	18	18	19

Percentage Distribution of Funds by Performer

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Universities and Colleges	98	99	97
Industry	—0—	—0—	1
Federal Laboratories	—0—	—0—	—0—
Other	2	1	2

Personnel and Other Factors

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Number of Scientist Years Supported	200	190	215
Cost of Scientist Support	$4,200,000	$4,500,000	$5,000,000
Number of Graduate Students Supported	425	420	460
Cost of Graduate Students Supported	$3,000,000	$3,300,000	$3,700,000
Other Personnel Costs	2,500,000	2,500,000	3,000,000
Land, Buildings and Fixed Equipment	—0—	—0—	—0—
Major Equipment	—0—	—0—	—0—
Other Equipment	2,519,704	1,848,000	2,500,000
Other Costs	7,999,700	8,130,000	8,300,000
Indirect Costs	4,700,000	5,000,000	5,400,000
Total	$24,919,404	$25,278,000	$27,900,000

OCEAN SCIENCES PROGRAM SUBACTIVITY $76,000,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Oceanography Project Support	$19,736,736	$21,850,000	$21,350,000	$24,600,000	$3,250,000
Coordinated Ocean Research and Exploration[1]	19,456,617	21,400,000	20,750,000	23,600,000	2,850,000
Oceanographic Facilities and Support	23,200,372	25,200,000	24,519,000	27,800,000	3,281,000
Total	$62,393,725	$68,450,000	$66,619,000	$76,000,000	$9,381,000

[1]The International Decade of Ocean Exploration is succeeded by this program element in 1981. FY 1979 and FY 1980 IDOE funding is included in this line and work supported in these years is included in the CORES budget justification.

Objectives and Description

The Ocean Sciences Program supports research that will improve understanding of the sea and its relationship to human activities. Two research programs, plus one to support ships, equipment and technicians, provide funds for this work. Oceanography Project Support awards nearly 400 grants to individual scientists to study basic problems in Physical Oceanography, Marine Chemistry, Submarine Geology and Geophysics, and Biological Oceanography. The Coordinated Ocean Research and Exploration element supports large scale, long term (3-5 years) multi-institutional projects. This element succeeds the International Decade of Ocean Exploration that has supported the large projects that have become an important and integral part of modern ocean science. Ships and equipment to carry out both large and small research projects are supported by Oceanographic Facilities and Support (OFS), which provides two-thirds of the total support for 27 of the research ships of the academic fleet, and seeks to upgrade these ships and facilities, based on continuing review and evaluation of ship performance and material condition, and through design and construction of replacement ships.

Significant Recent Achievements

Deep Sea Discovery of Unknown Animals and Areas Rich in Metals

The deep research submersible *Alvin* has continued to provide oceanographers with a view of important and unexpected sea floor processes. During 1979 two major diving expeditions in the eastern Pacific studied the circulation of seawater through the ocean crust and the effect of the heated discharging water on sea floor animals and sediments. Northeast of the Galapagos Islands marine biologists examined dense communities of animals which populate areas where seawater has temperatures of 20°C (more than 15°C hotter than normal). The communities of these areas contain

clams up to 30 cm (one foot) in length, mussels, crabs and forests of giant tube worms uniquely adapted to their sea floor environment. Sulfur-oxidizing bacteria in the sulfur rich discharging waters apparently form the base of the food chain. The communities therefore owe their existence to chemical energy supplied from the ocean crust rather than the solar powered photosynthesis in surface waters.

Near the mouth of the Gulf of California researchers observed and sampled discharging water with a temperature of 350°C. Copper, zinc, and iron sulphide minerals precipitate from this super-heated water, forming chimneys up to 9 meters in height. These metal rich deposits are similar to some ore deposits on land and should provide important insights to ore forming processes.

The chemical reactions between seawater and crustal rocks sustain the bacteria, form mineral deposits and also have important implications in controlling the chemistry of both seawater and the oceanic crust. Data from the Galapagos indicate that the amount of magnesium removed from sea water by crustal rocks equals the amount supplied to the oceans by rivers. Other elements such as calcium, barium and silica are removed from crustal rocks and supplied to the overlying seawaters.

Open Ocean Discovered to be More Productive Than Suspected

The open ocean has long been thought to be as unproductive of plant and animal life as terrestrial deserts. However, recent work by a number of scientists suggests that productivity of the open seas may have been underestimated by at least 20%. This suggestion sheds new light on a question that has long puzzled biological oceanographers, i.e., how do the observed animal populations of the open sea subsist in waters of low apparent productivity. New insight on this question comes from studies that show:

- Unknown, small plants (bluegreen algae) exist in the open sea in large numbers (up to one-third of the total number of plant cells). These plants were missed in earlier studies because their small size allowed them to pass through nets and filters previously in use.
- Some of these bluegreen algae are adapted to extremely low light levels and consequently occur in abundance at depths greater than those previously sampled.
- Some algae can rapidly take up nutrients from areas of abundance (i.e., near a dead or defecating animal) and use these nutrients to continue growing even when surrounded by the generally nutrient poor water of the open-ocean.

Shipboard Equipment Upgraded

Shipboard equipment was upgraded in FY 1980 through a 50% increase in funds committed to new equipment acquisition and basic shipboard improvements. This initiative developed from a growing concern of both funding agencies and the oceanographic research community about the general inadequacies of shipboard equipment, the widely differing capabilities of fleet ships, and the lack of comparable inventory maintenance and management procedures among ship operator institutions. Consequently the University-National Oceanographic Laboratory System in cooperation

with the National Academy of Sciences' Ocean Science Board sponsored a workshop in early 1979 to define the basic minimum ship and instrumentation capability, operation and maintenance for all UNOLS' ships. The FY 1980 funding initiative in support of this effort is focused on such basic ship improvements and permanent shipboard gear as modern electronic navigation equipment, oceanographic cable and related machinery, and state-of-the-art oceanographic instrumentation.

Progress in Ship Construction/Conversion

FY 1980 marked the second consecutive year in which a major initiative in the Ocean Sciences budget was the inclusion of funds for ship construction—$3.0 million in FY 1979 and $3.1 million in FY 1980. The FY 1979 initiative resulted in issuance of a solicitation for proposals to build and operate a 130-140 ft. coastal ship in accordance with one of two Foundation owned designs. The solicitation elicited nine proposals representing some 36 academic institutions including several formally constituted consortia and led to the award of a contract with University of Miami for construction of the FY 1979 ship. The FY 1980 award will be based on the same competitive review and may result in a two-ship purchase under a single contract. The FY 1979 ship is a replacement for a 208-ft. Navy owned ship costing twice as much to operate. The review and assignment of both the FY 1979 and FY 1980 ships has as its first consideration the achievement of the best possible improvement in the overall academic fleet inventory and a concomitant savings in annual operating costs. Completion of these ships in early 1980 will add a capability not now available—coastal research platforms with good year-round sea-keeping characteristics, adequate working space and capacity for handling modern instruments, yet cost-effective for frequent short cruises.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The $1,831,000 reduction from the FY 1980 budget request of $68,450,000 to a current plan of $66,619,000 results primarily from reprogramming to help support several NSF initiatives including the Ocean Margin Drilling Program and also from Congressional budget cuts. This reduction was distributed across both research and facilities support with resulting decrease in the number of research projects undertaken and decreased flexibility in scheduling research activities at sea.

FY 1981 Budget Highlights and Explanation of Increase and Decreases

The $76,000,000 requested for Ocean Sciences is $9,381,000 more than the FY 1980 Program of $66,619,000. This request will allow an increase in effort and partially counteract a steady trend toward decreased effort prevalent over the last 5 years. The 1981 increase is particularly important for continued development of ocean science. It comes at a time when the U.S. has assumed responsibility for managing the marine fisheries in the World's largest 200 mile zone. It comes at a time when National and World Climate Programs have been established to develop our ability to predict

climate changes. It comes at a time when pollution in, and mineral resources from, the oceans and sea floor are areas of great national concern. In all of these areas basic ocean science is needed to provide a solid foundation of scientific knowledge for managing living resources, understanding climatic variability, determining the pathways and impacts of pollutants, and exploring for mineral and hydrocarbon concentrations beneath the sea floor. The FY 1981 request will support a broad program of research with particular emphasis on studies in the following areas:

- water circulation in open ocean and continental shelf areas using modern satellite, acoustic and chemical tracer techniques;
- geochemical and biological processes associated with newly discovered areas where geothermally heated water circulates through the oceanic crust;
- ocean and animal evolution based on new coring techniques that allow collection of undisturbed ancient sea floor sediments; and
- open ocean productivity and food chain processes.

Major Research Questions

Despite the emphases described above, the overall objective of the Ocean Sciences Program will continue to be to support research to improve understanding of the sea and its relationship to human activities. Attaining this objective will require maintaining a broad research program into major unanswered questions about the ocean. Some of these questions are summarized below:

- What are the general features, characteristics and spatial scales of oceanic current patterns and vertical mixing processes? How and why do the circulation patterns change with time? How can we predict these changes?
- In what ways do circulation patterns and mixing influence distribution of heat and nutrients and hence weather, climate and biological productivity in the oceans? How does the temperature structure of surface waters in the North Pacific affect seasonal weather across North America?
- What are the effects of the moving plates that make up the crust of the earth? How do the processes at the plate boundaries cause earthquakes, volcanoes, concentrations of mineral resources and effusions of crustal and mantle material into the sea?
- What are the processes which control the generation, transportation, and modification of particulate matter in the ocean? How can seafloor sediments which form from the deposition of this particulate matter be used to reconstruct the history of the earth's physical, chemical and climatic environment? What are the geological and geochemical processes that modify sedimentary material to form hydrocarbon and mineral resources?
- How do marine organisms and communities react to pollution produced by activities such as marine waste disposal and sea floor mining?

- How do the distribution patterns and biochemical interaction of marine organisms control the distribution and population of fisheries resources and damaging events such as red tides?
- What are the general characteristics, reactions and inputs which control the chemical composition of seawater? How do chemical pollutants enter the ocean and how are they removed? What is the capacity of the ocean to absorb atmospheric carbon dioxide and what would be the effect on the oceans of increasing carbon dioxide in the atmosphere?

Coordination and Relation to Other Efforts

NSF provides about half of the federal funds used to support ocean research conducted by U.S. academic institutions. Most of these funds come from NSF's Ocean Sciences subactivity, but ocean research is also supported in the Division of Polar Programs, the Division of Atmospheric Sciences, the Division of Environmental Biology, and the Division of Earth Sciences. The Office of Naval Research (ONR), and the National Oceanic and Atmospheric Administration's (NOAA) Sea Grant Program are the other major federal agencies that provide funding for ocean research at academic institutions.

Interagency coordination of federal funding for ocean research is achieved through the federal Committee on Oceans and Atmosphere and with advice from the National Advisory Committee on Oceans and Atmosphere and the National Academy of Sciences. A special University National Oceanographic Laboratory System is supported by NSF, ONR, and NOAA to provide a formal mechanism for efficient use and maintenance of the academic portion of the oceanographic research fleet. Additional coordination is provided by the increasingly important mechanism of informal contact between NSF staff and their counterparts in other federal agencies.

Oceanography Project Support Program Element $24,600,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Physical Oceanography	$3,793,000	$4,250,000	$4,150,000	$4,650,000	$500,000
Marine Chemistry	3,506,960	4,000,000	3,850,000	4,350,000	500,000
Submarine Geology and Geophysics	7,182,756	7,750,000	7,550,000	8,450,000	900,000
Biological Oceanography	5,254,000	5,850,000	5,800,000	7,150,000	1,350,000
Total	$19,736,736	$21,850,000	$21,350,000	$24,600,000	$3,250,000

Objectives and Description

Oceanography Project Support seeks to develop fundamental knowledge about the oceans and the ocean basins through support of a broad spectrum of basic research projects. The projects deal with the physical, chemical, geological, and biological processes which occur in the ocean and at its boundaries with the atmosphere, the seafloor, and the shore line. These processes control the chemical composition and motions of ocean waters, the nature and distribution of marine life, and character of the solid earth beneath the sea. Studies directed toward understanding these processes are supported through four program subelements: Physical Oceanography, Marine Chemistry, Submarine Geology and Geophysics, and Biological Oceanography.

In physical oceanography, investigators study the motions of water masses and transport processes in oceans, estuaries, and large lakes. They seek to understand these motions in terms of the physical properties and boundaries of the water masses themselves and in terms of the driving forces, such as the wind, solar radiation, precipitation, the earth's rotation, and solar and lunar tides.

Researchers in marine chemistry determine the distributions of chemical elements and compounds in the oceans and large lakes and try to understand these distributions in terms of where the various chemical components have come from, how they have been mobilized, where they are going, how they are changed in transit, and how they affect and are affected by living organisms.

In submarine geological and geophysical research, scientists define the character and distribution of marine sediments and rocks and try to decipher the natural processes such as plate tectonics, sediment transport, earthquakes, and submarine volcanism which control the nature of the sea floor.

In biological oceanography, investigators describe the distributions of life forms in the oceans and large lakes and seek to understand these distributions in terms of the nature of the individual organisms, their interactions with one another in communities and their interactions with the surrounding physical/chemical environment.

In addressing the many aspects of these general problem areas, about 400 research projects involving some 700 highly qualified research scientists and graduate students will be supported in FY 1981. In size, these projects will range from several thousand to several hundred thousand dollars and in duration from several months to several years. In approach there is also much diversity. The projects may involve any one or combination of the following approaches: theoretical studies, analysis and synthesis, laboratory experiments which simulate important aspects of the real oceans, and field experiments which provide information about the actual marine environment and the natural processes occurring there.

The overall research program plays a significant role in developing basic understanding of the marine environment, how it behaves naturally, how human activities affect it, and how it can affect humans. More specifically, this research is improving our understanding of oceanic water masses, their response to atmospheric forcing (wind, air pressure), their influence on local weather conditions and global climate, and their role in transporting and dispersing pollutants. It is providing the scientific basis needed for the environmentally safe and economically sound exploitation of sea-

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floor mineral resources. It is developing knowledge of the physical, chemical and biological factors which regulate life in the sea and which ultimately control the living resources of the oceans. And it is extending our understanding of plate tectonics processes which provide a critical framework for earthquake prediction and oil and mineral resource exploration.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Responsibility for maintaining a broad base of support in all aspects of oceanography lies with the Oceanography Project Support Element. Because of this about one-half of the budgeted increases will help continue the diversity of support across the entire field. The remainder will allow increased emphasis in FY 1981 for the following four areas:

- open-ocean dynamics and transport field studies which make use of new tools and techniques such as satellite imagery and the chemical tracer freon;
- chemical, biological, and geological processes associated with the high temperature, high pressure fluids of the recently discovered sea floor hydrothermal vents;
- application of newly developed long coring techniques to studies of paleoceanography, sediment diagenesis, and the evolution of marine microorganisms;
- primary productivity and food chain processes in the open ocean.

Collectively the research in these four areas illustrates the vitality of the ocean sciences and indicates several continuing trends in the field. One of these trends is the increasing cross fertilization between the several disciplines. The use of chemical tracers in physical oceanography and the biological and geological implications of hydrothermal vents are prime examples. A second relates to the development and use of new tools and techniques in studying the oceans, eg. satellite imagery and the ability to take long continuous sediment cores. A third relates in part to the first two. It involves the increasing need to support intermediate scale projects which can effectively address a number of important and frequently interdisciplinary problems using powerful but often expensive new tools.

Physical Oceanography

This program subelement will support research in the following areas:

- Open Ocean Circulation: Focused regional field studies, descriptive and analytical studies, and modeling studies will continue to investigate questions about large scale ocean circulation and transport. Studies of processes on the mesoscale (100's of kilometers) and their effects on global energy and momentum transport will also continue. These large and medium scale circulation patterns control to a large extent the global transport and distribution of heat and pollutants in the oceans. An increase of $300,000 to an FY 1981 level of $2,150,000 will provide for increased development and use of new tools and techniques

including the tracer freon for upper ocean transport studies and satellite imagery for the continuing, large scale coverage needed in ocean dynamics studies.

- Estuarine and Coastal Studies: Field, descriptive, modeling and theoretical studies will continue to investigate physical processes of circulation, eddy generation, and turbulent mixing on the continental shelves. Efforts will continue on the mixing processes and circulation in rivers and bays where fresh water and ocean meet. These studies are aimed at understanding and predicting the circulation and resulting transport of materials introduced into these areas as a result of increased industrial and urban activities. An increase of $100,000 to an FY 1981 level of $1,300,000 will provide for increased emphasis on interdisciplinary studies of transport processes in the coastal zone.
- Waves and Tides: This area includes studies of wind-generated surface waves, internal waves, and tides. Knowing how wind energy is transferred into waves and then dissipated within the oceans is important to our understanding of ocean currents and to the improvement of forecasting and accurate monitoring of sea surface conditions. Considerable progress is being made toward the theoretical understanding of nonlinear interactions of internal waves and their consequences for the vertical transport of momentum and energy. Field programs are in progress to test the theories and to investigate the generation and dissipation of internal waves. Other ongoing studies are providing new insights into the global ocean tides and are making use of tidal measurements to understand better tidal variability on time scales from weeks to years. No increase is requested over the FY 1980 level of $500,000.
- Microstructure and Turbulence: These studies examine transport processes on very small scales (generally less than a meter), such as diffusion, conduction and convection, 3-dimensional turbulence, and the physical properties of seawater. Such mixing processes play an important role in the vertical transport of pollutants, nutrients, and energy in both the deep ocean and shelf/estuarine environments. Field, laboratory, and modeling efforts will continue on questions important to small-scale mixing in the ocean interior as well as at the air-sea interface and at the ocean bottom boundary layer. An increase of $100,000 to an FY 1981 level of $600,000 will provide for increased field studies relevant to the transport of sediments and the mixing and transport of physical and chemical properties in the bottom boundary layer of the ocean.
- Limnology: The physical processes of circulation and mixing in lakes are similar to those in the ocean except for the absence of salt in the lakes. Lakes often provide large natural laboratories for the study of some physical processes without the logistics problems of going to sea. Mixing processes in lakes are important because of the effects of cities and industries located on their shores. Some priority is maintained in this program for such studies, but no increase is requested over the FY 1980 level of $100,000.

Marine Chemistry

Research efforts in the following areas will be supported:

- Seawater Chemical Equilibria: Investigations will continue providing information on the equilibria of chemical species and compounds in seawater, and their availability for reacting with other chemical phases in the marine environment. An increase of $50,000 is requested to the FY 1981 level of $700,000, which will allow for greater emphasis to be placed on investigation of organo-metallic interactions. This area of Marine Chemistry is still in its infancy, but in all probability such interactions play a significant role in determining the chemical behavior of dissolved metals in the ocean.
- Sea Floor-Seawater Reactions: Studies of the reactions occurring in surface sediments and active hydrothermal areas of the sea floor are directed toward gaining an understanding of the fluxes between the sea floor and overlying seawater, and the fate of material deposited on the ocean floor. Such studies are of growing importance in our efforts to understand the role played by carbonate sediments in the global carbon dioxide balance, the potential environmental impacts of sea floor waste disposal and mining activities, and the role of seawater-basalt interactions in forming ore deposits. Increasing technological capabilities are providing a basis for conducting a larger spectrum of investigations on this area of marine environment. An increase of $150,000 to the FY 1981 level of $1,250,000 is requested. This will permit further support of research in this rapidly expanding area of Marine Chemistry, particularly in regard to studying chemical processes in areas of hydrothermal venting.
- Particulate Matter-Seawater Interactions: Research on the reactions that are occurring in seawater with suspended particulate material, both inorganic and organic, are aimed at determining how material is altered as it transits the water column and the effects of such alteration on the availability of nutrients and on the sedimentary record. This part of the program will be increased by $100,000 to a total of $700,000.
- Chemical-Biological Interactions: Research in this area seeks a better understanding of the interactions occurring between the chemistry and biology of the marine environment and of the degree to which each system drives the other and/or is dependent on it. These interactions strongly influence the primary productivity of the oceans as well as numerous regulatory processes in marine organisms. Thus their understanding provides an important basis for improving management of the ocean's living resources. An increase of $50,000 to an FY 1981 total of $1,250,000 is planned to allow for support of this developing area of Marine Chemistry. The primary emphasis will be on marine organic, chemical and biochemical investigations including the participation of microbiologists in field studies.
- Air-Sea Interactions: Studies of air-sea exchange phenomena are oriented toward determining whether the sea is a source or a sink for man-made and

naturally mobilized chemicals (e.g. nitrous oxides) and the degree to which transport through the air contributes to the chemical properties of the ocean surface. An increase of $50,000 to an FY 1980 level of $150,000 is planned. This will primarily be directed at measurements of seawater uptake rates of trace gases.

- Physiochemical Properties of Seawater: Investigation of the physical chemistry of seawater is supported to understand better the kinetic and thermodynamic reactions that are taking place in the marine environment as well as to describe the physical and chemical properties of seawater. New technologies are rapidly becoming available which offer a chance to make significant advances in this area. An increase of $100,000 is planned which will bring the total for FY 1981 to $300,000. The major area of emphasis will be on chemical kinetics and the solid-solution interface.

Submarine Geology and Geophysics

This program subelement support research in the following areas:

- Geologic Structure, Tectonics: Geophysical and geologic studies continue on the structure of the oceanic crust and overlying sedimentary layers. Support will be provided for studies of continental margins, oceanic rise systems, and deep-sea sedimentary basins with specific projects ranging from local detailed structural studies to exploring global crustal dynamic processes. Increased emphasis is to be placed on intermediate-scale and interdisciplinary studies of ocean crust formation and the deep structure of continental margins. These studies are strongly field-oriented with primary data sources of seismic, gravity, magnetic, bathymetric, thermal, and electromagnetic measurements coupled to determinations of the physical properties of geologic materials. The increase of $200,000 to the FY 1981 level of $3,400,000 will provide additional support for intermediate-scale geophysical studies of oceanic crust formation and continental margin projects.
- Ocean Crustal Formation, Volcanic Processes: Major efforts in this area involve chemical and mineralogic studies of the rocks and sediments that form the ocean floor. Support will continue for studies of the processes that control the exchange of heat and chemical elements between seawater and oceanic rocks. Increased emphasis is to be placed on tectonic and volcanic activity occurring at mid-ocean ridges associated with hydrothermal vent fields. The increase of $200,000 to an FY 1981 total of $1,700,000 will support field programs using the research submersible ALVIN and maintain basic studies of samples obtained from the Deep Sea Drilling Project.
- Marine Sedimentation: Geological and geochemical studies of oceanic sedimentary sections are directed toward understanding the physical processes of sediment decomposition and erosion, sediment distribution patterns, geochemical alteration of sediments with time, and the dominant geologic and oceanographic processes controlling marine sedimentary systems. Emphasis will be

on the analysis of Deep Sea Drilling Project core samples for organic geochemistry, physical properties, and stratigraphic and lithologic measurements and on the interaction of bottom water currents and sediment deposition and erosion. The $200,000 increase to the FY 1981 total of $1,800,000 will support improved mapping techniques and a slight increase in small independent research projects.

- Geologic History, Paleoenvironments: Studies are directed toward understanding the evolution of the ocean basins and the interaction of the geological systems with other environmental patterns. Continued support will be provided for study of past oceanic circulation patterns, paleoclimates, evolution of microfossil groups, and the interaction of land and oceanic geologic processes. Primary data sources are micropaleontologic and geochemical measurements from Deep Sea Drilling Project and conventional oceanic sediment cores coupled to chemical and biological models of the geologic and climatic history of the earth. The increase of $300,000 to the FY 1981 level of $1,550,000 will support new instrumentation for long coring capability to study paleoenvironments of the last 500,000 years and expanded studies of continuous core sequences from the Deep Sea Drilling Project.

Biological Oceanography

Research supported by this program subelement will be conducted in the following areas:

- Open Sea Populations and Processes: Research will be conducted on the distribution, abundance, physiology and life history of pelagic marine organisms, their interactions with the chemical and physical environment and their relationships with other organisms of the open sea. This research will include studies on phytoplankton productivity, structure and interrelations of pelagic food chains and roles and activities of microbial populations. It will emphasize identification of causal mechanisms regulating the distribution and abundance of pelagic organisms. The pelagic environment contains much of the ocean's biota and supports a number of important fisheries. An increase of $700,000 to an FY 1981 level of $3,300,000 will support increased research on the role of very small photosynthetic organisms in marine productivity and on the impact of predaceous zooplankton in structuring marine food chains.
- Shoreline Populations and Processes: Studies will be carried out on the distribution, abundance, physiology and life history of coastal marine organisms and their interactions with the physical and biological aspects of the benthic sea bottom environment. Emphasis will be placed on work on the structure of detritus-based food chains and on manipulative, experimental studies (mainly by SCUBA-equipped investigators) analyzing the factors which regulate the development of benthic communities. The near-shore zone is the ocean region most affected by human activities and most heavily exploited for fisheries and other purposes. An increase of $200,000 to an FY 1981 level of $2,300,000 will support additional manipulative field experiments on coral reefs and soft bottom communities.

- Ecology of the Deep Sea: Research will be supported on ecological investigations of the organisms, communities and biological processes of the floor of the deep sea. Work will emphasize interactions of biological processes of the sea floor with the overall ocean ecosystem and biological specializations of the organisms of this environment. *In situ* studies employing the deep submersible, ALVIN, may provide insight into the limitations in adaptability of organisms and may permit prediction of environmental effects of proposed activities such as deep sea dumping and mining. The amount requested for FY 1981 is $1,200,000, an increase of $450,000 over FY 1980. This increase will support an expansion of research effort on the ecology of deep sea hot springs, brine pools, rocky substrates and other deep sea environments different from the soft sediment areas which have received major study in the past.
- Ecology of the Great Lakes: Research will involve ecological investigations of organisms and communities of the Great Lakes with emphasis on factors regulating phytoplankton populations. Work in this area mainly parallels that conducted in Open Sea Populations and Processes but is directed specifically at the special problems of the Great Lakes. No increase over the FY 1980 level of $350,000 is requested.

QUANTITATIVE PROGRAM DATA
OCEANOGRAPHY PROJECT SUPPORT PROGRAM ELEMENT

Proposal and Award Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	746	800	900
Total Dollar Amount	$82,300,000	$90,800,000	$110,000,000
Awards:			
Number of Awards	362	375	400
Total Dollar Amount	$19,736,736	$21,350,000	$24,600,000
Average Dollar Per Award	54,521	56,933	61,500
Average Award Duration[1] (Months)	14	14.5	15

Percentage Distribution of Funds by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	99.4	99.4	99.0
Industry	—0—	0.3	0.8
Federal Laboratories	0.3	—0—	—0—
Other	0.3	0.2	0.2

Manpower and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of scientist man years supported	140	145	150
Costs of scientists supported	$3,396,000	$3,700,000	$4,000,000
Number of graduate students supported	230	235	245
Cost of graduate students supported	$1,591,000	$1,700,000	$2,000,000
Other manpower costs	3,102,000	3,400,000	4,000,000
Investment Costs:			
Construction	—0—		
Nonexpendable Equipment	1,732,000	1,900,000	2,300,000
Other Costs[2]	5,937,736	6,350,000	7,800,000
Indirect Costs	3,978,000	4,300,000	4,500,000
Total	$19,736,736	$21,350,000	$24,600,000

[1] Continuing grants involving multi-year commitments are included here as 12-month awards.
[2] Fringe Benefits, expendable equipment, travel, publication costs, computer costs, other direct costs.

Coordinated Ocean Research and Exploration Program Element $23,600,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Ocean Dynamics (Environmental Forecasting)	$6,778,307	$7,200,000	$9,500,000	$10,500,000	$1,000,000
Ocean Chemical Processes (Environmental Quality)	5,151,569	6,250,000	4,650,000	6,100,000	1,450,000
Seafloor Processes (Seabed Assessment)	4,891,823	5,050,000	4,400,000	5,400,000	1,000,000
Living Resources	2,548,600	2,300,000	1,600,000	1,000,000	-600,000
General Support	286,318	600,000	600,000	600,000	—0—
Total	[1]$19,456,617	[1]$21,400,000	[1]$20,750,000	$23,600,000	$2,850,000

[1] Numbers through FY 1980 are for the International Decade of Ocean Exploration, which ended in that year and is succeeded by this program element.

Objectives and Description

Coordinated Ocean Research and Exploration supports the complex, multi-institutional projects of the type that produced major advances in our understanding of the ocean in the 1970's.

In FY 1980 the International Decade of Ocean Exploration program element was restructured as the Coordinated Ocean Research and Exploration Section (CORES) to provide continuing support for the larger ocean science projects. Its close coordination with other NSF ocean sciences support ensures that the best projects continue to receive appropriate support, regardless of size or complexity.

Within CORES, three programs were reorganized to provide more flexibility in responding to the proposals of the ocean science research community during the 1980's. The Environmental Forecasting Program was redesignated the Ocean Dynamics Program, Environmental Quality is now termed the Ocean Chemical Processes Program, and the Seabed Assessment Program is now the Seafloor Processes Program. The Living Resources and General Support Subelements retain their original titles.

The Ocean Dynamics (Environmental Forecasting) Program supports major studies of ocean circulation, air-sea interactions, and the ocean's role in climate changes. Projects supported under this program subelement seek to expand our understanding of the ocean's influence on the atmosphere and climate and the role played by ocean currents in shaping weather and climate. The Ocean Chemical Processes (Environmental Quality) Program supports major studies of chemical transport into and within the ocean and the roles of marine organisms in these processes. Extensive use is made of pollutants such as those remaining from atmospheric testing of nuclear weapons, carbon dioxide from burning of fossil fuels, and pollutants released in coastal waters and estuaries to study chemical processes that might otherwise be impossible to detect. Seafloor Processes (Seabed Assessment) Program supports integrated large

scale projects that study processes controlling the formation and distribution of sediments and other deposits in the ocean, the formation and alteration of the oceanic crust and the structure and history of the ocean basins.

Living Resources projects provide basic knowledge about ocean processes that affect the development and abundance of marine organisms. These include studies of seagrasses, and of upwelled, nutrient-rich subsurface waters in coastal areas of high fish productivity.

General Support activities include management of scientific data, technique and instrument development, cooperative planning for the overall CORES program, and studies of the social, economics, and political implications of ocean science research.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Ocean Dynamics (Environmental Forecasting) Program

Research projects include the following:

The North Pacific Experiment a study of large-scale, long-period ocean-atmosphere coupling in the North Pacific Ocean, is scheduled to be completed in FY 1982 ($1,400,000). In this project, unusual sea-surface temperature conditions in the mid-latitudes of the Pacific Ocean have been related to abnormal winter weather over North America. To understand these phenomena and to permit improved seasonal forecasts, research has proceeded in five areas: (1) statistical studies of historical data on ocean conditions; (2) monitoring of ocean and atmosphere conditions using moored buoys; island stations and ships of opportunity; (3) investigations of air-sea interactions in the Central North Pacific Ocean; (4) theoretical studies of mixed layer formation and modeling of ocean processes on a regional scale, and (5) complementary efforts to develop satellite techniques and a comprehensive ocean model for use in global climate modeling.

International Southern Ocean Studies focus on the Antarctic Circumpolar Current that controls most of the water exchange among the South Atlantic, South Pacific, and Indian Oceans. This current system influences deep waters throughout the ocean. Understanding their characteristics and circulation patterns is fundamental to identifying the role played by the Southern Oceans in global weather and climate ($1,200,000).

Joint U.S./U.S.S.R. Central North Atlantic Dynamics Experiment a sequel to MODE-1, is studying interactions between the medium-scale eddy field and the average, large-scale ocean circulation. These experiments will improve our understanding of oceanic eddies which correspond to storms in the atmosphere. Data reduction will be completed in FY 1982. ($1,500,000)

The Pacific Equatorial Oceanic Dynamics project invoives experimental work (FY 1980-1985) focused on the equatorial ocean south and east of Hawaii. The work concentrates on vertical and horizontal waves trapped at the equator and the relationship of these waves to the large-scale currents and winds. Understanding these equatorial waves is vital to understanding the year-to-year variability of the tropical Pacific

Ocean which is responsible for El Nino off Peru-Chile and climate changes over much larger areas. ($2,500,000)

The Coastal Ocean Dynamics Experiment studies the response of shelf waters to changing winds and river discharge (FY 1980-1984) ($2,700,000). The experimental area is the continental shelf between Bodega Head and Pt. Arenas, California, a region where few modern data have been gathered. Results of the experiment should be correct, simplified models of water circulation that can be used for pollution, biological, transportation, and search and rescue applications.

A new three-year research project, scheduled to start in FY 1981, is the Ocean Acoustic Tomography project ($1,200,000). This project will develop remote-sensing techniques to monitor and study internal ocean weather. The technique has two steps: first, measuring fluctuations in acoustic travel time between each of a number of moored acoustic sources and receivers separated by 100 km, and second, computing the size, location and nature of the feature causing the disturbances. The project will use four acoustic transmitters and six receivers moored on opposite sides of a 300 km by 300 km area southwest of Bermuda.

The Ocean Dynamics program will increase by $1,000,000 to $10,500,000 in FY 1981. This increase will allow the initiation of the tomography project.

Ocean Chemical Processes (Environmental Quality) Program

Research projects now in various stages of completion include:

Pollutant Responses in Marine Animals is developing and evaluating physiological, biochemical, and morphological criteria that can be used to assess the health of marine animals subjected to pollutants. Effects of selected pollutants on specific marine organisms at the tissue, cellular and subcellular level are being assessed by project investigators. The project is scheduled for completion in FY 1983. ($700,000)

Sea-Air Exchange Project is investigating fluxes of organic and inorganic pollutants from the atmosphere to the ocean. Simultaneously different compounds in the air, rain, and dryfall are being measured in remote island locations to estimate global pollutant transfer rates. Completion of the project is scheduled for FY 1984. ($1,400,000)

Vertical Transport and Exchange of Materials in the Upper Waters of the Ocean will characterize particulate matter in the ocean and its role in scavenging chemicals (FY 1980-1983). The fate of pollutants in the oceans must be known to determine their partitioning between sediment and our food supply. ($750,000)

Transient Tracers in the Oceans will measure selected radiochemicals along with other parameters in sections of the North Atlantic Ocean to assess mixing processes and the exchange of carbon dioxide across the sea surface (FY 1980-1984). Physical measurements will be combined with these results to estimate ocean circulation and predict effects of fossil fuel burning. ($1,350,000)

The Warm Core Rings Project will determine the impact of western boundary ring currents on the transport of energy and organisms to the continental shelf. The relatively warm core waters in such rings carry organisms quite different from those in shelf waters with which they mix. ($1,200,000)

The Ocean Chemical Processes Program will increase by $1,450,000 to $6,100,000 in FY 1981. This increase will augment meteorological support for the Sea-Air Exchange project ($200,000), expand the study of the effect of western boundary current eddies on the continental shelf ($550,000) and initiate new projects on the impact of rivers on the ocean ($700,000).

Seafloor Processes (Seabed Assessment) Program

Research projects now underway include:

Manganese Nodule Project is investigating processes that control distributions and composition of deep-sea ferromanganese nodules. Studies of five sites are underway to relate nodule composition to the flux of metals into the seawater-sediment interface where the nodules form. The studies will be completed in FY 1985. ($1,500,000)

Cenozoic Paleoceanography Project is a coordinated study of changes in currents and sedimentation processes during the last 25 million years of ocean history. The project uses cores from the Deep Sea Drilling Project to study changes recorded in deep-sea sediments, and is scheduled to terminate in FY 1983. ($800,000)

South East Asia Tectonics and Resources project is completing studies of geological and geophysical processes along the active plate margins in East Asia. Emphasis is placed on processes that form metal deposits and hydrocarbon accumulations. Data was collected during the final year by ships, ocean and land based seismometers and by geologic and chemical mapping of islands. Final stages of data reduction will be underway in FY 1981. ($700,000)

Shelf Sediment Dynamics Project will assess processes responsible for sediment distribution and transport on continental shelves (FY 1980-1986). The project will concentrate its research on the benthic (near-bottom) boundary layer to develop predictive models relating sediment flux to wave and current conditions. ($1,200,000)

Large Aperture Seismic Experiment is a coordinated study of the deep structure of continental margins (FY 1980-1983). The project will use three ships equipped with multichannel profiling systems to provide resolution of sediment layers at greater depth than is possible using standard techniques. ($200,000)

The Seafloor Processes Program will increase by $1,000,000 to $5,400,000 in FY 1981. New areas of emphasis ($1,000,000) will include studies of the hydrothermal circulation of seawater through the oceanic crust and its effect on crustal chemistry, seafloor sediments and the chemistry of seawater.

Living Resources Program

Research projects now in their final stages include:

The Seagrass Ecosystems Study is studying benthic marine plant systems, particularly the processes that control the global distribution and species composition of seagrass ecosystems and their beneficial contributions to the marine environment. Such ecosystems have been shown to be stable and are perhaps the most productive regions in shallow coastal ocean areas around the world. The study will complete the synthesis of its 1978-79 field cruise data and publish the interdisciplinary results of its 5 year findings. ($300,000)

The Living Resources Program will decrease by $600,000 to $1,000,000 in FY 1981 as the Seagrass Ecosystems and Coastal Upwelling Ecosystems Analysis projects complete their syntheses and analysis phases. New areas of research emphasis ($700,000) include a study of ecosystem production and control mechanisms. One such ecosystem study will focus on the commercially and biologically important oceanic areas in the Northeastern and equatorial Pacific Oceans.

General Support

General Support activities ($600,000) seek to support general requirements of ocean science research activities, such as technique and instrument development, data storage, retrieval and dissemination, and studies of social, economic and political implications of ocean science research projects.

QUANTITATIVE PROGRAM DATA
COORDINATED OCEAN RESEARCH AND EXPLORATION SECTION

Proposal and Award Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of Proposals Received	300	340	380
Number of Awards	240	250	265
Dollars Proposed (Total)	$40,000,000	$45,000,000	$55,000,000
Dollars Proposed (Annual Rate)	85,000	68,000	9
Dollars Awarded (Total)	19,456,617	20,750,000	23,600,000
Dollars Awarded (Annual Rate)	60,000	62,000	67,000
Average Dollar Per Award	81,069	83,000	89,000
Average Award Duration (Months)	16	16	16

Percentage Distribution of Funds by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	92	92	93
Industry	1	1	1
Federal Agencies	4	4	3
Other	3	3	3

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Senior Scientists Faculty			
Number Work Years Supported	122	124	124
Amount of Faculty Support	$2,680,000	$3,250,000	$3,650,000
Post Doctoral Associates			
Number Work Years Supported	28	30	30
Amount Post Doctoral Support	400,000	450,000	480,000
Graduate Students			
Number Supported Per Award	0.6	0.6	0.6
Amount Grad Student Support	$785,000	$840,000	$900,000
Other Personnel Costs	3,390,000	3,630,000	4,100,000
Land, Bldgs and Fixed Equipment	—0—	—0—	—0—
Major Equipment	—0—	—0—	—0—
Equipment and Instruments	$2,350,000	$2,750,000	$3,050,000
Research Resources	600,000	650,000	750,000
Other Costs	5,331,617	4,980,000	6,220,000
Indirect Costs	3,920,000	4,200,000	4,450,000
Total	$19,456,617	$20,750,000	$23,600,000

Oceanographic Facilities and Support Program Element $27,800,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Operations	$18,905,909	$20,250,000	$19,719,000	$22,200,000	$2,481,000
Ship Construction & Conversion	3,109,626	3,100,000	3,100,000	3,600,000	500,000
Shipboard Equipment & Other Shared Facilities	1,184,837	1,850,000	1,700,000	2,000,000	300,000
Total	$23,200,372	$25,200,000	$24,519,000	$27,800,000	$3,281,000

Objectives and Decription

The Oceanographic Facilities and Support (OFS) program provides a major share of the support for 27 research ships and a number of specialized facilities operated by 16 academic oceanographic laboratories. The continuing objectives of this program are to (1) maintain and improve a cooperation system of oceanographic facilities and operational capabilities at key locations in the academic community, (2) promote shared use of facilities through the academic community organization entitled University-National Oceanographic Laboratory System (UNOLS), and (3) promote effective management of oceanographic facilities. Through these objectives, the program helps sustain a viable oceanographic research effort at the Nation's universities.

Oceanography is rapidly evolving from an exploratory descriptive science into a more highly analytic science requiring increasingly sophisticated tools and techniques for measuring complex processes. It remains, however, a predominantly field-oriented activity. Specialized facilities such as submersibles, towed devices, and aircraft are increasingly important tools for data collection; and remote sensing from unmanned platforms such as satellites, buoys, and moored equipment arrays is a rapidly developing field. But surface ships continue to constitute the major and indispensable facilities—meeting new demands for the deployment and monitoring of remote sensors as well as carrying scientific parties into the field.

Oceanographic ships and facilities not only serve the basic oceanographic programs of the Foundation but a considerable range of other sciences which also must derive some of their data and research materials from the ocean environment. Notable examples are biomedical research in metabolic processes, neurobiology, physiology, and pharmacology; atmospheric research, particularly in climate dynamics and long-range environmental forecasting; and geological and geophysical investigations by terrestrial rather than submarine specialists. These research activities have continued to use as much as 15 percent of OFS funded ship time.

The Operations program subelement provides support for the operation and maintenance of research ships, submersibles, and other platforms, for the salaries and expenses of marine technicians who maintain and operate shipboard scientific

systems; and for UNOLS and other community coordinating activities. The objectives of this subelement are to support and maintain the operational capability of a proper set of facilities needed for academic oceanographic facilities, and to promote liaison with the academic community and coordination of support activities among Federal agencies.

Support of the surface ships composing the academic fleet continues to be the largest component of the Operations subelement. In FY 1980, OFS will provide about 72 percent of the funds required to support fully 24 of the 27 ships currently constituting the fleet. Approximately the same level of support is projected for FY 1981. The remaining 28 percent of support derives from other Federal agencies—Office of Naval Research (ONR), Bureau of Land Management (BLM), DOE, USGS, NOAA and EPA—and from State and private sources. Layups of two or three major ships during part or all of the year will occur in 1980 and 1981 owing to an excess of available ship time over use requirements for funded research projects. Rapidly escalating price increases for fuel also contribute to the shortfall in fleet funding, exaggerating the impact of declining support from non-NSF sources. Adjustments in fleet composition, both in number and size distribution, have somewhat alleviated the support problem but further adjustments appear to be necessary to offset the persistent decline in ONR support for large open ocean ships and overall changes in utilization patterns. NSF utilization of the fleet is distributed over the entire range of ship sizes—extending from 64 ft. to 245 ft. in overall length—and accounts for over 80 percent of use on the under-150 ft. ships. This reflects a strong research commitment to the coastal and continental shelf regions as well as to open ocean studies.

Another significant component of the Operations subelement is support for the deep submersible (DSRV) *Alvin*, operated by the Woods Hole Oceanographic Institution as a UNOLS National Oceanographic Facility. An interagency agreement initiated in 1975 among NSF, the Navy, and the National Oceanic and Atmospheric Administration and extended through FY 1980 will be renegotiated with the intent of assuring continued multi-agency support of this valuable facility. In addition, a UNOLS sponsored study undertaken in late 1979 to assess current and projected requirements for submersible science facilities will provide alternatives and recommendations for planning possible new directions in the decade of the 1980's. In FY 1981 NSF will support approximately 100 use days on the existing submersible system at a cost of about $1,200,000.

Under the Ship Construction/Conversion subelement, funds may be provided for the design, construction, or conversion of ships and other platforms. FY 1980 marked the second consecutive year in which a major initiative in the Ocean Sciences budget was the inclusion of funds for ship construction—$3.0 million in FY 1979 and $3.1 million in FY 1980. The FY 1979 initiative resulted in the issuance of a solicitation for proposals to build and operate a 130-140 ft. coastal ship in accordance with one of two Foundation owned designs, and in the award of a contract with University of Miami for construction of the FY 1979 ship. The FY 1980 award will be based on the same competitive review and may result in a two-ship purchase under a single contract. A new solicitation will be issued for an additional coastal ship in FY 1981 expected to

cost $3,600,000. The review and assignment for the FY 1981 ship, like those funded in FY 1979 and FY 1980, has as its first consideration the achievement of the best possible improvement in the overall academic fleet inventory and a concomitant savings in annual operating costs.

The Shipboard Equipment and Other Shared Facilities subelement provides funds for acquiring, rehabilitating, and upgrading ships and major items of equipment and machinery. The specific objectives of the program are to achieve fleetwide comparability within classes of ships of basic equipment and outfitting. Specifically, efforts entail upgrading presently held ships and equipment; supporting the acquisition of new machinery and equipment for shared multi-project utilization; and, when funds permit, supporting the construction of shore facilities required for staging cruise operations.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

- Operations budget provides support for ship operations ($19,300,000), shipboard technicians ($1,500,000), specialized facilities such as submersibles and aircraft ($1,200,000), and UNOLS and other coordinating bodies ($200,000).
- Ship operations support increases $1,930,000 over FY 1980 and specialized facilities support (DSRV *Alvin*) increases $300,000 to match projected research requirements.
- Technician support increases $200,000 in response to assessment of a continuing need to improve substantially the calibration, maintenance and shipboard deployment of costly shared-use gear, cable, and equipment.
- Support for UNOLS and other coordinating bodies increases $51,000 to achieve improvements in community-wide scheduling and reporting of cruises in distant waters.
- Ship construction/conversion budget provides $3,600,000, an increase of $500,000 (16.1 percent) over FY 1980 to continue upgrading the inventory of academic fleet ships under 140-ft. in length for short-range intensive seasonal and synoptic studies of coastal and estuarine processes. Coastal ships in the 130-140 ft. size range are currently poorly represented in the academic fleet and are urgently needed to complement larger fleet ships whose operations are increasingly costly owing to rising fuel prices. These stable, seaworthy coastal ships are needed to mount new and expanded studies of nearshore processes such as movement and mixing of water masses, dynamics of continental shelf organisms, and the role of suspended particles in seaward transport of chemicals. These and other related areas of increased research emphasis are vital to understanding our economically important coastal waters.
- Shipboard equipment and other shared facilities budget provides an increase of $300,000 to a level of $2,000,000 in FY 1981 to continue a major thrust aimed at significant improvements in fleetwide standards for performance charac-

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teristics of deck machinery; wire and conducting cable; navigation, communication, data logging and processing equipment; contribution to acquisition of special one-of-a-kind systems such as swath-mapping sonar; and for for mid-life upgrading of one or several ships.

QUANTITATIVE PROGRAM DATA
OCEANOGRAPHIC FACILITIES AND SUPPORT PROGRAM ELENT

Proposal and Award Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	[1]80	94	100
Total Dollar Amount	$56,161,800	$30,220,000	$40,000,000
Awards:			
Number of Awards	60	80	80
Total Dollar Amounts	$23,200,372	$24,519,000	$27,800,000
Average Dollar Per Award	386,673	306,488	347,500
Average Award Duration (Months)	12	12	12

Percentage Distribution of Funds by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	100	100	100
Industry	—0—	—0—	—0—
Federal Laboratories	—0—	—0—	—0—
Other	—0—	—0—	—0—

Manpower and Other Factor

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of scientist man years supported	N/A	N/A	N/A
Costs of scientists supported	N/A	N/A	N/A
Number of graduate students supported	N/A	N/A	N/A
Cost of graduate students supported	N/A	N/A	N/A
Other manpower costs[2]	$8,500,057	$8,824,000	$10,036,520
Investment Costs:			
Construction	3,109,626	3,100,000	3,600,000
Nonexpendable Equipment	1,184,837	1,700,000	2,000,000
Other Costs[3]	8,754,214	9,185,000	10,210,000
Indirect Costs	1,651,638	1,710,000	1,953,480
Total	$23,200,372	$24,519,000	$27,800,000

[1] Three ship construction proposals totaling approximately $10,000,000 carried forward for funding consideration in FY 1980.
[2] Crew salaries, marine technician salaries, sea pay, and related fringe benefits.
[3] Fuel, food, insurance, maintenance, equipment and supplies.

ARCTIC RESEARCH PROGRAM SUBACTIVITY $6,100,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Atmospheric Sciences	$626,161	$600,000	$600,000	$600,000	—0—
Biological Sciences	1,630,760	1,700,000	1,700,000	1,800,000	100,000
Earth Sciences	906,841	900,000	900,000	900,000	—0—
Glaciology	1,783,690	1,700,000	1,600,000	1,600,000	—0—
Oceanography	897,131	900,000	900,000	1,000,000	100,000
Information & Advisory Services	129,417	200,000	132,000	200,000	68,000
Total	$5,974,000	$6,000,000	$5,832,000	$6,100,000	$268,000

Objectives and Description

The major objectives of the Arctic Research Program are to gain new knowledge on mechanisms of energy transfer between the magnetosphere, the ionosphere and the neutral atmosphere; the role of the Arctic Basin in influencing climate; the interactions of arctic and subarctic seas with the global ocean system; sea ice occurrence and behavior in coastal waters; the history of climatic changes as revealed in the study of ice cores obtained at depth in the Greenland ice sheet; permafrost properties and characteristics required to enable informed resource and land use developments and environmental management in the Far North; and the structure, function and regulation of arctic terrestrial and marine ecosystems.

The objectives of the program are pursued in several scientific disciplines:

- In atmospheric sciences the emphasis is on the collection and analysis of data on the ionosphere and magnetosphere received and recorded at Roberval, Canada, the geomagnetic counterpart of Siple Station, Antarctica. These data are used to investigate the effects on the ionosphere and magnetosphere of ultra low frequency and very low frequency radio waves transmitted from Siple Station, Antarctica.
- In biology the emphasis is on the development of an understanding of the processes that lead to the production of the unusually large numbers of animals on the continental shelf of the southeastern Bering Sea. The program focuses on the production of the Alaska pollock as a biological tracer of the highly efficient transfer of matter and energy from primary producers to and among higher-level marine life.
- In earth sciences emphasis is on permafrost research to learn more about the age, development, and stability of frozen soils. Field studies include drilling and geophysical probing in offshore areas, and laboratory research involves studies on physical processes and characteristics of permafrost. This knowledge is

essential to the wise use of arctic lands and the recovery of mineral resources in permafrost areas.

- In glaciology the emphasis is on the recovery and analysis of deep ice cores from Greenland for reconstruction of past climates, for developing an understanding of present world climate and for predicting future climatic trends.
- In oceanography the emphasis is on research to improve understanding of ocean and ice dynamics in polar regions, and the effect of the polar oceanic energy budget on global weather and climate.
- The Information and Advisory Services program element will continue to support centers for sorting and disseminating natural history specimens and ice cores from the polar regions and will provide funds for procurement of scientific advice from such groups as the National Research Council.

Major Research Questions

- How do summer stratus clouds and arctic haze influence the arctic energy balance and thus contribute to global climate?
- What is the precise role of the newly discovered system of oceanic fronts and interfront zones of the SE Bering Sea in the production of the enormous numbers of higher animals present there?
- In what ways can knowledge of the biological significance of oceanic fronts and interfront zones in the Bering Sea contribute to our knowledge of the role of fronts in the functioning of marine ecosystems on other continental shelves?
- When did the arctic continental shelves develop, and how old are the earliest unaltered sediments of the shelves?
- What is the geologic and tectonic relationship of Spitsbergen, Greenland, the arctic islands, to the rest of North America?
- What are the geochemical anomalies in the Greenland ice sheet that can be used to distinguish the annual accumulation layers?
- What causes the apparent stratification and structure in the Greenland ice sheet that is indicated by radio-echo signals that penetrate the ice?
- What caused the build up and subsequent disintegration of the major northern ice sheets of the last million years?
- How do the variations in heat and mass transport by ocean currents affect the stability of the sea ice cover?
- What are the significant time scales on which the polar heat sink operates?

Significant Recent Achievements

- Three years of research from oceanographic vessels operating in the Bering Sea have revealed a complex system of oceanic fronts and interfront zones that are the primary oceanographic features of the southeastern Bering Sea, and that are directly related to the transfer of energy and materials from the primary level of producers to the higher forms of marine life in that remarkably productive area.
- Investigations in the Isua region, Greenland, have discovered the earliest organic molecules and the earliest traces of meteorites, both approximately 3,800 million years old, known on earth.
- A new deep drill was developed, in cooperation with Denmark, and tested on the Greenland ice sheet in 1979. Larger versions of this battery powered electromechanical drill show promise of being capable of drilling through and recovering core from the thick central portion of the ice sheet where bottom ice may be as much as 100,000 years old.
- An array of twenty data buoys deployed over the Arctic Ocean has produced meteorological data for the Global Weather Experiment, and information on the synoptic-scale deformation of the sea ice cover.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan is $168,000 below the FY 1980 Budget Request, requiring minor adjustments to the Glaciology and Information and Advisory Services program elements.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $268,000 for FY 1981, an increase of less than five percent, is less than the current rate of inflation, and, therefore, represents no growth in total program activity. The 1981 Budget highlights are:

- Analysis of data on the ionosphere and magnetosphere collected at Roberval, Canada.
- Support of the fifth year of the biological study of the Processes and Resources of the Bering Sea Shelf.
- Field research will continue in Alaska, Greenland, and Svalbard, where geological and geophysical investigations are developing knowledge on tectonics, paleoclimate, and permafrost.
- The investigation of glacier dynamics and the paleoclimate of the Northern Hemisphere will continue with emphasis on drilling through the Greenland ice sheet and interpreting the glacial geology of the arctic regions.

- Biological productivity studies and marine ecosystem research will be extended to other arctic areas.

Coordination and Relationship to Other Efforts

Twelve Federal agencies are involved significantly with arctic research. Representatives of these agencies meet periodically at the NSF to discuss research priorities, plans for new arctic research programs, and the results of ongoing arctic research programs. Other Federal agencies often cooperate with NSF in funding arctic research.

QUANTITATIVE PROGRAM DATA
ARCTIC RESEARCH PROGRAM SUBACTIVITY

Proposal and Award Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	78	90	90
Total Dollar Amount	$11,932,000	$12,000,000	$12,000,000
Number of Awards	[1]87	76	79
Total Dollar Amount	$5,974,000	$5,832,000	$6,100,000
Average Dollar Per Award	68,700	76,700	77,200
Average Award Duration (Months)	12	12	12

Percentage Distribution of Funds by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	92.0	92.0	92.0
Industry	—0—	—0—	—0—
Federal Laboratories	4.0	5.0	5.0
Other	4.0	3.0	3.0

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of Scientist Years Supported[2]	36	40	41
Costs of Scientists Supported	$1,000,000	$1,205,000	$1,220,000
Number of Graduate Students Supported	67	70	71
Other Personnel Costs	913,500	664,000	672,000
Land, Buildings and Fixed Equipment	—0—	—0—	—0—
Major Equipment	—0—	—0—	—0—
Other Equipment	200,000	300,000	305,000
Other Costs[3]	2,900,500	2,863,000	2,785,000
Indirect Costs	960,000	1,000,000	1,118,000
Total	$5,974,000	$5,832,000	$6,100,000

[1] Includes split funded awards. Does not include purchase orders.
[2] Number of scientist years supported is low in comparison to number of grants because arctic research is a seasonal effort.
[3] Includes contract support, airlift, travel, expendable supplies and, equipment, computer costs, core storage expenses, and advisory services.

U.S. ANTARCTIC PROGRAM

PROGRAM ACTIVITY SUMMARY

FY 1981 PROGRAM TOTAL $63,400,000

Obligations by Subactivity

Page	Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
C-I	U.S. Antarctic Research Program	$ 7,281,809	$ 8,000,000	$ 8,000,000	[1]$ 9,300,000	$1,300,000
C-II	Operations Support Program	43,809,044	47,000,000	[3]47,840,000	[2]54,100,000	6,260,000
	Total	$51,090,853	$55,000,000	$55,840,000	$63,400,000	$7,560,000

[1]These funds will support scientific activities in Antarctica during the October 1981 to March 1982 austral summer field season.
[2]These funds will provide support for the research activities to be conducted in Antarctica during the October 1980 to March 1981 austral summer field season.
[3]Includes $840,000 supplemental appropriation request for FY 1980 costs of October 1, 1979, military pay increase.

Goals and Description

The U.S. Antarctic Program supports national goals to: maintain the Antarctic Treaty, insure that the continent will continue to be used for peaceful purposes only, foster cooperative research to contribute to the solution of regional and worldwide problems, protect the environment, and insure equitable and wise use of living and nonliving resources.

The U.S. scientific research program in Antarctica continues to be the principal expression of national interest and policy. The goal of the U.S. Antarctic Research Program is the scientific investigation of Antarctica and the surrounding oceans. Objectives are to develop an understanding of the role played by the antarctic ice sheets and the antarctic physical, biological, geological, meteorological, atmospheric, chemical and oceanographic processes.

The antarctic area is of further interest to the United States because it:

- Has a major influence on world weather and climate,
- Has the world's richest marine protein resource potential,
- Has other features of unique scientific and practical interest, and
- Provides an excellent environment for international cooperation.

The National Science Foundation has been assigned overall management responsibility for planning, funding, and implementing the national program in Antarctica.

The U.S. Antarctic Research Program subactivity supports a multidisciplinary research program on the Antarctic continent and in the adjacent oceans. The research is conducted at four antarctic stations, from remote temporary field sites, and aboard ships. Remote sensing techniques, using satellites, aircraft, rockets, balloons, and unmanned stations, are used in the conduct of the research. Cooperative research programs with scientists of other nations are commonplace.

The Operations Support Program subactivity provides for the direct support of science activities and the maintenance of an effective U.S. presence in Antarctica.

The National Science Foundation is designated as the single source of funding and management for the U.S. Antarctic Program. The Department of Defense and the Department of Transportation provide operational support as requested by NSF on a cost reimbursable basis. The Foundation also contracts for support services when it is cost effective.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan is $840,000 above the FY 1980 budget request. The increase of $840,000 is a FY 1980 supplemental appropriation request for FY 1980 costs of the October 1, 1979, military pay raise.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$51,090,853
FY 1980 Program	$55,840,000
FY 1981 Request	$63,400,000
Difference—FY 1981/FY 1980	$7,560,000

The $63,400,000 request for the U.S. Antarctic Program is $7,560,000 more than the FY 1980 program of $55,840,000.

The distribution of the FY 1981 budget amounts between the two budget subactivities and the percentage increases over FY 1980 are as follows:

U.S. Antarctic Research Program $9,300,000, up $1,300,000.
Operation Support Program $54,100,000, up $6,260,000.

The FY 1981 budget highlights are:

- Over one-half of the FY 1981 increase will be absorbed by inflation.
- Interdisciplinary research on the structure and function of the antarctic marine ecosystem will receive emphasis to provide information needed for the wise use and conservation of antarctic marine living resources.
- About forty percent of the operations support increase is for repairs to a crash-

damaged LC-130 aircraft and for modifications to extend the present service life of an older LC-130 aircraft.

- The McMurdo Station physical facilities rehabilitation program will be accelerated.

Coordination and Relationship to Other Federal Efforts

NSF coordinates all Federal activities in the Antarctic. NSF also funds individuals and groups of investigators from Federal agencies, educational institutions, and private companies submitting meritorious proposals for field research or analysis of data.

Policy guidance for U.S. activities is provided by the Antarctic Policy Group, chaired by the State Department.

The Arms Control and Disarmament Agency, under guidance of the Department of State, conducts periodic inspections provided for under Article VII of the Antarctic Treaty. NSF provides logistics support for the conduct of these inspections.

The Director, NSF, after consultation with the Secretary of State and other appropriate Federal officials, is responsible for implementation and administration of the Antarctic Conservation Act of 1978.

The General Accounting Office, in a study completed in 1978, concluded there should be no change in the basic roles of the various Federal agencies involved in the U.S. Antarctic Program. This study was undertaken at the request of the Senate Foreign Relations Committee.

During 1979 the Science, Research and Technology Subcommittee of the House Science and Technology Committee conducted oversight hearings of the program with particular reference to the role of DOD in support of the program. No changes in current arrangements were recommended as a result of the hearings.

Evaluation and Oversight

A major part of the staff effort in the NSF Division of Polar Programs (DPP) is devoted to the evaluation of the many, varied, and complex aspects of the program.

The dominant objective is the conduct of an effective multidisciplinary basic research program to take advantage of the unique research opportunities which exist on or near the Antarctic Continent. In the development of a science program for Antarctica the ever present severe environmental, logistic, and operational constraints are major factors. Intensive and continuous evaluation, planning and coordination takes place between DPP scientific and operations support staff, and among DOD, the NSF staff, and the supporting U.S. Navy and Coast Guard staffs and the civilian contractor.

An Advisory Committee for Polar Programs has been formed to evaluate the research program as well as the conduct of the Operations Support Program. The biology and glaciology sub-committees are organized and functioning. Special panels

of the Advisory Committee for Polar Programs will also conduct peer oversight reviews.

Both the science and support activities in Antarctica are monitored through periodic reports from all stations and major field activities. During the antarctic field season at least three DPP staff members are present to monitor or observe ongoing activities.

Joint NSF, Navy, and contractor evaluation and planning meetings are held several times each year. These meetings have proved to be an effective management tool.

The Navy's Facilities and Engineering Command provides, on a reimbursable basis, design reviews and oversight, as requested by NSF, of construction or facilities rehabilitation done in Antarctica under a civilian contract.

The Naval Audit Service conducts periodic audits of the supporting Navy organizations. DPP staff participate in developing the scope of the audits and receives copies of the audit reports.

U.S. ANTARCTIC RESEARCH PROGRAM SUBACTIVITY $9,300,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Atmospheric Sciences	$1,960,653	$2,000,000	$2,000,000	$2,300,000	$ 300,000
Biological Sciences	1,402,677	2,200,000	2,200,000	2,500,000	300,000
Earth Sciences	1,394,214	1,400,000	1,400,000	1,600,000	200,000
Glaciology	853,657	900,000	900,000	1,100,000	200,000
Oceanography	1,019,225	1,000,000	1,000,000	1,200,000	200,000
Information and Advisory Services	651,383	500,000	500,000	600,000	100,000
Total	$7,281,809	$8,000,000	$8,000,000	$9,300,000	$1,300,000

Objectives and Description

The major objectives of the program are to study the relationship of Antarctica to global weather and climate; to develop a better basic understanding of upper atmosphere physics, tectonics, terrestrial biology,and paleontology of Antarctica and their relationships to the rest of the world; to evaluate the renewable and nonrenewable resources, and to gain additional knowledge of the physical and biological characteristics of the continent and adjacent seas. An additional important objective is to foster cooperative international research contributing to these objectives and toward environmental protection and the equitable and wise use of living and nonliving natural resources.

The objectives of the program are pursued in several scientific disciplines—

- In the atmospheric sciences, upper atmospheric physics research is directed toward the development of more accurate knowledge of the earth's near-space environment. Unique studies of sun-earth relationships are possible because of Antarctica's physically stable location at high geomagnetic latitudes. Meteorological research is directed toward understanding the physical processes peculiar to the high latitudes and to determine the role that Antarctica has in affecting global weather and climate.
- In biology major attention is focused on studies concerning the structure and function of the vast marine ecosystem, stressing, in particular, the nature of the transfer of materials and energy through successive trophic levels from the primary producers, the phytoplankton, through the secondary consumers, the zooplankton, to the higher trophic levels including whales, seals, birds and fish. These studies are inter-disciplinary and includes ones of physical oceanography and nutrient distribution and regeneration, in an attempt to understand the remarkable productivity of the Southern Ocean.
- Earth sciences research in Antarctica is directed toward an improved under-

standing of the geology and geologic history of the region, to assess the mineral-resource potential of Antarctica, and to understand the role of Antarctica in the tectonics and geodynamic processes of the earth.

- Antarctic glaciology research is directed towards understanding the physical and chemical characteristics of the ice cover of the continent. This is being accomplished through integrated analysis of the ice sheet. Results include a historical record of climate over the last 100,000 years and are expected to yield a record of past solar activity and atmospheric chemistry. A major goal is to determine the stability and long-term variations in the ice sheets.
- The objective of oceanographic research is to increase our understanding of the dynamics of the ocean surrounding Antarctica with respect to currents, temperature structure, heat exchange, and sea ice formation, and water mass modification processes.

The Information and Advisory Services program element will continue support of curatorial centers for sorting and distributing natural history specimens and ice and ocean bottom cores. Publication of research plans and results of U.S. program activities will continue, and an antarctic bibliography will be maintained. Support will continue for U.S. participation in the Scientific Committee on Antarctic Research of the International Council of Scientific Unions.

Major Research Questions

- What role does Antarctica play in global weather and climate?
- What is the rate of increase in the levels of atmospheric pollutants, and how do these affect antarctic weather?
- What are the sun's effects on the earth's atmosphere, ionosphere and near space environment?
- What role does particle precipitation at sub-auroral latitudes play in maintaining the nightside ionosphere?
- What is the origin and generating mechanism for naturally occurring ultra-low-frequency waves?
- Do magnetospheric processes affect global weather?
- What are the propagation characteristics of very-low-frequency and ultra-low-frequency waves in space, and how do magnetosphere and ionospheric processes affect communications at these frequencies?
- What are the key relationships between the structure and dynamics of antarctic water masses and the biological processes leading to high productivity in secondary and tertiary trophic levels?

- What are the key biochemical, physiological, behavioral, and structural adaptations of the biota to existence in the polar environment?
- What features of the biology of Antarctic Krill are essential to understanding the population dynamics of this singularly important species?
- What was the tectonic relationship of West Antarctica to East Antarctica during geologic time?
- What are the origins, geology, and structure of the large, structural, ice-filled basins of West Antarctica?
- What is the composition and thickness of the unexposed base of the Dufek Intrusion?
- Why is Antarctica the only continent essentially free of earthquakes?
- What is the mineral-resource potential of Antarctica, including the continental shelf?
- What was the past climate, atmospheric chemistry and atmospheric particulate content, based on data from the ice sheets?
- Is the West Antarctic ice sheet collapsing or about to collapse?
- What is the age of the glacial ice at the base of the Earth Antarctic ice sheet?
- What are the dynamics of the large oceanic gyres along the antarctic coastal perimenter, and what are their effects on sea ice production, iceberg movement, and climate?
- What is the effect of high latitude air/sea exchange processes on the atmospheric budget of trace gases and carbon dioxide?
- What is the petrology and geochemistry of the major fracture zones in the Antarctic tectonic plate boundaries?

Significant Recent Achievements

- Investigators determined that high winds in the northwestern Weddell Sea exert a profound effect on the motion of sea ice, icebergs, and water masses in that region producing a strong effect on the climate of that region.
- Studies in the dry valleys near McMurdo Station have revealed a unique assemblage of microscopic plants living in rocks. This has led to speculation that similar life may exist in similar environments on other planetary bodies such as Mars and the ice moons of Jupiter.
- The results of work at the South Pole have indicated that some individuals living in a small isolated group, while showing no symptoms of illness, continue as carriers of some of the normally transient viruses causing colds, and they may do so over a period of several months. If this finding is verified, it will

change our understanding of the apparent rapid development of immunity to viruses causing respiratory infections usual in such situations, and thus our understanding of the reappearance of these infections while the groups remain isolated.

- Recent, intensive studies of important antarctic phytoplankton, the food base of the sea, have revealed that their metabolism appears to be different from that seen in other parts of the world's oceans. During photosynthesis, most of the carbon fixed by them is incorporated in fats. At 2°C, and in dim light, as much as 90% of the fixed carbon is in fats whereas in other parts of the oceans the amount is generally less than 10%. Why this occurs is still unknown, but this fact has great significance for some of the higher organisms feeding on the phytoplankton in that their diets include fats that have a much higher caloric value than proteins or carbohydrates.
- The known area of the Dufek Intrusion was substantially enlarged by results of airborne magnetic surveys in 1978. It is at least comparable in size to the Bushveld Intrusion in southern Africa. The Bushveld is the largest in the world. Such intrusions in other parts of the world are a source of many strategic minerals.
- For the third consecutive year large numbers of meteorites were found on the East Antarctic ice sheet. The 309 recovered in 1978/79 were 10 to 20 times the number of meteorites normally recovered annually in the rest of the world. The antarctic meteorites are proving to be extremely valuable in the study of extraterrestrial geology and organic chemistry.
- A correlation has been discovered between the amount of nitrate in South Pole snow and solar activity over the last 1,000 years. If this relationship proves to be correct, then an ice core through the antarctic ice sheet could contain a record of solar activity back 400,000 years.
- The planned field program of the Ross Ice Shelf Project was completed in 1978-79. Two access holes were bored through the shelf using a hot-water drill. An ice core through the entire ice shelf was also obtained. These studies aid in the explanation of the historical development and physical characteristics of this floating ice mass that is as big as Texas.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 current plan for research is the same as the budget request. However the FY 1980 Operations Support Program, which supports the research program funded with FY 1979 funds, has been impacted by inflationary cost increases. The military pay increase, effective October 1, 1979, was seven percent. Funds for it are included in the FY 1980 supplemental request. In addition, fuel price increases, also effective October 1, 1979, ranged from 26 to 36 percent, depending on the type of fuel (aviation fuel, heating fuel, etc.). If additional funding for operations support is not provided in FY

1980, or savings cannot be made in the current field operation, it may be necessary later in FY 1980 to reprogram some funds from the research program to the support program.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $1,300,000 to $9,300,000 for FY 1981 will be used to increase the level of research activity in all of the relevant scientific disciplines. The FY 1981 budget highlights (for field research to be conducted during FY 1982) are:

- Interdisciplinary research on the structure and function of the antarctic marine ecosystem will continue to provide information on the abundance, distribution, and ecology of antarctic krill. The work will be conducted in concert with that of other nations in an effort to obtain the information needed for the wise use and conservation of antarctic marine living resources.
- A major multi-discipline, multi-institutional, international project will be funded in FY 1981 for field activities in northern Victoria Land during FY 1982. Emphasis in the investigations of this complex area will be on geological structure, tectonics, paleontology, glacial geology, glaciology, mineral-resource potential, and geophysics. A temporary field camp in the central part of Northern Victoria Land will act as a logistics and support center. Transportation in the field area will be motor toboggans and helicopters.
- A expedition is planned to examine the oceanic and atmospheric processes which maintain the Weddell Polynya—an enormous ice-free area in the ice pack—through the austral winter.

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QUANTITATIVE PROGRAM DATA
U.S. ANTARCTIC RESEARCH PROGRAM

Proposals and Awards

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	188	200	200
Total Dollar Amount	$21,466,000	$22,000,000	$22,000,000
Number of Awards	[1]140	150	170
Total Dollar Amount	7,281,809	8,000,000	$9,300,000
Average Dollar Per Award	52,013	53,300	54,700
Average Award Duration	12 mos	12 mos	12 mos

[1]Includes split funded awards. Does not include purchase orders.

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	85.0	85.0	83.0
Industry	1.7	2.0	2.0
Federal Agencies	7.3	8.0	10.0
Other	6.0	5.0	5.0

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of Scientist Years Supported[1]	37	41	47
Cost of Scientists Supported	$1,043,000	$1,145,000	$1,331,000
Number of Graduate Students Supported	105	115	133
Cost of Graduate Students Supported	785,000	862,000	1,000,000
Other Personnel Costs	1,375,000	$1,510,000	$1,775,000
Land, Buildings and Fixed Equipment	—0—	—0—	—0—
Major Equipment	—0—	—0—	—0—
Other Equipment[2]	325,000	357,000	415,000
Other Costs[3]	2,003,809	2,204,000	2,479,000
Indirect Costs	$1,750,000	1,922,000	2,300,000
Total	$7,281,809	$8,000,000	$9,300,000

[1]Number of scientist years is low because antarctic research is a seasonal effort. Few researchers are supported year round.

[2]Equipment purchased by grantee institutions using grant funds. Most equipment in use in Antarctica is purchased by the Naval Support Force or the civilian contractor.

[3]Includes domestic travel, expendable supplies and computer services at the grantees' institutions; information, advisory and cartographic activities.

OPERATIONS SUPPORT PROGRAM SUBACTIVITY.....$54,100,000

Obligations by Program Element

Program Element	Estimate FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Direct Science Support	$ 7,573,545	$ 8,398,000	$ 8,398,000	$ 9,533,000	$1,135,000
Base Level Support	28,013,006	29,992,000	30,832,000	35,238,000	4,406,000
Major Construction & Procurement	8,222,493	8,610,000	8,610,000	9,329,000	719,000
Total	$43,809,044	$47,000,000	[1]$47,840,000	$54,100,000	$6,260,000

[1]Includes $840,000 supplemental appropriation request for FY 1980 costs of October 1, 1979, military pay raise.

The objectives of the subactivity are to provide the support facilities and services required for the conduct of antarctic research in the most cost effective means consistent with safety, reliability, and the maintenance of an effective U.S. presence in Antarctica.

It was determined, after a comprehensive interagency review, that efficient administration of the U.S. program in Antarctica requires a single source of funding and management. Since science serves as the primary expression of U.S. interest in Antarctica, the National Science Foundation was designated to manage this program.

The location, climate, and the absence of development in Antarctica require that all forms of support and services needed to conduct research must be imported. The provision of such support and services is grouped, for central management purposes, in the Operations Support Program subactivity. In the Arctic Research Program and most other Foundation programs, the full costs of the conduct of a research project, including all support and services, are included in the grants to academic institutions. This is not true in the Antarctic, where most support services and equipment are provided through operations support rather than as part of the research grant.

The major support services in this subactivity provide the antarctic program with the "Base Level Support" which makes the science program possible. These services are provided on a reimbursable basis by the Departments of Defense and Transportation and by civilian contractors.

The Naval Support Force, Antarctica (NSFA) provides the primary logistics support for the U.S. Antarctic Program. This includes the operation and maintenance of McMurdo Station, the main staging point for most U.S. activities on the continent. Also included is the year-round operation of Antarctic Development Squadron Six (VXE-6) which provides all air support in Antarctica with seven NSF owned ski-equipped C-130 aircraft and seven Navy UH-1N helicopters. Additionally the NSFA is responsible for surface and air transport of all cargo and personnel betweeen the west coast of the U.S. and New Zealand and Antarctica. This requires the charter of special mission C-141 and other aircraft from the Military Airlift Command. The primary

supply mode is through the use of two Military Sealift Command ships that deliver most of the cargo and all of the petroleum products used to support the U.S. program in Antarctica. Additionally, the NSFA is responsible for communications to and within Antarctica and maintains a communications and staging base detachment in Christchurch, New Zealand, on a year-round basis.

The civilian support contractor is responsible for much of the specialized support required for the U.S. Antarctic Program. This includes the operation and maintenance of all laboratory facilities as well as the operation and maintenance of a small research ship, the R/V *Hero*. The contractor also is responsible for the operation of three research stations: South Pole, Siple, and Palmer. As a result of a recent decision, the contractor is responsible for all major support program engineering design and construction in Antarctica.

The U.S. Antarctic Program depends upon the British Antarctic Survey ship *Bransfield* to provide sealift services in support of Palmer Station. The primary mission of this British ship is to support United Kingdom stations in the Antarctic Peninsula. Therefore, the additional service provided to NSF on a reimbursable basis is very cost effective.

The Department of Transportation, through the U.S. Coast Guard, provides icebreaker support to the U.S. Antarctic Program. Two icebreakers break a channel through the ice of McMurdo Sound and provide escort service for the Military Sealift Command ships during their transit through the ice pack and into McMurdo Station. Additionally, the icebreakers are utilized in direct support of marine research programs while they are deployed in Antarctica.

The program element "Direct Science Support" includes estimates of those costs which directly support science activity and would not be needed if the U.S. were to merely maintain the present stations as a "presence" in Antarctica. Within this element are such activities as operation of the ships for research, transportation of science personnel and equipment, and special support related to scientific work at the stations and in the field programs.

The program element "Major Construction and Procurement" includes estimates for the design, procurement, and construction of support facilities for base level and direct science support activity. Also, within the element is the procurement of vehicles, construction equipment, consumables and short life equipment needed to sustain the program.

Significant Recent Achievements

The Darwin Glacier Camp—From early November 1978 to mid-January 1979 a major field camp was established at the Darwin Glacier, a remote area of the Transantarctic Mountains, approximately 150 miles south of McMurdo Station. The field camp, consisting of several portable huts that were constructed on site, accommodated some 50 scientists and support personnel, including air crew for three helicopters that supported the scientists in their field work. All material for the field camp was air-

lifted to the site by C-130 aircraft operating from McMurdo Station. Nearly 700 helicopter hours were flown in support of the scientific research conducted from the camp.

Following the completion of the scientific research, the camp was completely dismantled and returned to McMurdo Station. In effect, the site was essentially left as clean as it was before the field project started.

Siple Station—Construction of the replacement Siple Station was completed in January of 1979 in time for its occupation by eight scientists and support staff during the 1979 winter. Siple Station is a small but extremely important part of the network of U.S. stations in Antarctica. The station is an upper atmosphere research facility ideally located for studies of very low frequency radio transmissions. It is unique in this regard because it is conjugate to a similar station in Roberval, Quebec, Canada in the northern hemisphere. The actual on-site construction of Siple Station started in 1978. All of the material was flown to the site by C-130 aircraft and the construction was carried out by a civilian support contractor. The station was officially dedicated on January 14, 1979 and has just completed its first successful winter.

McMurdo Station/Williams Field Construction—During the past year, two new 60 person dormitory buildings have been completed at McMurdo Station and the start of construction of three more is commencing during the 1979-80 field season. The addition of these new facilities will help relieve the serious berthing shortage that has been prevalent for the past several years.

The design and engineering for a new power plant at McMurdo Station has been underway and the construction of the facility will commence during the 1979-80 season.

At the Williams Field Air Operations Facility located on the Ross Ice Shelf near McMurdo Station, 54 modular buildings are being set up to replace an older outmoded facility. These buildings were occupied in December 1979. The building units are designed so that they can be moved as required to alleviate the serious snow drifting problems that occur on the Ross Ice Shelf. These buildings units were prefabricated in the United States and shipped to McMurdo Station by surface transport. The civilian contractor is responsible for establishing the facility on the Ross Ice Shelf.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The overall increase for the budget subactivity is about 14 percent and most of it is in the Base Level Support program element.

Direct Science Support

The program element Direct Science Support is increased by an amount of $1,135,000. The increase in Direct Science Support, combined with savings in other areas will allow for an increase in research ship charter time to compensate for the lay up of the research ship *Islas Orcadas* and a continuation of the upgrading of science laboratory equipment particularly at McMurdo and Palmer Stations.

The detail by cost element for all elements of Direct Science Support is shown in the following table.

Estimates of Direct Science Support

Cost Elements	FY 1979	FY 1980	FY 1981
Contractor Support Equipment & Operations	$3,667,606	$3,600,000	$4,455,000
Islas Orcadas (Research Ship)	100,000	—0—	—0—
Hero (Research Ship)	1,690,000	[1]2,106,000	1,743,000
Icebreaker Support (Research)	90,000	550,000	530,000
Ship Charter (Research)	270,939	392,000	1,000,000
Aircraft Operations	1,050,000	1,000,000	1,025,000
Transportation of Science Personnel	380,000	400,000	420,000
Transportation of Scientific Cargo	200,000	225,000	230,000
Subsistence Costs for Civilian Personnel	125,000	125,000	130,000
Total	$7,573,545	$8,398,000	$9,533,000

[1]Includes increase for overhaul in the U.S.

The contractor support equipment and operations element provides for the total cost of operating the South Pole, Siple, and Palmer Stations on a year-round basis and at least two seasonal field camps for support of science projects at remote locations during the austral summer. Additionally, this element includes the supply and operation of the Ecklund Biological Laboratory and the Berg Field Center at McMurdo Station. It is through these two major facilities that most of the scientific field activities are processed.

R/V *Hero* is a small wooden-hulled research ship which operates during the austral summer off the Antarctic Peninsula. It is particularly effective in the placement of small field parties in remote areas of the Antarctic Peninsula. It also transports scientists to and from Palmer Station and supports research in sub-antarctic waters and along the geologically related areas of southern South America.

The major portion of icebreaker support is to provide escort for the supply ships to McMurdo Station as well as to break a channel through the ice for cargo offloading directly at the station. Icebreakers are also used in the areas of heavy pack ice in connection with various scientific research programs. Icebreaker days involved in this work are charged to the direct science program element.

Aircraft operations included are the LC-130 and UH-1N flights which are conducted solely for science projects. The transportation of science personnel and cargo required by specific projects, as well as subsistence for scientists in Antarctica are also included in the above estimates. Not included are the flights made in support of the inland stations.

Base Level Support

For the program element base level support, the increase of $4,406,000 results mainly from increased maintenance repair and operating costs associated with LC-130

aircraft and helicopter operations and inflationary cost increases, mostly in military personnel costs.

Estimates of Base Level Support

Cost Elements	*FY 1979*	*FY 1980*	*FY 1981*
Personnel	$15,892,884	[1]$17,703,000	$18,643,000
Air Operations	7,125,380	7,229,000	9,675,000
Surface Transportation	1,558,000	2,050,000	2,350,000
Antarctic Continent Operations	2,450,600	2,700,000	3,200,000
U.S. and New Zealand Support Operations	986,142	1,150,000	1,370,000
Total	$28,013,006	$30,832,000	$35,238,000

[1]Includes $840,000 supplemental appropriation request for FY 1980 costs of October 1, 1979, military pay raise.

Personnel is the largest cost element in base level support and provides for the maintenance of the Naval Support Force, Antarctica on a year-round basis, including those military personnel stationed in Antarctica. It also covers personnel for the Antarctic Air Development Squadron Six (VXE-6) and the civilian support contracts. In addition to these major program elements there are certain units, such as the Navy cargo handling unit which are included in the personnel costs.

Air Operations includes not only the cost of the VXE-6 operations on the continent but the intercontinental airlift as well. The flight costs of VXE-6 include the standard maintenance of the aircraft and the cost of flight training as well as the actual flying on the continent. The maintenance costs are largely fixed depending on the number of aircraft, their age, and the hours of operation, however FY 1981 funds will support the post-recovery repair of the damaged LC-130 aircraft that will be recovered from East Antarctica in 1980-81. Additionally, funding of a Service Life Extension Program for the old LC-130 aircraft will commence in FY 1981.

Surface Transportation costs include the charter of one Military Sealift Command (MSC) cargo ship and one MSC tanker for the major resupply of McMurdo Station which, in turn, is the resupply base for operations in the interior of the continent. Also included are the icebreaker costs for the escort of the supply ships and the shipping costs for positioning cargo in New Zealand.

The Antarctic Continent operations costs are those associated with maintaining a major base at McMurdo, an air field adjacent to it, and the three other stations: South Pole, Siple, and Palmer.

The Naval Support Force maintains a home base at the U.S. Naval Station at Port Hueneme, California. The Antarctic Development Squadron Six has its home port at the Naval Air Station, Point Mugu, California. The required base support is furnished on a reimbursable basis. Additionally, there is an advance base in Christchurch, New Zealand and Navy communications function there.

Major Construction and Procurement

The increase of $719,000 in the program element major construction and procurement reflects about the same level of general procurement plus an increase of over $500,000 in the construction element.

Estimates of Major Construction and Procurement

Cost Elements	FY 1979	FY 1980	FY 1981
Construction	$2,534,628	$2,610,000	$3,154,000
Procurement			
Vehicular	1,440,300	1,500,000	1,475,000
General Purpose	4,247,567	4,500,000	4,700,000
Total	$8,222,493	$8,610,000	$9,329,000

The FY 1981 construction cost element reflects a continuing effort to upgrade facilities, particularly at McMurdo Station. Three more 50-bed dormitories will be constructed to replace the present 20-year old buildings without sanitary facilities. Construction of the new power plant will continue and construction of the salt water distillation plant will commence. Dormitory construction will continue and engineering and design of other replacement facilities will continue.

The general purpose procurement element will provide the consumables and short life equipment needed to support the program. Vehicle procurement will allow for the replacement of some outmoded equipment and allow for some limited procurement of new equipment.

QUANTITATIVE PROGRAM DATA
OPERATIONS SUPPORT PROGRAM ELEMENTS

	Actual FY 1979	*Estimate FY 198079*	*Estimate FY 1981*
Naval Support Force, Antarctica	$33,457,127	[1]$34,515,000	$38,925,000
Contract Support	9,048,385	10,842,000	11,825,000
Government of Argentina	[2]100,000	—0—	—0—
U.S. Coast Guard-Icebreakers	[3]686,700	1,533,000	1,800,000
Other Costs	109,349	300,000	240,000
British Government Agencies	136,544	258,000	310,000
Research Ship Charter	270,939	392,000	[4]1,000,000
Total	$43,809,044	$47,840,000	$54,100,000

[1]Includes $840,000 supplemental appropriation request for FY 1980 costs of October 1, 1979, military pay raise.
[2]Final costs for operation of *Islas Orcadas* (formerly *Eltanin*)
[3]Only one icebreaker available most of field season.
[4]Will provide for two extended cruises.

Cost Breakout, Naval Support Force

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Military Personnel	$12,510,191	[1]$13,808,000	$13,650,000
Aircraft Operations	8,476,387	8,129,000	[2]10,850,000
Intercontinental Airlift	2,763,781	2,377,000	2,700,000
Intercontinental Sealift	2,167,835	1,921,000	2,400,000
Ground Fuel and Power	1,268,376	1,926,000	2,800,000
Other Costs	6,270,557	6,354,000	6,525,000
Total	$33,457,127	$34,515,000	$38,925,000

[1]Includes $840,000 supplemental appropriation request for FY 1980 costs of October 1, 1979, military pay raise.
[2]Increase allows support of post-recovery repair in the U.S. of the LC-130 aircraft recovered in 1980/81 season and commence funding Service Life Extension Program (SLEP) of older model LC-130 aircraft.

OCEAN DRILLING PROGRAMS

PROGRAM ACTIVITY SUMMARY

FY 1981 PROGRAM TOTAL $27,300,000

Obligations by Subactivity

Page	Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
D-6	Deep Sea Drilling Project	$10,624,910	$15,400,000	$15,875,000	$17,300,000	$1,425,000
D-10	Ocean Margin Drilling Project:					
	Project Planning and Evaluation	1,000,000	2,100,000	3,600,000	—0—	-3,600,000
	Initial Implementation Phase	—0—	—0—	—0—	10,000,000	10,000,000
	Total	$11,624,910	$17,500,000	$19,475,000	$27,300,000	$7,825,000

Goals and Description

The Ocean Drilling Programs (ODP) are a unique worldwide effort to explore the earth's crust beneath the oceans. An interdisciplinary science program aided by deep-ocean drilling and coring of rocks and sediments is aimed at understanding the detailed composition and behavior of the submerged 75 percent of the earth's surface that is of ever increasing importance to people and countries. These programs are aimed at:

- substantiating and refining the plate tectonics hypothesis that portrays the earth as a dynamic planet on which the distribution of continents and oceans changes continuously over geologic time. This will aid in a better understanding of the cause of violent natural processes, especially the volcanic activity and earthquakes that occur at crustal plate boundaries;
- utilizing detailed sediment records that document the paleoenvironment over many millions of years, and provide opportunities to explain the impact of the changing surface features of our planet on oceanic circulation and corresponding climate changes; and
- establishing the geological framework and studying the specific processes which cause the formation of natural resources and guide their distribution. Resource exploration builds on this scientific base.

The Ocean Drilling Programs activity includes two subactivities, the Deep Sea Drilling Project (DSDP) and the Ocean Margin Drilling Project (OMDP). The National Science Foundation has overall management responsibility for these programs.

The Deep Sea Drilling Project has been supported by NSF since FY 1966 and has been operating since FY 1968. DSDP operations are managed for NSF by the University of California/Scripps Institution of Oceanography (SIO). Under subcontract to SIO

the drilling ship *Glomar Challenger* is operated by its owner Global Marine Inc. for DSDP. The scientific program for DSDP is guided by the Joint Oceanographic Institutions Inc. and their scientific advisory structure, the Joint Oceanographic Institutions for Deep Earth Sampling, which includes foreign members. The Deep Sea Drilling Project is now in the International Phase of Ocean Drilling to which five foreign countries, France, Germany, Japan, the U.K. and the U.S.S.R., each contribute $1,250,000 annually. DSDP/*Challenger* operations have been carried out in almost all of the world's oceans. Major contributions of DSDP are the first reconnaisance of the makeup of the earth's crust beneath the oceans and the most convincing research results to date in support of the plate tectonics hypothesis. Present NSF plans call for support of *Challenger* operations through FY 1981.

The Ocean Margin Drilling Project is a logical extension of DSDP. OMDP will attack the most important unresolved problems in the plate tectonics hypothesis as well as problems that have emerged from 11 years of Deep Sea Drilling Project efforts. The essential difference between OMDP and DSDP will be the transition from a general reconnaisance performed by DSDP to a problem-focused approach in OMDP. The major new initiative of OMDP will be an extensive investigation of the ocean margins. The passive margins with their thick sediment cover (e.g. the U.S. east coast) represent a major frontier for geologic exploration. Besides its great scientific importance, work on the deeply submerged ocean margins will constitute the first major effort to establish the geologic framework for determining the natural resource potential of these areas. The drilling system required for the ocean margin project greatly exceeds the capacity of the DSDP ship *Challenger*. The government-owned *Glomar Explorer* has been identified as an excellent candidate for the advanced drilling technology platform for OMDP.

In order to initiate the Ocean Margin Drilling Project a new approach has been taken. The U.S. petroleum industry has been invited to become a major partner and contributor in this project. Government/industry negotiations have proceeded to the point that a sufficient number of petroleum companies have indicated their willingness to participate and contribute during FY 1981. In that year engineering design and cost estimates for *Explorer* conversion, and the advanced deep-ocean drilling system as well as scientific program planning will proceed. Results of these efforts will provide the basis for a final go, no-go decision later in FY 1981 on the whole project as a joint venture.

Foreign participation in the Ocean Margin Drilling Program similar to the DSDP/International Phase of Ocean Drilling (IPOD) is a possibility. One country has already expressed interest in negotiating participation in OMDP. Other U.S. agencies, especially the U.S. Geological Survey and the Department of Energy may participate in OMDP according to their particular missions and interest.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan for DSDP/IPOD increases by $475,000 from $15,400,000 to $15,875,000. Foreign funds applied to the program in the Current Plan are reduced by $475,000 from $6,000,000 to $5,525,000 on the basis of a more up-to-date estimate of the timing of payments. The overall estimated program cost for DSDP/IPOD in FY 1980 remains the same at $21,400,000.

OMDP Planning and Evaluation: It is planned to increase OMDP funding in the FY 1980 Current Plan by $1,500,000 from $2,100,000 to $3,600,000. This increase is necessary for technical assessments, engineering studies, and scientific and environmental planning to develop the design for the advanced *Explorer* system, as well as to update cost estimates and to commence risk analysis. The aim is to provide the necessary scientific planning, engineering results and cost data to support OMDP implementation in FY 1981 and provide a further basis for funding by private industry.

The added scientific and engineering studies are: (1) riser design trade off studies—$500,000, (2) sea-floor equipment and well control evaluations and designs for the proposed *Explorer* drill sites—$250,000, (3) *Explorer* station keeping analysis including model tests to identify the need to upgrade thruster capacity to cope with severe weather conditions—$450,000, (4) technical planning and evaluation—$100,000, and (5) scientific and environmental planning—$200,000.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$11,624,910
FY 1980 Program	$19,475,000
FY 1981 Request	$27,300,000
Difference—FY 1981/FY 1980	$7,825,000

The $27,300,000 requested for the Ocean Drilling Programs is 40.2 percent more than the FY 1980 program of $19,475,000.

The distribution of the FY 1981 NSF funds budgeted between the two budget subactivities follows:

- Deep Sea Drilling Project/International Phase of Ocean Drilling is up $1,425,000 to $17,300,000.
- Ocean Margin Drilling Project is up $6,400,000 to $10,000,000.

The Deep Sea Drilling Project increase in NSF funding of $1,425,000 is necessary to cover increased costs for fuel, personnel and supplies and related expenses. The balance of the overall increase of $2,000,000 in DSDP is covered by increased foreign contributions.

The $6,400,000 increase in the Ocean Margin Drilling Project is needed to proceed from the OMDP planning and evaluation phase to project implementation. The $10,000,000 NSF budget for OMDP will be matched by industry contributions. This initial phase

of implementation will take the project up to the point of modifications to *Explorer*, drilling system procurement, and drilling site selection, and will provide a basis for the final go, no-go decision for the project as a joint venture.

Coordination and Relationship to Other Efforts

Within the National Science Foundation, support for research on DSDP cores and ship support for U.S./IPOD geophysical site surveys are coordinated with the Earth Sciences and Ocean Sciences subactivities and their advisory panels. Climate research on DSDP/IPOD materials is coordinated with the Atmospheric Sciences subactivity at NSF. Science guidance and coordination of DSDP/IPOD is provided by Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). Formal international coordination is achieved directly with the five foreign countries by NSF working through the Department of State. The scientific input from the foreign countries is through JOIDES.

The National Science Foundation coordinates support of the Ocean Drilling Programs with the work of other agencies through participation on interagency committees, and direct contact between NSF program managers and their counterparts in the U.S. Geological Survey (USGS), the Department of Energy (DOE), and other agencies. Current interagency cooperation and coordination include review of drilling programs in the U.S. (DOE and USGS). The technical problems, as well as the mineral/energy resource aspects of Ocean Margin Drilling, have stimulated the interest and cooperation of the USGS and DOE with the Office of Science and Technology Policy in a coordinating role. Special coordination concerning the potential use of *Glomar Explorer* has involved interaction with the U.S. Navy, presently the cognizant Department for this ship, as well as other agencies. The U.S. Navy and NSF have also coordinated use of *Glomar Explorer* with Ocean Minerals Company which is presently using *Explorer* for deep sea mining tests. Coordination with offshore programs in the private industry has been through an engineering committee of the Marine Board, National Academy of Sciences, and through direct negotiations with a number of major U.S. petroleum companies. Future foreign participation in OMDP will be considered with interested foreign countries by NSF with appropriate coordination by the Department of State.

Evaluation and Oversight

A major evaluation of future scientific deep-ocean drilling, including the International Phase of Ocean Drilling and the Ocean Margin Drilling Project began in early 1977 and was completed in July 1979. The review over this two and one-half year period focussed on the scientific need and plans for the Ocean Margin Drilling Project. It included scientific peer review by an *ad hoc* panel convened by NSF, technical review by commercial engineering contractors and an engineering committee of the Marine Board, National Academy of Sciences, and a review of the national role of such a

project by a high level Blue Ribbon panel convened by NSF. Representatives of the U.S. Geological Survey (USGS) and the Department of Energy also were involved in this process. Scientific and technical review is presently being carried out in foreign countries, with one country already interested in participation and others expected to follow soon. This extensive and multiple review process found DSDP/IPOD and OMDP scientifically very important and well justified. No insurmountable technical obstacles were identified, and *Explorer* was found to be an excellent candidate for the advanced OMDP drilling platform.

Oversight of DSDP/IPOD and OMDP will be in a variety of areas. Within the Foundation, the National Science Board has established an *ad hoc* committee on future deep sea drilling. A high level advisory committee made up of members from the academic community, the petroleum industry, and the public sector will advise the Director of NSF on Ocean Drilling Programs. The petroleum industry will also form an oversight committee to coordinate OMDP planning with NSF. DSDP/IPOD and OMDP operations will be scrutinized by a safety and pollution- prevention panel with members from scientific institutions, private industry and other U.S. agencies. The foreign countries have operated their own oversight apparatus for DSDP/IPOD and coordinated their effort with NSF. They are expected to continue this effort and to modify their oversight mechanism for their potential participation in OMDP.

DEEP SEA DRILLING PROJECT SUBACTIVITY $17,300,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Deep Sea Drilling Project, International Phase of Ocean Drilling.....	$18,624,910	$21,400,000	$21,400,000	$23,400,000	$2,000,000
Less Foreign Contributions (applied to program)	-8,000,000	-6,000,000	*-5,525,000	**-6,100,000	575,000
Deep Sea Drilling Project, NSF Funds	$10,624,910	$15,400,000	$15,875,000	$17,300,000	$1,425,000

*Foreign contributions applied to the IPOD program had to be reduced in the FY 1980 Current Plan because of changed timing of some IPOD-member country contributions.

**Includes $1.25 million for which no formal agreement exists as yet.

Objectives and Description

The Deep Sea Drilling Project's (DSDP) overall objective is to acquire additional knowledge of the sediments and hard rocks that form the earth's crust beneath the oceans. DSDP pursues this objective by drilling and coring in the world's oceans with the unique ship, *Glomar Challenger*.

The Deep Sea Drilling Project is internationally recognized as one of the great successes of earth sciences because of its decisive contributions to the understanding of our planet. Largely due to DSDP, a concept is now being refined in which our globe is viewed as a dynamic earth-ocean system. Over millions of years crustal (geological) plates form, break up, move, and collide, forming mountain ranges and ocean basins and affecting ocean circulation patterns, climates, and ultimately life on earth. These processes broadly affect people and countries through, for example, resource distribution, earthquakes, and climatic oscillations.

In addition, significant contributions have been made to ocean drilling technology. The technological innovations of DSDP, such as dynamic vessel positioning in deep water and multiple bore hole re-entry (that allows deeper bottom penetration), have already found wide acceptance and use by the offshore drilling industry. The recently-developed Hydraulic Piston Corer, and the new down-hole instrumentation packages and implantation procedures that are now being perfected will eventually open up major new approaches to marine geological and geophysical exploration.

Significant Recent Achievements

Down-Hole Measurements in the Deep Ocean

During two cruises off the mouth of the Gulf of California and Ecuador, a series of instruments (including an ultrasonic televiewer, a radiation recorder, permeability recorders, electrical resistivity and temperature sensing devices, and a down-hole seismometer to record earthquake activity) were lowered into holes drilled up to 1,000

feet below the ocean bottom. The successful completion of these down-hole experiments for the first time brings deep-ocean drilling into a new phase of direct observation and recording of the processes involved in the formation of the earth's ocean crust. This is probably best illustrated by the success of the down-hole seismometer that was left for over one month in *Challenger*-hole 482-C (off the mouth of the Gulf of California), and then retrieved. This instrument had recorded many earthquakes, unusually high temperatures, and possibly even tilting of the surrounding rocks, all direct evidence of a very active ocean crust.

Oceanic Paleoenvironmental Research Advanced by New Hydraulic Corer

A new era in paleoenvironmental research using ocean sediments began on *Glomar Challenger* with Leg 64 of the Deep Sea Drilling Project. A newly-developed, hydraulic piston corer (HPC) recovered a completely undisturbed sample of soft sediments from the Gulf of California. The cumulative cores were more than 500 feet long and represent a nearly continuous record of the past several hundred thousand years of earth history. Normal rotary drilling technique, which is the usual method employed by *Challenger*, disturbs the very soft upper sediments of the ocean floor. In contrast, the new HPC punches a cylindrical tube into the sediments without disturbing their thinnest layers. The HPC was deployed successfully again on a later *Challenger* voyage. This new technical achievement sets the stage for a tremendous increase in resolution, precision, and time-span of oceanic paleoenvironmental research, a fact that is clearly reflected in the enthusiasm with which the HPC was received by the scientific community.

Hydrocarbon and Mineral Exploration

Earlier DSDP drill cores from the Morocco Basin off northwest Africa had shown organic matter that had almost been converted into oil about a mile deep in ocean margin sediments. In the Pacific, in the Galapagos Spreading Center (a region which generates new ocean crust), *Challenger* drilled sea-bottom mounds formed by circulation of heated seawater through newly-formed ocean crust. Mineral oxides and sulfides, rich in iron and manganese, were encountered in these mounds indicating that processes on the ocean floor associated with sea-floor spreading and ocean-water circulation lead to formation of minerals. These two examples, that have been selected from among several such DSDP findings, illustrate the fortuitous combination of basic scientific results and valuable resource information made possible by deep-ocean drilling.

Major Research Questions

- How and why does a continent break up?
- What is the nature of the earliest ocean floor formed during the birth of an ocean?
- How is new oceanic crust formed at the mid-ocean ridges?
- What processes operate in geothermally active regions at or near mid-oceanic ridge crests? How are these processes related to the formation of ore bodies?

- What is the relationship between changing ocean surface circulation and the evolution and distribution of marine life?
- How are earthquakes, volcanic activity and formation of mountain ranges related to plate tectonic processes at active oceanic margins such as western Central and South America?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

In the Deep Sea Drilling Project/International Phase of Ocean Drilling (DSDP/IPOD) *Challenger* program for FY 1981 the ship will operate in the eastern and western North Atlantic, a change from earlier plans, allowing for a more cost-effective schedule. As proposed now, the FY 1981 drilling aims principally at beginning the investigation of the structure and history of passive continental margins. Passive margins are the boundaries created by continental break up and ocean basin formation. The eastern North American, and the Western European continental margin (especially the Bay of Biscay and Rockall Plateau areas) are typical examples of such passive or rifted ocean margins, and it is primarily in these regions that *Challenger* will drill. The eastern North American margin is covered with an extremely thick sediment layer and, hence, most critical targets on it are beyond the reach of *Challenger*. However, drilling here will serve as a precursor for the Ocean Margin Drilling Project, in addition to documenting at least part of the margin's history and structure. The Bay of Biscay and Rockall Plateau areas (off Europe), on the other hand, while similar in history to the U.S. east coast, lack a thick sediment cover, hopefully allowing *Challenger* to sample the transition from continental to oceanic crust across the passive margin. This may give an answer to the basic question. . .what causes continents to break apart?

Drilling in the margins of the North Atlantic during FY 1981 will also help to investigate the fundamental paleoenvironmental changes associated with the opening and widening of the Atlantic. The passive margin off the eastern U.S., for example, contains recorded in its sediment the oldest paleoenvironmental information available in the modern oceans. In contrast, the Rockall Plateau will furnish detailed information on paleoenvironmental oscillations that occurred in the northwest Atlantic during the last 50 million years. An additional paleoenvironmental target in the Caribbean Sea, also in the FY 1981 program, will provide similar information for this marginal sea. All FY 1981 targets will complement the South Atlantic paleoenvironmental targets slated for FY 1980 drilling.

In FY 1981 $1,425,000 of NSF funds are required towards a net increase of $2,000,000 in DSDP/IPOD project costs, covered in part by a $575,000 increase in foreign contributions. Actual cost increases for DSDP/IPOD in FY 1981 total $2,000,000 because of major individual increases of $500,000 for fuel; $275,000 for personnel costs; $510,000 for general supplies and expenses because of inflation; $1,000,000 for the drilling subcontract for *Glomar Challenger*; $135,000 for increased site survey costs; and $65,000 for overhead. These estimated cost increases of $2,485,000 are offset by expected decreases of $485,000 in the overall level of DSDP/IPOD activity in the last year of *Challenger* drilling presently planned.

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QUANTITATIVE PROGRAM DATA
DEEP SEA DRILLING PROJECT SUBACTIVITY

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of scientist years supported[1]	11	12	13
Cost of scientists supported	$310,000	$330,000	$420,000
Number of graduate students supported[2]	4	4	4
Cost of graduate students supported	$30,000	$30,000	$30,000
Other personnel costs	2,364,150	3,150,892	3,336,000
Investment Costs:			
Construction	—0—	—0—	—0—
Nonexpendable equipment	—0—	—0—	—0—
Other costs[3] (see below for details)	15,920,760	17,889,108	19,614,000
Indirect cost	—0—	—0—	—0—
Total DSDP	18,624,910	21,400,000	23,400,000
Foreign Contributions	-8,000,000	-5,525,000	-6,100,000
NSF Funds	$10,624,910	$15,875,000	$17,300,000

[1]The number of years worked during the program year by full-time regular scientific staff members in tasks required to accomplish the mission of DSDP.
[2]Defined as the number of students working whose activities are essential to the completion of a graduate degree program.
[3]Includes the following major items:

Other Costs

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Supplies and Expenses	$3,116,260	$4,290,844	$4,800,000
Drilling Subcontract	10,190,000	10,600,000	11,600,000
Travel	583,600	643,000	625,000
Interagency Agreement	140,000	140,000	164,000
Printing	352,250	539,500	550,000
Site Survey	1,200,000	1,365,000	1,500,000
Overhead	338,650	310,764	375,009
Total	$15,920,760	$17,889,108	$19,614,000

OCEAN MARGIN DRILLING PROJECT SUBACTIVITY $10,000,000

Obligations by Program Element

Program Element	*Actual FY 1979*	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
Planning and Evaluation	$1,000,000	$2,100,000	$3,600,000	—0—	$-3,600,000
Initial Implementation Phase					
Explorer Drilling System Engineering	—0—	—0—	—0—	14,000,000	14,000,000
OMDP Operations	—0—	—0—	—0—	—0—	—0—
OMDP Scientific Program	—0—	—0—	—0—	6,000,000	6,000,000
Total, OMDP	1,000,000	2,100,000	3,600,000	20,000,000	16,400,000
Less Industry Contribution (applied to project)	—0—	—0—	—0—	-10,000,000	-10,000,000
NSF OMDP Funds	$1,000,000	$2,100,000	$3,600,000	$10,000,000	$6,400,000

Objectives and Description

The objectives of the Ocean Margin Drilling Project are scientific studies of passive and active ocean margins, the oceanic crust and ocean paleoenvironment to further our understanding of the planet Earth within the framework of the plate tectonics hypothesis.

- Passive margin investigations are the major new initiative of OMDP. Intensive scientific studies culminating in deep drilling and coring will provide thorough examination of these remaining geologic frontiers. Major scientific questions about continental break-up and ocean basin formation probably will be answered. At the same time this effort will begin to establish a geologic framework for the thick sedimentary sections of the margins, which hold promise of natural resources such as hydrocarbons.
- Active margins are the areas where plate tectonic processes are most vividly demonstrated in deep-ocean trenches, in active volcanoes and in frequent earthquake activity. The *Explorer* system will provide the capability to reach and penetrate the deepest parts of the ocean trenches.
- Ocean crust studies will further refine the plate tectonics model of spreading centers, ocean crust creation and its fate in the spreading cycle.
- Ocean paleoenvironment studies using newly developed coring devices will help to unravel the geologic history of the ocean margins.

In essence Ocean Margin Drilling is a logical follow-on to DSDP, and will build on its significant achievements. The major difference will be the transition from the first broad DSDP reconnaissance of the earth's crust beneath the oceans to a focus in OMDP on the major problems remaining in the plate tectonics hypothesis, together with building a geologic framework for determining the natural resource potential of the ocean

margins. A replacement for *Glomar Challenger*, which has operated for the past 11 years and is now reaching the limits of her technical capabilities, is needed to achieve the OMDP objectives. Current plans are to use the U.S. government-owned *Glomar Explorer* as an advanced platform. *Explorer* will be equipped with a 13,000-ft. riser and a well control system. These together with a 35,000-ft. drill string will allow environmentally responsible penetration of margin sediments down to 20,000 feet below the sea-floor.

The Ocean Margin Drilling Project is planned as a 10 year program from FY 1981 to a phase-out in FY 1990. *Explorer* drilling system design engineering, ship conversion, equipment acquisitions and system completion are planned for the FY 1981 to FY 1984 period, to be followed by 6 years of *Explorer* operations from FY 1984 to FY 1989. An extensive scientific program of marine geophysics, physical oceanography, site surveys, drill site preparation, sample analysis and data evaluation and synthesis is planned to precede, accompany and follow *Explorer* drilling operations in order to maximize scientific return. Total cost for the 10 year OMD Project as presently planned amounts to $359,700,000 in the FY 1981-FY 1990 period in constant FY 1979 dollars. To obtain more realistic estimates under changing economic conditions the same OMDP was projected in the FY 1981-FY 1990 period assuming inflation rates of 7%, 10% and 15% annually which resulted in total OMDP estimates of $569,900,000, $692,800,000 and $957,500,000 respectively. For this OMDP budget estimate a 10% inflation rate was assumed resulting in the following breakdown of the $692,800,000 overall cost by fiscal year.

Ocean Margin Drilling Project by Fiscal Year
($ millions)

FY	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	Total
OMDP	20.0	32.0	60.0	72.7	80.0	88.0	96.7	106.4	117.0	20.0	692.8

In order to provide the major funding necessary for the OMDP the U.S. petroleum industry was invited to join this effort and to contribute half of the total 10 year OMDP cost. Negotiations with the petroleum industry have been successful, and at the present time a sufficient number of U.S. petroleum companies have expressed their willingness to cooperate in funding this effort. OMDP, with joint funding by the government and private industry, is envisioned as a scientific research project and is not intended to explore for oil and gas. Specifically, no drilling is planned on geological structures which are likely hydrocarbon reservoirs. The scientific program will be developed and guided by scientists from universities and private industry. The National Science Foundation will assume overall management responsibility in coordination with the contributing petroleum companies. A Systems Integration Contractor (SIC) to be selected through competitive procurement will design, assemble and operate the *Explorer* drilling system.

The Department of Energy and the U.S. Geological Survey may also participate and contribute to OMDP costs according to their specific interests. The possibility of foreign participation as it now exists in DSDP has been provided for in the arrangements

for OMDP and may be considered in the future, though requiring an increased level of contributions in line with the higher costs of OMDP as compared to DSDP. Any foreign contributions would reduce the project cost to both the U.S. government and industry.

Significant Recent Achievements

- Successful negotiations with the U.S. petroleum industry leading to a joint effort with the National Science Foundation and major contributions to OMDP from the private sector.
- Completion of two year (1977-1979) review and evaluation process of the proposed OMDP, including scientific peer review; technical review by engineering contractors and the National Academy of Sciences; and high level Blue Ribbon panel review. These reviews found that OMDP addresses some of the most important earth sciences problems in the 1980's, there are no insurmountable technical problems, *Glomar Explorer* is an excellent candidate for the advanced drilling platform, and, in comparison with other research and development requirements OMDP rates high priority.
- Establish the availability of *Glomar Explorer* at no cost to OMDP in negotiations with the present cognizant Department, the U.S. Navy.
- Coordination among the NSF, U.S. Navy, and a private consortium for deep sea mining, Ocean Minerals Company (presently using *Explorer*) for most efficient use of *Glomar Explorer* for future programs.
- Conduct of scientific and technical discussions and preliminary government to government interaction with foreign countries resulting in consideration of OMDP participation at greatly enhanced funding levels compared to DSDP.

Major Research Questions

- Where beneath the passive oceanic margins (such as the U.S. east coast) is the boundary between oceanic and continental crust?
- What is the geologic structure of these margins? Is this geologic picture consistent with the accumulation of petroleum?
- How and why does a continent break up?
- What is the nature of the earliest ocean floor formed during the birth of an ocean?
- How is new oceanic crust formed at the Atlantic mid-ocean ridges?
- What processes operate in geothermally active regions at or near mid-oceanic ridge crests? How are these processes related to the formation of ore bodies?
- What is the relationship between changing ocean surface circulation and the evolution and distribution of marine life?

- How are earthquakes, volcanic activity and formation of mountains related to plate tectonic processes at active oceanic margins such as in the Caribbean?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Fiscal Year 1981 will be the first year of OMD Project implementation after 3 years (FY 1978-1980) of gradually increasing planning efforts. FY 1981 also will be the first year of joint government/industry funding for OMDP with a major goal of reaching a final go, no-go decision for the project as a joint venture. The overall increase in FY 1981 amounts to $16,400,000, the increase in government funding is $6,400,000.

The three major categories of funding in FY 1981 are (1) the Systems Support Contractor (SSC) $3,000,000; (2) the Systems Integration Contractor (SIC) $11,000,000; and (3) the Science Program $6,000,000 for a total FY 1981 program of $20,000,000.

The Systems Support Contractor will continue to provide NSF with the engineering and project management support during the design, modification and operation phases of the project. Gradually the SSC role will change from evaluation of preliminary designs to monitoring and evaluating final design work performed by the Systems Integration Contractor and its subcontractors, and an in-depth assessment of overall project objectives, costs and schedules. An important SSC function will be liaison with the scientific community. The $3,000,000 SSC estimate includes: project management support $200,000; scientific liaison $150,000; engineering support and cost estimates $2,100,000; SIC monitoring $550,000.

The Systems Integration Contractor will perform the engineering design and cost estimates necessary to enable government and industry to make the final OMDP go, no-go decision prior to commencing the modification phase and purchase of any long lead hardware items. To provide a firm basis for cost estimates all design work will be completed and bid packages including specifications and comprehensive contract drawings will be sent to qualified shipyards. These design drawings and specifications will enable the shipyards to respond to the SIC with fixed price quotations for the modification phase. The total SIC FY 1981 estimate of $11,000,000 breaks down as follows: riser design $3,000,000; blowout prevention and well control system design $1,500,000; sea-floor support, wellhead and subsea-floor equipment design $1,500,000; vessel contract design and specifications, shipyard selection and evaluation $5,000,000.

The scientific OMD Project will be managed by Joint Oceanographic Institutions (JOI) Inc. with an advisory structure similar to the present Deep Sea Drilling Project arrangements. Scientists from academic institutions, industry, and where appropriate from other government agencies and foreign countries will jointly develop and guide the scientific program for OMDP. The major FY 1981 tasks will be to develop the scientific program in great detail. The $6,000,000 FY 1981 total for the science program for OMDP includes the following: JOI project management $310,000; OMDP science advisory program $500,000; scientific data synthesis $500,000; enhanced geophysical surveying capability, i.e. multichannel seismic systems $1,000,000; marine geophysics related to drill site selection and shiptime $3,300,000; and down-hole experiment design $390,000.

QUANTITATIVE PROGRAM DATA
OCEAN MARGIN DRILLING PROJECT SUBACTIVITY

Cost Element

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Contract Support	$849,000	$3,300,000	$20,000,000
Project Office Planning	16,000	100,000	—0—
Advisory Boards and Support	135,000	200,000	—0—
Subtotal	1,000,000	3,600,000	20,000,000
Less Industry Contributions	—0—	—0—	—10,000,000
Total NSF Funds	$1,000,000	$3,600,000	$10,000,000

Cost Breakout, Contract Support

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
System Support Contractor	$749,000	$2,300,000	$3,000,000
System Integration Contractor	—0—	—0—	11,000,000
Scientific Advisory and Management Contractor	125,000	1,000,000	6,000,000
Totals	$849,000	$3,300,000	$20,000,000

BIOLOGICAL, BEHAVIORAL, AND SOCIAL SCIENCES

PROGRAM ACTIVITY SUMMARY

FY 1981 PROGRAM TOTAL $182,000,000

Obligations by Subactivity

Page	Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
E-I	Physiology, Cellular and Molecular Biology	$62,292,455	$69,500,000	$67,218,000	$74,800,000	$7,582,000
E-II	Behavioral and Neural Sciences	33,073,342	36,900,000	35,443,000	38,700,000	3,257,000
E-III	Social and Economic Science	25,386,044	26,900,000	26,206,000	27,800,000	1,594,000
E-IV	Environmental Biology	33,952,783	38,950,000	37,664,000	40,700,000	3,036,000
	Total	$154,704,624	$172,250,000	$166,531,000	$182,000,000	$15,469,000

Goals and Description

The goal of the Biological, Behavioral, and Social Sciences (BBS) Activity is to expand knowledge and understanding of biological and social phenomena. The range of research supported includes acquiring rigorous physical and chemical information on the fundamental molecules of living organisms, the systems level interrelationships of organisms and their environment, the complex learning and behavior patterns of human beings, and the interactions of social, economic and cultural organizations and institutions.

Specific major objectives are to identify and fund research that will advance understanding of the:

- Molecular basis of structure and function in cells, organs, organ systems, and whole organisms;
- Interrelationships in terrestrial and freshwater ecosystems and key evolutionary relationships among the many species of plants, animals, and microorganisms;
- Biological, psychological, and cultural factors that underlie behavior; and
- Structure and function of economic and social institutions, and changes that impact on individuals and groups of the societal conditions they experience.

Over the long term, we expect the results of this fundamental research effort to contribute new ideas, options and opportunities for wisely utilizing the biological environment, maximizing human development potential, enhancing the quality of life, maintaining economic and social stability with progress, and increasing productivity.

The aims are ambitious, but to the extent that most national and international problems relate to people, their institutions and their interaction with the environment, the gain in understanding from this research can be invaluable.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The changes in the FY 1980 Budget Plan, down from $172,250,000 to $166,531,000, reflect adjustments resulting from the funds actually appropriated. The total of $172,250,000 excludes transfers to the new Cross-Directorate Program Activity.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$154,704,624
FY 1980 Program	$166,531,000
FY 1981 Request	$182,000,000
Difference—FY 1981/FY 1980	$15,469,000

The Foundation's FY 1981 budget request for Biological, Behavioral, and Social Sciences (BBS) is $182,000,000, an increase of $15,469,000 (or 9.3 percent) over the FY 1980 level of $166,531,000. This increase will support the base of science in the program subactivities that follow and provide for selected new research opportunities. Important, but currently less promising, lines of inquiry will be reduced in order to fund the new research opportunities.

The distribution of FY 1981 budget requests for the four BBS program subactivities is based on a thorough review of research needs and opportunities and consideration of the research supported by other agencies. The percentage increases are as follows:

Physiology, Cellular and Molecular Biology	11.3%
Behavioral and Neural Sciences	9.2%
Social and Economic Science	6.1%
Environmental Biology	8.1%

Explanation of Increases:

- $7,582,000 increase, for a total of $74,800,000 for Physiology, Cellular & Molecular Biology including increases for:
  - — studies of cell-cell interactions to increase our understanding of self recognition of cells in development and differentiation, and hormones and their receptors;
  - — procurement of instrumentation and development of new instrumentation;
  - — studies of membrane structure and function including pathways and movements of substances through membranes; and

  - research on the structure and function of macromolecules especially on the mechanism of heredity in the context of gene structure and functioning, biosynthesis of macromolecules, and the regulation of enzyme activity.
- $3,257,000 increase, for a total of $38,700,000 for Behavioral and Neural Sciences, including increases for:
  - studies of biochemical and hormonal mechanisms underlying behavior; and
  - anthropological research seeking human origins.
- $1,594,000 increase, for a total of $27,800,000, for Social and Economic Science, including increases for:
  - additional studies of economic instability, inflation and employment, both domestic and international; and
  - studies of allocation processes, decision rules, management behavior, and dispute resolution particularly in organizations such as large firms, government bureaucracies and other complex organizations.
- $3,036,000 increase, for a total of $40,700,000, for Environmental Biology including increases for:
  - research on various aspects of the ecology of crop and forest pests, acid rain, global carbon dioxide, and other pressing ecological problems; and
  - projects in long-term ecological research and maintenance of field research capability at representative sites.

Coordination and Relationship to Other Efforts

The Biological, Behavioral, and Social Sciences provide a significant portion of Federal support for basic research at universities in these sciences. In some disciplines such as environmental biology, political science, and anthropology, the National Science Foundation is the major source of university based research. In other areas, e.g., biochemistry and neurobiology, a larger fraction of the total basic research support is provided by other agencies. However, the health of these sciences, especially in providing opportunities for the advancement of new techniques, methodologies and model systems, is affected profoundly by the level and nature of Foundation support.

The Biological, Behavioral, and Social Sciences staff coordinates with other Federal programs to insure effective coverage of key scientific areas and to avoid duplication of efforts. Staff members also serve as formal liaison representatives on advisory committees for other Federal agencies or on interagency committees.

Rapidly expanding research by scientists of other nations requires that the Foundation actively foster efforts of U.S. scientists to keep up to date with research activities and developments in other countries, to share new findings, and occasionally to plan projects to minimize costs and maximize the comparability of data in different countries (cross-national surveys and ecosystem studies).

Within the Foundation, particularly close coordination is maintained with the Engineering and Applied Science program which builds directly upon some of the basic research supported through this activity (e.g., economic problems). In areas of scientific and technical convergence, coordination is maintained with Astronomical, Atmospheric, Earth and Ocean Sciences basic research projects and facilities (e.g., biological oceanography, geology, climate and polar programs); and with Mathematical and Physical Sciences (e.g., synchrotron radiation, neutron scattering, and computer science). Increasingly, BBS programs require coordination with Scientific, Technological, and International Affairs (e.g., social sciences in western Europe, tropical biology in western hemisphere countries, and anthropology and linguistics in the western hemisphere countries, Africa and Asia).

Evaluation and Oversight

Evaluations in the Biological, Behavioral, and Social Sciences include peer review of individual projects and periodic reviews of the aggregated activities of programs. In some cases, *ad hoc* panels are convened to provide both program reviews, on site evaluations, and advice in establishing new areas or de-emphasizing less productive research.

Most of the external oversight activities in BBS are performed by Advisory Committees for each program Division (subactivity). A sample of actions from 10 of 27 BBS programs was reviewed in FY 1979. Additional actions were subjects of internal audit. Four programs were reviewed in the NSF supported National Academy of Science study on peer review.

The advisory committees evaluated the quality of peer reviews and examined the scope and balance of the program, trends in size and distribution of awards, composition of the advisory subcommittees that peer review proposals for BBS, and in some instances relationship to other programs. The reviewers concluded that in general (1) the selection of reviewers was appropriate, (2) the peer reviews themselves were fair and adequate, though in some cases brief, and (3) that the program decisions were fair and impartial. Specific suggestions for improving the quality of peer reviews and instances where documentation of decisions could be improved were offered. Suggestions for improved management included more systematic efforts to identify important areas for long-range planning, budget development, procedural changes to provide more time for reviews and reorganization of one program area. Appropriate action has been initiated on all recommendations. These reviews and other planning and evaluation studies will be continued in FY 1980 and FY 1981.

QUANTITATIVE PROGRAM DATA
BIOLOGICAL, BEHAVIORAL, AND SOCIAL SCIENCES SUBACTIVITY

(SUMMARY)

Proposals and Awards

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number Proposals Received[1]	7,674	7,940	8,210
Number Awards	3,272	3,233	3,225
Dollars Proposed on Awards (Total)	$352,596,000	$379,741,000	$416,050,000
Dollars Proposed on Awards (Annual Rate)	261,321,200	216,670,000	237,130,000
Dollars Awarded (Total)	154,704,624	166,531,000	182,000,000
Dollars Awarded (Annual Rate)	128,398,200	138,130,000	151,090,000
Average $ per Award	47,280	51,500	56,400
Average Award Duration (Years)[2]	2.3	2.3	2.3

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	88.8	88.8	88.8
Industry	0.2	0.2	0.2
Federal Agencies	0.1	0.1	0.1
Other	10.9	10.9	10.9

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Senior Scientists Faculty[4]			
Number of scientist years supported	1,256	1,290	1,325
Amount of faculty support	$29,116,942	$32,041,000	$34,900,000
Cost per scientist year	23,180	24,800	26,300
Postdoctoral Associates			
Number of scientist years supported	639	660	680
Amount of postdoctoral support	$8,877,125	$9,835,000	$10,830,000
Cost per scientist year	13,890	14,900	15,900
Graduate Students			
Number supported	1,703	1,750	1,790
Amount of graduate student support	$9,681,731	$10,670,000	$11,620,000
Other Personnel Costs	13,859,424	15,382,000	16,810,000
Capital Items	—0—	—0—	—0—
Major Equipment	17,142,000	14,600,000	16,090,000
Equipment and Instruments	39,250,661	43,411,000	47,410,000
Other Costs	36,776,841	40,592,000	44,340,000
Indirect Costs	$154,704,624	$166,531,000	$182,000,000
Total			

[1]Includes proposals for committed renewals, etc.
[2]Includes awards for committed renewals, supplements, etc.
[3]Includes continuing grants for full length.
[4]Includes faculty associates and other professionals.
[5]Fringe benefits, expendable equipment, travel, publication costs, computer costs, other direct costs.

PHYSIOLOGY, CELLULAR AND MOLECULAR BIOLOGY PROGRAM SUBACTIVITY $74,800,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Molecular & Genetic Biosciences	$35,213,949	$38,641,000	$37,518,000	$41,300,000	$3,782,000
Cellular & Physiological Biosciences	23,939,188	26,859,000	26,200,000	29,600,000	3,400,000
Biological Instrumentation	3,139,318	4,000,000	3,500,000	3,900,000	400,000
Total	$62,292,455	$69,500,000	$67,218,000	$74,800,000	$7,582,000

Objectives and Description

The objectives of the Physiology, Cellular and Molecular Biology (PCM) subactivity are:

- To develop an understanding of how living organisms reproduce, grow, maintain themselves, and age; and
- To understand in physical and chemical terms how life processes occur at the molecular, cellular and organismal levels.

Examples of the importance of basic biological research include studies that may lead to improved agriculture and food production, an understanding of energy transduction, and to the solution of health-related problems. Research is carried out on whole organisms (both plant and animal), organs, single cells, subcellular organelles, bacteria, viruses, and specific molecules. To implement the objectives of this subactivity, NSF provides support for biological research including the purchase and development of advanced specialized equipment, and scientific conferences and workshops.

The Molecular and Genetic Biosciences program supports research on the molecular basis of life, structure-function relations of biological molecules, organization and function of hereditary material, metabolic processes, and studies on energy generation and use. An understanding of the chemical and physical properties of natural compounds is related to developing concepts of the way that molecular structures are responsible for biological functions. One example of this concept is how genes guide the production of a certain enzyme whose structure determines how it will interact with select substances to produce specific changes in these substances. Another area of support is the study of the pattern of molecular changes and interactions, and of the relationship of these patterns to function, such as making energy available to carry out biological work.

The Cellular and Physiological Biosciences program provides support of research on growth and development, studies relevant to prokaryotic and eukaryotic cells, and the physiological mechanisms that underlie biological functions. Emphasis is given to

research on cell organelles, individual plant and animal cells, organs, organ systems, and whole organisms. The conceptual synthesis of properties of individual cells and organs into systems descriptive of their interactions and function is a major thrust. Through the support of studies of comparative biology, information is obtained about evolution and the various strategies endured by biological entities in adapting to diverse environments.

Major Research Questions

Major research questions are:

- Cell-cell Interactions—What is the role of the cell surface in such interactions in the immune system? What is the nature of recognition of self or nonself? What is the recognition between plant and bacteria in the formation of a system capable of nitrogen fixation? What is the nature of the regeneration of whole plants from cell suspension cultures? How do pheromones work in their role as communication links between individuals of the same species? What is the nature of the interaction between the cytoskeleton and the cell membrane?
- Energy Transduction—What is the relation between photosynthesis and nitrogen fixation? What are the early events in the conversion of solar energy to chemical energy by living organisms? What is the nature of the conversion of chemical energy to mechanical energy such as in muscle contraction? What is the relation of the photobiological process to such processes as the genesis of methane?
- Membrane Structure and Function—How are membranes assembled? What are the interactions between hormones and receptors located in membranes? What is the relation of membrane structure to vision? What is the relation between the structure of membranes and their dynamics? How are membranes involved in transport? How may chilling injury in plants be related to the physiochemical properties of plant membranes? What is the relation of membrane structure to environmental stress and to nutrient uptake in plants?
- Structure and Function of Macromolecules—What is the structure of genes and how does this relate to their function in heredity? How is gene expression controlled? How can "gene-splicing" techniques be used to understand better gene function resulting in improved crop production? What is the mechanism for the regulation of the biosynthesis and degradation of proteins, nucleic acids, carbohydrates and lipids? What is the relation between the structure of molecules and their function?
- Adaptational Physiology—What is the relationship between an organism and its environment that may include biorhythms, thermal activation, hormone production, and physiological responses to stress? What is the mechanism of nutrient uptake by roots? How do organisms adapt to natural environmental stress such as heat, cold and toxins? Why do some plants utilize certain physiologically essential metal ions more efficiently than others?

The Cell Membrane in Information Transfer

Recent advances in cell and molecular biology have emphasized that gene expression can be modulated by external changes at the cell surface. Lewis Kleinsmith of the University of Michigan has found that sea urchins offer a unique opportunity to study the transmission of a signal from the cell surface to the nucleus. The amount of embryonic tubulin messenger ribonucleic acid (RNA) increased dramatically shortly after ciliary removal, confirming activation of genes in the nucleus by events occurring at the cell surface.

A second example of gene activation through events occurring at cell surfaces involves a polypeptide called epidermal growth factor (EGF). EGF can stimulate quiescent cells in culture to divide. Using isotopically labeled material, Robert W. Holley of the Salk Institute, has shown that EGF is first bound to receptors on the cell surface, then internalized.

A third approach is being taken by Clara Szego at the University of California, Los Angeles. Studies of the mechanism of action of steroid hormones conducted by Szego and colleagues provide information on how stimuli for gene activation are translocated from the cell surface to the genes. By a combination of cytochemical and biochemical techniques, Szego has demonstrated cell surface receptors for these hormones and the internalization and sequestration by liposomes, which then serve to move the hormone to the nucleus.

These three approaches will enable us to understand how molecules such as hormones acting at the cell surface affect the activity of genes.

Plant Molecular Biology

Plant hormones promote plant growth, propagation, flowering, and fruiting and provide defense against adverse environmental conditions. Bandurski and his colleagues at Michigan State University have been investigating the chemistry of the plant hormone, indole acetic acid (IAA). In all plants they analyzed, most of the IAA was bound either to a sugar or an amino acid. Binding of IAA to a sugar (myo-inositol) increased by 400 fold the rate at which the hormone moves from the seed (source) to the shoot where it performs its growth functions. The binding and the freeing of the hormone from the sugar provide the plant with a mechanism for control of the level of the active form of the hormone. In addition, binding of IAA to a sugar protects the hormone from destruction. These findings have provided researchers in the field with a new approach to help answer the ultimate mystery of how this hormone acts in promoting plant growth and development.

Ethylene, a gaseous hormone under physiological conditions, exerts a major influence on many aspects of plant growth, development, and aging. S. F. Yang of the University of California, Davis, has discovered a compound that is the immediate precursor of ethylene. Furthermore, Yang's laboratory has characterized the enzyme that promotes the formation of the precursor. This significant observation has now

opened doors for fundamental and applied research in ethylene biochemistry and physiology. For example, the plant stress response of waterlogging causes an increased production of ethylene in the shoot. Yang found that under such conditions ACC synthesis in the roots was greatly increased. The precursor is then transported upward from the roots to the shoots where it is readily converted to ethylene enabling the plant to develop.

Dynamic Genes

Transposons, small deoxyribonucleic acid (DNA) sequences that can move from one chromosome to another, have been found in bacteria, corn, and animals. Their discovery has necessitated a new understanding of the stability of DNA, the genetic material. This hypothesis of "jumping genes" recently has been supported by experimentation.

Using the bacterium, Salmonella, Melvin Simon and colleagues at the University, of California, San Diego, was one of the first groups to demonstrate that the position and orientation of a specific fragment of DNA determines whether a gene is expressed. In a series of experiments, Simon showed that a fragment of DNA adjacent to one of the structural genes could be inserted into the bacterial chromosome in two different orientations. When the orientation is in one direction, the bacterium produces one type of flagellum (an appendage for propulsion); but when the orientation is in the other direction, another type is made.

Nancy Kleckner and associates at the Massachusetts Institute of Technology have used the phenomenon of antibiotic resistance to demonstrate genetic engineering *in vivo*. They have shown that DNA containing a segment (or gene) encoding resistance to antibiotics can be transferred from plasmid to virus to bacteria. When such translocations occur, the elements directly alter genome expression as well as the arrangement of genetic material.

Some of the best evidence that DNA segments move in higher organisms was derived from the original studies of Barbara McClintock in 1940. More recently, Oliver Nelson of the University of Wisconsin is examining these mobile DNA segments or controlling elements to increase our knowledge of the mechanism of their effect on gene function. His laboratory has characterized the enzyme, glucosyl-transferase, which is encoded by a mutable gene, bronze. This gene must interact with a specific controlling element in order to be expressed. This work is invaluable to our understanding of gene function in plant cells.

Antibody molecules (proteins) consist of regions that are constant in amino acid sequence from one antibody molecule to another, and other regions that vary from one molecule to another. The variable regions give an antibody its specificity for a particular antigen. What genetic mechanism is responsible for the diversity of antibody molecules? Leroy Hood and his associates at the California Institute of Technology have shown that a rearrangement of DNA occurs in mammals. During development, this rearrangement is fundamental to the molecular events that commit the antibody-producing cell to the synthesis of a specific antibody. The group of genes

responsible for an antibody chain is comprised of an unknown number of gene segments coding for variable regions, and some gene segments coding for constant regions. In an antibody-producing cell, a specific antibody is made through an association of a particular variable gene with a particular constant gene. DNA rearrangement in variable and constant regions occurring during differentiation of antibody-producing cells provides new impetus for characterizing genetic changes in plants and animals.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 current operating plan for the Physiology, Cellular and Molecular Biology subactivity is $67,218,000, a decrease of $2,282,000 below the FY 1980 budget request of $69,500,000.

Fiscal year 1980 funding will permit: (1) partial funding for the most pressing equipment needs; (2) moderate emphasis on nucleic acid-protein interactions in the plant sciences; and (3) an augmentation of award amounts in view of significant increases in the costs of conducting biological research. More specifically, these adjustments provide support for areas emerging more rapidly than others, and for the encouragement of selected areas of research: studies to increase our understanding of genetics and the hereditary process; plant cell culture, early events in photosynthesis and plant cell genetics; studies on structure and function and transport; and basic studies to understand the physiological and chemical basis of environmental stress.

Changes in Budget Structure

The FY 1981 budget eliminates the program subelement, Human Cell Biology, from the Cellular and Physiological Biosciences program element. The continuing projects will be administered by Cell Biology and other subelements. The program was established at a time when it was necessary to stimulate collaborative research by investigators on mammalian cells. The program achieved its purpose and future research in these areas should compete with research in related areas.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$62,292,455
FY 1980 Program	$67,218,000
FY 1981 Request	$74,800,000
Difference—FY 1981/FY 1980	$7,582,000

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The budget request for fiscal year 1981 is $74,800,000. This amount is an increase of about $7,582,000 above the fiscal 1980 level of $67,218,000.

The percentage increases proposed for the program elements for FY 1980 are as follows:

Molecular and Genetic Biosciences	10.1%
Cellular and Physiological Biosciences	13.6%
Biological Instrumentation	11.4%

These increases are distributed in response to:

- Recognition of the need to promote new opportunity in research as a consequence of the development of new instrumentation or techniques.
- Recognition that different experimental approaches and novel ideas accelerate the acquisition of scientific knowledge and should be encouraged as changes in emphasis occur within the scientific community and as growth of capability in research areas increases.

Of the total increase of $7,582,000 million, approximately one-third will be used to maintain a minimum effort in the base program in the face of rising costs of research. The remainder will provide increases in the following high priority areas to be supported by the programs in Physiology, Cellular and Molecular Biology:

- Instrumentation—Provision of commercially available multi-user equipment for the development of new types of equipment.
- Cell-cell Interactions—Studies to increase our understanding of the interactions of different parts of the cell, hormones and their receptors and changes during differentiation.
- Membrane Structure and Function—Increased emphasis on pathways of movement of substances through membranes (including metal ions), building upon our current understanding of membrane structure.
- Structure and Function of Macromolecules—Fundamental studies on the mechanism of heredity which relates to gene-action, biosynthesis of macromolecules and the regulation of enzyme activity.
- Adaptational Physiology—Studies to increase our understanding of the mechanisms by which organisms maintain physiological integrity under normal and abnormal environmental stresses.
- Energy Transduction—Increased emphasis on fundamental research on the transfer of energy from one kind to another (e.g., solar to chemical), from one organelle to another, or from one molecule to another.

Components of the above five major research areas and biological research instrumentation are discussed later and represent specific research opportunities that will benefit from increased support.

A constant level of effort will be maintained in the following areas:

- Cell Organization and Function—Research in this area is important to our understanding of the relationships between the architectural components of cells and their function in living organisms.
- Studies on Enzymes—Enzyme research is essential to understand how chemical processes in cells are catalyzed.
- Macromolecular Structure and Function—Detailed information on the structure and chemical composition of cells is needed to understand the mechanisms underlying intercellular and intracellular reactions.
- Genetics—Major strides have been made recently in certain fields of genetics and the proposed level will continue efforts to maintain the momentum.

Coordination and Relationship with Other Efforts

Coordination with the research support activities of other Federal agencies is maintained through a variety of formal and informal mechanisms. Program Officers of the Physiology, Cellular and Molecular Biology (PCM) program subactivity at NSF attend study section and Council meetings at the National Institutes of Health (NIH) as observers. Similarly, NIH officials often attend PCM advisory committee and subcommittee meetings and provide NSF with information about the NIH plans to fund proposals. These steps enable each agency to monitor specific research proposals and avoid duplication of effort.

NSF staff members also serve as liaison representatives on a variety of advisory and interagency committees. For part of fiscal years 1978 and 1979, a program officer from NSF was detailed for part time work with the newly established competitive grants program of the Department of Agriculture (DOA). The NSF-initiated Interagency Committee for Plant Sciences continues to bring together, periodically, representatives from DOA, NIH, Department of Energy, National Aeronautical and Space Administration, Food and Drug Administration, Environmental Protection Agency, the Smithsonian Institution, and the National Academy of Sciences. Where appropriate, PCM participates in joint support of research with other Federal agencies. By these several means, close and continuous communication at the program level is maintained with other agencies and duplication is avoided.

Within the Foundation, close relationships of a similar type are maintained with program components of the Directorates for Engineering and Applied Science; Scientific Technological, and International Affairs; and Mathematical and Physical Sciences. Proposals will be examined for possible funding from the university/industry program. Possibilities for increased use of industry/university cooperative arrangements include genetic engineering technology.

Molecular and Genetic Biosciences Program Element $41,300,000

Obligations by Program Subelement

Program Subelements	Actual FY 1979	Estimate FY 1980	Estimate FY 1981	Difference FY 1981/80
Biochemistry	$8,673,010	$9,100,000	$10,000,000	$900,000
Biophysics	9,441,367	9,918,000	10,900,000	982,000
Genetic Biology	8,453,135	9,300,000	10,300,000	1,000,000
Metabolic Biology	8,646,437	9,200,000	10,100,000	900,000
Total	$35,213,949	$37,518,000	$41,300,000	$3,782,000

Objectives and Decription

Programs in this program element encompass the support of research in the following areas:

- Molecular basis of biological processes;
- The structure-function relations of biological molecules;
- The organization and function of hereditary material;
- Studies on energy generation and use; and
- Studies on the interaction of molecules with each other and with their environments.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The amount requested for the Molecular and Genetic Biosciences program element represents an increase of about $3,782,000 (10.1 percent) over the FY 1980 funding level of $37,518,000.

The program includes four subelements: Biochemistry, Biophysics, Genetic Biology and Metabolic Biology.

The Biochemistry subelement supports research aimed at understanding the molecular basis of biological processes. It provides support for conducting research on the biosynthesis of large molecules; on the mechanisms of enzyme catalysis; and how molecules function. Some of the current areas include the chemical and physical nature of pheromones, the nature of the enzymes involved in photosynthesis and nitrogen fixation, the way membranes are assembled, and the regulation of the biosynthesis of lipids, carbohydrates, proteins and nucleic acids. Research in Biochemistry will increase by $900,000 to the FY 1981 total of $10,000,000.

The Biophysics subelement supports research in which advanced physical techniques are used to investigate basic biological problems. It provides support for studies on the structure and dynamics of proteins and nucleic acids, the structure, fluidity and function of membranes, and the speed reaction of macromolecules with

each other or small molecules on the millisecond or picosecond time scale. Some current areas of emphasis include studies on the early events in the conversion of solar energy to chemical energy and the nature of the conversion of chemical energy to mechanical energy. Research in Biophysics will increase by $982,000, to the FY 1981 total of $10,900,000.

The Genetic Biology subelement is responsible for supporting research focused on the organization, function, transmission and regulation of expression of the hereditary material of all organisms. Typical recent areas of support include the use of gene-splicing in plants and animals, expression of genes and its control, studies of the genetics of plants. Research in Genetic Biology will increase by $1,000,000, to the FY 1981 total of $10,300,000.

The Metabolic Biology subelement supports studies of the chemical processes in animal, plant and microbial systems by which energy is provided and through which material is assimilated and broken down to simpler chemical substances. Areas of recent emphasis include the mechanism of ion uptake by roots, studies on the relation between photosynthesis and nitrogen fixation and studies on the biological genesis of methane. Research in Metabolic Biology will increase by $900,000, to the FY 1981 total of $10,100,000.

Cellular and Physiological Biosciences Program Element $29,600,000

Obligations by Program Subelement

Program Subelement	*Actual FY 1979*	*Estimate FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
Cell Biology	$6,300,000	$7,500,000	$8,700,000	$1,200,000
Developmental Biology	9,039,188	9,600,000	10,800,000	1,200,000
Regulatory Biology	8,600,000	9,100,000	10,100,000	1,000,000
Total	$23,939,188	$26,200,000	$29,600,000	$3,400,000

Objectives and Description

Programs in this element support research in the following areas:

- Growth and development at the several levels of biological organization;
- Studies on isolated prokaryotic cells;
- Physiological and molecular mechanisms that underlie biological functions;
- Mechanisms that integrate functions in tissues, organs and organisms; and
- Evolutionary development of these various functions.

FY 1981 Highlights and Explanation of Increases and Decreases

The amount requested for the Cellular and Physiological Biosciences program element represents an increase of $3,400,000 (13 percent) over the FY 1980 funding level of $26,200,000.

The program includes three subelements:

The Cell Biology subelement supports research directed toward understanding the mechanisms underlying the growth, division and behavior of cells. The two major thrusts are the clarification of the interrelationship between a cell's function or activity and its subcellular structure and how organisms recognize and respond to self versus non-self cells or tissues. Current areas of emphasis include the role of cell surfaces in such interactions as those in the immune response system, the nature of the interaction between the cytoskeleton and the cell membrane, and how membranes are involved in transport. Research in Cell Biology will increase by $1,200,000, to the FY 1981 total of $8,700,000.

The Developmental Biology subelement supports research focused on the basic mechanisms underlying development throughout the life span of animals, plants and microorganisms. Included are studies on fertilization, reproduction, cell, tissue and organ differentiation and interaction, pattern formation, regeneration, senescence and genetics. Currently the major area of support is developmental genetics. Of particular importance in both plants and animals are studies on (1) the significance of multigene inheritance, (2) gene expression during development as related to "controlling elements" (portable DNA sequences), (3) developmental analysis through use of mutants, and (4) genetic manipulation via cell fusion, protoplast regeneration and recombinant DNA. Research in Developmental Biology will increase by $1,200,000, to the 1981 total of $10,800,000.

The Regulatory Biology subelement supports studies of mechanisms that initiate, regulate and integrate physiological functions in tissues, organs and organisms. Supported areas range from analysis of these mechanisms at the molecular level to comparative studies of their evolution. Of particular interest are those physiological regulatory mechanisms that permit an organism to adapt to its environment: to heat, cold, altitude, chemical agents, diurnal and seasonal changes, mineral and water balance, and energy intake. Frequently, endocrine and neuroendocrine systems are the focus of support, especially studies of hormone receptors, hormone-gene interactions, pheromones, and regulatory substances in the nervous system. The subelement also supports research in the fields of membrane structure and the physiology of cells and tissues. Research in Regulatory Biology will increase by $1,000,000, to the FY 1981 total of $10,100,000.

Biological Instrumentation Program Element $3,900,000

Obligations by Program Element

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981	Difference FY 1981/80
Biological Instrumentation	$3,139,318	$3,500,000	$3,900,000	$400,000

Objectives and Description

The Biological Instrumentation program element is responsible for:

- Supporting purchase of research instruments to be used by groups of investigators; and
- Providing support for development of instruments that are not available from commercial sources and which provide capabilities for making improved measurements of biological significance.

FY 1981 Highlights and Explanation of Increases and Decreases

The Biological Instrumentation Program is a discrete activity formed from continuing efforts to emphasize instrument development and to foster increased access to equipment. A current frontier in understanding biological events at the molecular level is research on the organization of macromolecules into functional subcellular complexes. To cope with the size and complexity of these macromolecular assemblies, there is a need for the development of more sensitive instruments and the enhancement of state-of-the-art instrumentation. Increasing demands for use of costly equipment require encouragement of shared acquisition and use of instruments and facilities by groups of investigators in pursuing their individual research interests. The demand is being met in part by this program element.

Funding of multiuser instrumentation and of equipment development will be maintained. Development of new instrumentation permits measurements that could not be made previously and increases the accuracy and sensitivity of research observations. Since such improvements often lead to new discoveries, emphasis will be given to new equipment development. Some examples of equipment needs which require further development are better instruments for studying macromolecular structures and their interaction, improved devices for elemental analysis of biological materials, finer electrodes for making bioelectric measurements, better devices for preparation of tissues for electron-microscopic analysis; and instruments to separate cells or cell organelles. Such instruments could make major contributions in relating biological structure to biological function from the molecular to the whole tissue level.

QUANTITATIVE PROGRAM DATA
PHYSIOLOGY, CELLULAR, AND MOLECULAR BIOLOGY SUBACTIVITY

Proposals and Awards

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Number of Proposals Received[1]	3,174	3,350	3,530
Number of Awards[2]	1,344	1,305	1,270
Dollars Proposed on Awards (Total)	$165,809,000	$178,771,000	$198,948,000
Dollars Proposed on Awards (Annual Rate)	88,972,800	96,000,000	106,830,000
Dollars Awarded (Total)	62,292,455	67,218,000	74,800,000
Dollars Awarded (Annual Rate)	54,660,100	58,950,000	65,600,000
Average $ per Award	46,350	51,500	58,900
Average Award Duration (Years)[3]	2.4	2.4	2.4

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	93.0	93.0	93.0
Industry	0.3	0.3	0.3
Federal Agencies	—0—	—0—	—0—
Other	6.7	6.7	6.7

Personnel and Other Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Senior Scientists Faculty[4]			
Number of scientist years supported	552	570	600
Amount of faculty support	$9,755,803	$10,866,000	$12,090,000
Cost per scientist year	17,670	19,100	20,200
Postdoctoral Associates			
Number of scientist years supported	424	440	460
Amount of postdoctoral support	$5,245,056	$5,842,000	$6,510,000
Cost per scientist year	12,370	13,300	14,200
Graduate Students			
Number supported	539	560	590
Amount of graduate student support	$2,989,682	$3,330,000	$3,700,000
Other Personnel Costs	4,930,352	5,491,000	6,110,000
Capital Items			
Major Equipment	$9,841,900	$8,800,000	$9,790,000
Equipment and Instruments	14,895,957	16,591,000	18,460,000
Other costs[5]	14,633,705	16,298,000	18,140,000
Indirect costs	$62,292,455	$67,218,000	$74,800,000
Total			

[1] Includes proposals for committed renewals, etc.
[2] Includes awards for committed renewals, supplements, etc.
[3] Includes continuing grants for full length.
[4] Includes faculty associates and other professionals.
[5] Fringe Benefits, expendable equipment, travel, publication costs, computer costs, other direct costs.

BEHAVIORAL AND NEURAL SCIENCES PROGRAM SUBACTIVITY $38,700,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Neuroscience	$14,520,163	$16,100,000	$15,643,000	$17,000,000	$1,357,000
Cognitive Science	5,002,804	5,200,000	5,200,000	5,600,000	400,000
Behavioral Science	7,425,667	8,200,000	7,900,000	8,500,000	600,000
Anthropological Science	6,124,708	7,400,000	6,700,000	7,600,000	900,000
Total	$33,073,342	$36,900,000	$35,443,000	$38,700,000	$3,257,000

Objectives and Description

The major objectives of the Behavioral and Neural Sciences subactivity are to advance the understanding both of the behavior of human beings and lower animals and of the biological and cultural factors that underlie that behavior. Accomplishing these objectives requires research strategies that span the spectrum of the biological, behavioral, and social sciences. Anthropology, linguistics, psychology, the neurosciences, and biological research on animal behavior are specifically included. Basic research in these areas provides the scientific framework for understanding behavior on a variety of levels—from the molecular and cellular to the individual, group, and cultural levels. Increasing numbers of scientists are addressing research efforts toward understanding the brain and behavior.

Neuroscience research seeks to elaborate the structure and function of the nervous system which underlies behavior, and of the sensory systems through which people and animals receive and process information from the world around them. New instruments and techniques now make it possible for scientists to study the functioning of individual nerve cells in relation to behavior.

Cognitive science research includes psychological research addressed to complex cognitive behavior: reading, thinking, memory, problem-solving, and the development of these capacities in children. This area also includes research in linguistics which addresses general properties of language and its acquisition and the unique properties of individual languages. Sophisticated use of modern computer technology makes it possible for cognitive scientists to probe these fundamental human capacities and processes in depth. In the long term, this knowledge is essential to the improvement of educational practice.

Behavioral science research focuses on the behavior of individuals in relation to others in order to obtain a better understanding of the social interactions that underlie significant social problems, including aggression, crime, and divorce. Also emphasized is the development of social behavior in children. Research on animal behavior, which provides models for understanding the biological bases of human behavior and serves to aid in the management and control of wildlife and animal pests, is also an important component.

Anthropological research emphasizes the integration of the biological, behavioral and social sciences as they relate to understanding diverse cultures and the course of human evolution. It includes research in cultural and social anthropology, archaeology, and physical anthropology, and support of systematic anthropological research collections.

Major Research Questions

Examples of highly promising research questions currently being addressed by Foundation-supported research in the behavioral and neural sciences include:

- What rules govern how and where brain cells grow to make new or more effective connections during embryonic growth and repair? What substances act as the chemical messengers between brain cells? How do some messengers excite and some inhibit neural activity? How does early experience influence the subsequent growth and function of the sensory nervous system? By what mechanisms do brain circuits control body temperature, blood pressure, and heart rate? By what molecular processes do the taste or olfactory systems encode information about environmental stimuli? How are the attributes of sound perceived by the auditory system? How is light perceived by the visual system? What brain cell mechanisms underlie learning?
- What is the nature of the component processes involved in reading, understanding, and remembering written material? How do these processes interact? How is information stored in memory so that it can be retrieved and used at appropriate times? What is the relationship between the capacity to use language and the general capacity to store and retrieve information in memory? What aspects of the acquisition of language by children are universal, and what aspects depend on the particular characteristics of the language being acquired? What are the anatomical sites and physiological processes of the brain that are responsible for the ability to acquire and use language? How do people solve problems? How does this ability develop as children grow up? How do people learn to classify the information they receive on the basis of common properties so that appropriate categories (e.g., chairs, Greek letters, problems that can be solved with the quadratic formula) can be responded to similarly?
- How do people come to explain and predict the behavior of others? What factors affect the occurrence and reduction of conflict and aggression? What are the effects of prolonged exposure to environmental stressors? What factors affect the social and emotional development of the child? What are the internal biological changes that are correlated with adaptive behaviors? How do behaviors characteristic of the members of a particular species evolve, develop, and pass to succeeding generations? How does experience modify later behavior? What are the various means by which animals communicate, and do they show systematic regularities that may have implications for understanding human communication and language?

- When and where did the human species emerge? Can its development be traced over millions of years? What forces shaped its cultural and physical adaptation? Complex societies arose independently in many parts of the world. Can the interacting forces that underlie this basic process be isolated and understood? Can we gain a better understanding of traditional agricultural techniques and identify elements that have proven successful in meeting a community's food needs? Can techniques adapted from physics and chemistry, which are greatly increasing our ability to date the past and to understand prehistoric man's interaction with his environment, continue to be developed to further our basic goals? How have modernization and change affected traditional societies? Can we use this knowledge to predict the effects of specific kinds of inputs on the social organization, demography, and health of traditional societies?

Significant Recent Achievements

Repair of Nervous System Damage

When a nerve or spinal cord has been crushed, or cut, it often fails to recover because of the development of scar tissue obstructions. Yet, it has been known for a long time that nerve cells can and will regrow if given the right environment. This fact has motivated a vigorous new effort among neuroscientists to find out why scar tissue forms and how it can be broken down. James Huston of the University of Maine has focussed upon the molecular structure of the protein building blocks of the scar tissue, called tubulin and glial fibrillary protein. He has discovered tubulin-like molecules that are bound together by disulphide cross-bridges, a kind of molecular bond which is susceptible to destruction by commonly available enzymes. Huston's work may prove to be critically important in the development of means to permit the nervous system to repair itself after injury.

Infant Vision

The question of how well infants can see has puzzled philosophers and scientists for hundreds of years. New techniques have been developed to yield answers to this question, and the research has both basic and clinical significance. Davida Teller and her colleagues at the University of Washington, Seattle, have shown that an infant's ability to attend a visual stimulus consistently can be utilized in the laboratory to measure visual acuity. She has shown that a) infants have about 20/400 visual acuity at birth, b) infant acuity improves slowly over the first year almost reaching the normal adult capability of 20/20 by their first birthday, c) infants have limited color vision by two months of age, and d) even as young as 1 month of age, they have excellent night vision. Because of the innovative efforts of scientists like Teller, the new behavioral techniques can be readily adapted to measure auditory and other sensory capabilities as well. As a result, a new capability for understanding the development of the nervous system has been acquired. The research has provided immediate practical benefits as well in that it is now possible to screen infants at risk for sensory problems in clinical settings.

Magnetic Orientation

The question of how migrating and homing animals reach exactly the same far-off places over and over again has interested both scientists and laymen for centuries. A variety of cues that may be used in this long distance navigation have now been identified. Of particular interest is the recent discovery by James Gould of Princeton University and Charles Walcott of the State University of New York at Stony Brook that there are small amounts of a magnetic substance, magnetite, in the abdomens of honey bees and in the heads of homing pigeons. This discovery is particularly exciting because both pigeons and bees are sensitive to the earth's magnetic field, and can be disoriented when the magnetic field is experimentally changed. For the first time materials have been identified within these animals' bodies to account for that sensitivity. Better understanding of bees' magnetic sensitivity should help apiculturists improve their economically important pollination services to agriculture, and increase the honey production of their hives. Knowledge of birds' magnetic sensitivity is important in assessing the impact of large antenna systems and other human disturbance of the earth's magnetic field. Finally, awareness of new sources of sensory information may help us to understand some of the still-unexplained abilities of human beings.

Early Civilization and Plant Domestication

The recent discovery of domestic barley from an 18,000 year-old Nile Valley site is dramatically altering our understanding of how and where the first steps toward Western Civilization were taken. Anthropologists had long placed the origins of domestication in the Middle East at approximately 9,000 B.C. in an area north of the Tigris and Euphrates Valley. At a site in the Wadi Kubbaniya near Aswan in Egypt, Fred Wendorf of Southern Methodist University and his colleagues have found carbonized grains of domestic barley in a stone age site dated by radiocarbon to between 16,000 and 15,000 B.C. The great significance of this discovery lies not only in its early date and unexpected locale but in the new light it sheds on the origins of the Neolithic Revolution. Anthropologists have assumed that population pressures led to experimentation with new subsistence techniques and that domestication in turn started society directly down the road to civilization. These findings suggest that new subsistence techniques and domestication developed before changes in settlement size, population density or social organization. Thus, rather than domestication resulting from population pressure, it may have permitted such changes. Anthropological research such as this on early civilizations not only helps to provide a better understanding of the origins and development of man, but it also contributes insight into contemporary societal problems and their potential solution.

Mathematical Theory of Learnability

The study of the acquisition of language by children has typically been very empirical and descriptively oriented. The processes involved have generally been regarded as too complex and multifaceted to be susceptible to formal modeling and mathematical investigation. Recent work by Kenneth Wexler and Peter Culicover of the University of California, Irvine, however, has provided a major advance. Wexler and Cul-

icover have demonstrated that for it to be possible for a child to learn a language, the language must have certain very specific properties.

One such property requires consistency in the application of certain kinds of grammatical rules to parts of a sentence. It appears that these properties are universal and apply in all languages. Discovering such universal properties of language is a fundamental goal of linguistic science. Wexler and Culicover's research is especially important because these properties are empirical predictions derived from their formal theory of language acquisition. A valid theory of language acquisition will be a giant advance in our understanding of the human capacity to acquire and utilize language.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan of $35,443,000 is $1,457,000 less than the FY 1980 Budget Request ($36,900,000). This reduction will slow the rate of activity primarily in neuroscience and anthropological research.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$33,073,342
FY 1980 Program	$35,443,000
FY 1981 Request	$38,700,000
Difference—FY 1981/FY 1980	$3,257,000

By reducing research support in less competitive areas, as determined by peer review, some additional funds will be made available to both maintain the current level of effort in some areas and to focus attention on a few areas showing special promise for near-term advances. Since the additional funds requested are less than the costs incurred by inflation, the total number of projects and investigators supported will necessarily be reduced.

Archaeological and anthropological research to identify the origins of humankind will receive increased attention. Partial start-up costs for an African Deep Lake Coring project are included in this effort. Biochemical and hormonal mechanisms underlying behavior will receive increased attention in the neuroscience and behavioral science areas.

Percentage increases for the four program elements are as follows:

Neuroscience	8.7%
Cognitive Science	7.7%
Behavioral Science	7.6%
Anthropological Science	13.4%

Coordination and Relation to Other Efforts

The NSF plays an important role in the support of basic research in the behavioral and neural sciences conducted primarily in universities. The Foundation provides over 90 percent of the Federal support for investigator-initiated research in anthro-

pology and linguistics. In psychology and the neurosciences, NSF support represents a smaller but significant component of the Federal total. NSF provides the essential core support of basic projects that are less immediately related to problems of health and disease than are the research efforts for which the National Institutes of Health and the National Institute of Mental Health bear direct responsibility.

There are extensive formal and informal interactions between the Foundation's program staff and their counterparts in the National Institutes of Health, the Alcohol, Drug Abuse, and Mental Health Administration, the National Endowment for the Humanities, the National Institute of Education, the Office of Naval Research, and other research agencies. In the event that some proposals are also submitted to another Federal agency, all proposals to be recommended for awards are discussed with that agency staff to assure that duplicate support will not occur. NSF cooperates in the joint support of specific projects when it is beneficial to the scientific project.

The Behavioral and Neural Sciences subactivity jointly reviews and supports projects with other programs in the Foundation. In FY 1979, projects were jointly supported with programs in the Divisions of Applied Research, Earth Sciences, Environmental Biology, Integrated Basic Research, Mathematical and Computer Sciences, Ocean Sciences, Physiology, Cellular and Molecular Biology, and Social and Economic Science.

The Foundation is a sponsoring agency and NSF program staff members serve on the Committee on Vision and the Committee on Hearing, Bioacoustics and Biomechanics of the National Academy of Sciences/National Research Council, the Interagency Panel on Early Childhood Research and Development, and the Interagency Panel for Research and Development on Adolescence. Staff members also serve on the Interagency Primate Steering Committee, the Interagency Round Table for Language Study, and the Federal Noise Effects Panel of the Environmental Protection Agency. NSF staff members attend meetings of various Federal advisory committees and councils as liaison representatives.

Neuroscience Program Element $17,000,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Estimate FY 1980	Estimate FY 1981	Difference FY 1981/80
Neurobiology	$8,207,118	$8,843,000	$9,550,000	$707,000
Sensory Physiology and Perception	6,313,045	6,800,000	7,450,000	650,000
Total	$14,520,163	$15,643,000	$17,000,000	$1,357,000

Objectives and Description

Research in neuroscience seeks to understand the mechanisms of action of nerve cells and sensory receptors, as well as the function of nervous and sensory systems. As the primary organ system underlying all behavior and learning, knowledge of nervous

system functioning is vital to understanding behavior and furthering applied efforts in areas of major human concern including education and mental health.

Specific objectives of neuroscience are to:

- Examine the chemistry of nerve cell membranes, because these underlie transmission of nerve impulses from place to place throughout the nervous system.
- Identify the processes by which sensory receptors respond to stimuli impinging upon the organism.
- Identify the chemical transmitter substances that act as messengers between nerve cells.
- Discover how information that has entered the nervous system is analyzed, stored, and retrieved.
- Examine the basis of the development of the nervous system and the processes responsible for regrowth and repair of damaged neurons.
- Discover the roles of hormones and neuropeptides (a new class of messengers) in brain function, especially in the control of pain, and their connection to the action of addictive, opium-like substances.
- Trace functional pathways in the nervous system with an array of extraordinarily precise, new techniques which permit neuroscientists to follow specific cells and signals through the enormously complex tracts of the brain.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The accomplishments of neuroscience have grown rapidly during the past decade. This has resulted in part from substantial increases in the number of scientists dedicated to nervous system research. Their increased ability to pose and answer more precise questions about brain and sensory mechanisms and the neural substrates of behavior has been a primary factor. The development of new techniques and related instrumentation has provided an important stimulus to progress.

In addition to funds released by selective reductions in less competitive areas, an increase of $1.4 million, from $15.6 million to $17.0 million in FY 1981, is requested to enhance research activity in the following areas:

- Identification and characterization of substances that act as chemical messengers between brain cells, and of the molecular machinery of neuronal membranes on which they act.
- Determination of the factors governing embryonic growth and repair of the nervous system.
- Examination of the basic processes by which environmental stimuli are encoded and analyzed by the auditory, visual, olfactory and gustatory systems.

Cognitive Science Program Element $5,600,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Estimate FY 1980	Estimate FY 1981	Difference FY 1981/80
Linguistics	$2,474,512	$2,600,000	$2,800,000	$200,000
Memory and Cognitive Processes	2,528,292	2,600,000	2,800,000	200,000
Total	$5,002,804	$5,200,000	$5,600,000	$400,000

Objectives and Description

Cognitive science research is focused on understanding how human beings attend to, acquire, store, retrieve, and use the information that guides actions, thoughts, and the use of language. Research is supported on the mental representation of knowledge, the development of cognitive capacities and the acquisition of language, human learning and thought, and related topics, including the reading process. Development of new experimental and theoretical approaches is encouraged. Specific objectives of cognitive science are to:

- Understand how knowledge is represented in the mind, and how information is entered into and retrieved from memory.
- Determine the process and sequence of cognitive development in children, and assess means for enhancing such development.
- Describe the influence of various environmental and cognitive factors involved in the acquisition of language by children.
- Discover and explain the biological foundations of language.
- Describe a range of the world's languages, including sign languages, to provide a major data base for developing general theories of language.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The emergence of cognitive science as a major area of inquiry involving a number of different disciplines has followed closely on the heels of neuroscience. Both are attracting increasing interest and increasing numbers of scientists. In order to take advantage of new opportunities and new techniques, some areas will receive reduced support. An increase of $400,000 to $5.6 million will allow slight enhancement in the following areas:

- Development of a unified account of the mental representation of diverse sorts of knowledge.
- Characterization of what children can do cognitively at various stages of their development. Current research indicates that young children handle numbers,

logical relationships, problem-solving and other cognitive activities quite well at a much younger age than previously thought. New techniques allow the cognitive capacities of preverbal infants to be studied.

- Determination of universal aspects of the language acquisition process by studying the acquisition of languages other than English, including sign languages.
- Identification of the biological underpinnings of language and cognition.
- Description of how motor behavior is related to thought, how it is planned and how it is executed.

Behavioral Science Program Element $8,500,000

Obligations by Program Subelement

Program Subelement	*Actual FY 1979*	*Estimate FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
Psychobiology	$4,105,049	$4,600,000	$5,000,000	$400,000
Social and Developmental Psychology	3,320,618	3,300,000	3,500,000	200,000
Total	$7,425,667	$7,900,000	$8,500,000	$600,000

Objectives and Description

Behavioral science research focuses upon an important and complex task: increasing knowledge of the individual and social behavior of human beings and other organisms. To accomplish this goal, behavioral scientists use systematic observation and direct experimental techniques in both field and laboratory settings. Information about the development of behavior, its biological bases, and contributing social and environmental factors are all essential to a full understanding of this topic. Specific objectives of behavioral science are to:

- Describe and explain how an individual's experiences can have potent and long-lasting influences on future behaviors.
- Determine the relationship between biochemical events and the phenomena of learning and memory.
- Identify hormones which influence the behavior of both non-human animals and human beings, and analyze the nature of the influence.
- Explain and predict the occurrence of various forms of social interaction, including nonverbal communication, aggression, leadership, and altruism.
- Understand the many ways in which social and individual behaviors develop and change throughout the individual's life span.

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FY 1981 Budget Highlights and Explanation of Increases and Decreases

A remarkable trend toward synthesis is under way in behavioral science. Integration across disciplinary lines and between field and laboratory approaches is evident. In order to maintain an effective program and further encourage this trend, an additional $600,000 to a total of $8.5 million will be combined with funds reoriented from other areas to provide some increased activity in the following areas:

- Role of hormones in the production and control of behavior.
- Chemical communication, including field studies of the use of chemical signals in individual and species recognition, social organization, and prey-trailing.
- Developmental studies of behavior, including longitudinal research on human development throughout the life span.

Anthropological Science Program Element $7,600,000

Obligations by Program Subelement

Actual FY 1979	Estimate FY 1980	Estimate FY 1981	Difference FY 1981/80
$6,124,708	$6,700,000	$7,600,000	$900,000

Objectives and Description

Anthropological research shares with other disciplines the goal of discovering regularities in human behavior. What distinguishes anthropology is its emphasis on the integration of biological and social sciences and its comparative breadth across both time and cultures. Cross-cultural anthropological studies extend our knowledge of contemporary society. Archaeology adds the horizontal or chronological dimension. Specific objectives of anthropological science are to:

- Compare diverse cultures to identify rules that regulate cultural variation.
- Describe the growth of complex social systems from their simpler primitive precursors. In the context of about 4 million years of human history, man is still adapting to contemporary life with large aggregations of people in cities and continues reliance on domestic plants and animals.
- Trace the course of human evolution over several million years and describe the rise of particular civilizations over millenia.
- Examine the nutritional and demographic effects of such changes as the introduction of agriculture into hunting and gathering societies.

FY 1981 Budget Highlights and Explanation of Increases and Decreses

A major effort within anthropology has developed toward the search for human origins. Our knowledge of the emergence and development of the human species has increased dramatically as the result of increased cooperation between paleoanthropologists and biological and physical scientists. The decade of the '80s should see another generation of cooperative projects attempting to fill the final gaps in the fossil record. As a significant part of this focused effort, participants at the NSF-sponsored "Human Origins Conference" in May 1978 strongly recommended a major project to obtain a series of deep cores from tropical African lakes. This undertaking, with planning begun in FY 1980, will provide detailed evidence of the shifting climatic and environmental conditions in tropical Africa over the last several million years. The data will be of importance to climatologists and ecologists as well as paleoanthropologists. The additional $900,000 requested, to a total of $7.6 million, will allow the deep lake coring project and related efforts in the search for human origins to go forward. Within the available resources, an effort will be made to maintain at least a constant level of effort in the following areas:

- Skeletal biology, to learn how early humans were affected by changes in environment, diet, and style of life.
- Urbanization, industrialization, and the development of local elites and bureaucracies in contemporary societies.
- Ecological investigation to obtain an improved understanding of the relationships between human populations and the environments in which they live.

QUANTITATIVE PROGRAM DATA
BEHAVIORAL AND NEURAL SCIENCES PROGRAM SUBACTIVITY

Proposals and Awards

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Number Proposals Received[1]	2,196	2,250	2,310
Number of Awards[2]	783	753	740
Dollars Proposed on Awards (Total)	$74,271,000	$79,650,000	$86,970,000
Dollars Proposed on Awards (Annual Rate)	43,038,000	46,126,000	50,380,000
Dollars Awarded (Total)	33,073,342	35,443,000	38,700,000
Dollars Awarded (Annual Rate)	27,895,000	29,880,000	32,620,000
Average $ per Award	42,240	47,100	52,300
Average Award Duration (Years)[3]	2.2	2.3	2.4

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 198079	Estimate FY 1981
Universities and Colleges	89.8	89.8	89.8
Industry	0.1	0.1	0.1
Federal Agencies	0.3	0.3	0.3
Other	9.8	9.8	9.8

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 198079	Estimate FY 1981
Senior Scientists Faculty[4]			
Number of scientist years supported	251	260	270
Amount of faculty support	$5,714,035	$6,378,000	$6,960,000
Cost per scientist year	22,770	24,500	25,800
Postdoctoral Associates			
Number of scientists years supported	85	100	100
Amount of postdoctoral support	$1,603,428	$1,790,000	$1,960,000
Cost per scientist year	16,880	17,900	19,600
Graduate Students			
Number supported	527	550	560
Amount of graduate student support	$2,682,098	$2,994,000	$3,270,000
Other Personnel Costs	3,265,163	3,645,000	3,980,000
Capital Items			
Major equipment	—0—	—0—	—0—
Equipment and instruments	$3,920,100	$2,900,000	$3,170,000
Other Costs[5]	8,279,522	9,242,000	10,090,000
Indirect Costs	7,608,996	8,494,000	9,270,000
Total	$33,073,342	$35,443,000	$38,700,000

[1] Includes proposals for committed renewals, etc.
[2] Includes awards for committed renewals, supplements, etc.
[3] Includes continuing grants for full length.
[4] Includes faculty associates and other professionals.
[5] Fringe benefits, expendable equipment, travel, publication costs, computer costs, other direct costs.

SOCIAL AND ECONOMIC SCIENCE PROGRAM SUBACTIVITY $27,800,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Economics, Geography & Political Science	$14,524,147	$15,300,000	$15,002,000	$15,800,000	$798,000
Social Measurement & Analysis	10,861,897	11,600,000	11,204,000	12,000,000	796,000
Total	$25,386,044	$26,900,000	$26,206,000	$27,800,000	$1,594,000

Objectives and Description

The Social and Economic Science subactivity focuses on research in the social and economic sciences that is designed to assist the development of principles describing how social and economic systems work, how they change, and how they affect the lives and well-being of individuals and groups. Adequate knowledge of these systems can assist decisionmakers in formulating effective policies and in anticipating the results of alternative courses of action.

The body of fundamental social and economic knowledge of today is inadequate for effective application to many problems of current policy. Since the Foundation is the only agency of the Federal government with a broad mission to support basic research in the social sciences, NSF programs are directed toward increasing the base of social and economic information. By supporting research in advanced methods and theory, the Foundation aims to strengthen U.S. social and economic sciences and improve our ability as a Nation to deal effectively with complex social and economic issues.

Major Research Questions

The major research questions engaging the attention of basic researchers in the social and economic sciences reflect the enduring, long-range concerns confronting our society, and include the following:

- How are economic decisions affected by anticipations of the future state of the economy, and how are such anticipations formed?
- How do governmental regulations, government fiscal and monetary policies, and other governmental actions affect the performance of the economy?
- How do economic, social and cultural factors affect the stability of legal and political systems?

- What social conditions influence the strategies that organizations pursue to survive or grow, and what accounts for differential rates of organizational growth or contraction?
- How does the growth of large scale organizations affect the composition, compensation, productivity, and satisfaction of the labor force?
- What factors influence the location of industries and migration of people within and between geographical regions?
- How do governmental actions, economic conditions, environmental preferences, population composition, and citizen participation in legal and political decision-making influence the growth and decline of cities and the selection of places of residence within metropolitan areas and nonmetropolitan areas?

Significant Recent Achievements

Inflation and the Impact of Taxation

There is increasing public concern, and a corresponding research interest, about the way inflation changes the impact of taxation. While some issues of theory remain to be resolved, significant recent research contributions have involved the compilation of empirical evidence and systematic quantitative analysis. One such research effort by Martin Feldstein and Laurence Summers of the National Bureau of Economic Research analyzes the effects of inflation on the taxation of corporate income. Their calculations show that in 1977, the extra taxes caused by the mis-measurement of depreciation and inventories exceeded $32 billion, more than one-third of the total tax paid on corporate source income by corporations, their shareholders and their creditors. Inflation raised the 1977 effective tax rate on the total real income of the nonfinancial corporate structure from 43 to 66 percent, a return to the level of the mid-1950's before the impact of accelerated depreciation and the investment tax credit.

Previously, some analysts argued that inflation does not increase the tax on corporate income because firms deduct nominal interest payments (rather than real interest payments) in calculating taxable profits. Feldstein and Summers show that this argument is wrong because the extra tax paid by creditors on inflated interest payments is as large as the tax savings by corporations and their owners. They conclude that debt can be ignored in evaluating the net impact of inflation on the total tax burden on corporate capital.

Feldstein and associates' research on inflation shows both the importance and feasibility of studying how tax laws affect individual behavior. Since government analyses of proposed tax changes typically assume that the behavior of taxpayers would be unchanged, further behavioral studies of taxation should provide a new type of measurement that can improve the evaluation of alternative laws and public policies.

The Consequences of Organizational Size

The growth of large scale organizations to embrace most features of modern life has stimulated mounting research on the influence, flexibility, and viability of such organizations. A major influence identified by several NSF funded projects has been the effect that large organizations have had in fostering careers that are tied increasingly to organizations rather than to occupations or professions. Employers play a crucial role in the process of social stratification in the U.S.: the jobs they provide are the primary mechanism by which individuals are distributed among occupations and by which earnings are distributed among persons. But the vast majority of research on socioeconomic achievement ignores employers completely, concentrating instead on individual characteristics. Ross Stolzenberg of the University of Illinois has been studying employer effects on inequality and has found that the size of the organization or firm in which the employee works is a major factor affecting the socioeconomic achievement of the employee. Income attainments of individuals vary greatly within occupations or professions but those who work in larger organizations earn more, largely because there are more opportunities for advancement. A related finding is that the structure of large organizations creates conditions that make it especially convenient for them to act as if schooling were relevant to job performance, whether or not a relationship between workers' schooling and productivity actually exists. It would then follow that increases in the average size of establishments will tend to increase the importance of schooling in determining workers' earnings and occupational status.

Developmental Factors in Later Attainment

The processes of social mobility, and of socioeconomic attainment in the United States and in other countries have been a focus of attention for the past 20 years. Discussion continues on the degree of inequality of opportunity and the factors that determine achievement. Many past analyses rest on incomplete data or inadequate methodology; that consequently, investigators are unable to sort out complex factors and there have been contradictory findings. A particularly apt example during the International Year of the Child is the influence of time devoted by parents to children on the child's cognitive development and subsequent adult economic status.

Using data from the National Time Use Survey conducted by the University of Michigan's Institute for Social Research in 1975-76, C. Russell Hill and Frank P. Stafford have examined how much time parents devote to their children, particularly in the preschool years, and whether social class and education differences can account for the process of intergenerational transfer of income inequality. The results reveal substantial differences in per-child care across levels of parental education. For example, a college educated mother with *two* preschoolers in the home will spend as much time in per-child care as will a high school educated mother with *one* preschooler in the home, and more than twice as much time in per-child care than a grade school educated mother with *one* preschooler in the home. Although increases in family size reduce per-child care, better educated parents and those of higher socioeconomic status provide significantly greater amounts of per-child care even with

larger numbers of children in the home. The analyses of Hill and Stafford also reveal that more educated parents interact more with their children throughout the childrens' youth, not just in the preschool years. They surmise that it may be consistency and variety of interaction over a long time period that create differences in child development. Morever, the greater contribution of more educated parents in providing time and financial support to older children may count heavily for the later functioning of their children in the labor market and other spheres of adult life. The analyses on child care have important implications insofar as they show substantial differences in childhood environments according to level of parental education and economic status. In addition they represent only one example of work that can be done with National Time Use Data.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan for the Social and Economic Science subactivity represents an overall decrease of nearly $700,000 below the FY 1980 Budget Request from $26.9 million to $26.2 million. The decrease has been allocated between the two program elements, with Economics, Geography and Political Science reduced by $298,000 and Social Measurement and Analysis by $396,000. This distribution was made on the basis of the different size of the component sub-elements of the two program element sections, the nature of ongoing commitments, and present knowledge of the most promising new research directions. The adjustments will reduce the size and pace of new work in social indicators development, research on social movements, and basic research with potential for application in housing, transportation, and medicine. New research efforts will have to be funded at minimal or pilot levels.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$25,386,044
FY 1980 Program	$26,206,000
FY 1981 Request	$27,800,000
Difference—FY 1981/FY 1980	$1,594,000

The requested increase of $1,594,000 from $26,206,000 to a total of $27,800,000 is below the expected level of inflation and follows several years of essentially level funding.

Percentage increases for the two program elements are as follows:

Economics, Georgraphy and Political Science	5.3%
Social Mesurement and Analysis	7.1%

Areas of research to be emphasized in the FY 1981 Budget include:

- Improving the scientific adequacy of survey operations and the quality of survey data used for basic research in the social sciences.

- Research on the formation of expectations about future market considerations and prices, the stickiness in the economy created by long term contracts, macroeconomic modelling techniques to incorporate changing expectations, and fundamental processes of population redistribution.
- Further development of social indicators and improvements in the utility and accessibility of Federal statistical data.

These emphases will require an actual decrease in the level of effort compared to FY 1980 in many areas of research support. New projects will be supported as existing grants are terminated and as less competitive topics (as determined by peer review) are phased out. This approach will allow the continuation and initiation of basic research pertaining primarily to important work on the economy, large scale organizations, and social institutions, and social science data resources, as described in greater detail in the sections that follow.

Coordination and Relation to Other Efforts

NSF plays a unique role in support of social science research. It provides about half of the total Federal support for basic research to scientists in colleges and universities. Other funding sources rarely provide assistance for theoretical work, methodological development,and data resource improvement. Social science activities in other Federal agencies are oriented toward more immediate action and policy concerns and are not designed to develop the fundamental knowledge necessary for long-range progress and improvement in the utility of the social sciences. Research studies supported by other agencies commonly draw on basic knowledge from the relevant disciplines to which NSF supported research has made an important contribution. For example, NSF has supported basic work on price indexes which measure changes in the quality of goods and services; the results of this work have been incorporated into the standard computation of the GNP deflators. The macroeconomic models currently used in the Department of Commerce are direct descendants of a Brookings Institution model that resulted from experimental work supported by the Foundation in the early 1960's. Research on econometric methodology continues to be supported by NSF, and this work feeds into the econometric models now in use in various governmental units but does not duplicate the work supported there.

Coordination is maintained with scientists and research administrators in other agencies, especially in Health and Human Services (including but not limited to the National Institute for Child Health and Development and the National Institute of Mental Health), the Department of Commerce (including but not limited to the Bureau of the Census and the Bureau of Economic Analysis), Treasury, Justice, Labor, the Federal Reserve and the Council of Economic Advisers.

Economics, Geography and Political Science
Program Element $15,800,000

Objectives and Description

The interdependence of economic, political, legal, and locational variables in our society has become increasingly apparent. Consequently, the objective of this program is to support research that gives particular attention to those issues that cross traditional lines and promise to improve scientific understanding of the processes underlying the performance of the economy, the causes and consequences of governmental actions, and the geographic distribution of social phenomena.

Basic research activities in economics are directed toward increasing the rigor and generality of economic theories and the reliability of their testing and quantitative implementation. The emphasis is divided between the analysis of microeconomic phenomena and theoretical and empirical issues pertaining to inflation and unemployment. Attempts to unify these two main branches of theory, linking the behavior of the micro units of the economy with the aggregative consequences are given special emphasis.

Research in geography and regional science is directed toward advancing understanding of the criteria, processes, and problems involved in locational decisions. Recent work has focused on location theory, regional economic development and stagnation (including urban regions), population redistribution, environmental management, and the spatial analysis of societal problems. One general phenomenon observed in the United States and in other industrial countries, has been the growth of housing demand in rural areas as a consequence of migration to nonmetropolitan areas. Excess demand for this type of housing has driven prices up to the point where traditional theoretical explanations involving the tradeoff between housing costs and commuting costs no longer seem valid. The recent increase in fuel prices, however, is affecting this trend and research is now focusing on the relationship between changes in commuting and housing costs and the spatial demand for housing. Continuing research on residential location theory and population redistribution, including analyses for a broad range of different types of households—the poor, elderly, disabled and for minority and single parent families—promises to provide additional fundamental knowledge about how household location decisions are made. Knowledge of the household location decision process has implications for understanding and anticipating shifts in the distribution of population and for providing improved quantitative forecasts of area population growth which affects such public policy concerns as adequate housing, unemployment, the provisions of public services and energy consumption.

One of the objectives of political science research is to increase basic knowledge about the complex and dynamic interrelationships between citizens, their governments, and larger societal institutions. Support is provided for studies of trends in

turnout and voter decisionmaking. Current attention is directed to the role of the media in elections, changing election laws, and citizens attitudes towards candidates and government. Work on political change outside of the United States context is also supported. For example, U.S. researchers collaborating with Western Europeans are assessing long-run trends in citizen and governmental support for greater European unification while another set of scholars is examining the development and viability of democratic institutions and loyalities in the new European regimes. Among studies in the area of political economy are those that examine the effects of international investments and the varying role of the state in political and economic development, and the effects of these changes on the distribution of national wealth and resulting patterns of political changes in less developed countries.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

An increase of $798,000 from $15,002,000 to a total of $15,800,000 is requested for this program element, of which approximately two-thirds will be directed toward research in economics. Major emphases include:

- Micro-level decisions and the macro-outcomes of national income, employment and prices;
- Interaction of fiscal and monetary variables, particularly as they relate to the transmission of the response to economic disturbances;
- Nature and consequences of non-market decisionmaking in both the private and public sectors;
- Determinants of market structures, from competition to monopoly, and their differential effects on economic efficiency and income distribution;
- Decision processes in multinational and multiregional firms that create and dissolve business and industrial linkages, affecting the expansion or contraction of employment and economic activity in an area;
- Changing geographic organization of land use and its effects on travel and traffic patterns, environmental quality, energy consumption, employment locations, urban decline, population distribution and the provision of public services;
- Effects of Federal urban policies on the political processes of urban communities;
- Impacts of alternative bureaucratic structures on policy making and the delivery of public services.

Social Measurement and Analysis
Program Element $12,000,000

Objectives and Description

The objectives of the research supported by this program are: (1) to improve basic understanding of human social interaction in communities, complex organizations and small groups; (2) to facilitate the development of fundamental knowledge about the operation and change of social institutions, including legal and scientific institutions; and (3) to improve the methods and data resources for social research.

The central role of complex organizations at every level of our society has highlighted the importance of knowing more about their structure, operation, adaptability to change, and impact on the larger social setting. A parallel and complementary research goal is directed toward the study of decisionmaking in units of varying sizes and structure. The impact of law, differing methods of dispute resolution and the cause of change in the legal system are topics of special interest. So too are studies to illuminate the factors that affect the use of law as well as the nature, sources, and consequences of variations in legal institutions. Other research focuses on the study of science as a specialized form of social organization. Underlying this effort, is support for the development of social science measurement methods and data resources. Currently funded efforts include major data resource projects that will provide important data for future analysis relating to such basic and policy concerns as migration, factors underlying trends in fertility and mortality rates, and the processes underlying shifts in the composition of the labor force.

Monitoring major changes in national social trends such as the decline in fertility, the reversed migration trends that are bringing new growth to rural areas and central cities, the increasing proportion of the aged and the rising participation of women in the labor force is the province of many agencies. Improving the way these measures are taken and analyzing their implications are parts of this element's research activity. Basic knowledge about the processes bringing about these social and demographic behaviors is crucial for understanding their consequences. For example, smaller family and household size raise questions about the distribution and organization of social services. Changing age structure affects job opportunities, community needs, and the allocation of resources among constituent groups.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The requested increase of $796,000 from $11,204,000 brings the total funding in FY 1981 to $12,000,000. Enhanced activity will focus on complex organizations, social impacts of population change and family change, and evaluation of research and

measurement methods. Other topics will be maintained at previous levels or subject to selective reductions. Major research areas include:

- New methods and models for the quantitative analysis of social statistical data;
- Survey operations research to make survey data more reliable and valid;
- Development and testing of new social indicators, including expanded time-use series;
- Mechanisms of dispute resolution and the conditions influencing compliance with law;
- Processes of theory change in science and the interaction of science and social forces;
- Assimilation of recent immigrant groups and their adaption to U.S. society;
- Basic principles of social behavior in small groups and large organizations;
- Consequences for families, organizations, and communities of changing availability and costs of energy resources.

QUANTITATIVE PROGRAM DATA
SOCIAL AND ECONOMIC SCIENCE PROGRAM SUBACTIVITY

Proposals and Awards

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Number of Proposals Received[1]	1,089	1,100	1,110
Number of Awards[2]	460	480	500
Dollars Proposed on Awards (Total)	$44,725,000	$46,140,000	$48,940,000
Dollars Proposed on Awards (Annual Rate)	29,901,300	30,870,000	32,740,000
Dollars Awarded (Total)	25,386,044	26,206,000	27,800,000
Dollars Awarded (Annual Rate)	19,889,100	20,520,000	21,770,000
Average $ per Award	55,190	54,600	55,600
Average Award Duration (Years)[3]	1.9 yrs.	1.9 yrs.	1.9 yrs.

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	85.5	85.5	85.5
Industry	—0—	—0—	—0—
Federal Agencies	0.2	0.2	0.2
Other	14.3	14.3	14.3

Personnel and Other Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Senior Scientists Faculty[4]			
Number of scientist years supported	235	230	225
Amount of faculty support	$6,883,516	$7,127,000	$7,560,000
Cost per scientist year	29,290	31,000	33,600
Postdoctoral Associates			
Number of scientist years supported	45	40	40
Amount of postdoctoral support	$983,359	$1,018,000	$1,080,000
Cost per scientist year	21,850	25,500	27,000
Graduate Students			
Number supported	313	300	300
Amount of graduate student support	$2,042,362	$2,115,000	$2,240,000
Other Personnel Costs	1,790,218	1,853,000	1,970,000
Capital Items			
Major Equipment	—	—	—
Equipment and Instruments	171,700	100,000	100,000
Other Costs[5]	6,606,158	6,840,000	7,260,000
Indirect Costs	6,908,731	7,153,000	7,590,000
Total	$25,386,044	$26,206,000	$27,800,000

[1]Includes proposals for committed renewals, etc.
[2]Includes awards for committed renewals, supplements, etc.
[3]Includes continuing grants for full length.
[4]Includes faculty associates and other professionals.
[5]Fringe benefits, expendable equipment, travel, publication costs, computer costs, other direct costs.

ENVIRONMENTAL BIOLOGY PROGRAM SUBACTIVITY $40,700,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Ecology	$4,942,244	$5,600,000	$5,222,800	$5,500,000	$277,200
Ecosystem Studies	11,663,199	12,750,000	12,372,800	13,000,000	627,200
Systematic Biology	7,550,647	8,100,000	7,922,800	8,400,000	477,200
Biological Research Resources	4,696,561	7,200,000	6,922,800	8,100,000	1,177,200
Population Biology and Physiological Ecology	5,100,132	5,300,000	5,222,800	5,700,000	477,200
Total	$33,952,783	$38,950,000	$37,664,000	$40,700,000	$3,036,000

Objectives and Description

Environmental biology focuses on living systems and the interaction of these systems with the environment. One objective of the Foundation's research support in the Environmental Biology subactivity is understanding ecological interrelationships among components of terrestrial and freshwater ecosystems. The studies of interrelationships are focused on several levels of biological and genetic principles that describe the adaptations of plants and animals to their specific microenvironments; the interrelationships among species of natural assemblages are a central interest of community ecology; ecosystem studies focus on the totality of interrelations among coexisting organisms and their non-living environment, especially on productivity, nutrient cycling, and system responses to stress.

A second objective of Environmental Biology is to identify and interpret evolutionary relationships among the living and extinct species of plants, animals, and microorganisms. Systematic biologists employ a variety of molecular and mathematical techniques, in addition to traditional methods, in assessing the significance of species characteristics for a complete classification of all living entities. A third objective is to develop and maintain biological research resources, vital to effective research in all fields of biology, such as systematic collections, living stock centers, field research facilities, and controlled environment laboratories.

Major Research Questions

- How do mutualistic interactions, such as pollination, balance competitive interactions in biological systems?
- What attributes of ecosystems confer resiliency and resistance on the system in response to environmental disturbance?

- What are the taxonomic and biological characteristics of tropical plant and animal species in endangered habitats?
- What are the temporal patterns of ecological systems over periods of five to ten or more years?
- What is the adaptive significance of geographic patterns of enzyme variability within populations?
- How do the biota interact with the atmosphere to control atmospheric carbon dioxide and in response to acid rain?

Significant Research Achievements

Forest Ecosystems

Peter Vitousek, University of Indiana, and several colleagues at other universities are studying the physical and biotic processes which affect forest nutrient turnover rates. They have identified several major processes in forest development that prevent nitrogen loss. These processes, if disturbed, result in losses of nitrogen and other elements. The most important are biological and include plant uptake of nitrogen after perturbation, nitrogen immobilization, nitrification and microbial activity which converts ammonium to nitrite and nitrate in the soil. In some systems, principally in western wet coastal forests, the amount of water that flows through the system and transports nitrate is very important on a seasonal basis. On steep slopes in the West, the movement of dead wood debris as well as increased movement of soil sediments may account for a much larger loss of nutrients than flow through the soil into ground water.

Of all these processes perhaps the most important is nitrogen immobilization. Clear cutting can create problems because the immobilizing source, the forest community, itself is removed. In the East where considerable debris is left after harvest, there is less of a problem. In the West where a large proportion of the biomass is removed during clear cutting, the effect is more serious.

In a related effort, Martha Christensen of the University of Wyoming has been investigating the role of mycorrhizae, soil- and litter-living fungi, in reclamation of seriously disturbed lands. Disturbed sites are frequently produced in mining and construction activities and pioneer plant species are often slow in becoming established. Consequently, there is heavy erosion and continued land degradation. Christensen has found that fungal mycorrhizae, widespread root-symbionts of native grassland communities, improve the growth and survival of domestic plant hosts when inoculated into stripmined sites.

Carbon Dioxide

Increased consumption of fossil fuels augments the carbon dioxide in the atmosphere, an increase that could result in pronounced climatic changes. Ecosystem scientists have been studying the biota as a source or a sink of CO_2.

The main approach has been to predict CO_2 levels with mathematical models that utilize data on carbon transfer in atmospheric, terrestrial and aquatic compartments. Oak Ridge National Laboratory (ORNL) has constructed a model to measure turnover times of carbon in the biosphere. Initial results suggest that in order to maintain carbon in the atmosphere at a constant level, the area allowed for regrowth must exceed the area deforested by a factor of six.

The ORNL group has had considerable success with modeling climate. A temperate forest model has been run for a 16,000-year period to predict the vegetation in past times. The output has been checked against the pollen profile describing the paleovegetation for the eastern U.S. and there has been a very good fit between the simulation and the available data. This suggests that a model can be a potentially valuable tool for creating dependable understanding of carbon flow through the biosphere.

A Terrestrial Carbon Model is being developed at the Marine Biological Laboratory, Massachusetts (MBL) to examine the contribution of soils and waters to the carbon balance. This model indicates that oceanic CO_2 uptake *via* diffusion and mixing alone is not large enough to account for the difference between the estimated contribution from the CO_2 sources and the measured atmospheric increase over the past few decades.

Both the MBL and the ORNL efforts conclude that the key to understanding the global carbon problem involves carbon balance calculations in the terrestrial biota since models of oceanic CO_2 indicate that current rates of uptake and mixing are not sufficient to balance the global carbon budget. Both studies point conclusively to the fact that major studies must be made of carbon dynamics in soils of key representative areas selected across the earth.

Advances in Population Genetics

Classical population genetics theory holds that natural selection acts on the characteristics of individual organisms such that individuals possessing favorable characteristics survive and reproduce more successfully than those lacking such characteristics. Natural selection thus acts indirectly on the genes that govern these traits. This indirect action is well understood for many single gene traits (Mendelian inheritance) but evolutionary change in polygenic traits (controlled by several genes) is less well-understood because of the complex interactions among them.

In general, experimental analysis of multiple gene traits is possible for plants and some animals but not for humans. Therefore, Marcus Feldman and colleagues at Stanford University have been using mathematical models to study patterns of inheritance and rates of evolution of polygenic traits in human beings. One study involves the inheritance of susceptibility to disease. Their modeling effort assumes a simple gene system to assess the evolutionary effects of contagious and familial-transmitted disease. Contagious transmission occurs when the disease is passed from member to member of the population; familial transmission is from parent to child. Both are common types of disease transmission. The results indicate complex patterns of the evolution of disease resistance that are quite different from the simple Mendelian

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pattern. Resistance is dependent not only on the degree of deleterious effects of the disease, but also on how the disease is transmitted. This suggests that the genetic basis and evolution of resistance to contagious diseases is quite different from the inheritance and evolution of familially transmitted diseases. In addition to testing basic assumptions of evolutionary theory, these results have potential for developing a more complete understanding of disease transmission and the evolution of susceptibility to disease in human populations.

Evolution of the Rice Grasses

The unexpected discovery of rich and extensive new fossil floras and faunas during field work in Nebraska in 1978 has enabled Joseph Thomasson of Black Hills State College to document an unusual eight million year old phylogenetic trend in several important grasses, including the genus of rice grass, *Oryzopsis*. It is usually difficult to trace the development of grasses into the past since the key characters used to determine relationships are not preserved in fossils. In the case of rice grass, fossil plants have been collected in quantity and variety at nearly all stratigraphic levels and in a condition in which the cells of the reproductive organs of the plants are well preserved. These cells show distinctive changes in characteristics from the oldest to youngest strata of rock and demonstrate clearly the development of these plants over a span of 5-7 million years.

In addition to the grasses, the Nebraska deposits are yielding abundant fossil materials of mastodons, horses, rhinoceroses and tortoises. At least eight genera of fossil plants have been found in association with the vertebrate remains. The associated plant and animal fossils allow unparalleled interpretation of the paleoecology of the late Tertiary strata. The flora and fauna recovered suggest that the climates 5-7 million years ago in the Ash Hollow region were warmer than that which presently characterizes the region. It was approximately similar to that presently found in Western Sudan—a savanna community with a mean annual rainfall of 50-70 cm.

Systematics of Soil Nematodes

Soil-inhabiting nematodes form a significant component of the biotic world. Cyst and root-knot nematodes *Meloidogyne* and *Heterodera)* are considered by agriculturists to be one of the five most important plant pathogens in the world. These organisms are extremely interesting biologically in addition to their proclivity for plant damage. They reproduce by a complex series of heriditary mechanisms involving both parthenogenesis (asexual reproduction) and modification of chromosome number.

Anastasios Triantaphyllou of North Carolina State University has studied species of cyst and root-knot nematodes from the viewpoint of morphology, physiology, cytology, and DNA composition. He and his collaborators have shown that extensive changes in reproductive pattern and chromosomal structure have resulted in certain damaging species that do poorly in natural habitats, but are highly successful under cultivated crop conditions. They exploit the artificial and relatively recent environment provided by man's agricultural activities.

Triantaphyllou's research findings build on fundamental biological knowledge and lead to a better understanding of present and past relationships of organisms that have come to have a significant impact on agricultural activities. The fact that one can track the previous history of the parasites and relate it to current farming practices and problems may be important in developing future studies on the ecology and control of these important organisms. Continued efforts to discover resistant crops and to plant them in intelligent crop rotation will minimize conditions favorable for nematode development.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The changes in the FY 1980 Budget Plan reflect minor adjustments that were required by the amounts appropriated to the National Science Foundation.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$33,952,783
FY 1980 Program	$37,664,000
FY 1981 Request	$40,700,000
Difference—FY 1981/FY 1980	$3,036,000

The $40,700,000 requested for Environmental Biology in FY 1981 is $3,036,000 more than the FY 1980 program of $37,664,000. This will help reduce the full impact of inflation on environmental biology.

Percentage increases for the five program elements are as follows:

Ecology	5.3%
Ecosystem Studies	5.1%
Systematic Biology	6.0%
Biological Research Resources	17.0%
Population Biology and Physiological Ecology	9.1%

Projects scheduled for increased attention in FY 1981 include:

- $600,000 for increased support on biogeochemical cycling and ecosystem dynamics, especially related to global carbon dynamics and response to acid rain.
- $300,000 for increased support on the ecology of organisms in endangered tropical forest environments, for microbial ecology, and for studies of ecological interactions.
- $400,000 for increased support on the systematics of organisms, especially those from poorly known but endangered tropical habitats.
- $1,200,000 for increased funding of resources for long-term ecological research and maintaining field research capability.

- $400,000 for increased funding of genetics of natural, pest, and wildlife populations basic to understanding the dynamics of plant, animal and human populations under a variety of environmental stresses.

Coordination and Relationship to Other Efforts

According to an analysis of the reports published in key journals, the NSF, through the Environmental Biology program provided essentially all of the Federal support for basic research in systematic biology, population (of non-human organisms) biology and ecology. Other Federal agencies, such as Departments of Agriculture, Interior, and primarily Energy and the Environmental Protection Agency, support applied environmental research. Many of these activities are built upon basic research findings supported by NSF. There is coordination through interagency coordinating committees and task forces to fit the basic and applied research thrusts together. This is especially true in connection with problems of tropical deforestation, acid rain, global carbon dioxide, and development of research natural areas and biosphere reserves.

Ecology Program Element $5,500,000

Objectives and Description

The Ecology program element supports research primarily at the levels of (1) interacting populations of two or more species, and (2) biotic communities in which many species populations interact in complex fashion. These studies involve terrestrial, freshwater, and estuarine environments, and include environments managed or impacted by man.

The objectives of research are to improve knowledge in several broad areas, including:

- The role of microbial interactions in controlling the basic fertility and productivity of ecosystems.
- The role of interactions among higher organisms, including competition, herbivory, predation, and pollination, in regulating the abundance and activity of the participating species. This research is basic to the development of strategies for integrated pest management in agroecosystems.
- The interacting roles of past (evolutionary, biogeographic, and historical) and present (species interactions and biotic succession) factors in determining the structure and function of biotic communities.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $277,200, from $5,222,800 to $5,500,000, will support continuation of research on:

- Dynamic aspects, including molecular, of species interactions, such as predation and those of herbivores on plants in natural and agricultural systems. Particular emphasis will be on the complex interactions in tropical forests, and in crop systems.
- Role of soil microorganisms in controlling rates of decomposition and other transformations of both natural and pollutant compounds. This research is crucial for understanding nutrient cycling in both temperate-zone and tropical ecosystems.

Ecosystem Studies Program Element $13,000,000

Objectives and Description

The objectives of the Ecosystem Studies program element are to increase understanding of ecosystem structure, function and relationships and to improve methods for predicting the probable environmental consequences of man's activities in managing and exploiting both renewable and nonrenewable natural resources. This program focuses on the multiple interrelationships occurring among arrays of organisms in the context of their total environment. Properties and responses of whole ecosystems, such as productivity, nutrient cycling, reservoirs for toxic materials, and resistance to disturbance, are examined.

The specific objectives of the Ecosystem Studies program element are to:

- Increase basic information on structure and function of natural, managed and human-dominated ecosystems;
- Develop new methods to predict stability and change in complex, highly variable ecosystems;
- Encourage the acquisition of basic ecosystem research information for the purpose of solving pressing problems of ecosystem management, such as global carbon dioxide and acid rain.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The $627,200 increase, from $12,372,800 to $13,000,000, will help support research in the following areas:

- Nutrient Cycling and Global Biogeochemistry. Mineral cycling has been an important thrust of the program. Improved understanding of biotic relationships

for specific ecosytems can now be used in coordination with the physical sciences to address problems emerging on a global scale. Carbon, nitrogen, and sulfur are of primary interest, and human activity has had an impact on each. In addition, man has introduced a wide array of toxic compounds into most ecosystems. Their fates and ecosystem effects require elucidation. Ecologists working with geochemists and atmospheric scientists can contribute to research on important questions of the global cycle; namely, whether terrestrial biomass is a net source of or sink for carbon dioxide. The role of tropical forests is of great interest. The fundamental research supported here provides models and new techniques for more applied research of other agencies, such as the Department of Energy.

- Patterns of Ecosystem Stability and Change. Ecosystems can be understood as being stable, as in a natural reserve, or highly dynamic, as in rivers and wetlands. The temporal patterns of ecosystem structure and function are poorly known, yet are important in a theoretical sense and also in evaluation of management alternatives and land planning.

Systematic Biology Program Element $8,400,000

Objectives and Description

The research supported by the program element of Systematic Biology identifies, describes, and interprets the myriad forms of plant and animal life. By establishing evolutionary relationships, a natural system of classification is developed.

The primary objectives of the Systematic Biology program element are to develop:

- Information on the identities, relationships, and distributions of living species, and to use the fossil remains of extinct species to provide knowledge of the organic changes through the course of the earth's history;
- Principles and methods that will allow more efficient gathering, processing and analyzing of information on relationships among these myriad species.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $477,200, from $7,922,800 to a total of $8,400,000, will help support the following areas:

- Biomolecular Studies. These studies are allowing systematists to derive data that reflect the basic genetic attributes of species to supplement data derived indirectly from morphological studies. The data are helping to resolve some questions of evolutionary relationships that have long been disputed.
- Numerical Taxonomy. The availability of biomolecular data to supplement existing morphological data has necessitated new quantitative and automated techniques to measure degrees of similarity and ancestry.

- Biology of Humid Topics. The rich and little-known assemblages of plants, animals and microorganisms of tropical forests are rapidly undergoing disturbance and extinction. As a result, the majority of tropical forest may be lost in 20 to 50 years. Much more knowledge of the systematics and ecology of the organisms composing tropical forest systems is necessary for an understanding of their biology, as well as for applied studies.
- Paleobiology. The concept of plate tectonics, developed within the geological sciences, has opened a whole new realm of research in paleobiology. Development of new oceanic basins, such as that of the modern Atlantic, has had profound effects upon the diversity of life on earth. Thus, paleobiologists are approaching a time of synthesis in which geological, geophysical and evolutionary data can be unified with respect to realistic interpretations of the history of life.

Biological Research Resources Program Element $8,100,000

Objectives and Description

The Biological Research Resources program element is designed to provide support for major scientific tools and facilities that are of crucial importance to research in biology. These include living collections of various kinds, field facilities such as experimental ecological reserves and field stations, and systematic research collections.

The NSF staff continues to work closely with scientific societies to identify and assist biologists planning for the development, management, and utilization of biological resources of national importance.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The $1,77,200 increase, from $6,922,800 to a total of $8,100,000, will provide support for the following:

- Further development of projects on long-term ecological measurements and maintaining field research capability. Only long-term research in environmental biology can fill the critical void in understanding the kinds and effects of long-term changes in natural systems. Without knowledge of long-term trends, as opposed to cyclic changes, it is not possible to evaluate the effects of man's alterations of the environment. The initial projects will be conducted at representative sites within a network of experimental ecological reserves.
- Expansion of computerization of data-processing for systematic collections of national significance. There is an increasing need by ecologists and resource planners for ecological as well as systematic data about specimens used to verify identifications.

- More adequate centers for preservation of genetic resources. This need is especially significant given extinction of tropical species.

Population Biology and Physiological Ecology Program Element $5,700,000

Objectives and Description

The program element of Population Biology and Physiological Ecology provides support for basic research on the adaptations of species through studies of their ecology, physiology, behavior, life history, and genetic composition.

The objectives of the program element are to:

- Discover the principles that describe the physiological, behavioral and social adaptations of animals and plants to their respective environments;
- Understand the life histories of plants and animals in terms of evolutionary biology and natural selection;
- Understand the process of evolution by studying the frequencies of specific genes with known metabolic and physiological roles.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

An increase of $477,200, from $5,222,800 to a total of $5,700,000 in FY 1981, is requested for the following:

- Biochemical Aspects of Adaptation. Extensive surveys of many populations have revealed that an unexpectedly large proportion of the individuals of each differ in the molecular configurations of numerous enzymes that may modify certain metabolic processes. Some cases suggest that the widespread molecular variability of enzymes persists because it enables some individuals to survive almost any environmental conditions encountered by the population. Increased emphasis is needed to test the generality of this hypothesis.
- Long-term Studies of Population Genetics and Ecology. Few studies of population biology have analyzed specific populations for more than five years, yet studies of long-term changes in environmental characteristics, concomitant shifts in the genetic structure of populations, and changes in that population's environment are all closely linked. Analysis would provide greater understanding and therefore predict and not merely monitor shifts. Analysis and prediction are fundamental to larger ecosystem monitoring and could suggest approaches for use in agricultural systems.

QUANTITATIVE PROGRAM DATA
ENVIRONMENTAL BIOLOGY PROGRAM SUBACTIVITY

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Number of Proposals Received[1]	1,215	1,240	1,260
Number of Awards[2]	685	695	715
Dollars Proposed on Awards (Total)	$67,791,000	$75,180,000	$81,200,000
Dollars Proposed on Awards (Annual Rate)	39,409,100	43,680,000	47,200,000
Dollars Awarded (Total)	33,952,783	37,664,000	40,700,000
Dollars Awarded (Annual Rate)	25,954,000	28,780,000	31,100,000
Average Dollar per Award	49,570	54,200	56,900
Average Award Duration (Years)[3]	2.2	2.2	2.2

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	82.6	83.0	83.0
Industry	—0—	—0—	—0—
Federal Agencies	—0—	—0—	—0—
Other	17.4	17.0	17.0

Personnel and Other Award Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Senior Scientists Faculty[4]			
Number of scientist years supported	218	230	230
Amount of faculty support	$6,783,588	$7,670,000	$8,290,000
Cost per scientist year	31,030	33,400	36,000
Postdoctoral Associates			
Number of scientist years supported	75	80	80
Amount of postdoctoral support	$1,045,282	$1,185,000	$1,280,000
Cost per scientist year	13,940	14,800	16,000
Graduate Students			
Number supported	324	340	340
Amount of graduate student support	$1,967,589	$2,231,000	$2,410,000
Other Personnel costs	3,873,691	4,393,000	4,750,000
Capital Items			
Major Equipment	—0—	—0—	—0—
Equipment and Instruments	$3,209,200	$2,800,000	$3,030,000
Other Costs[5]	9,469,024	10,738,000	11,600,000
Indirect Costs	7,624,409	8,647,000	9,340,000
Total	$33,952,783	$37,664,000	$40,700,000

[1]Includes proposals for committed renewals, etc.
[2]Includes awards for committed renewals, supplements, etc.
[3]Includes continuing grants for full length.
[4]Includes faculty associates and other professionals.
[5]Fringe Benefits, expendable equipment, travel, publication costs, computer costs, other direct costs.

ENGINEERING AND APPLIED SCIENCE

PROGRAM ACTIVITY SUMMARY

FY 1981 PROGRAM TOTAL $137,000,000

Obligations by Subactivity

Page	Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
F-I	Electrical, Computer, & Systems Engineering	$17,020,988	$18,160,000	$17,606,000	$22,500,000	$4,894,000
F-II	Chemical & Process Engineering	12,975,094	14,320,000	13,880,000	16,650,000	2,770,000
F-III	Civil & Environmental Engineering	8,151,770	9,630,000	9,300,000	10,125,000	825,000
F-IV	Mechanical Sciences & Engineering	10,708,730	11,990,000	11,665,000	13,325,000	1,660,000
F-V	Applied Research	*17,608,213	*18,200,000	*17,628,409	*18,700,000	*1,071,591
F-VI	Problem-Focused Research	*32,538,834	*30,400,000	*28,885,000	*30,500,000	*1,615,000
F-VII	Intergovernmental Programs	5,131,539	5,000,000	5,500,000	7,000,000	1,500,000
F-VIII	Small Business Innovation & Industrial Technology	5,724,816	6,000,000	7,370,000	18,200,000	10,830,000
	Total**	$109,859,984	$113,700,000	$111,834,409	$137,000,000	$25,165,591

* Does not include approximately $2.2 million (FY 1979) and $2.0 million (FY 1980 and FY 1981) in Applied Research and $1.4 million (FY 1979) and $1.0 million (FY 1980 and FY 1981) in Problem Focused Research for small business solicitations. These funds are now included and displayed in the Small Business and Industrial Technology subactivity.

** Does not include $0.9 million in FY 1979, $2.7 million in FY 1980 Budget Request, $3.85 million in FY 1980 Current Plan, and $2.7 million in FY 1981 for the Experimental Program to Stimulate Competitive Research, which is an EAS effort but displayed for budgetary purposes in the Cross-Directorate program.

Goals and Description

The Foundation's Engineering and Applied Science (EAS) Activity seeks to strengthen the Nation's engineering and applied science research base and enhance the links between fundamental research and applications in addressing selected national goals. This is accomplished by identifying and supporting basic research across a broad spectrum of the engineering sciences, applied research, and related activities that have the highest potential for contributing to the understanding and resolution of significant societal problems.

The specific objectives of EAS are to:

- Advance basic knowledge of fundamental engineering principles that might be applied to the analysis and design of a large variety of manmade systems;
- Strengthen the academic engineering research base in order to address the need for more basic research underlying industrial technology and for more graduating engineers working at the forefront of research.
- Stimulate the application of fundamental scientific and engineering knowledge to the solution of significant problems in the public and private sectors, and

shorten the time between scientific discoveries and their application for societal use;

- Focus U.S. scientific and technological capabilities on selected problems of national significance where NSF can make a unique contribution, such as earthquake hazards mitigation, human nutrition, and others;
- Increase fundamental scientific knowledge in selected problem areas where additional knowledge can contribute to their long-term solution;
- Provide mechanisms to increase the effectiveness of the public and private sectors in appropriately utilizing science and technology;
- Facilitate the integration of scientific and technical resources into the activities of State and local governments;
- Explore new ways to improve cooperation between universities and industry in research and industrial innovation; and
- Draw upon the research capabilities of the Nation's small businesses, with a view towards moving the most promising research along the continuum to commercialization as soon as possible.

On July 1, 1979, the National Science Foundation formed the Engineering and Applied Science Directorate by combining the Engineering activities within the Foundation with the Applied Science and Research Applications Directorate. Many activities between the two were highly complementary. By combining these organizations, NSF is now better able to:

- Strengthen the engineering programs of the Foundation by giving them a single, more visible place in the NSF organization;
- Enhance NSF's program of applied and problem-focused research by providing a broader base of science and engineering on which to build; and
- Recognize the key role of engineering in the transfer of science into technology by placing the Foundation's major engineering, industry-related, and problem-oriented efforts in one organization.

The EAS budget is organized around eight subactivities: Electrical, Computer, and Systems Engineering; Chemical and Process Engineering; Civil and Environmental Engineering; Mechanical Sciences and Engineering; Applied Research; Problem-Focused Research; Intergovernmental Programs; and Small Business Innovation and Industrial Technology.

Electrical, Computer and Systems Engineering supports, basic and applied research in large scale integrated circuit electronics, integrated optics, optical communications, automation and robotics, and mathematical studies of complex interactions in the manmade world.

Chemical and Process Engineering emphasizes research on: the basic mechanisms of catalysis and various chemical and biochemical processes, and the methods of putting the resulting knowledge into industrial applications; general theories of mass

transfer and separation processes, including the characterization and processing of fine particles; and the efficient recovery and use of resources that feed important industrial processes.

Civil and Environmental Engineering focuses on: activities in which the earth's surface itself is involved (such as foundations and dams); the science of designing structures in such a way as to give the most efficient and economical service in response to given demands; and studies of the flow of above- and below-ground water, utilizing principles of engineering, biology, and chemistry to protect and improve the physical environment.

Mechanical Sciences and Engineering addresses problems in: the transfer of heat, a major carrier of power; solid mechanics, which emphasizes the problems of machines under high stress and strain; fluid mechanics, which looks at lubrication, questions of turbulence, and other areas connected with fluid flow; and mechanical systems, which involves the synthesis of all these elements into an appropriate "design."

Applied Research seeks to accelerate the rate of technological innovation growing out of significant advances in selected fields of science and engineering. The program supports unsolicited proposals as well as research in certain coherent areas; the latter involving the selective support of interrelated applied research projects having a high probability of providing a broad knowledge base for major technological innovations or for contributing to the solution of significant public policy issues.

Problem-Focused Research concentrates research on critical societal problems where it is clear that such research is essential for dealing effectively with the problems. Currently, four program areas are supported: Earthquake Hazards Mitigation; Alternative Biological Sources of Materials; Science and Technology to Aid the Handicapped; and Human Nutrition. The subactivity also supports efforts in: Problem Analysis, which examines a wide range of potential research topics and problem areas for use in selecting research directions; and Integrated Basic Research, which provides additional support to basic research topics related to problem areas of existing or emerging major importance.

Intergovernmental Programs supports research that attempts to facilitate the integration of scientific and technical resources into the activities of State and local governments. Efforts are directed not only at individual jurisdictions but also those encompassing statewide, regional, and national networks.

Small Business Innovation and Industrial Technology seeks to: develop selected incentives that the Federal government may use to increase R&D investment in the private sector, with particular emphasis on the role of small business in such activities; and combine the scientific and technological resources of universities and industries in cooperative efforts designed to accelerate industrial innovation and enhance productivity.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan of $111,834,409 is below the FY 1980 Budget Request of $113,700,000 by $1,865,591. The Request level does not include $2,700,000 and the Plan does not include $3,850,000 for the Experimental Program to Stimulate Competitive Research, which is now a Cross-Directorate Program.

Increases include:

- $1,800,000 for initiation of the new Appropriate Technology program, as directed by Congress.
- A $500,000 increase for the Aid to the Handicapped Program as directed by Congress, from $1,800,000 requested to $2,300,000 currently planned. However, the increase in this Problem-Focused Research (PFR) program is offset by a decrease in all of PFR by $1,515,000, from $30,400,000 to $28,885,000, which was accomplished by reductions coming primarily in the Alternative Biological Sources of Materials Program.
- A $500,000 increase in the Intergovernmental Programs subactivity, from $5,000,000 to $5,500,000, to accommodate the new, Congressionally-mandated State Science, Engineering, and Technology Program. However, the initiation of this program at the directed level of $1,500,000 forced reductions of $1,000,000 spread among the other program elements of the subactivity.

Other areas which experienced decreases in addition to those cited above include:

- Electrical, Computer, and Systems Engineering by $554,000, from $18,160,000 to $17,606,000, with reductions in all programs except Solid State and Microstructures Engineering.
- Chemical and Process Engineering by $440,000, from $14,320,000 to $13,880,000, with the reductions occurring primarily in Engineering Energetics and Thermodynamics and Mass Transfer research.
- Civil and Environmental Engineering by $330,000, from $9,630,000 to $9,300,000, with cuts applied primarily to Geotechnical Engineering.
- Mechanical Sciences and Engineering by $325,000, from $11,990,000 to $11,665,000, with reductions in research in Fluid Mechanics and Heat Transfer.
- Applied Research by $571,591, from $18,200,000 to $17,628,409, with the cut directed mainly to the Applied Social and Behavioral Sciences program.
- Industrial Technology, now part of the Small Business Innovation and Industrial Technology Subactivity by $430,000, from $3,000,000 to $2,570,000.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The proposed FY 1981 increase of $25,165,591, which will raise the EAS program from $111,834,409 to $137,000,000 in FY 1981, would incorporate the following increases:

- Electrical, Computer, and Systems Engineering by $4,894,000, from $17,606,000 in FY 1980 to $22,500,000 in FY 1981, primarily for a sharply-focused effort in microstructures and computer engineering research. Such an effort will address research in areas where the U.S. has recently been lagging in comparison to foreign countries, and also direct research towards a field which has high potential for productivity improvement and industrial innovation.
- Chemical and Process Engineering by $2,770 ,000, from $13,880,000 to $16,650,000, for efforts particularly in engineering energetics, with an emphasis on upgrading facilities for plasma chemistry and arc technology. Another thrust is in thermodynamics and mass transfer, with support for research in novel and energy-efficient separation processes.
- Civil and Environmental Engineering by $825,000, bringing that program from $9,300,000 to $10,125,000. Emphasis will be on research in structural mechanics, particularly as directed towards probabilistic design methods and optimization techniques on structures subjected to off-shore, wind, and earthquake environments.
- Mechanical Sciences and Engineering by $1,660,000, from $11,665,000 to $13,325,000. Concentration will be on mechanical systems research with emphasis on control theories as applied to manufacturing processes, which provide the foundation for later research in improved manufacturing methods and robotics.
- Applied Research by $1,071,591, raising the program from $17,628,409 to $18,700,000. Such an increase will allow for a new research thrust to examine the impact on the economy of a transition from heavily-regulated to less-regulated industries and services, and also to expand work in areas of manufacturing processes and materials handling.
- Problem-Focused Research by $1,615,000, from $28,885,000 to $30,500,000, principally for expanded efforts in earthquake hazards mitigation.
- Intergovernmental Programs by $1,500,000, from $5,500,000 to $7,000,000, to be applied entirely to the State Science, Engineering, and Technology Program and that program's efforts to implement capacity-building programs in State and local governments to access scientific and technological information.
- Small Business Innovation and Industrial Technology by $10,830,000, from $7,370,000 to $18,200,000, to accommodate significantly heightened efforts in support of small business research and university-industry cooperative research centers, both of which were keystones in the President's Industrial Innovation Initiative announced last fall.

Percentage changes between FY 1981 and the FY 1980 Current Plan for the subactivities are as follows:

Electrical, Computer, & Systems Engineering	28%
Chemical & Process Engineering	20%
Civil and Environmental Engineering	9%
Mechanical Sciences & Engineering	14%
Applied Research	6%
Problem Focused Research	6%
Intergovernmental Programs	27%
Small Business Innovation & Industrial Technology	147%

Changes in Budget Structure

As was noted, the Engineering and Applied Science Directorate was formed on July 1, 1979. It included the programs of the former Applied Science and Research Applications (ASRA) Directorate as well as the Division of Engineering of the Mathematical and Physical Sciences and Engineering (MPE) Directorate.

Formerly, there were five subactivities in the ASRA budget; now, in the applied research portion of EAS, there are four—Applied Research, Problem-Focused Research, Intergovernmental Programs, and Small Business Innovation and Industrial Technology. Two, former ASRA subactivities, Problem Analysis and Integrated Basic Research, have been subsumed under the Problem-Focused Research subactivity as program elements.

The former Intergovernmental Science and Public Technology (ISPT) subactivity has been separated into components for budgeting purposes. The current Intergovernmental Programs subactivity is the former Intergovernmental program element of ISPT; former subelements of the Intergovernmental program element are now program elements in the new subactivity. One new program element has been established, State Science, Engineering, and Technology. Finally, the Experimental Program to Stimulate Competitive Research, which was formerly a program element of ISPT, is now found in the Foundation's Cross-Directorate Activity.

Further, the Industry program element of ISPT is now a program element in the new Small Business Innovation and Industrial Technology subactivity. The latter was established as a separate subactivity in FY 1981 with comparable amounts for the Small Business program shown for FY 1979 and FY 1980. The President included funds for a special initiative in this program in the Foundation's budget for FY 1981. Finally, the Appropriate Technology program element, which was not part of the FY 1980 Budget Request, has also been placed in the Small Business Innovation and Industrial Technology Subactivity.

In the engineering portion of EAS, four new subactivities have been formed from the prior Engineering subactivity of MPE; (1) Electrical, Computer, and Systems Engineering (ECSE), which in the FY 80 Budget comprised the Electrical Sciences and Analysis programs; (2) Chemical and Process Engineering (CPE), which formerly contained the Engineering Chemistry and Energetics programs; (3) Civil and Environ-

mental Engineering (CEE), which formerly held the Civil and Environmental programs; and (4) Mechanical Sciences and Engineering (MSE), which contained the Mechanical Sciences and Engineering programs.

In addition, several new program elements have been added to engineering; in Chemical and Process Engineering (CPE), Kinetics, Catalysis and Reaction Engineering, as well as Chemical and Biochemical Systems, were formed from the prior Chemical Processes Program Element; in Mechanical Sciences and Engineering (MSE), the Mechanical Systems program Element was established.

Further discussion of these changes is addressed at the appropriate subactivity levels.

Evaluation and Oversight

EAS is building on extant systems of evaluation and oversight that were in place in the former Applied Science and Research Applications Directorate and the Division of Engineering.

Various formal as well as informal processes of evaluation—at the project, program, and the directorate level—provide EAS with a pass-back mechanism directed toward achieving an efficient allocation of its resources. This evaluation function is an important part of the budgetary/planning processes and the FY 1981 budget incorporates the many efforts associated with these processes.

For EAS, as in the rest of NSF, the major project-by-project evaluation effort is the proposal review process. The intellectual importance or long-term benefit from a given fundamental research effort is often not discernible until after the work is completed. Therefore, this evaluation reflects primarily the estimated quality of the expected research results.

Most of the external evaluation activities for each EAS subactivity are carried out by a formally constituted Advisory Committee consisting of two to three members for each program element. These members normally serve for three, one-year terms arranged so that approximately one-third of the membership changes each year. The committee normally meets once or twice a year. Following each meeting, the Committee prepares a written report, and a written response is provided by the Assistant Director for EAS after discussion with the appropriate program staff.

In a larger framework, EAS is guided in its directions and priorities by its recently reconstituted Advisory Committee. This Committee, which is made up of eminent representatives from universities, industry, and professional organizations, provides advice and counsel on major goals and policies pertaining to EAS.

There are other, internal mechanisms that provide continual oversight concerning the directorate's current efforts and future plans. In addition to frequent internal evaluation through mechanisms such as program reviews held for the Director and the random sampling of proposal files by NSF's Office of Audit and Oversight, a major internal evaluation vehicle is the annual long-range planning process. These plans,

together with the annual updates of the Divisions' Status of Science Reviews and the Assistant Director's Priorities in Support of Science, define areas of future promise for consideration by the priority-setting and resource-allocating mechanisms within EAS.

Finally, EAS is continuing with the process of providing a formal system to evaluate the results of its supported research. The system draws on peer reviewers to evaluate reports and other research products produced as a result of EAS grants.

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QUANTITATIVE PROGRAM DATA
ENGINEERING AND APPLIED SCIENCE

Proposal and Award Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	4,278	4,963	5,372
Total Dollar Requested (Millions)	$448.3	$500.3	$567.2
Awards:			
Number of Awards[1]	1,694	1,711	1,944
Total Dollar Amount (Millions)	$109.9	$111.8	$137.0
Average Dollar Per Award (Thousands)	64.9	65.4	70.5
Average Award Duration (Months)	16	16	16

Percentage Distribution of Funds by Performer[2]

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	79.8	80.8	75.5
Industry	9.8	8.9	14.5
Small Business (all of EAS)	(7.8)	(6.6)	(12.3)
Small Business as % of applied research portion of EAS	(13.6)	(12.5)	(22.7)
Other	(2.2)	(2.2)	(2.2)
Non-Profit (nonacademic)[3]	7.1	6.1	5.7
State and local government	1.8	2.7	3.1
National Laboratories	0.2	0.2	0.1
Federal Agencies	1.5	1.3	1.1

Personnel and Other Award Factors (dollars in millions)

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Faculty			
Number of years support	655	662	732
Amount of Faculty Support	$18.5	$19.7	$23.0
Postdoctoral Associates			
Number of years supported	192	193	204
Amount of Postdoctoral Support	$2.8	$3.0	$3.3
Graduate Students			
Number supported per award year	1,607	1,628	1,819
Amount of graduate students support	$14.3	$15.1	$18.1
Other personnel Costs	14.8	13.8	20.8
(Small Business personnel costs)[4]	(2.5)	(2.0)	(7.3)
Land, Buildings and Fixed Equipment	0.03	0.03	0.03
Major equipment	0.7	0.5	0.7
Other equipment	11.5	12.1	13.5
Other costs[5]	18.5	18.2	21.5
Indirect Costs	28.7	29.3	36.0
Total[6]	$109.9	$111.8	$137.0

[1] Includes the number of basic research awards receiving supplemental funding under Integrated Basic Research (IBR) program.
[2] May not add due to rounding.
[3] Including "other" category in engineering subactivities.
[4] Small Business solicitations only.
[5] Fringe benefits, expendable equipment, travel, publication costs, computer costs, other direct costs.

ELECTRICAL, COMPUTER, AND SYSTEMS ENGINEERING SUBACTIVITY $22,500,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Automation, Bioengineering and Sensing Systems	$3,528,154	$3,545,000	$3,360,000	$4,150,000	$790,000
Electrical and Optical Communications	3,286,256	2,950,000	3,438,000	4,100,000	662,000
Computer Engineering	647,267	1,200,000	1,000,000	2,150,000	1,150,000
Quantum Electronics, Waves and Beams	3,454,729	3,610,000	3,210,000	3,700,000	490,000
Solid-State and Microstructures Engineering	2,878,748	3,350,000	3,360,000	4,600,000	1,240,000
Systems Theory and Operations Research	3,225,834	3,505,000	3,238,000	3,800,000	562,000
Total	$17,020,988	$18,160,000	$17,606,000	$22,500,000	$4,894,000

Objectives and Description

The objective of the Electrical, Computer, and Systems Engineering subactivity is to support the acquisition of new knowledge of fundamental engineering principles applicable to the analysis and design of a large variety of man-made systems. NSF supports research on a range of topics including Automation, Bioengineering and Sensing Systems; Electrical and Optical Communications; Computer Engineering; Quantum Electronics, Waves and Beams; Solid-State and Microstructures Engineering; and Systems Theory and Operations Research. Research in these areas includes studies on electronic materials and devices, sensors and imaging systems, very large-scale integrated circuits, computer engineering, integrated optics and optoelectronics, optical communications, machine intelligence and robotics, automation, laser systems and plasmas. New knowledge in these areas provides the basis for improvements in communications and data networks, more efficient energy generation and transmission, better structures and machines, and more efficient manufacturing processes.

Major Research Questions

Among the major questions being addressed are:

- How can techniques of microfabrication be improved further and what kinds of new man-made microstructures can be made with these improved techniques?
- What opportunities are there for the use of these man-made microstructures as sensors, transducers, information processing systems, and microprosthetic systems?
- What are effective ways for exploring the use of very large-scale integrated circuit systems of high complexity?

- What are the opportunities in the newer areas of submicron acoustic probing and imaging, integrated optics and optoelectronics, and superconducting electronics?
- In computer engineering, given the availability of very large-scale integration of circuits, what new powerful and useful architectures are possible?
- How can the techniques of several technical areas be integrated effectively to yield powerful results in automation and robotics?

Significant Research Achievements

- Whenever an optical beam or an optical image is propagated through a medium which exhibits a nonuniform refractive index—for example, the earth's atmosphere or an optical fiber—it becomes distorted, and its capacity for carrying information is decreased. Researchers at the University of Southern California recently demonstrated that for any distorted wave, a conjugate wave can be generated using a nonlinear four photon mixing process. When the conjugate wave is passed through the distorting medium a second time, the original distortions are compensated for and an undistorted wave is obtained. These studies currently are being extended by several other researchers, and applications are apparent in areas ranging from optical communications to fusion energy sources.
- By using focused ion beams it is possible in microfabrication to "write" diffusion patterns in material substrates or cut patterns in thin films. Researchers at the Submicron Facility at Cornell report that with a new type of ion source it will be possible to produce structures as small as 100 angstroms (one angstrom is equal to one hundred millionth of a centimeter) directly onto such substrates in a simpler manner. This research has important implications for electronics. It can facilitate exploration of the limits of small size and high speed electronic components and enable complex structures to be fabricated for use with ultraviolet light and x-rays.
- The invention of the laser and the subsequent discovery of ultra thin, low-loss optical fibers have made it possible to use light as a viable medium to transmit information. Over the past few years, an entire new generation of compact optical devices based on the precise guiding of laser light has been devised. A very recent and important result has been obtained through NSF supported studies at Cornell University which have demonstrated, for the first time, rapid electronic tuning of certain types of lasers. Such information has important implications for communications systems, where tunability is fundamental, and for uses associated with spectroscopy and radar.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan of $17,606,000 is $554,000 below the FY 1980 Budget Request of $18,160,000. Reductions were made in all program elements except Solid State and Microstructures Engineering.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$17,020,988
FY 1980 Program	$17,606,000
FY 1981 Request	$22,500,000
Difference—FY 1981/FY 1980	$4,894,000

The proposed FY 1981 total of $22,500,000 is an increase of $4,894,000, or 28 percent, above the FY 1980 Current Plan. This increase will:

- Provide for a significant emphasis on basic microstructures research in coordination with more mission-oriented efforts by other agencies.
- Expand the Computer Engineering program element to a level of $2,150,000 an increase of 115 percent, thereby accommodating substantive efforts in computer vision and applications as well as robotics.

Percentage changes between FY 1981 and the FY 1980 Current Plan, by program element, are as follows:

Automation, Bioengineering and Sensing Systems	24%
Electrical and Optical Communications	19%
Computer Engineering	115%
Quantum Electronics, Waves and Beams	15%
Solid-State and Microstructures Engineering	37%
Systems Theory and Operations Research	17%

Coordination With and Relationship to Other Efforts

Program directors are in constant communication with research managers in associated areas in other agencies, not only those supporting basic research, but also those in applied research and development. As specific examples, electronics research is coordinated with related programs in the Office of Naval Research, the Air Force Office of Scientific Research, the Army Research Office, the Department of Defense Advanced Research Projects Agency, NASA, NBS and NIH through an ad-hoc interagency coordination committee. Systems research is coordinated with corresponding efforts in the Department of Energy and Department of Transportation through common participation in technical society workshops and through informal meetings. Plasma and laser research is coordinated with the activities of DOE. Bioengineering staff members are participants in an Interagency Committee on the Biological Effects of Non-Ionizing Electromagnetic Radiation.

Within the Foundation, the staff coordinates extensively with members of other organizational units, particularly Mathematical and Physical Sciences and the Applied Research Division in EAS.

Changes in Budget Structure

Electrical, Computer, and Systems Engineering is now a subactivity within the newly organized Engineering and Applied Science Activity. In the FY 1980 Budget this subactivity was a program element within the Engineering subactivity. In addition, Computer Engineering is a newly identified program element; it was not displayed in the FY 1979 and FY 1980 Budgets. It was established during FY 1980. Earlier efforts in this area were spread among several other program elements.

Automation, Bioengineering and Sensing Systems Program Element $4,150,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$3,528,154	$3,545,000	$3,360,000	$4,150,000	$790,000

Objectives and Description

The objective of this program is to increase the knowledge base in components, techniques, and systems involved with machine intelligence and control. With the rapid increase in computer capability and the concurrent decrease in size, new opportunities exist for improved machine reasoning and intelligent electronics. As a key to the development of machine intelligence, one of the important research efforts in the electrical sciences is aimed at determining the physical limitations that are inherent in physical, chemical, or biological sensors. Rapid advances in memory devices and in microminiaturization provide data bank and information processing capability that eliminates the need for large central processors. Research in distributed microprocessor networks, which can perform local storage and preprocessing prior to system utilizations, will yield advanced architectures and systems configurations. Results obtained by research in machine intelligence and control have broad application in areas ranging from industrial processing and non-destructive testing to improved health care delivery and minimizing disturbance in medical diagnostic procedures.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Emphasis in FY 1981 will be on research directed toward intelligent electronics, imaging systems, self-learning systems, and robotics as well as on fundamental studies of machine reasoning systems.

The proposed increase of $790,000, to a total of $4,150,000, makes possible continued support of basic studies and expanded experimental programs in sensors and distributed microprocessor networks. Utilizing high density memory elements, such networks perform preprocessing and machine decision and control. New advances in microminiature network design open opportunities for additional research in biomedical sensing, noninvasive diagnostics, and quantitative assessment.

Electrical and Optical Communications Program Element $4,100,000

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$3,286,256	$2,950,000	$3,438,000	$4,100,000	$662,000

Objectives and Description

The objective of this program is to increase the fundamental understanding necessary to create economical, efficient, high capacity communication systems to respond to the increasing demands to send information from one location to another for a variety of applications. The complex nature of communication systems that will transmit this information through the atmosphere and space, using satellites, over optical fiber cables, or employing a combination of both, requires research in the areas of optical communications, large scale computer communication networks, information theory, electronic circuit theory and digital signal processing. Research in each of these areas is aiding in the creation of a complex network of communication processors, computers, and satellites. All are interconnected by communication links. The prospect of transmitting and processing information at optical frequencies, with inherent tremendous signal-carrying capacity, is being pursued through systems considerations and device research, particularly in integrated optical circuits that are coupled to optical fiber transmission lines. Large scale computer communication networks, interconnected with optical fibers and using optical components, depend upon further research on concurrent processing and network architecture and a fundamental understanding of the dynamics of these networks. New studies in information theory in the area of multiple-user communications promise to provide the

basic structure needed to build efficient communication systems. The continued evolution of electronics to the high density form of very large scale integrated microelectronics is having a profound influence on all elements of the program. It is now possible to consider implementation of new complex algorithms which, in turn, lead to new fundamental issues in the nature of information processing.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The emphasis in FY 1981 will be on communications network research involving large scale computer communications and multiple user networks, and integrated optical systems.

The proposed increase of $662,000 to a total of $4,100,000 provides the opportunity to examine more thoroughly new concepts in terminal-oriented networks and concurrent processing in large scale computer communications networks.

Some aspects of digital signal processing, such as computational complexity and implementation of complex algorithms, especially as they relate to computer architecture, will be transferred to the Computer Engineering program.

Computer Engineering Program Element $2,150,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$647,267	$1,200,000	$1,000,000	$2,150,000	$1,150,000

Objectives and Description

The objective of this program is to provide a broader base of understanding of the principles of design, analysis, implementation, and use of computers in an engineering environment. This involves the interconnection of mathematics and computer hardware and software. Principal interest is in the digital computer as a machine and particularly as part of a system. The Foundation expects to support other engineering fields by providing new and useful software research tools.

Research is supported in such areas as the design and use of Large-Scale Integrated (a single silicon chip may contain tens of thousands of transistors) and Very Large-Scale Integrated (hundreds of thousands or near a million transistors per chip) microelectronics for novel special purpose hardware and new computer architecture; the relationships between classes of algorithms and their hardware implementation as well as types of computer architecture that lend themselves to better algorithms; the research issues involved in distributed processing and parallel proc-

essing networks and man-machine and machine-machine interfaces to computers; and hardware and software issues involved in computer vision and speech. To provide the knowledge base for engineering of future intelligent mechanical systems, research will be supported on knowledge representation for computing systems, object modeling (mathematical modeling, computational geometry and efficient computing algorithms), and computer engineering for robotics.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

In FY 1980 research supported in the area of computer engineering in the Electrical, Computer and Systems Engineering Division was brought together to form the new Computer Engineering Program to emphasize and highlight this area of research. The proposed increase of $1,150,000 to a total of $2,150,000 for FY 1981 provides the opportunity to explore the potential for new computer architectures made possible by the dramatic developments of Large-Scale Integrated and Very Large-Scale Integrated microelectronics.

The emphasis in FY 1981 will be on new computer architectures particularly suited for computer vision and speech applications and on the use of parallel processing to increase the efficiency of calculations, for example in computational geometry and in robotics. Research involving the transformations between different computer representations of three-dimensional objects will also be encouraged.

Quantum Electronics, Waves and Beams Program Element $3,700,000

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$3,454,729	$3,610,000	$3,210,000	$3,700,000	$490,000

Objectives and Description

The objective of this program is to increase understanding of electromagnetic radiation and its generation, propagation, and interaction with matter. The program will focus on studies of lasers, electromagnetics, acousto-electronic devices, and plasmas. Laser research includes new and improved coherent sources for the infrared, visible, and ultraviolet spectral regions; generation of picosecond laser pulses and interaction of short pulses with materials; novel laser spectroscopic methods; nonlinear optics; and free electron laser studies. Electromagnetics research includes analysis of propagation through random media, numerical methods for the solution of scattering

problems and nonlinear wave phenomena, antennas, and waveguides. Acoustoelectric device research includes linear and nonlinear effects in surface acoustic wave structures, acoustic resonators and other bulk devices, and sonar related studies. Plasma research is concerned with properties of the fourth state of matter, the state formed when materials are maintained at temperatures sufficiently elevated to render them active collections of freely moving charged particles. Program activities center on generation of plasmas, wave effects in plasmas, and properties of charged particle beams.

1981 Budget Highlights and Explanation of Increases and Decreases

The proposed increase of $490,000 to $3,700,000, will allow support of vacuum ultraviolet and soft X-ray laser studies, short pulse generation and measurement in the far-infrared, free-electron laser investigations, and optical interactions in materials on picosecond time scales.

Emphasis will be on quantum electronics research directed toward investigation of new optical techniques in the ultraviolet and far-infrared portions of the spectrum. This is important because conventional approaches developed for use in the visible and near-infrared often are not applicable at larger and shorter wavelengths. A number of potential applications of lasers and optics await further development of devices and techniques at these wavelengths.

Support of research in electrical machinery will be reduced by approximately $100,000 because the field is well developed and appears to be dominated by in-house research at industrial organizations.

Solid-State and Microstructures Engineering Program Element $4,600,000

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$2,878,748	$3,350,000	$3,360,000	$4,600,000	$1,240,000

Objectives and Decription

The objective of this program is to expand the knowledge base needed for future advances in electronic components and systems. Emphasis is placed on the exploration of new device concepts, improved materials systems, and advanced fabrication techniques. The program supports research: in analog and digital semiconductor components, with emphasis on novel designs, device modeling, noise properties and high frequency effects; in solid-state devices, with emphasis on special electronic

functions such as motion and chemical sensing, solar energy conversion, and high power switching; in thin film growth for device structures and investigations of electronic transport properties in materials; in studies of novel and improved microfabrication techniques; in superconductive electronics, including high speed electronic switching and microwave detection; and in surface acoustic wave and magnetic bubble electronic systems for signal processing, computer memory, and related electronic system functions. The relationship of these studies to small structures containing submicron dimensional features provides a major focus of present program activity. The National Research and Resource Facility for Submicron Structures at Cornell is supported by the Program.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $1,240,000 to a total of $4,600,000 will be used, in coordination with efforts from other program elements, to implement an initiative in microstructures to enable the academic community to contribute to basic research in this area. This will also complement the more directed efforts supported by other Federal agencies. Some specific subareas of opportunity include the advancement of understanding of ion beam interaction with semiconductors materials. Emphasis will also be placed on studies of new techniques for combining insulators and semiconductors to produce high speed electronic memory components on high capacity surface acoustic wave signal processors.

Systems Theory and Operations Research Program Element $3,800,000

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$3,225,834	$3,505,000	$3,238,000	$3,800,000	$562,000

Objectives and Descriptions

The objective of the Systems Theory and Operations Research program is to develop mathematical methods for the analysis, modeling, and optimization of natural and man-made systems. In particular, techniques are developed that enhance the understanding of system behavior, expedite system control to achieve desired objectives, or optimize system operation and performance. The program supports all aspects of systems theory, ranging from the abstract fundamental basis to the ultimate sophisticated mathematical models of complex real-world systems. Since most real-world

problems involve interactions among a large number of subsystems, in both man-made and socio-technical systems, the present emphasis is on the development of mathematical models, analysis techniques, and optimization methods and algorithms applicable to large scale, complex interconnected systems. The research supported by the program involves mathematical analytical methods increasingly aided by computers, useful both in the simplified and efficient design of complex engineering systems and in the optimal operational aspects of large-scale process management and service delivery systems. The research is interdisciplinary in nature and is strongly motivated by applications.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The proposed increase of $562,000 to a total of $3,800,000 will allow the support of some cooperative interdisciplinary research projects in large-scale socio-technical systems. It will also allow slightly increased support in adaptive decision and control techniques for stochastic systems, which are important because they provide tools for systems design and operation in the presence of disturbances or widely varying environments that do not result in catastrophic degradation of performance. These techniques are applicable to many real world complex systems.

Emphasis in FY 1981 will be on modeling, analysis, and decentralized decisionmaking and control of large-scale interconnected systems in the presence of uncertainties. Research in the operational sciences aspects of complex systems and processes will also be emphasized.

QUANTITATIVE PROGRAM DATA
ELECTRICAL, COMPUTER, AND SYSTEMS ENGINEERING SUBACTIVITY

Proposal and Award Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	734	800	880
Total Dollar Amount	$82,327,509	$96,000,000	$113,000,000
Awards:			
Number of Awards	340	330	410
Total Dollar Amount	$17,020,988	$17,606,000	$22,500,000
Average $ Per Award[1]	50,061	53,351	54,878
Average Award Duration[2] (Months)	18	18	18

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	98.2	98.0	98.0
Industry	1.8	2.0	2.0
Other	—0—	—0—	—0—

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Faculty[3]			
Number years supported	[4]102	100	120
Amount of faculty support	3,180,388	3,186,000	3,900,000
Postdoctoral Associates			
Number years supported	37	36	42
Amount of postdoctoral support	563,000	590,000	690,000
Graduate Students			
Number supported per award year	380	380	510
Amounts of graduate student supported	3,304,000	3,440,000	4,900,000
Other Personnel Costs	486,000	506,000	650,000
Land, Buildings, and Fixed Equipment	—0—	—0—	—0—
Major Equipment	280,000	160,000	300,000
Other Equipment	2,171,000	2,500,000	2,700,000
Other Costs[5]	2,776,000	2,806,000	3,500,000
Indirect Costs	4,260,600	4,418,000	5,860,000
Total	$17,020,988	$17,606,000	$22,500,000

[1] Not including Industry/University Cooperative Component.
[2] Continuing grants involving multi-year commitments are included here as 12-month award.
[3] Includes faculty associates and other professionals.
[4] Distributed among 370 individuals.
[5] Fringe benefits, expendable equipment, travel, publication costs, computer costs, other direct costs.

CHEMICAL AND PROCESS ENGINEERING SUBACTIVITY $16,650,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Kinetics, Catalysis and Reaction Engineering	$1,835,320	$2,468,000	$2,520,000	$2,960,000	$440,000
Chemical and Biochemical Systems	2,330,150	2,352,000	2,400,000	2,750,000	350,000
Engineering Energetics	2,785,382	2,860,000	2,500,000	3,260,000	760,000
Thermodynamics and Mass Transfer	3,586,591	4,050,000	3,680,000	4,440,000	760,000
Particulate and Multiphase Processes	2,437,651	2,590,000	2,780,000	3,240,000	460,000
Total	$12,975,094	$14,320,000	$13,880,000	$16,650,000	$2,770,000

Objectives and Description

The Chemical and Process Engineering programs provide support for basic engineering research relevant to the entire range of chemical, petrochemical, nuclear, biochemical, food, mineral and process industries. Examples of areas supported include catalysis, reaction kinetics, biochemical and polymer process fundamentals, plasma chemistry, combustion, thermodynamics and transport properties, nucleonics, separation techniques, fine particle characterization and processing, and interfacial phenomena.

The chemical and process industry (CPI) has been one of the strongest performers in the U.S. economy with an unprecedented growth in the past half-century. It has helped provide this Nation with an unparalleled standard of living. It also accounts for two million jobs in the U.S. labor market and a favorable trade balance of over $5 billion per year.

The National Science Foundation, through its Chemical and Process Engineering programs, plays an important part in strengthening the support of basic research on the fundamental principles, process strategies, mathematical models, and experimental techniques relevant to a broad range of CPI operations.

The objectives of the Chemical and Process Engineering programs are to:

- Establish fundamental principles governing the chemical and transport processes of industrial interest;
- Promote an understanding of the interactive effects of these processes;
- Develop mathematical models and data base structures representing these processes and interactions;
- Develop experimental techniques and correlational procedures to verify the mathematical models and establish the data base; and
- Advance design methods and control strategies relevant to the synthesis and scale-up of chemical process systems.

Basic research in Chemical and Process Engineering is focused on five programs: (1) Kinetics, Catalysis and Reaction Engineering, which addresses reaction rates and mechanisms and their implication on the dynamics and design of chemical reactors; (2) Chemical and Biochemical Systems, which looks at enzymatic, microbial, electrochemical and macromolecular reaction systems in terms of both the detailed aspects of the individual reactions as well as the reaction system as a whole; (3) Engineering Energetics, which involves energy conversion and material processing under unusual and extreme conditions; (4) Thermodynamics and Mass Transfer, which emphasizes research on thermodynamic properties and transport processes as they are related to molecular structure on one hand and process requirements on the other; and (5) Particulate and Multiphase Processes, which examines characteristics of particles and heterogenous systems and their implication for the processing and separation of these systems in important industrial situations.

Topics of special importance include heterogeneous catalysis, biochemical and polymer processing systems, plasma chemistry and arc technology, separation processes, particulate characterization and processing, combustion and fluidized bed technology. Particular emphasis is also given to the support of young investigators, upgrading of instrumentation capabilities, and encouragement of joint industry-university research efforts.

Major Research Questions

- How can an understanding of the physical interactions on catalytic surfaces lead to the design of more efficient catalysts for industrial processes, including synthetic fuel production?
- Can the noble-metal catalysts currently used in many processes, including hydrocracking and automotive emission control, be replaced with less expensive systems without loss of effectiveness?
- How can phenomena occurring in individual microbial cells be incorporated into models useful to the optimal design and operation of biochemical processes?
- How can studies of reaction kinetics and transport processes in food materials lead to models for prediction of the storage life of foods and nutrient losses in selected processing techniques? How can these models lead to the development of methods and procedures promoting the retention of nutrients and other quality factors in processing and storage?
- How can relationships between process conditions and the properties of polymers be established so that product quality can be properly controlled?
- What fundamental data are needed to enable the design of separation processes which are more economical and energy-efficient than those presently used in chemical and process industries? How can these data be measured, analyzed, and codified so that they have maximum usefulness?

- To what extent do particle size and shape influence the processing of particles in the chemical, biochemical and mineral industries?
- How can more selective and efficient methods of particle separations be developed to help make coal liquefaction processes more economically viable?
- What is the effect of bound nitrogen in coal and other fossil fuels on the formation of the oxides of nitrogen upon combustion?

Significant Recent Accomplishments

- High Gradient Magnetic Separation is a method whereby a strong magnetic gradient is applied across a fibrous filter to make possible the recovery of weakly magnetic and paramagnetic substances. One new concept for the capture of nonmagnetic particles has been developed by Purdue University and may have great significance in the separation of aluminum minerals from alunite which is found in abundance in the United States.
- The need for polymers with special properties and uses is widely recognized. Plasma-induced polymerization of both conventional and unconventional monomers has produced materials with unique properties and a wide variety of potential applications. Under support from the Foundation's Engineering Energetics Program, researchers at the Massachusetts Institute of Technology have uncovered new information which can lead to the economical production of novel and unique fluorinated polymers.
- Large-scale processes employing living microorganisms currently serve society in many ways including the manufacture of pharmaceutical, food, and agricultural products. Biological wastewater treatment is another vitally important application, and there is significant potential in the future for microbial production of fuels, feeds, and new chemicals. Recent NSF funded research at the University of Houston has yielded experimental and theoretical techniques which can be used to explore the ways in which microbial reactor design and operation influence the makeup and kinetics of the population of microorganisms cultivated in the reactor.
- A new apparatus for measuring properties of small particles has been developed at the University of Delaware. It is the technique of extended X-ray absorption fine structure, a valuable tool for measuring the properties of catalyst particles. Previously this technique required high-intensity x-ray sources, available at only a few locations in the U.S., or weeks of irradiation using laboratory sources. The new apparatus permits such data to be collected within one hour using common laboratory sources of X-ray.
- NSF supported researchers at SRI International have discovered that water and carbon monoxide can methylate aromatic compounds over a rhodium catalyst. Although much needs to be done to define the limits of this process, this repre-

sents a promising avenue for the production of high-octane fuels from coal. Most coal conversion processes produce a liquid fuel which requires extensive refining and much loss before a fuel suitable for internal combustion engines is produced. Successful development of this process could greatly increase the amount of "gasoline" obtainable from a ton of coal.

- A joint General Electric-University of Pennsylvania team of chemical engineers has successfully combined the concepts of catalysis and membrane separation into a highly efficient membrane reactor capable of integrating the separation-enrichment step with the reaction, thus potentially reducing the energy and cost of the entire process by as much as 60 percent. This is a crucial factor if converting biomass into useful products such as alcohol is going to become an economic reality.
- Under joint sponsorship of NSF's Particulate and Multiphase Processes Program and the Department of Energy, chemical engineering researchers at the Illinois Institute of Technology achieved a novel filtration method for separating fine particles from non-aqueous colloidal suspensions by attracting the particles to a central electrode using a high voltage gradient. This method is very useful in removing ash and undissolved carbon from extraction solutions in making synthetic crudes and ash-free solid fuels, among many other applications.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan of $13,880,000 is $440,000 below the FY 1980 budget request of $14,320,000. The decrease represents a combination of reductions made by Congress as well as a realignment of NSF budget priorities.

The combined FY 1980 current plan of $4,920,000 for Kinetics, Catalysis and Reaction Engineering and Chemical and Biochemical Systems is slightly larger than the FY 1980 budget request of $4,820,000 for the Chemical Processes program element they replaced because of the acquisition of the food and bioprocess engineering subelement. The corresponding decrease in the Thermodynamics and Mass Transfer Program element and a deemphasis of gas hydrates research cause a total reduction of $370,000 from the request of $4,050,000 to its current plan of $3,680,000. The increase of $190,000, from $2,590,000 to $2,780,000, in the Particulate and Multiphase Processes Program is the result of newly perceived opportunities in particulate characterization and processing while the decrease in Engineering Energetics, from $2,860,000 to $2,500,000 is because of predicted lower activity level.

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FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$12,975,094
FY 1980 Program	$13,880,000
FY 1981 Request	$16,650,000
Difference—FY 1981/FY 1980	$2,770,000

The increase of $2,770,000 is to be distributed among high priority areas as follows:

- Kinetics, Catalysis and Reaction Engineering program element will be increased by $440,000, from $2,520,000 to $2,960,000, to emphasize electrosynthesis and electocatalysis.
- Chemical and Biochemical Systems program element will be increased by $350,000, from $2,400,000 to $2,750,000, for biochemical process fundamentals, including microbial production of important macromolecules and the use of enzymes relevant to harnessing solar energy.
- Engineering Energetics program element will be increased by $760,000 from $2,500,000 to $3,260,000, to support the major upgrading of research facilities in plasma chemistry and arc technology.
- Thermodynamics and Mass Transfer program element will be increased by $760,000, from $3,680,000 to $4,440,000, to promote research in novel and energy-efficient separation processes and to develop measurement techniques for interfacial properties such as interfacial viscosity and tension in porous media related to resource recovery.
- Particulate and Multiphase Processes program element will be increased by $460,000, from $2,780,000 to $3,240,000, to promote the unification of the descriptions of macromolecular and submicron particulate processes and to support grantee participation in the research activities of the International Fine Particle Research Institute.

Percentage changes between the FY 1981 Request and the FY 1980 Current Plan for the Chemical and Process Engineering program elements are:

Kinetics, Catalysis and Reaction Engineering	18%
Chemical and Biochemical Systems	15%
Engineering Energetics	30%
Thermodynamics and Mass Transfer	21%
Particulate and Multiphase Processes	17%

Coordination With and Relationship to Other Efforts

Program staff in the Chemical and Process Engineering subactivity interact extensively with other NSF programs as well as with various Federal agencies. Examples of areas (and agencies) where close coordination takes place are: (1) catalysis related to

coal utilization (DOE); (2) biochemical processes related to biomass utilization (DOE); (3) combustion (DOE); (4) thermodynamic properties (National Bureau of Standards); and (5) particulate processes related to mineral beneficiation (Bureau of Mines, Department of the Interior). Program staff also attend the advisory panel meetings of other, research-relevant divisions within NSF as well as other agencies such as DOE, NASA and DOD. Some of these coordination activities are through longstanding interagency panels, such as the Interagency Advanced Power Group, while others occur through ad hoc task groups, such as the Cooperative Automotive Research Program Planning Group and the NBS Chemical Engineering Workshop.

Changes in Budget Structure

Chemical and Process Engineering is now a subactivity within the newly organized Engineering and Applied Science activity. In the FY 1980 Budget this subactivity was a program element within the Engineering subactivity. In addition, the Kinetics, Catalysis and Reaction Engineering and the Chemical and Biochemical Systems program elements are new. They were established during FY 1980 and comprise the activities of the former program element, Chemical Processes.

Kinetics, Catalysis, and Reaction Engineering Program Element $2,960,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$1,835,320	$2,468,000	$2,520,000	$2,960,000	$440,000

Objectives and Description

The Kinetics, Catalysis, and Reaction Engineering Program supports research in the areas of kinetics, catalysis, reaction engineering, and reactor simulation and design. The specific objectives of the program are to:

- Understand the rate processes governing chemical reactions of industrial utility and orient this understanding to the development of design principles of industrial processes.
- Elucidate the fundamental mechanisms of catalytic processes, including the elaboration of chemical pathways and the role of physical configuration in catalytic action.
- Develop methodology for designing new catalytic systems with regard to both chemical composition and physical form.

- Integrate theories of chemical kinetics and transport processes into a reaction engineering theory.
- Develop new techniques for chemical analysis and surface characterization for application to problems in kinetics and catalysis.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The proposed increase of $440,000, to a total of $2,960,000, will provide support for expanded heterogeneous catalysis research in the areas of:

- Relating physical forms of catalysts to their operational efficiency.
- Development of less expensive catalytic systems that could replace the noble-metal catalysts used in synfuel production and automotive emission controls.

Major thrusts in FY 1981 will be on techniques for characterizing catalytic surfaces, the effects of surface structure on the efficiency and selectivity of catalysts, the development of new types of catalytic structures, and the synthesis of reaction engineering theory. This research may have significant applications in industrial design, deep-well mining, pollution control, and synfuel production.

Chemical and Biochemical Systems Program Element $2,750,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$2,330,150	$2,352,000	$2,400,000	$2,750,000	$350,000

Objectives and Description

The objective of the Chemical and Biochemical Systems Program is to advance understanding of the fundamental mechanisms and dynamic behavior of chemical and biochemical processes. Major areas supported include: biochemical processes, food processing, polymer processing, electrochemical processes, and process synthesis and control. Research supported in the area of biochemical processes involves the development of microbial processes for the production of important macromolecules, the utilization of inexpensive and abundant raw materials such as agricultural wastes, and the bioconversion of intermediates. This is an area that will be emphasized in FY 1981. Research in food processing examines basic aspects ranging from extrusion to reaction kinetics and transport processes in food materials and the effect of processing on physical properties and nutritional value. Such fundamental research provides the underpinning to more applied efforts found in the Nutrition program of the Problem-Focused Research subactivity.

Research in polymer engineering encompasses the fundamental effects of reaction and process conditions on polymerization and/or polymer properties. Support will be provided for mathematical modeling of polymer rheology and polymer processing. Process synthesis and control research will focus on design strategies for complex chemical processes, research in process and system optimization, and modeling of individual process units. Modeling techniques for complex reaction systems with the limiting mechanisms of coupled heat and mass transfer with reaction kinetics will be advanced for simulation and control purposes.

Research supported in the area of electrochemical processes involves mechanistic studies of electrodeposition, fuel cells, batteries, and corrosion reactions.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The proposed increase of $350,000, to a total of $2,750,000, will provide additional support for biochemical engineering and polymer processing. Emphasis is on the fundamentals of microbial and enzymatic processes for the production of important macromolecules and harnessing solar energy through bioconversion.

Engineering Energetics Program Element $3,260,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$2,785,382	$2,860,000	$2,500,000	$3,260,000	$760,000

Objectives and Description

The objective of the Engineering Energetics Program is to provide fundamental scientific and engineering knowledge in the areas of plasma chemistry and arc technology, combustion, nucleonics, and energy conversion. The field of plasma chemistry technology deals with the chemistry of the gas phase in which there exists a high concentration of ionized particles. Research in arc technology encompasses analytical and theoretical work on basic problems of arc heater dynamics. Combustion research covers basic chemical and physical aspects of burning coal, oil, gas and other materials, and the characterization of conditions leading to better energy conservation. Basic research in nucleonics deals with fundamental investigations and applications of nuclear science. Research in energy conservation is oriented toward basic phenomena in several areas including magnetohydrodynamics, thermionics, and radioactive voltaic cells. There is a great need for research in all of the above areas. NSF support in the area of energetics is for basic and fundamental research with engineering relevancy wherein better and more efficient use of energy is expected as the final product.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The proposed increase of $760,000, to an FY 1981 total of $3,260,000, is mainly for the initial funding of major upgrading of facilities for plasma chemistry and arc technology research. The research activities would be directed towards a better understanding of the basic physical and chemical principles which govern chemical reactions, heat and mass transfer, change of phase, and surface physics under plasma conditions. The aim is to bring together investigators using special equipment not affordable on an individual basis.

Thermodynamics and Mass Transfer Program Element $4,440,000

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$3,586,591	$4,050,000	$3,680,000	$4,440,000	$760,000

Objectives and Decription

This program supports fundamental engineering research in the area of thermodynamics, transport properties, mass transfer, separation processes and interfacial phenomena. Examples of thermodynamic and transport property research include property measurement techniques, correlation and prediction, with emphasis on the fundamental relations between molecular structure with interactions and physical behavior. In interfacial phenomena, support is given to fundamental studies of equilibrium and transport processes at interfaces, including measurement and prediction of surface rheological properties, surface diffusion, interfacially driven instabilities, adsorption, characterization of structured membranes, and analysis of the behavior of colloidal systems. Research on mass transfer and separation processes emphasizes transport mechanisms and process fundamentals in conventional unit operations such as absorption, extraction, adsorption, distillation, leaching and fractional crystallization and unconventional techniques such as membrane separation.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The proposed increase of $760,000, to a total of $4,440,000, will be used mainly to support the development of measurement techniques for interfacial properties in porous media related to resource recovery. Another thrust will be in thermodynamic and transport properties of coal derived materials at extreme temperatures and pressures, such as those encountered in conversion operations and supercritical solvent

extraction. Both new theoretical and experimental methods must be developed. Basic research aimed at developing novel and energy-efficient separation techniques will be emphasized.

Particulate and Multiphase Processes Program Element ... $3,240,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$2,437,651	$2,590,000	$2,780,000	$3,240,000	$460,000

Objectives and Description

The objective of this program is to increase understanding of particulate and multiphase processes in three major areas: (1) particle and particulate system characterization, such as size, shape, electrical charge and chemical composition; (2) particle generation and size modification, which are an integral part of the processing of particulate systems in which particle behavior is usually size dependent; (3) and interfacial and colloidal phenomena, in which interparticle forces determine the possibility of particle separation and play a dominant role in multiphase flow through porous media, in spontaneous emulsification, and in foam stability. The increased understanding gained from the support of basic research in this program may be used to better predict the behavior of these processes, to determine the optimal ranges of the operating variables, to establish a basic methodology required for the design and scale-up of existing and new processes, and to design automatic control or on-line optimization systems for improving energy and material efficiency in the chemical, biochemical and mineral processing industries.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The increase of $460,000, to a total of $3,240,000, will be used to support research on the unification of macromolecular and submicron descriptions of particulate processes. Grantee participation in the research activities of the International Fine Particle Research Institute will also be encouraged.

QUANTITATIVE PROGRAM DATA
CHEMICAL AND PROCESS ENGINEERING SUBACTIVITY

Proposal and Award Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	581	610	650
Total Dollar Requested	$79,997,739	$79,000,000	$85,000,000
Awards:			
Number of Awards	277	283	310
Total Dollar Amount[1]	$12,975,094	$13,880,000	$16,650,000
Average Dollar Per Award	46,841	49,045	53,709
Average Award Duration (Months)	16	16	17

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	92.7	92.5	92.5
Industry[2]	6.5	6.5	6.5
Other	0.8	1.0	1.0

Personnel and Other Award Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Faculty			
Number years supported	69.4	72	80
Amount of Faculty Support	$1,862,409	$2,000,000	$2,380,000
Postdoctoral Associates			
Number years supported	24	25	28
Amount of Postdoctoral Support	$323,915	$350,000	$420,000
Graduate Students			
Number supported per award year	254	265	295
Amount of graduate student support	$2,712,911	$2,910,000	$3,470,000
Other Personnel Costs	486,109	520,000	600,000
Land, Buildings, and Fixed Equipment	—0—	—0—	—0—
Major Equipment	—0—	—0—	—0—
Other Equipment	2,888,449	3,100,000	3,710,000
Other Costs	1,548,435	1,610,000	2,020,000
Indirect Costs	3,152,866	3,390,000	4,050,000
Total	$12,975,094	$13,880,000	$16,650,000

[1] Excluding Industry-University Cooperative Research Activity.
[2] Including Industry-University Cooperative Research Activity.

CIVIL AND ENVIRONMENTAL ENGINEERING SUBACTIVITY $10,125,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Geotechnical Engineering	$2,418,993	$2,800,000	$2,200,000	$2,400,000	$200,000
Structural Mechanics	1,959,000	2,390,000	2,300,000	2,700,000	400,000
Water Resources and Environmental Engineering	3,773,777	4,440,000	4,800,000	5,025,000	225,000
Total	$8,151,770	$9,630,000	$9,300,000	$10,125,000	$825,000

Objectives and Description

The objective of the Civil and Environmental Engineering subactivity is to increase understanding of basic structural engineering principles and the interaction between natural and man-made environments. It is anticipated that such an understanding will enable mankind to modify the physical environment wisely and safely, without destroying the ecological balance.

The three major program elements comprising this subactivity are Geotechnical Engineering, Structural Mechanics, and Water Resources and Environmental Engineering. Geotechnical Engineering covers activities in which the earth's surface itself is involved, such as foundations, dams, and the general behavior of soils subjected to static or dynamic load conditions. Structural Mechanics represents the science of designing structures, such as buildings, bridges, ships, airplanes, etc. in such a way as to give the most efficient and economical service in response to given demands. Water Resources and Environmental Engineering supports studies of the flow of water, both above and below ground, and uses the principles of engineering, biology and chemistry research to protect and improve the physical environment, especially with respect to the reduction and possible elimination of pollutants in the air and in the water supply system.

Although the research supported by this subactivity is of fundamental character and intended primarily for the development of additional knowledge of basic phenomena as well as new methodologies to cope with new demands, the results of the research are expected eventually to be translated into direct benefits for coping with major environmental or societal problems. Among the former are the dangers of earthquakes, high winds, or floods, while the latter include the problems of finding additional energy resources while protecting the environment. For this reason, special priority is given to investigations covering construction materials and their most efficient use, soil and rock mechanics, water flows, erosion, and sediment transport. Topics of special importance include off-shore structures, high strength concrete, geotechnical in-situ instrumentation, and estuary dynamics.

Major Research Questions

- What is the effect of size in predicting the response of geological media and structures to mechanical load?
- How can in-situ instrumentation be used to determine geological structure and material properties as applied to engineering needs?
- What is the response of rock at elevated temperatures, and what is the combined heat and moisture flux in geological media in association with large deformations?
- In full scale controlled field experiments on natural phenomena of interest to environmental engineering, what are the most useful observations for testing theory, what are the best measurement methods, what are the needed levels of accuracy for these measurements, and what is the optimum number of observations?
- What control strategies for the activated sludge process will maximize reliability, minimize energy utilization, and still meet effluent requirements?
- What is the chemical mechanism by which potentially hazardous trace metals (e.g. cadmium, nickel, lead) are absorbed irreversibly by the common clay minerals in suspended sediment and soil, and how can we evaluate the potential for tracemetal attenuation by sediments and soils under high waste loading?
- How can the strength of fiber reinforced structural materials, including that of concrete, be improved?
- How can analysis of the response of structures to random loads be improved? In particular, what is the best method of analysis of the dynamic response of submerged structures?
- How can the design of large structural systems be optimized?

Significant Recent Achievements

- When buildings are subjected to dynamic loads (such as earthquakes, tornados, etc.) the continued functioning of essential equipment (life-sustaining, communications, fire fighting, electric power, etc.) is vital. Major progress has recently been made in analyzing the response and in predicting the survival of such equipment under dynamic load conditions. Researchers at the University of California at Berkeley, under the direction of J. L. Sackman, have developed a more accurate and more efficient computational technique of analysis, which makes it possible to predict the response of very complex systems to dynamic load conditions. This improved capability, which removes the guess-work from the design of such systems, has the potential for eventually leading to more efficient design codes and reduced construction costs.

- Recent advances in systems analysis techniques and in computer technology have been applied to the optimal operation of a modern water resources system. The development of this methodology can be an aid to systems managers in resolving the conflicts arising from various water uses. As a result of these research achievements, which were obtained by W. Yeh and his associates at UCLA, it may be possible to effect cost savings in public projects through better and more efficient utilization of water resources.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan of $9,300,000 is $330,000 below the FY 1980 budget request of $9,630,000. This reduction affects primarily the Geotechnical Engineering program element, in which a number of activities will have to be curtailed, at least temporarily. However, an increase of $360,000 in the Water Resources and Environmental Engineering program element over the FY 1980 Budget Request from $4,440,000 to $4,800,000,was deemed necessary in order to sponsor a number of highly promising, projects involving full-scale field experiments covering the discharge of jets and sewers into the ocean and other bodies of water.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$8,151,770
FY 1980 Program	$9,300,000
FY 1981 Request	$10,125,000
Difference—FY 1981/FY 1980	$825,000

The proposed increase of $825,000, from $9,300,000 to $10,125,000 in FY 1981, has been allocated among the three program elements, with the Structural Mechanics element receiving the largest increase. This will permit emphasis in FY 1981 on the following topics: full-scale in-situ experiments on the diffusion of sewer and other discharge; size effects in soils and rocks through the use of the centrifuge; and probabilistic design methods and optimization techniques in connection with wind and off-shore structures.

The percentage changes, by program element, between the FY 1981 Request and the FY 1980 Plan are as follows:

Geotechnical Engineering	9%
Structural Mechanics	17%
Water Resources and Environmental Engineering	5%

Coordination and Relationship to Other Efforts

There is very little fundamental research in water resources and environmental engineering sponsored by other Federal agencies. Both EPA and the Corps of Engineers sponsor research that is essentially ad-hoc and mission-oriented; nevertheless,

frequent contact with officers of these agencies assures the avoidance of any possible duplication of effort. NASA, Office of Naval Research, Army Research Office (Durham) and the Office of Scientific Research (Air Force) sponsor research in Structural Mechanics. The problems with which these agencies deal, however, are germane to their special missions, rather than of the fundamental character which is typical of NSF sponsored research. Regular contact is maintained not only to avoid duplication, but also to apprise the agencies of the content and progress of NSF research. Geotechnical Engineering research is of interest broadly within the realm of the U.S. Geological Survey and DOE. Contact is maintained with program managers in these areas.

Changes in Budget Structure

Civil and Environmental Engineering is now a subactivity within the newly organized Engineering and Applied Science activity. In the FY 1980 Budget this subactivity was a program element within the Engineering subactivity.

Geotechnical Engineering Program Element $2,400,000

Obligations by Program Element

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$2,418,993	$2,800,000	$2,200,000	$2,400,000	$200,000

Objectives and Description

The objective of this program is to increase our understanding of surface and subsurface earth materials, systems, and forces. Such an understanding is necessary for the advancement in construction methods and extraction processes. Accordingly, this program element sponsors research in soil, rock, snow, and ice mechanics as well as in foundation, mining and drilling engineering. Unlike research in geology and geophysics, research in Geotechnical Engineering must involve time scales as well as geometries which have relevance to engineering problems.

In considering construction, mining and drilling processes, and in-situ energy recovery schemes, there is a single problem which is predominant: the inability to characterize adequately the engineering and geological features of the site being considered.

The reasons for this difficulty are essentially two-fold. In the first place, the random underground location of most of the material makes it extremely difficult to obtain adequate samples in order to establish a detailed understanding of geological structure. Minor geological detail is critical in engineering. In the second instance,

Geotechnical Engineering deals with materials which have developed naturally over an exceedingly long time span and under exceedingly diverse conditions. As a result, the materials are extremely heterogeneous and often multiphasic, that is, having solid, liquid and gas components, and are therefore very difficult to characterize and to place into a mathematically tractable, stress-strain relationship.

In view of these difficulties, a major objective of the Geotechnical Engineering program element is to correlate mathematical models and laboratory data with field studies to account for inconsistencies stemming from a fundamental problem known as size effect. Because construction or extraction sites are usually large in size and the materials involved are not readily accessible, it is necessary to develop strategies to predict the probable presence and behavior of the material on the basis of a limited number of explorations. These strategies, together with the establishment of criteria for a suitable data base for the subsequent determination of material properties and material profiles should be systematic, and based on probabilistic techniques. The establishment of these principles, together with the development of easily useable analysis techniques, represents one of the major thrusts of this program element.

Further problems arise from the fact that the behavior of geotechnical systems subjected to enormous forces, as may occur in dams or building foundations, cannot be adequately determined by prototype testing such as is done with aircraft and space vehicles. A method of representing the actual forces and force relationships is achieved by the expedient of using a centrifuge to simulate scaled gravitational fields. Recent research results on the dynamic response of piles in granular media, which were obtained in a first-generation centrifuge, and other related developments make it appear likely that this line of research will yield useful results which can eventually be translated into practical economies. For example, the topic of slope stability deals with the question of the maximum slope that a given material can sustain without collapse. The importance of this question within the construction and mining industries, both from an economical point of view and from the point of view of safety, is self-evident.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The FY 1981 program will be increased by $200,000, from $2,200,000 to $2,400,000. Emphasis will be placed on site exploration, procedures and the third-generation centrifuge facility. These areas are essential in the search for methods of predicting the types of foundation materials to be found on construction sites, and for predicting the behavior of these materials under the enormous forces which are typical of large-scale construction.

Structural Mechanics Program Element $2,700,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$1,959,000	$2,390,000	$2,300,000	$2,700,000	$400,000

Objectives and Description

The field of structural mechanics covers the behavior of engineering structures such as bridges, buildings, etc., and their response to environmental conditions. The objective of structural mechanics research is to develop additional knowledge and to use this knowledge for the purpose of designing structures that are both safe and economical.

The analysis of the response of a structure to environmental forces, which may be represented by wind, snow, earthquakes, oceanwaves, or to man-imposed loads such as automobiles and trains, consists of two parts. The first part involves the analysis of material behavior, and research is directed toward improving this behavior and making it more suitable for the purpose for which the structure is to be used. The second part is represented by placing the knowledge gained into a mathematical format so that structures can be analyzed efficiently and economically within the computational capabilities available. The objective of the research is to make the structures more economical since, with improved power of analysis, it is possible to reduce uncertainty and improve safety.

Steel and concrete are the most widely used materials in construction. The behavior of steel is widely understood in the elastic range; additional research is needed, however, to gain a better understanding of the behavior of steel when it undergoes large deformations, that is, when it enters the inelastic range. This is true especially in the case of earthquake design, in which very large deformations may be possible under exceptional circumstances. In contrast, reinforced concrete, is produced artificially on the construction site and is often dependent on the characteristics of the materials which are locally available. Research on concrete seeks to characterize concrete behavior as a function of the large number of variables involved, and its objective is to develop types of concrete which satisfy special demands such as high strength, impermeability, or high temperature resistance.

As for the analytical aspect of structural mechanics, interest is currently centering on wind and ocean engineering. The difficulty in these areas is that wind and ocean forces are variable and unpredictable, and their characterization is often confined to statistical description. This leads directly to the problem of risk analysis, and especially toward the basic problem of structural analysis: how to minimize risk at minimum cost.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The Structural Mechanics program will be increased by $400,000, from $2,300,000 to $2,700,000. In FY 1981 the emphasis will be on probabilistic design methods and optimization techniques. This area is of importance because the forces acting on structures in off-shore, wind, or earthquake environments can be predicted only on a statistical basis, and the optimal design involves techniques that have as yet not been fully developed.

Water Resources and Environmental Engineering Program Element $5,025,000

Obligations by Program Element

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$3,773,777	$4,440,000	$4,800,000	$5,025,000	$225,000

Objectives and Description

The field of water resources and environmental engineering deals with the mechanical, chemical, and biological behavior of water and other fluids in the natural environment. The objective of the program element of Water Resources and Environmental Engineering is to gain a better understanding of this behavior, with the expectation that such improved understanding can provide better utilization of our natural resources and protect our environment.

Both theoretical and experimental research is involved. The theoretical work consists of the application of fundamental equations of fluid flow to the actual complex phenomena involved. This complexity is due to the effect of biological and chemical factors, the irregularity of the shape of actual environmental systems, and the multiplicity of materials which make up the fluid under investigation. For example, the erosion and transport of sediment, the diffusion, dispersion, and biological interaction of pollutants, and the flow through granular materials present special analytical difficulties. Further areas of interest are the mechanics of jets and plumes, the interaction between wind and waves, and environmental acoustics and aerodynamics. Because of the great analytical difficulties involved, special emphasis is placed on the mathematical modeling of the environment and the efficient solution of the resulting highly complex equations through improved computer techniques.

The reliability of numerical solutions depends on the accuracy of the data used in these equations, and these data often have to be obtained through experimentation. Unfortunately, in spite of their expense, full-scale experiments on actual environmental systems cannot be avoided, and the development of full-scale tests and testing techniques

is one of the current thrusts of the program element. Nevertheless, laboratory experiments are equally essential. The purpose of these experiments is the development of basic knowledge regarding the reactions of simplified and idealized systems. Armed with this knowledge, the researcher can then design full-scale experiments to reduce uncertainty and to maximize the utility of the information gained. This preliminary step is necessary because in view of the size of actual environmental systems, even full-scale experiments can deal only with a small portion of the total systems, and it is therefore essential that the information so obtained be as significant as possible. Phenomena to be investigated include thermally and wind-driven circulation in estuaries, discharge of jets and plumes into estuaries, and interaction of estuaries with rivers and ocean currents.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The Water Resources and Environmental Engineering program will be increased by $225,000, from $4,800,000 to $5,025,000 with an emphasis on full scale field experiments in the diffusion of sewers and jets into bodies of water.

QUANTITATIVE PROGRAM DATA
CIVIL AND ENVIRONMENTAL ENGINEERING SUBACTIVITY

Proposals and Awards

	Estimate FY 1979	*Estimate FY 198079*	*Estimate FY 1981*
Proposals:			
Number of Proposals	403	430	445
Total Dollars Requested	$45,160,212	$52,000,000	$58,000,000
Awards:			
Number of Awards	132	140	145
Total Dollar Amount	$8,151,770	$9,300,000	$10,125,000
Average $ per Award	61,756	66,429	69,828
Average Award Duration (Months)	18	18	18

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Universities and Colleges	98.9	98.9	98.9
Industry	0.8	0.8	0.8
Other	0.3	0.3	0.3

Personnel and Other Factors

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Faculty			
Number of Years Supported	50	53	55
Amount of Faculty Support	$1,468,500	$1,680,000	$1,830,000
Postdoctoral Associates			
Number of Years Supported	21	22	23
Amount of Postdoctoral Support	$281,000	$320,000	$350,000
Graduate Students			
Number Supported Per Award Year	170	185	190
Amount of Graduate Student Support	$1,485,000	$1,700,000	$1,850,000
Other Personnel Costs	262,000	300,000	330,000
Land, Buildings, and Fixed Equipment	—0—	—0—	—0—
Major Equipment	—0—	—0—	—0—
Other Equipment	1,161,600	1,330,000	1,450,000
Other Costs	1,504,427	1,710,000	1,860,000
Indirect Costs	1,988,643	2,260,000	2,455,000
Total	$8,151,770	$9,300,000	$10,125,000

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MECHANICAL SCIENCES AND ENGINEERING SUBACTIVITY $13,325,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Fluid Mechanics	3,573,306	$3,955,000	$3,800,000	$4,100,000	$300,000
Heat Transfer	3,294,694	3,770,000	3,600,000	3,900,000	300,000
Solid Mechanics	2,840,730	3,065,000	3,065,000	3,325,000	260,000
Mechanical Systems	1,000,000	1,200,000	1,200,000	2,000,000	800,000
Total	$10,708,730	$11,990,000	$11,665,000	$13,325,000	$1,660,000

Objectives and Descriptions

The objective of the Mechanical Sciences and Engineering subactivity is to develop a better understanding of the physical processes associated with power developed by various machines and engines. By applying this understanding through improved mathematic formulation and advanced methodology, the problems of analysis and design can provide the basis for more efficient use of power in industry.

Research in mechanical sciences and engineering has taken on additional significance in view of the energy problems and the problems of industrial competitiveness which are facing the United States in the 1980s. Increasing demands on the efficient and economical use of energy have required a reevaluation of a great many existing industrial machines, engines and processes.

Heat is a major carrier of power. Associated with the use of heat are lubrication problems and fluid flow. The Fluid Mechanics program element seeks to increase our understanding of biomechanics, hydrodynamics, stability and turbulence, and viscous flow.

The Heat Transfer program element supports research aimed at increasing the basic understanding of transport mechanisms in thermal energy transfer. Research on a broad range of phenomena and processes such as multiphase heat transfer, high flux transfer, combustion flames, ionized gases, and porous media is essential if we are to understand and enhance the use of heat energy.

Increasing demands for more efficient industrial processing techniques have created a need for improvements in material strength and for improved understanding of solid materials. The Solid Mechanics program element focuses on the prediction and measurement of the mechanical strength of solids and on the way that strength may change as a result of exposure to a given loading or environment. Unexplained fatigue fractures in solid materials require an accelerated study of fracture mechanics and fatigue damage.

Incorporation of the principles developed through research in mechanical sciences and engineering into design is difficult. Specifically, how does one apply re-

search in fluid flow, heat transfer, and solid materials to the industrial environment through improved machinery, engines and processes. To meet these needs and to bring into sharper focus this emerging area of research, the Mechanical Systems Program Element was established.

Major Research Questions

- What is the constitutive theory and damage accumulation rule for creep-fatigue interaction, especially to high temperature phenomena in power generation?
- How can flaws be detected in solids through non-destructive evaluation, and how can the critical nature of flaws be assessed?
- What are the rules of heat conduction, convection, and thermal radiation, and what is their quantitative description in thermal energy transfer processes that are important in energy conservation, power generation, and chemical processing?
- In turbulent shear flow past bluff bodies, what is the interaction mechanism between free stream vorticity and boundary-layer induced vorticity?
- How can nonlinear stability theory, such as bifurcation theory, be applied to hydrodynamic stability and laminar turbulent transition?
- What is the best and most effective method of application of control theory to mechanical operations?
- How can recent developments in computer technology best be applied to automated manufacturing processes, with particular reference to robotics?

Significant Recent Achievements

- Progress in our understanding of heat transfer mechanisms operating in porous insulation systems has made it possible to design more efficient insulation for homes and industrial plants. This has been achieved by C. L. Tien and his associates at the University of California at Berkeley through the development of a method of predicting moisture transport and heat transfer effects in porous structures.
- The unexpected failure of structural or machine elements is very often due to the presence of flaws in the material. The discovery of these flaws by non-destructive means, such as through the analysis of wave scattering in flawed solids, is therefore important in predicting and preventing such failures. A major advance in this direction is represented by the development of a new and improved computational technique ("T-matrix") by Y. H. Pao and his coworkers at Cornell University.

Changes Between FY 1980 Budget and FY 1980 Current Plan

The Current Plan of $11,665,000 represents a decrease of $325,000 from the FY 1980 Budget Request of $11,990,000. This decrease has been divided between the Fluid Mechanics and Heat Transfer program elements.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$10,708,730
FY 1980 Current Plan	$11,665,000
FY 1981 Request	$13,325,000
Difference—FY 1981/80	$1,660,000

The proposed increase of $1,660,000, from $11,665,000 to $13,325,000 has been allocated largely to the new Mechanical Systems program element, with that program receiving an additional $800,000. The remaining portion, $860,000, is distributed among the other three programs, with the Solid Mechanics program receiving the smallest increase because several topics in that program are being transferred to Mechanical Systems.

In FY 1981, emphasis will be placed on: design of mechanisms, such as gears and linkages; control theory, particularly as applied to mechanical systems; turbulence and bluff body dynamics; multiphase and high flux heat transfer; and fracture and fatique mechanics.

Percentage changes between FY 1980 Current Plan and the FY 1981 Budget Request, by program element, are as follows:

Fluid Mechanics	8%
Heat Transfer	8%
Solid Mechanics	9%
Mechanical Systems	67%

Coordination With and Relationship to Other Efforts

Areas of mutual interest exist with some branches of DOD and to a lesser extent with DOE. Responsible officers of the relevant agencies are in constant communication with the officers of this subactivity for the purpose of coordinating the effort and of avoiding duplication. Regular meetings take place with officers of the Office of Naval Research, Naval Research Laboratory, and the David W. Taylor Naval Ship Research and Development Center. Other frequent contacts are with NASA (Langley, Lewis) and the Army Research Office (Durham). The format of these meetings depends on the degree of potential overlap and the extent of desirable cooperation. Interagency committees, such as with the Taylor Research and Development Center, meet at regular intervals, while other, less formal groups meet only to discuss specific issues as they arise.

Changes in Budget Structure

Mechanical Sciences and Engineering is now a program subactivity, whereas in FY 1980 it was a program element. Giving Mechanical Sciences and Engineering subactivity status focuses budget information on a research area of longstanding engineering importance. In addition, the Mechanical Systems program element is a new element in the budget; efforts in this area in prior years were primarily concentrated in the Solid Mechanics program element.

Fluid Mechanics Program Element $4,100,000

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$3,573,306	$3,995,000	$3,800,000	$4,100,000	$300,000

Objectives and Description

The objective of the Fluid Mechanics program is to increase our understanding of the dynamical behavior of flow of fluids related to technical and scientific applications, such as combustion, mixing, and dispersion in the atmosphere and the ocean, and bioengineering.

It is recognized that turbulent flow plays an essential role in most natural or man-made mixing and transport processes. The need for better understanding of the structure of turbulence, in particular the role of coherent structure, is important since this may well be the mechanism for mixing and induced transport of material and energy. Coherent structure can be modeled by discrete vortices. Hence the study of dynamical interaction of vortices is essential. Furthermore, the detailed examination of the formation and convection of these vortical structures is a major feature of the current research on transition from laminar to turbulent flow. There has been a lack of analytical research in this area due to the complexity of the phenomena. However, semi-analytical numerical experiments will be emphasized to achieve a better balance in the development of this sub-field.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The FY 1981 effort will be increased by $300,000, bringing the program from $3,800,000 to $4,100,000. In this effort, research will be concentrated in the area of turbulence and blunt body dynamics because of the potential savings in energy that may result from a better understanding of these areas.

Heat Transfer Program Element $3,900,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$3,294,694	$3,770,000	$3,600,000	$3,900,000	$300,000

Objectives and Description

The objective of the Heat Transfer program is to advance the basic understanding of transport mechanisms in thermal energy transfer. A broad range of phenomena and processes occurring in engineering systems and in their environment is covered. There is a need for a new or extended fundamental data base for thermal processes and material behavior, to advance the necessary experimental and theoretical techniques, and to devise more efficient thermal processes.

Enhanced support is provided for research in multiphase heat transfer. This area includes two phase flow, boiling, evaporation, vapor explosion, and condensation. Emphasis is on the construction of predictive models based on physical understanding. Research in high flux heat transfer is concerned especially with the attainment of heat fluxes which are substantially greater than those obtained by conventional means for a prescribed temperature difference. Support is provided for understanding the performance characteristics of high flux devices and for establishing advanced high flux concepts that are compatible with energy and material conservation. Factors that lead to thermally deleterious effects on these devices, such as flow separation and heat transfer fouling, are also given attention.

High temperature transport research deals with combustion flames and ionized gases. This is a rapidly developing field. Increased support is provided for delineating the various mechanisms for heat transfer and for assessing the influence of these mechanisms on the reaction products. Research in porous media heat transfer is directed at a better understanding of the transport phenomena in soils and thermal insulation systems fibers, powders and foams. This area is receiving increased research support to provide an improved understanding of the effects of moisture, fiber geometry, and temperature-dependent properties.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The FY 1981 program will be increased by $300,000, from $3,600,000 to $3,900,000 and will be directed at research in multiphase and high flux heat transfer, which has direct and immediate relevance to energy-related industries.

Solid Mechanics Program Element $3,325,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$2,840,730	$3,065,000	$3,065,000	$3,325,000	$260,000

Objectives and Description

The objective of the Solid Mechanics Program is to advance the knowledge and understanding of the fundamental principles which underlie the behavior of solid materials.

The major program activity focuses on the prediction and measurement of the mechanical strength of solids, and on the way in which the strength may change as a result of exposure to a given loading or environment. Historically, the approach taken has been phenomenological, but the trend increasingly is to supplement this approach with considerations based upon behavior at the microstructural, and sometimes even the atomistic, level. In practice, this means an increasing use of principles developed within the areas of materials science, physics and chemistry.

Particular problem areas in which significant advances are being realized are: (1) multiphase solids such as oil shale, (2) determining the size, shape and location of flaws in solids using ultrasonic techniques, and (3) understanding the effect of these flaws on the strength characteristics of structural and machine elements. These developments are occurring within a broader background of applications and mission-oriented research. This background provides the motivation for support of the research and at the same time increases the likelihood that the results of the research will be utilized.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The FY 1981 program will be increased $260,000, from $3,065,000 to $3,325,000. Emphasis will be placed on research in the area of fracture and fatigue mechanics, especially in the sense of combining continuum mechanics with structure. Research in this area is vital in the prediction and prevention of sudden crack failures.

Mechanical Systems Program Element $2,000,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$1,000,000	$1,200,000	$1,200,000	$2,000,000	$800,000

Objectives and Description

The Mechanical Systems program element, which was initiated in FY 1980, is intended to fill a major gap in the research effort in the subactivity of Mechanical Sciences and Engineering. It represents the design phase of mechanical engineering.

Some of its objectives are transferred from the Solid Mechanics program element, with additional emphasis on design. This includes the area of rigid body dynamics and the design of mechanisms. Since the purpose of a mechanism cannot be achieved within the framework of a finite number of available parameters to be selected by the designer, the task of synthesizing a mechanism is reduced to determining the optimal configuration. This becomes especially complex with respect to three-dimensional mechanisms. Another important problem of rigid body dynamics is the analysis of vehicular stability, with special application to the stability of railroad vehicles.

A major thrust of the new program element is tribology, that is, surface mechanics and lubrication. An example of major significance in this field is the design of gears in such a way as to minimize wear and tear, chatter, and the development of heat. Other areas of research will be rotor dynamics, general machine dynamics, and acoustics. The latter is significant from an environmental point of view through its connection with efforts to reduce noise in the workplace.

Support for mechanical systems has two major facets: (1) the study of mechanics and materials, and converting better understanding into more efficient design procedures; and (2) the application of recent developments in computer technology to the automation of the manufacturing process, with eventual application to robotics.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

It is anticipated that this program element will see substantial increases in future years as increasing demands for improved design in industrial machinery, engines, and processes begin to reflect the research results in fluid mechanics, heat transfer, and solid mechanics. An initial increase of $800,000 in FY 1981, bringing the program from $1,200,000 to $2,000,000 will be used to support research in control theory as applied to manufacturing processes. Such an increase will provide for the foundation on which later research in improved manufacturing methods and robotics can be based.

QUANTITATIVE PROGRAM DATA
MECHANICAL SCIENCES

Proposals and Awards Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	471	495	600
Total Dollar Requested	43,754,766	50,000,000	65,000,000
Awards:			
Number of Awards	194	205	220
Total Dollar Amounts	10,708,730	11,665,000	13,325,000
Average Dollar Per Award	55,200	56,902	60,568
Average Award Duration (Months)	18	18	18

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	99.0	99.0	99.0
Industry	0.7	0.7	0.7
Other	0.3	0.3	0.3

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Faculty:			
Number years supported	60	62	64
Amount of faculty support	$1,806,000	$2,015,000	$2,208,000
Postdoctoral Associates:			
Number of years supported	28	29	30
Amount of postdoctoral support	$400,300	$435,000	$480,000
Graduate Students:			
Number supported per award year	226	230	240
Amount of graduate student support	$2,150,000	$2,300,000	$2,580,000
Other Personnel Costs	748,000	815,000	915,000
Land, Buildings, and Fixed Equipment	—0—	—0—	—0—
Major Equipment	—0—	—0—	—0—
Other Equipment	1,513,000	1,540,000	1,760,000
Other Costs	1,729,700	1,925,000	2,250,000
Indirect Costs	2,361,030	2,635,000	3,132,000
Total	$10,708,730	$11,665,000	$13,325,000

APPLIED RESEARCH SUBACTIVITY $18,700,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Applied Social & Behavioral Sciences	$8,324,353	$8,900,000	$8,545,000	$9,040,000	$495,000
Applied Physical, Math, & Biological Sciences & Engineering	9,283,860	9,300,000	9,083,409	9,660,000	576,591
Total	*$17,608,213	*$18,200,000	*$17,628,409	*$18,700,000	*$1,071,591

*Does not include approximately $2.2 million in FY 1979 and $2.0 million both in FY 1980 and FY 1981 for small business solicitations. These funds are now included and displayed in the Small Business and Industrial Technology subactivity for these years.

Objectives and Description

The objectives of the Applied Research subactivity are to provide an improved understanding of a range of social, economic and policy problems and to increase the rate of technological innovation growing out of significant discoveries in basic sciences and engineering.

The Foundation has made and continues to make large investments in basic research. Frequently, this work leads to significant conceptual, measurement, or instrumentation developments which have the potential for exciting new technological innovations and applications of knowledge which might aid in ameliorating some of the nation's pressing economic, environmental, resource, and social problems.

The application of knowledge gained through basic research is pursued both through applied research programs in Federal mission agencies as well as industrial research in private industry. Moving basic research results along the continuum towards applications, however, is a complex process and there is a strong likelihood that important applications may remain undeveloped because the research required to bring them to fruition is still too long term or too risky or because the work cuts across the concerns of more than one agency and thus is no agency's concern. As a result, the realization of benefits flowing from the nation's investment in basic research is delayed, if not postponed indefinitely.

The range of such applied research opportunities is wide. Recent advances in basic understanding of membrane transport phenomena, for example, make possible an acceleration of more focused, interdisciplinary work on separation and purification technologies which could lead to significant breakthroughs in the recovery of metals from low-grade ores and the removal of industrial wastes from water. Developments in engineering, computer science, artificial intelligence and mathematics provide the scientific underpinning for an acceleration of applied research on problem areas such as computer vision, mechanical sensors, machine tools, systems design and parts

modeling. Such work directly provides a technical base for substantially improving industrial productivity in batch process manufacturing.

Similarly, in the social sciences, current applied work in the critical policy areas of inflation accounting and company pension liabilities is firmly rooted in basic research on the theory of the firm. Such research provides a basis for developing accounting standards which more nearly reflect the true costs of long term liabilities in a period of rising interest rates. Work in psychology, political science and law provides the groundwork for applied research on human reactions to emergency situations or to laws and administrative regulations.

The Foundation's objective in supporting an applied research activity is to provide a framework for supporting such interdisciplinary, problem-oriented proposals. The program provides a flexible framework for identifying emerging opportunities to support, selectively, the extension of basic scientific knowledge to significant technical, social and economic problem areas which lie outside of or cut across the research priorities of other Foundation programs or the programs of other mission agencies.

Significant Recent Achievements

- Sonar, an acoustic reflection technique long used for detecting objects underwater, offers promise as a technique for seeing into rock. Early efforts by researchers at Texas A&M to utilize a single acoustic frequency were discouraging, as the rock formations of salt caused the beam to diverge, resulting in multiple return signals. A high frequency transducer, driven at two frequencies, was successful in overcoming this problem, however, and produced the narrow beam return necessary to obtain accurate reflections of changes in salt formations and their locations. This provides a basis for experimenting with the use of sonar for seeing into a variety of other rock formations for potential hazards routinely encountered in tunneling and mining.
- In batch process manufacturing, a common arrangement is to have one or more parts move past a human operator who sorts and assembles them to make a finished component. In a growing number of cases, robotic arms are replacing human operators, freeing them from monotonous routine and allowing them to do more challenging tasks. However, because these robotic arms are limited in their ability to respond to uncertainty or change in the parts environment, their operations must be precisely pre-programmed and carefully structured, thus limiting their general utility. A hardware/software vision module for sensing and processing images, developed by the Stanford Research Institute (SRI), holds out the possibility of industrial robots with vision. The module consists of three major components: a solid state TV camera; a microcomputer, storing a library of vision subroutines previously developed at SRI; and an interface preprocessor performing general purpose functions. Trained by showing, it can determine the identity, position and orientation of parts and holes. A number of research groups and companies have each obtained one of

these modules and are currently at work trying to link them up with robotic arms.

- It has long been claimed that regulation may, under some circumstances, prove to be an impediment to innovation and technological progress. This belief is one of the factors motivating current policy reviews of regulation in the trucking and railroad industries. A recently completed study by researchers at the University of Wisconsin and Northwestern University provides new evidence on this issue. During the period from 1953 to 1974, Canada substantially reduced its public control of railroads while the United States maintained its long-standing, detailed regulation of American railroads. This situation provided a natural experiment for examining the differential impact of national regulation on this sector of the economy. The study results show conclusively that the rate of technological change and productivity gains in American railroads were substantially less than they were for Canadian railroads during this twenty year period. These investigators concluded that these differences were due primarily to differences in the degree of regulation in the two countries.
- A small macro-model of the U.S. economy, developed by Robert Hall of Stanford University and Dan McFadden of MIT, has been used to examine the effects of exogenous price shocks, such as sharp energy price increases, on the American economy. The initial results of this work show that unexpected increases in world oil prices drive down investment and push employment below the full-employment level. By examining how monetary and fiscal policies interact with these effects, the investigators are able to demonstrate that higher investments and decreased unemployment can be achieved with increased general price levels. This research provides an important tool to policy makers for analyzing the feedback mechanisms between the energy sector and the economy.
- The technical feasibility of a new membrane separation process for the recovery of nickel, cobalt, and copper from domestic, low-grade oxide ore has been established by Bend Research, Inc. The process involves sequential separation of metal ions through specially fabricated fibers containing selective ion-exchange liquids. This is an exciting breakthrough in ore separation, because it requires minimal energy and reduces the large volume of the solutions that must be handled by the processor.
- An outgrowth of the energy storage requirements of the thermonuclear fusion program is a return to the kind of electrical generator which Faraday invented in 1831. Grady Rylander and his colleagues at the University of Texas in Austin have recently shown that this machine, the homopolar generator, has important advantages for welding. The generator acts as a reservoir of energy which is dissipated at the weld joint in a short pulse of large current at hundreds of thousands of amperes. This system permits large areas to be welded quickly, requires no fluxes or inert gas atmospheres, and allows some annealing through control of the current pulse. Since the generator accumulates energy at a low rate, its power demands are relatively modest, but the power output is large

for the short time required to make the weld. Applications are foreseen in railroad rails, pipelines, and shipbuilding.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan represents an overall decrease of $571,591 below the FY 1980 Budget Request of $18,200,000. This decrease is a part of the broader response of the Foundation's Engineering and Applied Science Directorate to a Congressional cut in the NSF appropriation request of $1,500,000 for all applied research from $62,400,000 to $60,900,000.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$17,608,213
FY 1980 Program	$17,628,409
FY 1981 Request	$18,700,000
Difference—FY 1981/FY 1980	$1,071,591

The $18,700,000 requested for this subactivity is $1,071,591 more than the FY 1980 program of $17,628,409. These funds will be used to:

- Initiate a new research thrust to examine the impacts of transitions from heavily regulated to less regulated industries or services. As public policy discussions consider a wide range of alternatives to the present regulatory regime, it is crucial to begin a systematic examination of the organizational, social, market, and technological changes which occur following substantial reduction in public regulation of an activity. Such research will begin to provide an improved knowledge base for adjusting regulatory policies in the United States.
- Expand work in areas of manufacturing processes and materials handling. Research on grinding and surface finish, detection of machine tool wear and automatic feedback, and analytic modeling and study of scheduling problems is needed to improve computer-based planning in flexible manufacturing systems and to provide the technical basis for automating certain machine processes as a part of these systems. An expansion of this work is necessary to preserve program balance and to take advantage of advances in other facets of automated manufacturing research supported by the Applied Research Division and other parts of the Engineering and Applied Science Directorate.

Percentage changes between FY 1981 and the FY 1980 Current Plan for the Applied Research program elements are:

Applied Social and Behavioral Sciences Element	6%
Applied Physical, Mathematical and Biological Sciences and Engineering	6%

Coordination With and Relationships to Other Efforts

Program managers meet with the EAS Interagency Coordinating Committee to review emerging applied research areas and to discuss future program directions. Individuals on the Coordinating Committee serve as key contacts for staff members wishing to have proposals reviewed, for coordination purposes, by relevant persons in a mission agency. Thus, the review of individual proposals by one or more agency representatives, using a special review form designed specifically for this purpose, constitutes an important part of the coordination process.

Staff members serve on numerous interagency committees and review panels. This provides another point for interactions with other applied research programs and personnel elsewhere in Government. In the recent past, for instance, they have participated in meetings of the Interagency Joint Aquaculture Committee, the Outer Continental Shelf Mining Policy Task Force, the Inter-Agency Task Force on International Computer Communication Policy, the Interagency Committee on Man and the Biosphere, and the Interagency Committee for Coordination of Research on Acid Rain. The Division supports several committees of the National Academies of Science and Engineering. In FY 1980, these included the U.S. National Committee on Tunneling, the U.S. National Committee on Rock Mechanics, and the Board on Telecommunications—Computer Applications. Research conferences are supported in such areas as production research and telecommunications. They provide a means for drawing together researchers, research funders, policymakers, and industrial and governmental users of research from across the Federal government, private industry, U.S. and foreign academic institutions, and research organizations.

Applied Social and Behavioral Sciences Program Element $9,040,000

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/'80*
$8,324,353	$8,900,000	$8,545,000	$9,040,000	$495,000

Objectives and Descriptions

The United States faces a number of pressing public issues as it enters a new decade: continuing inflation; accommodation to new energy and environmental constraints; shifting demands and expectations for public services more efficiently managed; and a leveling off in industrial productivity. Increasing numbers of social and behavioral scientists are interested in bringing their scientific skills, theoretical frameworks and methodologies to bear on these and other problems to provide analytic tools

and systematic data bases for policy makers, managers, and others who have some responsibility for alleviating or resolving them.

This Foundation program element provides support to investigators in the social and behavioral sciences who wish to undertake applied research on high priority issues. Since these policy issues frequently cut across conventional disciplinary boundaries, the review process is explicitly structured to provide for an interdisciplinary assessment of problem significance, scientific merit and potential policy utility. Special encouragement will continue to be given to research dealing with regulatory policy, telecommunications, intergovernmental fiscal management, employment, and inflation.

Public Policy and Regulation ($5,425,000)

This area provides support for research aimed at providing more and better information on policy issues of national concern.

In particular, research in this area:

- Examines questions in international trade and investment;
- Examines the implications of inflation accounting for public policy;
- Characterizes the role of expectations in economic models and their significance for shaping domestic stabilization policies;
- Provides information on the impacts of regulation on financial institutions;
- Explores issues in telecommunications policy emerging from scientific advances and technological innovations; and
- Assesses the impact of technology on civil litigation and administrative conflict resolution.

The level of support for this area will be increased by $495,000 over the current plan for FY 1980, i.e., from $4,930,000 to $5,425,000. This increment will be used to initiate research on the economic, legal, social and technological consequences of partial or total deregulation of an industry, profession or service. This research will expand the knowledge base for the growing public debate on the costs and benefits of different levels of regulation.

Public Service Delivery and Urban Problems ($1,770,000)

Issues associated with the delivery of public services at the Federal, State and local levels range all the way from questions about the causes and consequences of public disenchantment with public programs to concerns about the characteristics of the emerging intergovernmental fiscal system, the impact of demographic changes or population migration on taxes, the demand for services, and the "quality of life" in both urban and rural areas. Of particular interest is research which:

- Explores the nature of the intergovernmental fiscal system, the flow of funds through that system, and their impact on State and local fiscal conditions and program priorities;

- Assesses the impact of public and private performance standards and codes of ethics on the delivery of professional and semi-professional services;
- Studies and evaluates organizational changes or the introduction of new incentive systems, management information systems or management styles as they effect productivity or quality of services; and
- Develops or expands regional or state economic models, and examines revenue and expenditure forecasting models with a view to improving their policy utility.

The level of support provided in this area remains $1,770,000, the same amount as planned for FY 1980.

Industrial Organizations and Markets ($1,165,000)

Research in this area provides policy-relevant information on industrial organizations and markets by:

- Developing a better understanding of the relative growth and decline of various economic sectors in the U.S. economy, with increased emphasis on empirical studies;
- Developing testable models for better assessment of the implications for U.S. economic activity of resource and environmental constraints, with particular emphasis on incorporating technological change, resource depletion, and waste recycling into economic models;
- Examining the impact of public policies on the productivity of labor and capital markets;
- Broadening the understanding of changing employee-employer relationships;
- Assessing the impacts of new telecommunications, micro-electronic and robotic technology on workers, management and the organization of work in different firms; and
- Developing a better understanding of the psychological and social meaning and organization of work, occupations, and careers.

The level of support in this area remains $1,165,000, the same amount as planned for FY 1980.

Individuals and Group Processes ($680,000)

Imbedded in most discussions of significant public policy issues are critical assumptions about human values, preferences for risk, performance and response capabilities, and decisionmaking and information processing capabilities, as well as assumptions about non-hierarchical group interaction and judgment processes. Research in this part of the Applied Social and Behavioral Sciences program element analyzes such assumptions in the context of significant technological, social, economic or policy issues. During the past year, this area has encouraged research which:

- Provides information for policy guidelines aimed at changing or regulating individual or group behavior or limiting exposures to risky technical, physical or social events;
- Reveals the cognitive and physiological responses involved in decision-making and information processing by human beings under normal and emergency conditions; and
- Examines the interaction of individuals or groups with technological and material devices and environments.

The level of support provided in this area remains $680,000, the same amount planned for FY 1980.

Major Research Questions

- What are the costs and benefits of alternative governmental policies for affecting the economic behavior and decision-making of individual firms, workers and consumers?
- How can changes in organization design, management, personnel policies, and budgeting and control systems improve public service delivery by State and local governments? What effects does the continuing evolution of the intergovernmental system have on local priorities, fiscal conditions, and service delivery?
- What are the mechanisms by which exogenous price shocks are transmitted to domestic price levels? How do fiscal and monetary policies interact to moderate these shocks? How are expectations incorporated into economic models, and how do they shape economic policy.
- How do individuals and groups make decisions and process information under emergency conditions? What can be done to improve their ability to respond under such circumstances?
- How are innovations in telecommunications, microelectronics, robotics, and information technology affecting managerial decision-making, job design, productivity and the quality of work in public and private organizations?

Applied Physical, Mathematical, and Biological Sciences and Engineering Program Element $9,660,000

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$9,283,860	$9,300,000	$9,083,409	$9,660,000	$576,591

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Objectives and Description

The objectives of this program are to identify and support high risk, frequently interdisciplinary research aimed at exploring and extending the application potential of basic knowledge in the natural sciences to a wide range of significant applied problem areas. It is receptive to proposals from investigators in all areas of the natural sciences and engineering on applied topics of their own choosing which do not duplicate work supported by mission agencies. Special encouragement is given to work related to problems in batch process mananufacturing, non-fuels minerals processing, minerals exploration technologies and techniques, and the management of plant and animal resources in terrestrial and aquatic environments.

Physical, Math and Engineering Applications ($5,315,000)

Applied research growing out of developments in the physical or mathematical sciences or engineering is supported under this program element.

Of particular interest is research which:

- Draws on work in engineering, computer science, intelligence systems and materials science for advancing the automation of diverse tasks in batch process manufacturing;
- Extends work in sophisticated computer languages, tactile and force sensing, and computer vision for communicating with and controlling advanced industrial robots;
- Draws on work in lasers and plasmas for potential applications in the production and purification of chemicals, polymers or metallic aloys;
- Applies basic knowledge in the fields of catalysis and electrolysis towards the solution of existing and future industrial processing problems; and
- Extends research in biochemistry and synthetic organic chemistry to create synthetic enzymes for industrial applications.

The level of support for this area will be increased by $576,591 over the current plan for FY 1980; i.e., from $4,738,409 to $5,315,000. This increment will be used to expand work in areas of manufacturing processes and materials handling in order to take advantage of significant advances in other facets of automated manufacturing research supported by the Foundation.

Biological and Ecological Applications ($2,845,000)

This area provides support for research on a broad range of significant applied problem areas growing out of fundamental work in the biological and ecological sciences. High priority has been given to work which:

- Takes advantage of recent advances in cell propagation, genetic engineering, and protoplast fusion to explore opportunities for research on the production of

secondary metabolites and the cloning of desirable characteristics in plants or animals;

- Applies basic understanding of ecosystem structure and functioning to environmental management problems arising from interactions between human, technological, and natural systems; and
- Provides an improved knowledge base for managing living resources, drawing on advances in understanding of the physiological and behavioral characteristics of plants and animals in terrestrial, freshwater, estuarian and oceanic environments.

The level of support for this area remains unchanged from the currently planned FY 1980 level of $2,845,800.

Geophysical and Environmental Applications ($1,500,000)

This program area supports research directed at increasing the rate of technological innovation and application of basic knowledge growing out of discoveries in physics, biology, electrical engineering, geology, and the environmental sciences. Two issues have especially significant social, economic and technical importance for the nation in the coming decade: (1) the increasing scarcity of non-fuel minerals in the continental United States; and (2) the increasing pollution of groundwater by seepage from surface dump sites, buried waste and polluted streams. Thus, particular encouragement will be given to work which holds out a promise for innovative technology and techniques for:

- Seeking mineral deposits which have no surface manifestations;
- Processing non-fuels minerals; and
- Assessing and alleviating the growing problem of groundwater pollution.

The level of support for this area will be held constant at the planned FY 1980 level of $1,500,000.

Major Research Questions

- Can significant tasks involved in parts assembly be fully automated through the development of advanced sensor equipped robots and computerized materials handling and scheduling systems?
- Can an improved understanding of manufacturing processes, such as grinding, machining and other techniques for material shaping and removal, lead to the development of improved technologies and automated sensing and control systems for automating parts production?
- Can the seismic reflection or refraction techniques currently utilized for oil and gas exploration in sedimentary rock be successfully adapted for the exploration

of non-fuel minerals in igneous or metamorphic rocks? Is there a way to utilize our understanding of the geophysical properties of rock to differentiate between an ore body and its containing host rock?

- Are there techniques that will utilize ionic exchange or other geochemical processes to attenuate potential pollutants seeping through the soil? Can models be developed which can accurately predict the migration of potential pollutants in three dimensional space for various types of soil and rock? How does such pollution affect the microbial populations of the surrounding soil and with what long-term consequences?
- What new processes and technologies can be developed for improving the efficiency of separation of minerals from low grade ore bodies and the handling of the resulting processing wastes?
- Can we draw on basic advances in understanding of the physiological and behavioral characteristics of plants and animals to improve our ability to manage these resources more efficiently and effectively?

QUANTITATIVE PROGRAM DATA
APPLIED RESEARCH

Proposals and Awards Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	550	725	850
Total Dollar Requested	85,583,000	98,600,000	110,500,000
Awards:			
Number of Awards	153	190	190
Total Dollar Amount	17,608,213	17,628,409	18,700,000
Average $ Per Award	115,394	92,781	98,421
Average Award Duration (Months)	18	16	16

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	73.0	75.0	76.0
Industry	9.0	7.0	6.0
Small Business	(6.0)	(4.0)	(3.0)
Other	(3.0)	(3.0)	(3.0)
Nonprofit (nonacademic)	18.0	17.5	17.5
State and Local Government	—	0.5	0.5
National Laboratories	—	—	—
Federal Agencies	—	—	—

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Faculty			
No. years supported	93.5	90	90
Amount of faculty support	$2,479,713	$2,638,935	$2,800,000
Postdoctoral Associates:			
No. of years supported	82.2	81	81
Amount of postdoctoral support	$1,273,004	$1,316,401	$1,400,000
Graduate Students			
No. supported per award year	130.2	118	124
Amount of graduate student support	$1,352,571	$1,287,330	$1,370,000
Other Personnel Costs	2,953,112	2,810,668	2,980,000
Land, Buildings, and Fixed Equipment	33,814	32,183	34,000
Major Equipment	387,737	369,035	390,000
Other Equipment	429,441	408,727	435,000
Other Costs	2,817,855	2,681,938	2,850,000
Indirect Costs	5,880,966	6,083,194	6,441,000
Total	$17,608,213	$17,628,409	$18,700,000

PROBLEM-FOCUSED RESEARCH SUBACTIVITY $30,500,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Earthquake Hazards Mitigation	$16,473,344	$17,900,000	$17,900,000	$19,400,000	$1,500,000
Chemical Threats to Man and the Environment	3,152,998	—0—	—0—	—0—	—0—
Alternative Biological Sources of Materials	4,132,858	3,900,000	2,936,000	2,900,000	-36,000
Community Water Management	724,517	—0—	—0—	—0—	—0—
Science and Technology to Aid the Handicapped	1,329,672	1,600,000	2,100,000	2,100,000	—0—
Human Nutrition	993,031	1,000,000	989,000	1,100,000	111,000
Integrated Basic Research	4,781,731	5,000,000	4,460,000	4,500,000	40,000
Problem Analysis	950,683	1,000,000	500,000	500,000	—0—
Total	*$32,538,834	*$30,400,000	*$28,885,000	*$30,500,000	*$1,615,000

*Does not include approximately $1.4 million in FY 1979 and $1.0 million both in FY 1980 and FY 1981 for small business solicitations. These funds are now included and displayed in the Small Business and Industrial Technology subactivity for those years.

Objectives and Description

The Problem-Focused Research (PFR) subactivity concentrates research on critical societal problems where it is clear that such research is essential for dealing effectively with the problems. The subactivity provides the organizational setting for the support of research programs that advance basic scientific knowledge and its applications in areas directly relevant to the health and welfare of the nation. PFR's efforts are quite varied from program to program: from the identification and support of basic research in areas judged to be problems of long-term concern to the provision of support for research that extends into practical applications of immediate benefit. The type and number of research topics and programs change over time as new problems and issues are selected and on-going programs are completed, transferred, or disestablished.

High scientific content, a focus on existing or emerging nationally important problems, and a utilitarian demonstration of the value of basic research are common attributes of all PFR program elements. PFR programs are generated through the development of research agendas which specify the scope of the problem addressed, identify critical issues to be examined, and establish an end-point for the research.

Currently, the research efforts of the subactivity consists of six program elements: Earthquake Hazards Mitigation; Alternative Biological Sources of Materials; Science and Technology to Aid the Handicapped; Human Nutrition; Integrated Basic Research; and Problem Analysis.

The Earthquake Hazards Mitigation program is an integral component of the President's National Earthquake Hazards Reduction Plan and provides the primary source of Federal support for basic and applied research in earthquake engineering and policy-related issues.

The Alternative Biological Sources of Materials program supports research to provide new and secure domestic sources of critical materials and chemicals of commercial importance.

Programs in Science and Technology to Aid the Handicapped and Human Nutrition were introduced in FY 1979. The Aid to the Handicapped program supports research on ways to aid the physically and mentally impaired by capitalizing on recent, basic advances in science and technology. Human Nutrition research focuses on the assessment of the nutritive value of processed foods by investigation of the physical, chemical, and biochemical changes which occur in these foods during cooking, processing, packaging and storage.

Integrated Basic Research provides strong ties between basic and applied research by providing joint funding with the NSF basic research programs for projects which are responsive to selected nationally important problem areas.

Problem Analysis supports assessments of particular emerging problems having significant scientific content to determine whether a concerted research effort is appropriate and, if so, the options for NSF.

Programs on Chemical Threats to Man and the Environment, which was established in FY 1971, and the Community Water Management, which began in FY 1973, were terminated in FY 1979. Many of the objectives of these two programs are now being carried out under other NSF program elements or in mission agencies, including the National Institutes of Health and the Environmental Protection Agency.

Significant Research Achievements

- In response to the El Centro/Calexico, California earthquake, which occurred on October 15, 1979, PFR-supported investigators took the following actions:
  - The Universities Council for Earthquake Engineering Research conducted a field survey of the damage site to determine specific, near-term research needs, capitalizing on valuable information recorded on ground motions and the damage state of existing buildings, storage tanks and bridges.
  - Prior to the earthquake, James Brune of the University of California, San Diego had established ground motion measuring devices in this area as well as northern Mexico. These devices were able to record the major shock waves, the records of which are now being processed. In addition, Brune immediately installed a portable array of instruments at strategic points in the region to record aftershocks for several days following the main event.
  - Christopher Arnold, a research architect and president of Building Systems Development, Inc. in San Francisco, is leading a team of researchers to study the nature and extent of damage to the non-structural components of buildings in the primary impact zone.
  - George Mader of William Spangle and Associates, Portola Valley, California, who has been examining land use management alternatives for earthquake hazards mitigation, is working with Federal Emergency

Management Agency representatives on the application of his work to reconstruction planning and management activities.

- New Mexico State University researchers have developed a low-cost, non-destructive method for testing highway bridges for seismic resistance to locate and evaluate the weaker elements in an existing bridge which could fail during an earthquake.
- International cooperative research efforts have been formally established with with Japan's Science and Technology Agency and Ministry of Construction to conduct seismic tests on large-scale structures. These activities are planned for the Ministry of Construction's unique test facilities which can simulate the dynamic effects of an earthquake on a full-sized, multistory building.
- An alternative to the use of fossil resources as raw materials for the production of chemicals may be the use of biomass derived from plant and microorganisms. One possibility is the use of lignocellulosic biomass (e.g., wood, straw, corn stover, etc.) as a source for chemical feedstocks. Research at the University of Idaho has shown that lignin can be degraded by certain strains of bacteria. Further work is now in progress to characterize the modifications of lignin in wood and to use the bacteria for beneficial industrial microbial conversions. In addition, companion research activity at Virginia Polytechnic Institute and State University has shown that microbially-modified lignins may have a potential for use in the manufacture of phenol-formaldehyde resins.
- Research on the development of guayule, a shrub native to the southwestern United States, as a domestic source of natural rubber is currently following two lines of inquiry. Researchers are attempting to improve latex yield by breeding superior plant varieties and also by investigating the use of chemical bio-regulators to improve yield. These researchers recently showed that certain compounds, when sprayed on 18-month old field grown plants, can increase the guayule rubber content from 5-7% to 18-20%. This three-fold increase begins to place guayule in a competitive range with *Hevea braziliensis*, the tree which is the present commercial source of natural rubber.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan for PFR is $28,885,000 which is $1,515,000 less than the FY 1980 Budget Request of $30,400,000. This net reduction is the result of reductions in the Alternative Biological Sources of Materials, Integrated Basic Research and Problem Analysis program elements were primarily the result of redirections that had to be made because of decreased appropriations for the activity's applied science programs. In addition, Congressional instructions for the development of a new program on Appropriate Technology, now placed within the Small Business Innovation and Industrial Technology subactivity, and increased support for Science and Technology to Aid the Handicapped have created further demands upon the applied science budget.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$32,538,834
FY 1980 Program	$28,885,000
FY 1981 Request	$30,500,000
Difference—FY 1981/FY 1980	$1,615,000

The Budget Request of $30,500,000 for the PFR program is $1,615,000 more than the FY 1980 Current Plan of $28,885,000. These funds are to be used for the following purposes:

- Earthquake Hazards Mitigation is increased by $1,500,000 from $17,900,000 to $19,400,000. These additional funds will permit societal response research on the effectiveness of regulations to achieve given levels of earthquake protection, and on the impact of earthquake warning and prediction measures on the socio-economic environment in the community. Special studies of the El Centro, California earthquake will be continued to gain the maximum benefit from available seismic instrument records and damage surveys. In addition, the Design subelement will be increased to support the development of the first phase of the U.S.-Japan Cooperative Project on Large-Scale Structure Testing. The U.S.-Japan project is based on the FY 1980 Budget initiative for which preliminary planning and coordination efforts are now complete.
- Alternative Biological Sources of Materials will be decreased by $36,000, from $2,936,000 to $2,900,000. Research support will be continued in two areas: Biomass Conversion, with an emphasis on biological and chemical conversion of lignin and solvent separations of woody plant constituents; and Arid Land Plant Products, focusing on the isolation and characterization of speciality chemicals and development of new arid land crops for commercial production.
- Science and Technology to Aid the Handicapped will be continued at the FY 1980 funding level of $2,100,000. Primary emphasis will be placed on new, efficient, and low-cost ways to improve sensory systems, locomotion and manipulatory capabilities of those impaired.
- Human Nutrition is increased by $111,000, from $989,000 to $1,100,000. The increase will permit the initiation of interdisciplinary research on the improvement of methods to extrapolate from current nutrition studies using lower forms of biological life to the likely response in humans.
- Integrated Basic Research will increase by $40,000, from $4,460,000 to $4,500,000. Basic research will emphasize: Advanced Measurement Investigations; Deep Mineral Resources; Biogeochemical Cycles of Carbon, Nitrogen and Sulfur; and Population Redistribution.
- Problem Analysis will continue unchanged at $500,000. The principal activity for this program will be a comprehensive analysis of the potential for genetic change in commercially important plants so as to improve their performance and productivity under stress conditions, such as high salinity, low water, heat, cold, or low nutrient levels.

Percentage changes between FY 1981 and the FY 1980 Current Plan, by program element areas follows:

Earthquake Hazards Mitigation	8%
Alternative Biological Sources	-1%
Science and Technology to Aid the Handicapped	—0—
Human Nutrition	11%
Integrated Basic Research	1%
Problem Analysis	—0—

Coordination with and Relationship to Other Efforts

Problem-Focused Research program elements are closely coordinated with complementary activities in other Federal agencies through a variety of mechanisms. Such mechanisms include: formal interagency committees established by the Executive Office of the President, the Congress or Agency initiative; research workshops; problem definition studies; and informal project-by-project collaboration.

More specifically, the National Earthquake Hazards Reduction Program, developed by the Executive Office, has designated NSF as the lead agency for basic and applied research on earthquake engineering and policy. NSF is an active member of several research coordination groups such as the Interagency Committee on Seismic Safety in Construction, and the Interagency Discussion Group on Disaster Mitigation which is sponsored by the PFR staff. These groups meet regularly to consider recent developments in the field, current programs and future activities in both the public and private sectors. In addition to the program of research support for non-Federal organizations, program funds are provided annually to maintain and operate the Seismic Engineering Branch of the U.S. Geological Survey. At the international level, Earthquake Hazards Mitigation program staff members serve as the NSF representatives in several intergovernmental activities. For example, under the auspices of the U.S.-Japan Natural Resources Development Program, NSF and the Ministry of Construction and the Science and Technology Agency of Japan have established a Cooperative Earthquake Research Program on Large-Scale Testing. A second example is the earthquake engineering information exchange program conducted through the U.S.-U.S.S.R. Cooperative Agreement in the Field of Housing and Other Construction. Currently, NSF is collaborating with the U.S. Geological Survey on the development of a cooperative earthquake research program with the People's Republic of China. The program with the Chinese will be implemented under the U.S.-P.R.C. Joint Commission on Scientific and Technical Cooperation.

Aid to the Handicapped research efforts continue to be closely involved with programs in the Veterans Administration, the National Institute for Handicapped Research and elsewhere through the Interagency Committee for Handicapped Research, the Interagency Committee on Rehabilitation Engineering, and the White House Conference on Handicapped Individuals Implementation Unit. Program staff also serve on the recently organized Federal Interagency Committee for the International Year for Disabled Persons.

Federally-sponsored nutrition research efforts, including those of PFR, are coordinated by two formal interagency groups: the Federal Interagency Communications in Nutrition Committee and the Joint Subcommittee for Human Nutrition Research of the Federal Coordinating Council on Science and Engineering and Technology. In addition, the PFR program maintains continuous contact with the research interests and activities of USDA's Human Nutrition Center.

In the Biological Sources of Materials program PFR has the responsibility for representing NSF on the Joint Commission for Guayule Research and Commercialization, established under P.L. 95-592 to develop guayule as a domestic source of natural rubber.

Finally, individual PFR projects are reviewed by staff members in other Federal agencies having related programs or potential needs for the study results. Often, Federal employees from the policy and/or program levels are included in PFR project advisory, oversight, or user groups. In a number of cases joint funding of specific projects by several agencies has been undertaken.

Changes in Budget Structures

In the FY 1979 and 1980 Budgets for the former Applied Science and Research Applications Directorate, Problem Analysis and Integrated Basic Research were separate subactivities. In the EAS budget they are program elements of the PFR subactivity.

Earthquake Hazards Mitigation Program Element $19,400,000

Obligations by Program Subelement

Program Subelement	*Actual FY 1979*	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1980/81*
Siting	$9,004,272	$9,800,000	$9,800,000	$9,800,000	—0—
Design	6,669,073	7,100,000	7,100,000	7,800,000	700,000
Societal Response	799,999	1,000,000	1,000,000	1,800,000	800,000
Total	$16,473,344	$17,900,000	$17,900,000	$19,400,000	$1,500,000

Objectives and Description

The broad aims of the Earthquake Hazards Mitigation program element are to support research which develops an understanding of earthquakes in relation to constructed facilities and to reduce casualties, damage and social and economic disruption as a result of earthquakes. The actions necessary to attain these goals are heavily dependent upon capabilities which require development through research.

The primary objectives of this research are:

- To determine the nature of strong ground shaking from instrument data taken during earthquakes, to develop analytical procedures to predict the spatial and temporal distribution of strong ground motion at different sites, and to understand the dynamic behavior of soil and rock subjected to strong shaking;
- To determine the nature of the interaction of structures and the supporting soil during earthquakes;
- To develop procedures for performing dynamic analyses of proposed or existing construction under earthquake loadings, to develop an understanding of materials and structural components subjected to damaging dynamic loads, and to develop procedures for analysis and design of non-structural and architectural systems for earthquake effects;
- To study the influence of architecture and urban planning activities on earthquake vulnerability of regions; and
- To develop and evaluate measures which individuals, private groups and government can use to mitigate and respond to earthquake impacts. These measures include emergency preparedness, land use planning, building codes, insurance, and information and education.

Achievement of these objectives will involve a long-term effort by a variety of disciplines. Because the program spans such a variety of activity, ranging from basic research needed to develop an understanding of phenomena to the development of design methods and information which may ultimately be adopted by designers, there is a special need to provide mechanisms to facilitate the flow of information and data from the originators to the users of information. To facilitate this information transfer, coordination is maintained with other government agencies, such as the Federal Emergency Management Agency, the Nuclear Regulatory Commission, the Department of Transportation, the National Bureau of Standards and the Department of Housing and Urban Development.

This program element is an integral part of the National Earthquake Hazards Reduction Program which, in accordance with the Earthquake Hazards Reduction Act of 1977, seeks to reduce risks to life and property from earthquakes. Basic and applied research on earthquake engineering, social response and research for utilization are the responsibility of NSF's Earthquake Hazards Mitigation program. These efforts are closely coordinated through formal and informal mechanisms to achieve the objectives set forth in the National Program.

The program element is organized into three subelements: *Siting*, *Design*, and *Societal Response*. *Siting* research seeks a fundamental understanding of the physical nature and engineering effects of potentially damaging earthquake-generated ground motions in various types of solid and liquid media. Research is conducted on how the ground motions are modified by the media transmitting the earthquake energy, and on the impact of these ground motions on natural and man-made structures. *Design* research provides the technical basis for improving the safety and structural integrity

of all types of fixed construction and civil works subjected to seismic effects. *Societal Response* research strengthens and facilitates the adoption and implementation of technological, social and management practices that minimize earthquake damage and facilitates rapid recovery from earthquake disasters.

A good example of the program's efforts can be seen by its role in the ongoing analysis of the earthquake last fall near El Centro, California. That earthquake, which registered 6.4 on the Richter scale, resulted in personal injuries to local residents and property damages totaling more than $10,000,000. The most spectacular damage was the partial collapse of the six-story Imperial County General Services Building in El Centro, where the earthquake-generated forces virtually exploded the base support columns at one end of the building. As a result of previous strong-motion instrumentation placements for PFR-supported research in both the building which was damaged and the surrounding countryside, this event is providing a unique opportunity for earthquake engineering research. It is the first occasion in which a major array of ground motion instruments was able to record the real-time propagation of major seismic waves through surface soils over significant distances. Follow-up research activities on the El Centro earthquake are underway through continuing support from the Earthquake Hazards Mitigation program element. This is a special interest within the program to capitalize on this unparalleled opportunity to gain significant, new information on the relationship between earthquake-generated ground motions and the response of buildings and other structures to these motions.

Major Research Questions

- How can new structures of all types be designed and constructed to be earthquake resistant and at reasonable cost?
- How earthquake-vulnerable are existing structures and how can their vulnerability be economically and efficiently reduced?
- What is the appropriate mix of land use planning, building codes, engineering standards, hazards insurance, disaster preparedness and incentives required to achieve a level of protection which is compatible with costs and community goals?
- How can disaster preparedness, relief, rehabilitation and restoration measures and programs reduce the impact of earthquakes and hasten the return of affected communities to their normal predisaster conditions?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$16,473,344
FY 1980 Program	$17,900,000
FY 1981 Request	$19,400,000
Difference—FY 1981/FY 1980	$1,500,000

The Earthquake Hazards Mitigation program element will be increased by $1,500,000, from $17,900,000 to $19,400,000. The FY 1981 program provides for the continuation of the role assigned to NSF in the National Earthquake Hazards Reduction Program to support basic and applied research on earthquake engineering and societal response. The program will continue to stress the development of scientific knowledge about earthquake phenomena and their impacts on engineered structures and environments, better techniques for locating earthquake hazard zones and for estimating the earthquake forces, and procedures for effective community disaster preparedness and response. The $1,500,000 increase will be distributed among the following priority efforts:

- Implementation of the U.S.-Japan Cooperative Project on Large-Scale Structure Testing;
- Continuation of special research projects on the October, 1979 El Centro, California earthquake to determine relationships between observed strong ground motions and related soil phenomena and damage profiles in several types of structures; and
- Studies on earthquake hazards mitigation planning at the local and State levels.

SITING SUBELEMENT $9,800,000

Objectives and Description

This subelement supports research designed to explain the physical basis of earthquake energy generation and the transmission of resultant shock waves through various geological strata and bodies of water. This research also deals with the interaction between earthquake-generated ground motions and structures and the development of engineering guidelines for the mitigation of damage to buildings, towers, dams, pipelines, and other structures. The specific objectives of this subelement are to:

- Establish the attenuation, propagation and spatial characteristics of seismic motions through deployment of strong-motion instrument arrays;
- Determine how the damaging earthquake ground motions are modified by local geological and geotechnical conditions;
- Develop seismic risk assessment procedures based on physical and statistical data and the application of these procedures in planning and engineering design;
- Investigate the three-dimensional characteristics of soil response and soil-structure interaction for various soil conditions subjected to seismic forces; and
- Develop siting and planning capabilities for improved seismic safety of major structures and industrial facilities that serve our communities and cities.

Increased emphasis on engineering of life support systems such as water and power transmission lines and geotechnical earthquake engineering concerned with

the influence of soils and rocks on seismic resistant planning and design will be in integral part of the FY 1981 effort. Efforts will be made to gain a fundamental understanding of the earthquake response of lifeline and major industrial facilities which service U.S. communities. Research will be continued to improve methods for determining the dynamic properties of soils, to develop *in situ* and laboratory test techniques, and to establish new analytical methods for predicting possible soil failure or alleviating its consequences.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The Siting subelement will be maintained at a level of $9,800,000 to continue the essential scientific research concerning strong ground motions, geotechnical and lifeline earthquake engineering, and implementation of the multi-national plan for the development of three-dimensional strong motion recording instrument arrays in selected locations throughout the world. In addition, emphasis will be placed on the following issues in FY 1981:

- The design and installation of networks and arrays of instruments to measure strong earthquake ground motions and their effects on constructed facilities;
- The development of analytical and empirical models to evaluate spatial characteristics and ground motions necessary for the rational selection of input motion parameters in structural analysis and design; and
- The characterization of the linear and nonlinear behavior of earth and rock materials subjected to seismic loadings.

DESIGN SUBELEMENT $7,800,000

Objectives and Description

Improvement of safety and performance of structures such as buildings, dams and pipelines will depend in large part on advances in engineering analysis and design procedures. This subelement supports research to improve the technological basis for the design of new earthquake-resistant facilities. It also supports research on methods to upgrade the integrity of existing structures which do not provide an acceptable level of safety and resistance to earthquake hazards. The specific objectives of this subelement are to:

- Develop analytical and experimental methods and procedures to predict the response of all types of buildings, life supporting systems, and other civil works to severe earthquake forces;
- Determine actual dynamic behavior of various structural systems to confirm analysis and construction methods through tests on large-scale structures;
- Develop analytical, experimental and construction methods and procedures to determine the behavior of existing structures subjected to seismic actions;

- Incorporate into practical applications lessons learned from inspection of buildings damaged in actual earthquakes;
- Develop techniques and facilities to transfer new research information and computer programs to the design profession, researchers, and regulatory agencies.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The Design subelement will be increased by $700,000, from $7,100,000 to $7,800,000, to permit implementation of the research program of the U.S.-Japan Cooperative Project on Large-Scale Structural Testing for Seismic Resistance.

The request is for the second year of a five year period of cooperative research using experimental facilities in the U.S. and Japan. Unique to this effort are the Tsukuba full-scale structure test platforms in Japan, which will be made available to scientists from the U.S. and Japan for prototype experiments. The Cooperative Project is designed to obtain data on the behavior of building structures under simulated earthquake loadings in the most efficient manner by integrating the financial, facility, and scientific manpower resources of the two countries. In FY 1980, the first year of the effort, work will have been initiated on tests of multistory reinforced concrete buildings having design features common to those structures in highly seismic zones in both countries. In addition, coordinated small-scale model and structural component tests on dimensionally similar building elements will have been conducted in a variety of locations in the U.S. and Japan. The purpose is to determine the energy absorption characteristics of structures and to establish the scaling relationships between model and prototype. Funding for this cooperative effort is shared by both countries with no direct exchange of funds.

SOCIETAL RESPONSE SUBELEMENT $1,800,000

Objectives and Description

The Societal Response subelement seeks to increase understanding of the adjustments society can make to earthquake hazards and to facilitate the adoption of such adjustments. This requires research on such measures as emergency preparedness, land use planning, insurance, building standards and codes, and relief and rehabilitation. Research on public information and education efforts is also needed so that relevant knowledge can be effectively disseminated to appropriate user groups.

The specific objectives of this research are to:

- Develop knowledge of the socioeconomic aspects of hazards mitigation;
- Increase the base of knowledge on preparedness for earthquakes and other hazards;

- Improve the understanding of disaster impacts and responses; and
- Provide a basis for improving the dissemination of information on earthquake hazards and its utilization by decision makers and the public.

Many communities have done little to protect themselves against earthquakes and other natural hazards. Some have adopted useful emergency preparedness, land use, and building construction strategies. Projects were initiated by NSF in FY 1977 and FY 1978 to study local government earthquake mitigation and preparedness programs. New studies will be initiated in FY 1981, especially to find alternative strategies for encouraging effective seismic safety at the local and State levels. To complement these studies, there will be projects to develop cost-benefit methods of analysis to assist officials in choosing among possible earthquake mitigation actions. During FY 1981, NSF intends to play a major role in expanding the base of knowledge on alternative adjustments to earthquakes and in identifying the social, economic, political, legal and related factors which facilitate or hinder the adoption of social and technological measures to reduce disasters and earthquake hazards.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The development of sound geotechnical and structural engineering capacity to mitigate earthquake hazards is not enough. Research in the physical sciences and engineering must be complemented by a strong and continuing research effort in the organizational, legal and economic aspects upon which the implementation of technological practice depends. Accordingly, the Societal Response subelement will be increased by $800,000, from $1,000,000 to $1,800,000. These additional funds will provide support for research to identify and evaluate alternative adjustments to earthquakes. They will also be used to support research to determine the factors which hinder and facilitate the adoption of known social and technological adjustments to earthquakes by individuals, families, organizations and government entities. These measures include land use planning, building codes, hazard insurance and information and education. Special emphasis will be made on:

- Earthquake hazard mitigation planning at the local and State levels;
- Cost-benefit analysis of alternative disaster recovery programs;
- Socioeconomic monitoring of communities following earthquake prediction; and
- Post-disaster audits.

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Alternative Biological Sources of Materials Program Element $2,900,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$4,132,858	$3,900,000	$2,936,000	$2,900,000	$-36,000

Objectives and Description

The Alternative Biological Sources of Materials program supports research leading to the development of new, domestic sources of critical industrial chemicals and materials from underutilized plant and microbial biomass, as well as novel processing techniques to produce these materials commercially.

The objectives of this research are to:

- Develop effective biological processes for converting biomass and renewable resources to chemicals and useful industrial materials. The current focus is on lignin transformations and utilization and the production of hydrogen.
- Develop effective separation treatments for biomass constituents. Research is currently directed toward separation of the major components of underutilized hardwoods and agricultural residues (cellulose, hemicellulose and lignin) by using appropriate organic solvents and catalysts.
- Develop commercially attractive chemicals from underutilized plants (terrestrial and aquatic) and microbial biomass. Among the most promising plants are guayule, jojoba, crambe and marine algae.

This program initiative seeks to develop the efficient utilization of indigenous biomass resources through the timely application of the results obtained from the basic research programs of the Foundation. The program aims to provide the scientific and technological bases for use by mission agencies and the private sector in managing renewable resources.

Two major research thrusts have been selected for investigation: the conversion of lignocellulosic biomass into industrial chemicals, and the production of useful substances from underutilized arid land plants. The first topic deals with a substitution question—the replacement of depletable oil and coal by renewable plant and microbial biomass as the organic raw materials for producing chemicals, intermediates, and polymers. The conversion of lignocellulose and other biomass substances into useful materials now being derived from petrochemical feedstocks is an essential element of this thrust. The second topic focuses on the use of arid land plants as a source of useful materials and chemicals to replace products imported from foreign countries.

Many native American plants adapted to the arid environment of Southwestern United States and Northern Mexico produce materials and chemicals which could

replace various products important to the economy. The shrub guayule produces a rubber identical to the natural rubber imported from the *Hevea* plantations in Southeast Asia. For several years this NSF program element has been the principal source of Federal support for guayule research in the U.S. The potential of guayule as a domestic source of natural rubber is now well recognized. With the passage of the Native Latex Commercialization Act of 1978 (PL 95-592) and the assignment of the Department of Commerce and the Department of Agriculture to implement the provisions of the Act through a Joint Commission, NSF is transferring in FY 1980 all guayule research activities directly relevant to the commercialization efforts to the Joint Commission. Support for guayule research will be continued in such other projects as may be appropriate for NSF because of innovative character or scientific value, particularly research involving tissue culture. Jojoba, another arid land plant, produces a seed oil which is very similar in composition to sperm whale oil, an essential component of lubricants for high pressure machinery. This program supports research on the breeding and selection of superior strains of this plant that may lead to the development of a practical and economical substitute for sperm whale oil as a lubricant. Other potentially useful products from arid land plants are hard wax from candillila, industrial gums from guar and chia, and antioxidants and fungicides from the creosote bush.

Major Research Questions

- What degree of substitution for petrochemicals can be achieved through the the use of lignocellulosic biomass?
- What basic industrial chemicals can be derived efficiently and economically from plant and microbial biomass, including biosaline resources?
- What are the most innovative and economically attractive uses of biomass polymers, modification to new polymers, or their degradation to monomeric species?
- What is the cause of the enhanced heat stability of thermophilic microorganisms and how can this stability be used advantageously for industrial processing?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

	Obligations
FY 1979 Actual	$4,132,858
FY 1980 Program	$2,936,000
FY 1981 Request	$2,900,000
Difference—FY 1981/FY 1980	$-36,000

The program element budget will be decreased $36,000, from $2,936,000 to $2,900,000. No new areas of research will be initiated in FY 1981 and the principal current objectives will be supported.

The following research activities will be pursued in FY 1981:

- Characterization of microbially and chemically modified lignins;
- Identification and isolation of industrially significant chemicals from marine and aquatic biomass;
- Investigation of enzymatic synthesis of polymeric materials;
- Regeneration of whole plants from cell cultures of guayule and jojoba; and
- Investigation of the production of useful materials from arid land plants including jojoba, sagebrush and crambe.

Science and Technology to Aid the Handicapped Program Element $2,100,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$1,329,672	$1,600,000	$2,100,000	$2,100,000	—0—

Objectives and Description

Physical and mental handicaps sharply reduce our Nation's human resources and add considerably to our society's economic burden. Estimates of the number of handicapped persons in the United States vary from 10 to 40 million. Although these estimates vary widely, it is clear that the numbers are very large and that the financial burden of disability, in the form of benefit payments and loss of productivity, is on the order of several billions of dollars annually. Added to these costs are the personal losses suffered by the handicapped and their families from limitations imposed on their ability to participate in many aspects of life—losses that cannot be measured in dollars.

Over the years, technology has helped to restore lost functions and augment residual physical or intellectual abilities to allow the handicapped to lead more independent, useful, and fulfilling lives. Eye glasses, hearing aids, artificial limbs, canes for the blind, wheelchairs, and cardiac pacemakers—to cite a few examples—have become indispensable to those that need them. Recent progress in science and technology, such as the advent of microprocessors and the development of new, biocompatible materials, provides even greater possibilities for major advances which will contribute to productivity and the quality of life of the handicapped.

NSF is working in cooperation with the newly created National Institute of Handicapped Research to provide support for scientific research in engineering and the natural, social and medical sciences to improve the quality of life of people with physical and mental handicaps.

The specific objectives of this program are to:

- Improve locomotion and sensory and manipulatory capability;
- Ensure that the most promising developments are tested through the feasibility phase;
- Focus the research capabilities of universities, industry, small business, and nonprofit institutions on new, low-cost approaches to aid the handicapped;
- Determine incentives required to ensure the development and use of low-cost technological aids which satisfy the physical, social and economic needs of the handicapped; and
- Identify the economic, social, and institutional factors which may be disincentives to fuller participation of the handicapped in society.

Major Research Questions

- What device will be most useful to the blind to supplement the long cane during ambulation?
- How can information best be displayed to compensate for losses of sight, hearing or touch?
- What are the most appropriate techniques of communication for non-speaking persons?
- Can electrical and magnetic fields accelerate healing of damaged bone and other tissue?
- What are the most important factors influencing the transfer of research results to the manufacturer of products for the handicapped?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$1,329,672
FY 1980 Program	$2,100,000
FY 1981 Request	$2,100,000
Difference—FY 1981/FY 1980	—0—

No change in budget from the FY 1980 level is requested for FY 1981. The program will continue to pursue its current objectives with special emphasis given to:

- Applications of microprocessors as sensory aids for deaf or blind persons;
- Ocular control systems that allow the creation of synthetic speech for the non-vocal;
- Innovative teaching systems for those persons with cognitive and learning disabilities.

Human Nutrition Program Element $1,100,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$993,031	$1,000,000	$989,000	$1,100,000	$111,000

Objectives and Description

The Human Nutrition program element, developed according to Congressional instruction in FY 1979, supports research to increase our understanding of the consequences of life-long dietary patterns for human health and well-being. Since Americans derive about three-quarters of their food energy needs from refined and processed foods, knowledge of the nutritional impact of such foods is essential for the design and effective implementation of a human nutrition policy for the United States and to guide consumers in the selection of foods. Studies are encouraged that develop new methodologies and instrumentation, as well as interdisciplinary research that includes participation of disciplines not traditionally related to human nutrition. In addition, the program builds on research efforts of the Chemical and Biochemical Systems program element.

The program is focused on determining the effects of processing, including cooking, packaging, storage, fortification and use of additives on the nutritional value of foods. NSF supports scientific investigations of the physical, chemical and biochemical changes that occur in foods as a result of processing. These include studies of:

- Changes in the amount and composition of essential nutrients, changes in binding of nutrients by undigestible elements of the diet, and interactions between nutrients and additives and other processing factors affecting the nutrients in foods;
- Changes in the bioavailability of the nutrients in processed foods because of alterations in assimilability;
- Changes in metabolism, including functional changes in gut microflora, in response to eating processed foods; and
- Formation of substances that may have a deleterious impact.

The program will continue to sponsor research workshops on selected topics in order to define gaps in knowledge, opportunities for research that should be exploited, and potential new research approaches. The topics of interest include short-term studies that may permit conclusions about life-long effects of diet, and estimating the bioavailability of nutrients in food combinations from data on individual foodstuffs.

Major Research Questions

- What is the cumulative effect of life-long ingestion of processed foods as principal components of a diet?
- How can we use results from animal tests and other model systems to obtain better estimates of the effects of processed foods on the human population?
- What factors affect the nutritional value of food which is either lost or acquired when food is refined or otherwise processed?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$993,031
FY 1980 Program	$989,000
FY 1981 Request	$1,100,000
Difference—FY 1981/FY 1980	$111,000

The program element will be increased by $111,000, from $989,000 to $1,100,000. Emphasis will be placed on the development of short-term reliable tests that estimate the nutritional value of a variety of processed foods.

Integrated Basic Research Program Element $4,500,000

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1980/81*
$4,781,731	$5,000,000	$4,460,000	$4,500,000	$40,000

Objectives and Description

The objective of the Integrated Basic Research program (IBR) element is to improve the Nation's ability to deal with major long-term problems by increasing scientific knowledge about selected problem areas where additional fundamental knowledge can contribute to their solution.

The program provides joint funding with NSF basic research programs for proposals having application potential and which deal with the scientific needs of selected problem areas. The selection of topic areas for augmented support has been accomplished through a very broad screening procedure using: (1) internal Foundation staff; (2) NSF Advisory Committees representing academic and industrial research communities; and (3) conferences that bring together academic research workers with those from industry and government. From a very large number of suggested topics, a recommended priority list was developed by the EAS Advisory Subcommittee for Integrated

Basic Research, which is composed of representatives of the U.S. research community selected from each of the NSF basic research advisory panels. From this priority list, EAS then has selected those problem areas which could be adequately supported with available funds. The main thrust of the program is directed at four priority topic areas: Advanced Measurement Investigations; Deep Mineral Resources; Biogeochemical Cycles of Carbon, Nitrogen and Sulfur; and Population Redistribution.

- Advanced Measurement Investigations

  Currently, two areas of research are receiving special emphasis—surface and boundary properties of materials, and the structural characteristics of biologically-important molecules. It seems certain that current barriers to basic research on catalytic processes and microcircuit fabrication can be reduced by improving measurements of surface boundary properties of materials. The structural characteristics of organic molecules is another area where new methods for the generation of X-rays from both synchrotron radiation and laser-generating sources are providing opportunities for studies of trace-metal interactions in organic metallic compounds.

  In FY 1981, support will be directed toward continuing development of techniques such as extended X-ray absorption fine structure, efforts to improve the determination of second-order bonding structure in organo-metallic compounds, and new measurement techniques to extrapolate aging and deterioration phenomena in surfaces of semiconductor and composite materials.

- Deep Mineral Resources

  A wealth of minerals are potentially available at depths of one mile or more below ground. For deep mineral exploitation the scientific challenges are to find the deposits and then to devise feasible ways to extract them. The IBR program focuses on non-fuel minerals while the Department of Energy is directing its attention toward the fuel minerals. New subjects for emphasis in FY 1981 include: the mechanism of chemical leaching by organic and biological agents, mineral resources of the deep crystalline basement of the mid-western plains states, and hydrothermal ore forming processes that are now being observed at spreading ridges on the sea floor of the Red Sea and the Gulf of California.

- Biogeochemical Cycles of Carbon, Nitrogen and Sulfur

  Research efforts are being focused on the carbon cycle to understand better its regulation and interaction with other cycles, its role in the global energy budget and its effects on all biota. Support is also being provided for research on the various aspects of the biogeochemical cycles of nitrogen and sulfur.

  In FY 1981, this topic area will continue to focus on cycles of carbon, nitrogen, and sulfur with special emphasis on the biogeochemistry of nitrogen in the environment. Marine nitrogen fixation, speciation of nitrogen in freshwater and saline systems, and modeling of the generation, transport and fate of nitrogen compounds in the troposphere will be highlighted.

- Population Redistribution

  An enhanced understanding of the processes underlying decisions about migration, industrial location, and residential choice is necessary to provide more nearly complete explanation and improved prediction of population redistribution patterns. New submodels, methodologies and sources of data need to be explored. IBR supplements funds awarded by the basic research divisions for research in geography and regional science, economics, sociology, anthropology, systems theory and operations research and statistics addressing this topic.

  One major event that will significantly affect the direction of this effort will be the 1980 Census of Population and Housing. The Census of Population is the most comprehensive source of information on the composition and distribution of the U.S. population and will offer IBR unique opportunities for detailed and systematic research on a range of social, economic, housing and demographic issues—including research on changing patterns of population migration and mobility.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$4,781,731
FY 1980 Program	$4,460,000
FY 1981 Request	$4,500,000
Difference—FY 1981/FY 1980	$40,000

Integrated Basic Research will be increased by $40,000 in FY 1981. This increase will provide only for a maintenance of effort level and no funds will be available to initiate new topic areas.

Problem Analysis Program Element $500,000

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1980/81*
$950,683	$1,000,000	$500,000	$500,000	—0—

Objectives and Description

The objective of the Problem Analysis program is to identify and analyze important societal problems with significant scientific content to provide a preliminary assessment of the appropriate role of science and technology, the Federal government, and NSF in their solution. The program provides analyses of a wide range of potential

research topics and problem areas for use in selecting research directions and allocating resources among existing or emerging new programs.

NSF receives many suggestions for new areas of engineering and applied science support from a variety of sources such as, the research community, professional and scientific associations, private industry, State and local governments and other Federal agencies. These suggestions are carefully analyzed and assessed so that they may be weighed by the Foundation's staff against competing programmatic demands and, if selected, implemented in the form of new research initiatives or expansions of ongoing programs.

Potential new research areas are examined in light of the following questions:

- What is the nature and significance of the program and what issues are researchable?
- Will new or additional research significantly contribute to a better understanding of the problem and to the development of a scientific base which will contribute to its solution?
- Are there reasons for Federal support?
- What is the state-of-the-art, what are the gaps in knowledge and technology, and what are the performer capabilities to fill the gaps?
- What is the appropriate organization for supporting any additional research? Is there a unique role for NSF and EAS?

The Problem Analysis staff relies on a variety of inputs and mechanisms to provide answers to these questions, including special studies and analyses conducted either in-house or by the research and user communities, and special seminars and workshops. Additional information comes from NSF advisory committees, interagency panels, and internal working groups. The Problem Analysis staff integrates information on current programs and proposed new activities into a set of analytic papers and recommendations for use in determining budgetary priorities.

Once the decision has been made to undertake a new research program, the Problem Analysis staff works with the staff of the appropriate EAS division or office to assure the smooth implementation of the program.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$950,683
FY 1980 Program	$500,000
FY 1981 Request	$500,000
Difference—FY 1981/FY 1980	—0—

During FY 1981, a comprehensive analysis of the opportunities to develop stress-resistance in economically important plants will be undertaken. Population growth places increasing pressure on our ability to produce sufficient food and fiber. This

pressure results from increasing demand for the products of plant growth, encroachment of human activities on agricultural lands, and by deterioration of the suitability of some lands for plant growth (e.g., salinization). One answer is to produce plants that are more tolerant of environmental stress factors such as salt, water, heat, cold, nutrient depletion, and soil toxins. These new varieties and species would help to solve the problem by retaining productivity on deteriorating land and by bringing into production lands that are currently unsuitable for plant growth. The barriers to solving these problems appear to reside in our limited understanding of the mechanisms of stress tolerance and of the natural genetic variability in tolerance. There are no current programs that seek to systematically gain the requisite information.

The remaining activities of Problem Analysis will include the support of several analyses of problem areas with significant scientific or engineering content to determine research needs and program options.

QUANTITATIVE PROGRAM DATA
PROBLEM ANALYSIS PROGRAM ELEMENT

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Number of Proposals	1,009	960	940
Total Dollar Amount	$104,550,000	$101,200,000	$100,500,000
Number of Awards[1]	432	350	340
Total Dollar Amount	32,538,834	28,885,000	30,500,000
Average Dollar Amount	75,300	82,700,000	90,400,000
Average Award Duration (Months)[2]	15.5	15.5	15.5

Percentage Distribution of Funds by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	77.7	80.0	80.0
Industry			
Small Business	10.2	9.8	8.0
Other	—0—	—0—	—0—
Nonprofit (nonacademic)	6.6	6.1	7.0
State and local government	0.5	—0—	—0—
National Laboratories	—0—	—0—	—0—
Federal Agencies	5.0	4.1	5.0

Personnel and Other Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Number of scientist years supported	245	220	230
Cost of scientists supported	$8,530,000	$5,990,000	$6,810,000
Number of graduate students supported	405	360	370
Cost of graduate students supported	$2,980,000	$2,830,000	$3,120,000
Other personnel costs	4,210,000	3,460,000	3,860,000
Major equipment	—0—	—0—	—0—
Equipment and instrumentation	3,160,000	2,870,000	2,860,000
Other Costs[3]	$6,628,834	$5,785,000	$5,860,000
Indirect Costs	9,030,000	7,950,000	8,590,000
Total	$32,538,834	$28,885,000	$30,500,000

[1]Includes the number of basic research program awards receiving additional Integrated Basic Research funding. These amounted to 165 in FY 1979, 150 in FY 1980, and 141 in FY 1981.

[2]Continuing grants involving multi-year commitments are included according to the award period for which fiscal year funds are provided.

[3]Fringe benefits, expendable equipment, travel, publication costs, computer costs, other direct costs.

INTERGOVERNMENTAL PROGRAMS SUBACTIVITY $7,000,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Local Government	$2,641,699	$2,850,000	$2,400,000	$2,400,000	$—0—
State Government	2,128,069	1,800,000	1,360,000	1,360,000	—0—
Science and Technology Resources	361,771	350,000	240,000	240,000	—0—
State Science, Engineering, and Technology	—0—	—0—	1,500,000	3,000,000	1,500,000
Total	$5,131,539	$5,000,000	$5,500,000	$7,000,000	$1,500,000

Objectives and Description

The objective of the Intergovernmental Programs subactivity is to integrate scientific and technical resources into the policy formulation, administrative management, and programmatic operation activities of State and local governments. This objective is pursued through programs in individual jurisdictions and the establishment and strengthening of statewide, regional, and national networks.

The strategy of the Intergovernmental Programs is to assist State and local governments, and the regional and national organizations which represent them, as they investigate systematically alternative approaches for increasing the use of scientific and technical resources. In addition, increased communication among State and local governments in scientific and technology-related matters is a continuing objective of the program. The direction and content of the Intergovernmental Programs are developed with considerable State and local government input from organizations and associations that represent State and local officials, such as the National Governors' Association, the U.S. Conference of Mayors, and the International City Management Association. Emphasis is placed on encouraging institutionalization, where appropriate, and on promoting replication of successful, innovative institutional arrangements.

The Local Government element has been highly innovative in developing a series of successful networks of cities and counties in which major economic benefits and major improvements in operational efficiencies are being achieved. The strategies explored in the State Government element are alternative approaches to expanding scientific capability in legislative committees, leadership staffs, or interns, university faculty on loan for extended periods, and single-purpose task forces. The Science and Technology Resources element seeks to draw upon various science and technology resource bases—such as universities, industries, and Federal laboratories—to serve State and local governments. State Science, Engineering, and Technology (SSET) focuses on programs designed to build the capacity of states to access scientific and technical information for use in the public policy development process.

Major Questions Addressed

Intergovernmental Programs address such questions as:

- What alternative mechanisms are available to facilitate the integration of scientific and technical resources into the policy formulation and problem solving activities of local and State governments?
- What alternative structures are available to foster cooperation on a regional or national basis among units of local or State government to help address critical issues of common concern?
- What alternative systems are available to promote the development of improved intergovernmental cooperation in the planning and implementation of national research and development agendas?
- Will the mechanisms, developed during the study phase of the SSET Program, enable the gubernatorial and legislative leadership of the States to strengthen their capacity to access and use scientific, engineering, and technical resources?
- Will such mechanisms be institutionalized, without Foundation support, assuming that they warrant continuation after the three-year, Foundation-support period?

Significant Recent Achievements

- The International Urban Technology Exchange Program, with partial support from NSF, is evaluating foreign technology that may be of value to U.S. cities and counties. For example, the program has applied the French ROMA system, which is a computerized refuse routing and districting system, to St. Petersburg, Florida. The districting aspect alone is projected to result in an estimated annual savings of $50,000—$100,000. The system currently is being replicated in Yonkers, New York, and Dallas, Texas.
- The New England Innovation Group has organized and is operating a technology-based Energy Management Program impacting both public and private sectors in New England and other regions of the country. Based on support from the Federal Laboratory Consortium, the program involves the use of new innovative technologies to determine insulation characteristics in public and private buildings. The program has led to significant reduction in energy consumption in many applications.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan of $5,500,000 is $500,000 more than the FY 1980 Budget Request of $5,000,000. This increase reflects the combination of two factors: (1) the decision by Congress to fund the SSET Program, for which funds were not requested in

the FY 1980 Budget, at $1,500,000 and (2) a decrease of $1,000,000 in the other elements of the Intergovernmental Programs subactivity.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	*$5,131,539
FY 1980 Program	**$5,500,000
FY 1981 Request	$7,000,000
Difference—FY 1981/FY 1980	$1,500,000

*Did not include any funds for SSET Program.
**Includes $1.5 million for SSET Program.

An increase of $1,500,000 is requested for Intergovernmental Programs over the $5,500,000 level currently planned for FY 1980. The increase will be applied entirely to the SSET Program. At the $7,000,000 level, Intergovernmental Programs will:

- Provide reduced support within the Local Government Program for fifteen ongoing innovation groups, three national networks, and five programs with associations of local officials.
- Support reduced number of State government projects in individual jurisdictions and six programs with associations of State officials.
- Provide minimal support for the Federal Laboratory Consortium Program to improve the linkage to the public and private sectors.
- Support additional Executive and Legislative Branches of State governments in their efforts to implement capacity building programs designed to access scientific and technological resources.
- Initiate for an assessment of the implementation phase of the SSET Program.

The percentage changes from FY 1980 by program element are as follows:

Local Government	—0—
State Government	—0—
Science and Technology Resources	—0—
State Science, Engineering, and Technology	100%

Changes in Budget Structure

The Intergovernmental Programs subactivity was formerly the Intergovernmental program element in the Intergovernmental Science and Public Technology subactivity. The four, former subelements of the Intergovernmental program element have now become program elements of the new subactivity.

Coordination With and Relationship to Other Efforts

The program is coordinated regularly within the Federal government. In many cases, this coordination results in partial support of Intergovernmental projects by other Federal agencies. Examples of NSF-initiated activities receiving support from other Federal agencies include the Urban Consortium for Technology Initiatives, and the legislative Model Interstate Science and Technology Information Clearinghouse. Moreover, other Federal agencies, such as the Department of Energy, are using a number of NSF-initiated innovation groups, regional networks, and national networks to assist their own research and development activities.

Further, the program's activities are a major source of information and data for and are well coordinated with the activities of the Intergovernmental Science, Engineering, and Technology Advisory Panel (ISETAP) in the Office of Science and Technology Policy.

Extensive coordination also occurs with representatives of State governments (e.g., National Governors' Association and National Conference of State Legislatures) and local government (e.g., National League of Cities, United States Conference of Mayors, International City Management Association, and National Association of Counties).

Local Government Program Element $2,400,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$2,641,699	$2,850,000	$2,400,000	$2,400,000	$—0—

The objective of the Local Government element is to support the establishment of statewide, regional, and national innovation networks to provide cooperative approaches for solving common problems with scientific and technical components.

Local governments are experiencing unprecedented demands to assume decision-making and management responsibilities for a broad range of complex issues, many involving major scientific and technical components. This program emphasizes approaches to strengthen the capacity of local governments to identify their needs and ensure that research is appropriately targeted to important problems.

Examples of these statewide and regional innovation networks are those in California, Georgia, Ohio, Texas, Oklahoma, Tennessee, and New England; national networks are the Urban Consortium, the Urban Technology System, and the Community Technology Initiatives Program. The interests of both rural and urban America are supported in this program. At the national level, the networking system facilitates the development of national research and development agendas relevant to local needs.

The FY 1981 emphasis will be on strengthening the networks and information exchange among the networks, as well as attempting to increase the use of universities, industries, and the Federal labs as resource bases.

State Government Program Element $1,360,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$2,128,089	$1,800,000	$1,360,000	$1,360,000	—0—

The objective of the State Government element is to foster cooperation on a regional and national basis, to assist individual states in their capacity strengthening efforts, and to address critical issues of common concern.

The increased complexity of issues facing the country continues to place a heavy burden on States' public management capacity. State governments need examples of successfully tested institutional mechanisms that they can integrate into their executive or legislative policy management process.

During FY 1981, emphasis in the State Government Program (Executive) will be placed on strengthening the scientific and technological capabilities of national organizations, such as the National Governors' Association, the Council of State Planning Agencies, and the Council of State Governments. In addition, emphasis will also be placed on supporting projects in individual states to examine of new approaches for using scientific and technical resources from various resource institutions, such as universities.

For FY 1981, the State Government (Legislative) Program will emphasize support of projects in individual states. New approaches, such as university-based information systems, will be tried in some states (e.g., Texas), while replications of past successful efforts will be attempted in others (e.g., Arkansas). It is anticipated that projects in Massachusetts and South Carolina will be institutionalized during the year. National networks, such as the Legislative Information System, will emphasize improved communication among the states.

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Science and Technology Resources Program Element $240,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$361,771	$350,000	$240,000	$240,000	$—0—

The objective of the Science and Technology Resources element is to increase the potential of various scientific and technical resource organizations (universities, Federal laboratories, and industry) to serve the needs of State and local governments more effectively.

One of the key elements of the S&T Resources Program is the Federal Laboratory Consortium for Technology Transfer. The Consortium, with over 180 member laboratories, facilitates the transfer of existing science and technology to assist in the solution of problems. The laboratories are a resource for national and regional networks of local government (e.g., the Community Technology Initiatives Program and New England Innovation Group). The Federal Laboratory Consortium also provides national publications, shares computer data bases, and holds national and regional meetings with the user communities to ensure the broadest application of new information, research results, and successful technologies.

During FY 1981, emphasis will be placed in two areas: one, in developing an expanded role for universities in working with State and local governments; and, two, in strengthening the computer conferencing system within and between individual laboratories and the national and regional innovation groups.

State Science, Engineering, and Technology Program Element $3,000,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$—0—	$—0—	$1,500,000	$3,000,000	$1,500,000

The objective of the State Science, Engineering, and Technology program is to increase the capacity of the gubernatorial and legislative leadership of the States to access and utilize scientific, engineering, and technical resources in the formulation and management of public policy and in the resolution of critical issues in subject areas with significant scientific or technical components.

The State, Science, Engineering, and Technology (SSET) program continues, with an implementation phase, the study and planning phase of the program previously authorized by the National Science Foundation Authorization Act for FY 1977 (P.L. 94-471). Under this study phase, awards were made during FY 1977 and 1978 involving 49 Executive Branches and 42 Legislatures. The intent of that phase of the SSET program was to assist States in identifying the need for and the contributions that can be made by policy analyses, research results, and scientific, engineering,and technical resources in their policy-formulation and decision-making processes. The final reports from all the awardees will have been submitted to the Foundation by the middle of Fiscal Year 1980. During the FY 1980, $1,500,000 will have been made available through competitive awards to initiate in sixteen to twenty branches of State governments the implementation phase of the plans and programs developed under the study phase of the SSET program.

The FY 1981 program will allow for an $1,500,000 increase over FY 1980, thereby bringing the program to $3,000,000. Such increase will:

- Support, after competitive selection, an additional twelve to sixteen Executive and Legislative Branches of State government to initiate the implementation phase of their plans and programs.
- Provide support to the National Governors' Association and the National Conference of State Legislatures to continue their role in ensuring the effectiveness and quality of the program through the provision of information and technical services, the conduct of meetings, and the analysis of documents produced.
- Initiate an assessment of the implementation phase of the program.
- Continue second year support for those branches of State government receiving their first year award in FY 1980.

QUANTITATIVE PROGRAM DATA
INTERGOVERNMENTAL PROGRAMS

Proposals and Awards Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	82	93	142
Total Dollar Requested	5,171,539	8,500,000	12,200,000
Awards:			
Number of Awards	75	73	89
Total Dollar Amounts	5,131,539	5,500,000	7,000,000
Average Dollar Per Award	68,421	75,342	78,652
Average Award Duration (Months)	12	12	12

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	13.0	9.5	7.4
Industry	4.2	1.1	0.9
Small Business	(4.2)	(1.1)	(0.9)
Other	(—0—)	(—0—)	(—0—)
Nonprofit (nonacademic)[1]	43.5	32.7	30.0
State and Local Government[2]	34.0	52.7	58.5
National Laboratories	4.5	3.6	2.9
Federal Agencies	0.9	0.4	0.3
Other	—0—	—0—	—0—

Personnel and Other Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Faculty			
Number years supported	15	15	15
Amount of faculty support	$600,000	$600,000	$600,000
Postdoctoral Associates:			
Number of years supported	—0—	—0—	—0—
Amount of postdoctoral support	—0—	—0—	—0—
Graduate Students			
Number supported per award year	20	20	20
Amount of graduate student support	$100,000	$100,000	$100,000
Other Personnel Costs	2,900,000	3,150,000	4,100,000
Land, Buildings, and Fixed Equipment	—0—	—0—	—0—
Major Equipment	—0—	—0—	—0—
Other Equipment	—0—	—0—	—0—
Other Costs	900,000	970,000	1,300,000
Indirect Costs	631,539	680,000	900,000
Total	$5,131,539	$5,500,000	$7,000,000

[1] Includes public interest group, such as the National Conference of State Legislatures.
[2] Percentage to state and local governments increases substantially over FY 1979 because of initiation of SSET program. This is also the reason for the decline in percent of universities and colleges as well as non-profit institutions.

SMALL BUSINESS INNOVATION AND INDUSTRIAL TECHNOLOGY SUBACTIVITY $18,200,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Small Business Innovation	*$3,686,589	*$3,000,000	*$3,000,000	$13,000,000	$10,000,000
Industrial Technology	2,038,227	3,000,000	2,570,000	5,200,000	2,630,000
Appropriate Technology	—0—	—0—	1,800,000	—0—	-1,800,000
Total	$5,724,816	$6,000,000	$7,370,000	$18,200,000	$10,830,000

*The Small Business Innovation program element did not exist as a separate program element in the FY 1979 and FY 1980 budgets; it was established for the FY 1981 budget and up to that time funds for solicitations in the small business program were included primarily in the Applied Research and Problem-Focused Research activities. However, it is shown here and in the description at the program element level to reflect the appropriate amounts for the program in those years.

Objectives and Description

This is a new program subactivity established as a result of the President's Industrial Innovation Initiative announced last fall. Program elements were previously dispersed through other components of the Applied Research program of EAS. The objectives of the program are to:

- Draw upon the reservoir of scientific and technological research capabilities in the Nation's small businesses and universities, with a view towards moving the most promising research into commercialization efforts as soon as possible.
- Combine the scientific and technological resources of universities and industry in innovative programs which accelerate the introduction of new technologies in U.S. business.

The Small Business Innovation program element provides an opportunity and an incentive for small science and technology-based firms to perform research on important scientific and technical problems that could have significant public benefit if the research is successful. It also encourages the use of Federal research to stimulate innovation in the private sector. The program is divided into three phases: Phase I, which provides for limited funds to explore the research validity and feasibility of the proposed innovative research idea; Phase II, which supports with expanded funding research efforts associated with those projects judged most promising after Phase I; and Phase III, which is the development phase conducted by the small business firm with private funds.

The Industrial Technology program element sponsors research on: incentives designed to increase the commitment of U.S. industry to research and development; establishment of university/industry cooperative research programs in generic technologies (a high priority item in the President's Domestic Policy Review on Innovation); and selected projects designed to draw together the results coming out of a number of basic research

projects when there appears a high likelihood for synergistic effect on U.S. technological capability. Such commitments are necessary to increase the flow of innovative products and processes. This increased level of innovation is essential to increased productivity, a favorable balance of trade, and a higher standard of living for the U.S. Present experiments concentrate on institutional arrangements which aggregate the research interests of several firms through a university relationship.

The Appropriate Technology program element provides research support to strengthen the science base needed to identify and develop promising appropriate technologies. The program also seeks to improve the understanding of appropriate technology as a concept and to assess its role and impact on U.S. society and its economy. The NSF program is based on a plan submitted early in 1979 to Congress at its request. Congress subsequently directed that the Foundation initiate the program on an experimental basis beginning in FY 1980. No funds are requested in FY 1981 for the program pending an evaluation of the first year's results.

Major Research Questions

- How can the innovative capacity of small business best be stimulated?
- What incentives are needed to stimulate small business interest in participating in Federal R&D?
- What topic areas are small businesses likely to gravitate toward in addressing possible innovative technologies?
- Which areas of science and technology will best attract industry funds to a university research center?
- What style of University/Industry Center management most favors the professional career of the university personnel, as well as the continuity of the center program after conclusion of NSF support?
- Under what conditions can University/Industry Centers be made totally self-sustaining?

Significant Recent Achievements

- The experiences emanating from the efforts in the university-industry cooperative research program over the past 7 years, and the small business innovation program over the past 3, contributed significantly to the President's Domestic Policy Review of U.S. industry and the subsequent plan to revitalize innovation in that sector of the economy. The research results indicating the receptivity of American industry to generic technology centers (i.e., centers involving technologies that underlie multiple industrial sectors) and the success of the small business efforts have been lauded and serve as linchpins in the President's Industrial Innovation Initiative.

- A project studying the feasibility of a high pressure water jet for highway surface maintenance has been successfully completed. The project, jointly funded with the Federal Highway Administration, has shown that this research on high pressure water jet technology could result in advanced, more efficient highway maintenance procedures. As a result, the Federal Highway Administration is currently procuring equipment for field testing and implementation.

Changes Between the FY 1980 Budget Request and the FY 1980 Current Plan

The FY 1980 Current Plan of $7,370,000 is $1,370,000 more than the FY 80 Budget Request of $6,000,000. This increase occurs as a result of Congress' directing that the NSF initiate an Appropriate Technology Program at $1,800,000 and at the same time decreasing the Industrial Technology Program by $430,000.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$5,724,816
FY 1980 Program	$7,370,000
FY 1981 Request	$18,200,000
Difference—FY 1981/FY 1980	$10,830,000

The increase of $10,830,000, from $7,370,000 in FY 1980 to $18,200,000 in FY 1981, includes a $10,000,000 increase for Small Business Innovation research and a $2,630,000 increase for Industrial Technology. These increases are partially offset by a decrease of $1,800,000 for the Appropriate Technology Program. More specifically,

- The $10.0 million increase in the Small Business Innovation program allows the program to move out of an experimental phase, where it was spread among several subactivities, and has become a significant thrust in its own right. At this level, two annual solicitations for proposals from small businesses can be accommodated, the number of the topic areas in which proposals are solicited expanded, and unsolicited small business proposals encouraged.
- In the Industrial Technology Program
  - — One or more additional university/industry cooperative research centers will be selected from the previously awarded planning grants or from other proposals. These centers will be in areas of "generic" science such as computer science, applied mathematics, reactant polymers and metal fusion. In addition to the above, the program will support continuing university/industry cooperative research centers and planning grants for innovative experimental designs for future centers. ($2,000,000)
  - — One or two major Technology Innovation Projects in areas such as high energy pulse welding or the modeling of cognitive processes and visual systems are planned ($630,000).

The percentage changes, by program element, from the FY 80 Current Plan to the FY 1981 Budget Request are as follows:

Small Business Innovation	333%
Industrial Technology	102%
Appropriate Technology	-100%

Changes in Budget Structure

As was previously noted, the Small Busines Innovation and Industrial Technology Subactivity is a new subactivity. The Small Business Innovation program element is also new. Formerly, the small business effort was supported with funds from other programs of the directorate and did not appear as any one specific item. The Industrial Technology program element is the former Industry program element of the Intergovernmental Science and Public Technology subactivity.

Small Business Innovation Program Element* $13,000,000

Obligations by Program Element

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$3,686,589	$3,000,000	$3,000,000	$13,000,000	$10,000,000

*This program element was established for the FY 1981 Budget, having previously been a part of efforts in prior years in Applied Research and Problem-Focused Research. Funding for small business solicitations in those years is shown to reflect the level of effort in such years.

Objectives and Description

This is a new program element introduced as a result of the President's Industrial Innovation Initiative which added $10.0 million to the NSF Small Business Innovation program. This program had been previously supported on an experimental basis with funds from other directorate programs and had been managed within the Industry program of the Intergovernmental Science and Public Technology subactivity.

The goal of the program is to draw upon the research base of the Nation's small businesses and direct that research toward technological innovation and commercial applications. In addition, the approach also couples EAS research to other critical elements in the innovation process, such as sources of venture capital, commercial market demand, management capability, and financial negotiations between the small firm and potential investors. The objectives of the program are to:

- Couple Federal research to private venture capital and market demands.
- Fund high-risk innovative research on advanced concepts that may not be attractive to private investors because of heavy, front-end costs; and

- Initiate technology transfer at the beginning of the research process rather than after R&D has been completed or a product procured.

The NSF Small Business Innovation program is a three-phased program. Phase I and II involve NSF-funded research on EAS program objectives; Phase III involves private funding of the development phase to pursue commercial objectives.

More specifically, Phase I provides up to $25,000 for small research efforts of up to 6 months to prove the feasibility of the idea and the research competence of the small firm. Phase I serves as a screening phase and provides a feasibility-oriented research report which is important in determining whether NSF and private sources should make any further investment in the project.

Phase II funding supports those projects judged most promising after the first phase. Such projects are eligible for larger funding and from 12 to 24 months of support. Phase III is the development phase to pursue commercial applications. It is conducted by the small business firm and privately funded from a third-party source. While Phase III is not funded by NSF, Phase II proposals that receive a commitment for follow-on funding (i.e., Phase III) receive extra consideration in the evaluation process.

Since its inception in FY 1977, the program has made considerable progress. The first solicitation resulted in 42 Phase I and 21 Phase II awards. While presently in the middle of Phase II awards, a number of firms have been involved with follow-on funding with venture capital firms and large businesses. The second solicitation, in FY 1979, produced 54 Phase I grants. The third solicitation has just been issued.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$3,686,589
FY 1980 Program	$3,000,000
FY 1981 Request	$13,000,000
Difference—FY 1981/FY 1980	$10,000,000

As a result of the heightened emphasis in the program, the number of solicitations in FY 1981 will be increased from one to two and the topic areas covered under the solicitation will be expanded to reflect the full range and scope of the directorate's programs.

Coordination With and Relationship to Other Efforts

The Small Business Innovation program involves coordination with all divisions of the Directorate. Research topics for each solicitation are obtained from EAS divisions in important areas for research within EAS regular program objectives. Proposals upon receipt are referred to these same divisions and the most relevant program areas for peer review and evaluation.

As part of the Domestic Policy Review the President has proposed expanding the program into other Federal agencies, and NSF will serve, where requested, in an

advisory role to assist the Office of Management and Budget and other agencies. The program is currently coordinated with the Small Business Administration and with all other agencies with substantial R&D budgets. This coordination is strengthened through the annual NSF Small Business Conferences on Federal R&D.

Industrial Technology Program Element $5,200,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$2,038,227	$3,000,000	$2,570,000	$5,200,000	$2,630,000

Objectives and Description

The productivity and international competitiveness of U.S. firms depend upon science and technology, but investment in basic research and fundamental science by U.S. firms is a declining percentage of sales. The Industrial Technology program tests experimental institutions and incentives which will increase the commitment of U.S. industry to research and development. The chief area of experimentation is the coupling of academic resources to industrial needs.

The specific objectives of the program are to:

- Design and support experimental mechanisms to couple the longer range and more fundamental perspectives of academic science with the research needs of industry;
- Aggregate fundamental research interests across certain technologies which can benefit many firms, but which no single firm could afford on its own; and
- Draw together results of various basic research efforts when it appears likely that a synergistic effect on U.S. technological capability could occur.

The principle areas of program research activity have been the University/Industry Cooperative Research experiments and the Technology Innovation Projects. The program has funded ten different University/Industry Cooperative Research Centers. Some of these centers are new and in the planning stage, while others have operated 7 or more years. Important lessons have been learned from some 50 center-operation years. Some of these lessons were incorporated into the Presidential Initiative and the associated Domestic Policy Review on Industrial Innovation. A chief result of these experiments is the observed support of industry for research centers in "generic" technologies (i.e., technologies that underlie multiple industrial sectors) rather than organization of research centers by product groups. Such centers will lay the basis for future efforts directed at productivity enhancement and innovation in the industrial sector of this Nation.

The areas of generic research selected for University/Industry centers have depended largely upon proposals from university departments and associated industry funding commitments. Active planning grants, proposals, and proposal interest have been shown in the areas of computer science, applied mathematics, reactant polymers, metal fusion, computer-aided design (CAD), polymeric coatings, venture capital analysis, microprocessors, and chemical circuit elements.

The Technology Innovation Projects (TIP) subelement will continue research on automated assembly with special emphasis on modeling of visual systems and integration of these systems into the computer control of the assembly process. The research on high energy impulse welding begun in FY 1980 will continue with increased industrial and Federal support.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$2,038,227
FY 1980 Program	$2,570,000
FY 1981 Request	$5,200,000
Difference—FY 1981/FY 1980	$2,630,000

The increase of $2,630,000 in FY 1981, from $2,570,000 in FY 1980 to $5,200,000, will support additional University-Industry centers in areas such as computer science, applied mathematics, computer-aided design (CAD), reactant polymers, metal fusion, polymeric coatings and venture analysis ($2,000,000). Technology Projects in areas such as cognitive and visual systems as well as high energy impulse welding will be emphasized ($630,000).

Coordination With Relationship to Other Efforts

Every year an Industrial Technology program grantee conference is held at which researchers report their progress during the past year and their plans for the future. These conferences are well attended by academic, industry, and government leaders.

Whenever possible, the Industrial Technology program supports projects jointly with mission agencies to provide a smooth flow of the technology from the research stage to its application. For example, in FY 1980 an experiment for high-energy pulse welding applied to railroad welds will be funded cooperatively with the Federal Railroad Administration.

QUANTITATIVE PROGRAM DATA
SMALL BUSINESS AND INDUSTRIAL TECHNOLOGY

Proposals and Awards

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	448	850	865
Total Dollar Requested	$8,700,000	$17,000,000	$23,000,000
Awards:			
Number of Awards	81	140	240
Total Dollar Amount	$5,724,816	$7,370,000	$18,200,000
Average $ Per Award	62,910	52,643	75,823
Average Award Duration (Months)	15	15	15

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	24.4	35	19
Industry	75.6	60	80
Small Business	(64.6)	(52)	(76)
Other	(11.0)	(8)	(4)
Nonprofit (nonacademic)	—0—	5	1
State and Local Government	—0—	—0—	—0—
National Laboratories	—0—	—0—	—0—
Other	—0—	—0—	—0—

Personnel and Other Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Faculty:			
Number of Years Supported	20	50	78
Amount of Faculty Support	$600,000	$1,600,000	$2,700,000
Postdoctoral Associates:			
Number of Years Supported	—0—	10	2
Amount of Postdoctoral Support	—0—	$150,000	$30,000
Graduate Students:			
Number Supported Per Award Year	22	70	70
Amount of Graduate Student Support	$200,000	$560,000	$700,000
Other Personnel Costs	2,700,000	2,240,000	7,560,000
Small Business Solicitation Personnel Costs	(2,480,000)	(2,000,000)	(7,300,000)
Land, Buildings, and Fixed Equipment	—0—	—0—	—0—
Major Equipment	—0—	—0—	—0—
Other Equipment	218,816	290,000	628,000
Other Costs	575,000	650,000	1,850,000
Indirect Costs	1,431,000	1,880,000	4,732,000
Total	$5,724,816	$7,370,000	$18,200,000

SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS

PROGRAM ACTIVITY SUMMARY

FY 1981 PROGRAM TOTAL $28,850,000

Obligations by Subactivity

Page	Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
G-I	International Cooperative Scientific Activities*	$10,603,513	$10,515,000	$12,014,000	$12,900,000	$886,000
G-II	Policy Research and Analysis	5,459,033	5,800,000	5,749,000	6,650,000	901,000
G-III	Science Resources Studies	3,071,607	3,200,000	3,188,000	3,400,000	212,000
G-IV	Information Science and Technology	4,428,155	5,200,000	5,152,000	5,900,000	748,000
	Total*	$23,562,308	$24,715,000	$26,103,000	$28,850,000	$2,747,000

*Excludes activities under the U.S.-U.S.S.R. Agreement on Cooperation in the Fields of Science and Technology which are presented separately in the Cross Directorate Program Budget.

Goals and Description

Science and technology are national and international resources. Domestically the scientific and technological enterprise of the United States yields new knowledge and practices which improve the quality of life and lead to new products, processes, and services. Abroad, science and technology are increasingly seen as a means to economic growth and social development. Efficient, effective, and timely international exchange of scientific information also contributes to U.S. international objectives. Science and technology more and more affect governing institutions, the industrial and academic sectors, and the role of individual citizens. Consequently, there is greater concern about science and technology policy and funding of the networks linking science and technology (S&T) to society at large.

The goal of the Scientific, Technological, and International Affairs (STIA) program activity is to promote the understanding and effective functioning of the Nation's scientific and technological enterprise. STIA supports activities designed to provide information and systematic analysis of the Nation's S&T enterprise, and to enhance domestic and international exchange of S&T information.

Each program subactivity contributes to attaining the overall STIA goal in a specific way. The Policy Research and Analysis subactivity pinpoints critical S&T policy issues through extramural and intramural research and examines the impact and effectiveness of alternative Federal policies for science and technology. Thus it contributes to the knowledge base for policy formulation. The Science Resources Studies subactivity

develops comprehensive descriptions of the Nation's available human and financial resources for scientific and technological activities. Together, these two subactivities carry out most of the monitoring and policy research and analysis activities of STIA.

The remaining two subactivities are concerned with the improvement of S&T information exchange. International Cooperative Science programs benefit the U.S. scientific effort by gaining knowledge about scientific activities or resources in other countries and by promoting mutually beneficial cost and facility sharing. At the same time, these programs help the United States to implement foreign policy objectives which have S&T content. The Information Science and Technology subactivity supports basic and applied research leading to timely and resourceful use of information especially by the science and technology enterprise.

The objectives of each STIA subactivity are derived from the NSF Act:

International Cooperative Scientific Activities (INT), in accordance with NSF statutory authority, foster the interchange of scientific information between U.S. and foreign scientists, and initiate and support scientific and technical activities relating to international cooperation. U.S. scientists and engineers from virtually every field benefit from the several types of activities supported. Formal and informal cooperative activities with other countries offer opportunities for research and the exchange of S&T information to the benefit of all parties. Modes of cooperation range from the travel support of individual U.S. scientists serving as key speakers at international conferences to substantial contributions toward dues and administrative costs associated with U.S. participation in international scientific organizations.

Policy Research and Analysis (PRA) meets to the Foundation's obligation to provide a source of information and analysis for policy formulation to the Executive Office of the President and other Federal agencies. Its programs aid policymakers by supporting studies of the relationships between science and technology, the economy, and quality of life; the processes and management of innovation; improved environmental, energy, and resource policies; and assessments of technologies and the benefits and risks of technological alternatives.

Science Resources Studies (SRS) is responsive to the NSF mandate to collect, interpret and analyze data on scientific and technical resources in the United States. This subactivity maintains a unique data base and develops comprehensive descriptions and analyses of National and international R&D funding, and the supply and utilization of scientific and technical personnel. This is done through the conduct of periodic surveys and studies. SRS surveys and studies are essential to appraising the adequacy, distribution, and characteristics of resources available for scientific and technical activities in the United States and abroad.

Information Science and Technology (IST). The Foundation's charge to foster the exchange of scientific and technical information has led to the support of basic and applied research in information science and technology. Effective use of the information resource requires improvements in storage, transmission, and retrieval. Research is needed to define new concepts and to provide a theoretical base for future advancement in society's ability to handle ever larger volumes of information. Research

is supported in the following areas: 1) standards and measures, 2) structure of information, 3) behavioral aspects of information transfer, 4) models of information flow, and 5) information technology.

Changes Between the FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan for the Scientific, Technological and International Affairs program activity is $26,103,000. This amount is $1,388,000, or 5.6 percent, above the FY 1980 Request to Congress, $24,715,000.

About $1.1 million was reprogrammed for three thrusts in international scientific cooperation where: 1) increasing U.S. scientific interaction with countries of Western Europe promises exceptional opportunities through shared expertise, resources, and facilities; 2) increased scientific exchanges with China honor the recent U.S.-China Agreement on Cooperation in Science and Technology; and 3) provisions for scientific cooperation with developing countries are in line with the U.S. posture and policies expressed at the UN Conference on Science and Technology for Development; at the same time, this third thrust opens some unique environments to U.S. scientific inquiry. The remaining $300,000 is devoted to extending U.S.-Japanese capabilities in photosynthesis-related energy conversion research.

The current plan of $26,103,000 excludes the NSF Planning and Evaluation subactivity and activities under the U.S.-U.S.S.R. Agreement on Cooperation in Fields of Science and Technology. Previously included in the STIA budget, both now appear separately in the Cross Directorate Programs Budget.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$23,562,308
FY 1980 Program	$26,103,000
FY 1981 Request	$28,850,000
Difference FY 1981/1980	$2,747,000

The FY 1981 budget request for STIA, $28,850,000, exceeds the FY 1980 Current Plan by 10.5 percent, or $2,747,000. Through internal adjustments and no growth restrictions in some ongoing programs, this small increase nonetheless maintains the three international cooperative science thrusts of FY 1980 and permits other strategically planned activities in each of the four subactivities. Percentage increases in the subactivities follow:

International Cooperative Scientific Activites	7.4%
Policy Research and Analysis	15.7%
Science Resources Studies	6.6%
Information Science and Technology	14.5%

Program increases are described below:

International Cooperative Scientific Activities. Ongoing programs and exchanges, including the thrusts initiated in 1980, are maintained, although they continue to face dollar value pressures overseas. The requested $886,000 increase will:

- Expand the cooperative research thrust in Western Europe where scientific and technical capabilities in some fields rival or surpass those in the U.S. and where U.S. scientists can benefit most from cooperation ($286,000), for a total program of $1,800,000.
- Cover significantly increased dues and operating costs associated with U.S. participation in international scientific organizations ($500,000; total program, $4,100,000).
- Enable approximately one hundred more U.S. scientists and engineers to participate in major international conferences ($100,000; total program, $800,000).

Policy Research and Analysis

- An increase of $750,000 initiates a new research and analysis program in international economic policy that will build upon current work focusing on international technology transfer.
- An increase of $151,000 permits additional risk analysis activities to improve methods for evaluating long-term comparative risks and benefits of alternative technologies.

Science Resources Studies. Completion of several large studies funded in FY 1980 and an increase of $212,000 permits:

- A key survey of U.S. scientists and engineers identified by the 1980 Decennial Census. This continues a thrust begun in FY 1979 which has planned, sequential phases running through 1984. The data obtained will serve as a base for the Federal Government's statistical information on the adequacy, distribution, and characteristics of the Nation's S&T personnel.
- Support of two special projects designed to update the Nation's information and data concerning small R&D firm's industrial activity and the R&D of independent nonprofit institutions.

Information Science and Technology

- An increase of $748,000 allows growth in three program elements: support of research on information transfer and related human behavior aspects ($400,000); investigations of the information economy ($148,000); and research on new and promising information technology ($200,000).

Coordination and Relationship to Other Federal Efforts

A critical part of STIA's goal—improving the understanding and effective functioning of the Nation's S&T enterprise—involves direct relationships with users of STIA output. This relationship requires continued formal and informal contacts and coordination with policymakers in the public and private sectors. And, it requires two-way communication with S&T community researchers, administrators, educators, and industry representatives.

Several mechanisms are employed by STIA. Within the Government, close links are maintained with the Executive Office of the President, particularly OMB and OSTP, and with other Federal agencies—notably the Departments of State, Commerce, and Energy. Illustrative examples of coordination include: 1) STIA staff participation in interagency working groups which coordinate Federal R&D efforts (e.g., Task Force on the Federal Information Locator System, the NSF-State Department steering group reporting to U.S.-Mexico Commission for S&T Cooperation, and the Federal Education Data Acquisition Council); and 2) staff analyses provided as input to special Presidential policy reviews with S&T content (e.g., Industrial Innovation Domestic Policy Review and Non-fuels Mineral Policy Review.)

In addition, ongoing informal contact between staff members of various agencies ensures the flow of current information concerning program plans and output. Furthermore, it prevents unnecessary duplication of efforts among the agencies. Such contacts frequently lead to joint review and project monitoring where there are common interests.

STIA uses advisory committees as a major mechanism for gaining direct feedback and expert guidance, especially from the educational and private sectors. Other methods of reaching public and private sector users include informal consultation and structured workshops sponsored by NSF for obtaining advice from groups of educational institutions, industrial organizations, and scientific societies. State and local governments are also consulted in similar ways.

Changes in Budget Structure

The overall structure of the FY 1981 STIA budget remains identical to that presented to Congress for FY 1980. However, three changes have occurred at the subactivity level:

- A new program element—International Economic Policy—is added to the Policy Research and Analysis subactivity. Activities supported under this element will focus on international issues affecting domestic economic progress and the conduct of foreign relations.
- Risk analysis activities have been officially added to the Technology Assessment program element within the Policy Research and Analysis subactivity. The program's name has been changed to Technology Assessment and Risk Analysis, reflecting the complementarity of the two kinds of activity and providing more visibility to the Foundation's efforts in risk analysis.

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- An additional program element—Information Technology—has evolved within the Information Science and Technology subactivity. Through this program element, new information system uses and ideas not pursued within the private sector will be examined, and the use of more effective instrumentation for information science research will be promoted.

Evaluation and Oversight

Final reports resulting from STIA supported extramural policy research receive evaluation. A number of methods are used: mailed peer review, panel review, commissioned papers, conferences or workshops. Each method is a way of bringing professional researchers, policymakers, and the interested public into the examination of research results and their potential use. This policy of evaluation also covers intramurally written studies and reports prepared at the request of other government organizations. These staff-prepared products must be similarly evaluated prior to formal distribution outside the National Science Foundation. Further, as in FY 1980, other mechanisms continue to be employed. They are:

- Reviews of strategic plans and project results by three permanent advisory committees;
- Special reviews of program plans and results by ad hoc consultants and professional organizations;
- Surveys of prospective users to determine the utility of STIA products;
- External contracts for independent evaluation of individual program effectiveness; and
- Inclusion of evaluation requirements in extramural projects supported by STIA.

QUANTITATIVE PROGRAM DATA
SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS ACTIVITY

Proposals and Awards

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Proposals:			
Number—Total	685	760	839
Total Dollars Proposed	$58,595,224	$66,750,000	$82,300,000
International Travel Support Applications			
Number—Total	677	800	850
Total Dollar Support Requested	$1,616,100	$2,500,000	$2,800,000
Awards:[1]			
Number—Total	455	438	451
Dollars Awarded:			
Total Amount	$22,977,944	$25,403,000	$28,050,000
Average $ per Award	50,501	57,998	62,195
Average Award Duration (months)	16	16	16
International Travel Support:			
Total Number of Successful Applications	303	325	354
Dollar Support Provided:			
Total Amount	$584,364	$700,000	$800,000
Average $ per Successful Application	1,929	2,154	2,600

Distribution of Funds Awarded by Performer

	Actual FY 1979	*Estimate FY 198079*	*Estimate FY 1981*
Universities & Colleges	$11,192,529	$12,268,000	$13,980,000
Non-Profit Institutions	1,696,448	1,950,000	2,100,000
For-Profit Business and Industry	2,312,717	2,785,000	3,155,000
Federal Laboratories & Other USG Agencies	1,431,205	1,440,000	1,590,000
National Academy of Sciences & Professional Societies	6,540,589	7,150,000	7,500,000
Other[2]	388,820	510,000	525,000
Total	$23,562,308	$26,103,000	$28,850,000

Personnel Support and Other Factors

	Actual FY 1979	*Estimate FY 198079*	*Estimate FY 1981*
Scientists:			
Number Supported	519	555	578
Amount of Support	$4,238,534	$4,795,000	$5,265,000
Other Professionals:			
Number Supported	148	161	176
Amount of Support	$1,083,050	$1,275,000	$1,490,000
Graduate Students:			
Number Supported	142	155	171
Amount of Support	$925,935	$1,070,000	$1,240,000
Other Personnel Costs	1,824,597	1,982,000	2,280,000
Other Costs[3]	10,944,865	11,996,000	12,890,000
Indirect Costs	4,545,327	4,985,000	5,685,000
Total	$23,562,308	$26,103,000	$28,850,000

[1] Includes purchase orders and interagency agreements for programmatic work.
[2] State and Local Governments, individuals, FFRDC's managed by any performer listed.
[3] Expendable equipment, publication, computer and other direct costs.

INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES PROGRAM SUBACTIVITY $12,900,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Cooperative Science*	$6,638,359	$6,115,000	$7,614,000	$7,900,000	$286,000
Scientific Organizations & Resources	2,946,854	3,700,000	3,700,000	4,200,000	500,000
U.N. Conference on Science & Technology for Development	388,936	—0—	—0—	—0—	—0—
International Travel	584,364	700,000	700,000	800,000	100,000
Total	$10,603,513	$10,515,000	$12,014,000	$12,900,000	$886,000

* Excludes activities under the U.S.-U.S.S.R. Agreement on Cooperation in the Fields of Science and Technology which are presented separately in the Cross Directorate Programs section of the budget.

Objectives and Description

The vigor of science and technology in the United States is enhanced through international links. Researchers share unique facilities or resources and exchange information. International cooperative programs implement the statutory authority of NSF to "initiate and support specific scientific activities in connection with matters relating to international cooperation" (P.L. 81-507, Section 3 (b)).

There are two principal, interrelated objectives of International Cooperative Scientific Activities:

- to help meet the needs of U.S. science through trade of scientific and technical information with other countries, and
- to assist in the design and implementation of science activities and programs in support of international objectives of the United States.

Three program elements are included in this subactivity:

- The Cooperative Science program provides support for participation of U.S. scientists in bilateral research programs with countries in Europe, Latin America, Asia, Africa, and Oceania; for exchange of scientists; and for collaborative activities to assist in building science infrastructures in developing countries.
- The Scientific Organizations and Resources program provides support for participation of U.S. scientists in international scientific organizations, and for studies and analyses relevant to U.S. participation in these organizations and to NSF cooperative science activities.
- The International Travel program provides support for the participation of U.S. scientists in major international scientific meetings held abroad.

Significant Recent Achievements

Recovery and Use of Nutrients from Whey

Large quantities of essential nutrients are lost to the world's food supply and become environmental pollutants because of inadequate methods to recover them from the waste products of food production. A major example of this problem is whey, a nutritious by-product of cheese manufacture which is largely disposed of as waste. The Second Whey Research Workshop, held in 1979 under the U.S.-Australia Cooperative Science Program, assessed progress made by researchers of the United States, Australia, and New Zealand during the 4 years since the First Whey Workshop was held. All three countries have dairy industries of major importance. In identifying current research areas of high priority, the participants agreed to cooperate on research projects related to whey processing, whey protein concentrates, and modifications of whey components especially as diet for patients suffering kidney or liver damage. These workshops have fostered fruitful trilateral collaboration among scientists of the United States, Australia, and New Zealand.

Devices for Solar Energy Conversion

For solar energy conversion to be efficient and economically attractive, solar radiation must be absorbed by surfaces that do not re-emit the trapped energy as infrared rays as the absorber heats up. Present surface designs utilize costly multilayer systems that tend to deteriorate at high temperatures. Under the U.S.-France Cooperative Science Program, researchers of the two countries are jointly studying the optical properties of materials showing promise for use in single-layer surfaces. For the first time, under this binational effort, comprehensive optical measurements of these materials have been made. Results indicate ways that may lead to devices for efficient and economical solar energy conversion.

Natural Resource Planning

At the International Institute of Applied Systems Analysis (IIASA) and at the University of British Columbia, an approach to environmental assessment and management known as the "adaptive" approach has been developed by an international team of ecologists and environmental resource managers. The adaptive approach recognizes that uncertainty is an inevitable and significant part of all environmental planning and management. The challenge is to develop an understanding of the key elements and processes involved and to design policies that permit environmental systems to adapt to, and thus survive, stress. The approach has been successfully applied by the U.S. Fish and Wildlife Service to river quality assessment and water resource management studies, and by a U.S. resource development firm in assessing and managing environmental impacts of mining projects.

Seminar on Liquid Chromatography

Liquid chromatography is a method widely used in research and manufacturing for separating chemicals in solution. The National Science Foundation and the Japan Society for the Promotion of Science jointly sponsored a seminar to bring together leading researchers of the two countries in this rapidly developing field. Discussions dealt with progress and needs, focusing primarily on new stationary phases including bonded and porous polymers, and on detection methods including mass spectrometry. Japanese scientists are making leading contributions in the field of liquid chromatography, but publication of their work in the open literature is often slow. Thus, the seminar provided an important opportunity for U.S. experts to meet with Japanese colleagues to discuss new findings and exchange important information well in advance of published reports.

Early Human Artifacts in the Philippine Islands

U.S. scientists have collaborated with scientists from the Phillippine National Museum in a project involving geological mapping and studies of stratigraphy and sedimentation in the Cagayan Valley in Luzon. The objective of the project is to investigate the relationship between tools believed to have been produced by early man and animal fossils collected since 1971 by Philippine field parties. The Cagayan Valley is one of only a few localities in the world where artifacts and extinct fauna can be related to a stratigraphic and temporal framework. The joint research, which includes new field work and also fossil dating efforts in both countries, is making a contribution to an understanding of Pleistocene cultural development and the faunas and environment of southeastern Asia.

Models of Land Subsidence

U.S. and Mexican scientists have brought their complementary knowledge and experience together in a cooperative investigation of how land subsides as a result of groundwater or petroleum withdrawal. Land subsidence, often leading to ground failures, slides, and cave-ins, is also of particular interest to the United States in relation to the development of geothermal energy. The researchers are testing and improving a system of equations describing fluid behavior in relation to particular soil properties. Two different computer-based models, independently developed by the two groups of researchers, are being tested cooperatively with extensive data on land subsidence. The results are expected to improve understanding of the relationships between soil and fluid withdrawal and assist prediction and control of land subsidence.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The FY 1980 Current Plan exceeds the FY 1980 Budget Request by $1,499,000. Of this total, $1,199,000 is allocated to the Cooperative Science program element to permit augmentation of three significant program thrusts. The first thrust is increased

cooperation with the scientifically advanced countries of Western Europe, where research capabilities are comparable to those in the United States in a number of scientific fields. The thrust includes expansion of cooperative science programs with France and Italy and development of new arrangements for collaborative activities with Switzerland, Germany and Belgium. The second thrust is the development of cooperative programs which focus on scientific problems of importance to developing countries and which contribute to the building of science and engineering capabilities in these countries. This thrust is a direct result of preparation for the 1979 U.N. Conference on Science and Technology for Development and the conference itself. The third thrust, to increase scientific exchanges with China, is part of the development of closer ties in science and technology between the United States and China resulting from the 1979 agreement for cooperation in science and technology signed by the two countries. Another $300,000 added to Cooperative Science is designated for a special joint effort in photosynthesis research with Japan as part of a 1979 Executive-level initiative in energy research collaboration.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$10,803,531
FY 1980 Program	$12,014,000
FY 1981 Request	$12,900,000
Difference—FY 1981/FY 1980	$886,000

The $12.9 million requested for the International Cooperative Scientific Activities Program Subactivity for FY 1981 is 7.4 percent more than the FY 1980 program.

Cooperative Science	3.8%
Scientific Organizations & Resources	13.5%
International Travel	14.3%

The FY 1981 Budget includes:

- *Cooperative Science*—support of bilateral cooperative programs and exchanges with countries of Western Europe, Eastern Europe, Asia, Latin America, Africa, and Oceania ($7,900,000). An increase of $286,000 over FY 1980 will be used to maintain the momentum of new thrusts initiated in FY 1980 which emphasize increased cooperation with Western Europe and expanded cooperative research on problems important to developing countries.
- *Scientific Organizations and Resources*—support for U.S. membership and participation in the International Institute of Applied Systems Analysis and in the International Council of Scientific Unions and member unions; and for studies and analyses related to international scientific activities ($4,200,000); an increase of $500,000 over FY 1980, primarily to cover increased costs of dues to maintain membership in international scientific organizations.

- *International Travel*—support of travel by U.S. scientists to attend major international scientific meetings and conferences overseas ($800,000); an increase of $100,000 over FY 1980 to help provide adequate representation of the U.S. scientific community.

Coordination and Relationship to Other Efforts

NSF staff participates in the Committee on International Science, Engineering and Technology, with the Department of State as lead agency, and in three of its interagency working groups. The working groups are studying coordination, long-term planning, and personnel training with respect to science and technology and international diplomacy.

NSF coordination with the Department of State on international scientific programs occurs in the following activities: obtaining approval for science agreements with foreign governments, payment of dues to international scientific organizations, clearance for certain research projects and certain staff travel, negotiations, and program initiatives. In addition, there is frequent policy and program coordination with the Office of Science and Technology Policy, such as in the development of new international science initiatives and in Joint Commission activity. Program officers also maintain contact and coordinate with their counterparts in technical agencies of the Government on various international activities.

Cooperative Science Program Element $7,900,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$6,683,359	$6,115,000	$7,614,000	$7,900,000	$286,000

Objectives and Description

The major objectives of the Cooperative Science program are to (1) provide opportunities for U.S. scientists to acquire and share information about current research activities with scientists in foreign countries; (2) encourage international sharing of research costs and to provide access to major research facilities; and (3) support scientific and technological activities relevant to international objectives of the United States. As an element of cost sharing, collaborating institutions in foreign countries must provide support for their participating scientists or make their facilities available to visiting U.S. scientists.

The Cooperative Science program element includes three major activities:

- Bilateral research programs. These programs are set up under formal bilateral agreements or informal arrangements between the United States and countries in Europe, Latin America, Asia, Africa, and Oceania. Programs with some 30 countries support participation of U.S. scientists in cooperative research projects, joint seminars and workshops, and scientific visits.
- Interacademy exchanges. These scientist exchange programs are managed by the National Academy of Sciences and the national academies of the U.S.S.R. and seven Eastern European countries. Scientific and scholarly exchanges are also supported between the United States and China.
- Science in Developing Countries. This program supports research and teaching that relate to the application of science and engineering to problems of development in Asia, Africa, Latin America, and the Caribbean. Awards under this program provide funds for cooperative research, joint conferences, and dissertation support, in accordance with criteria developed by the National Science Board.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The budget request of $7,900,000 is $286,000 above the FY 1980 level. The FY 1981 program includes the following activities:

- Cooperation with Western Europe ($1,800,000); an increase of $286,000 over FY 1980 to continue the thrust to develop closer scientific cooperation with the advanced countries of this region.
- Cooperative programs under formal bilateral agreements with countries in Asia, Eastern Europe, Latin America, and Oceania ($2,700,000); a decrease of $300,000 from the FY 1980 plan to realign activities in favor of cooperation with advanced countries and the Science in Developing Countries Program.
- Cooperative activities with developing countries under the Science in Developing Countries thrust ($1,100,000); an increase of $300,000 over FY 1980 chiefly to expand activities in Latin America and the Caribbean.
- Exchanges managed by the U.S. National Academy of Sciences with the U.S.S.R. and seven East European countries ($1,600,000); no change from FY 1980.
- Exchanges with China managed by the Committee for Scholarly Communication with the People's Republic of China ($700,000); no change from FY 1980.

Scientific Organizations and Resources Program Element ... $4,200,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$2,946,854	$3,700,000	$3,700,000	$4,200,000	$500,000

Objectives and Description

There are two objectives for the Scientific Organizations and Resources Program:

- To support participation by U.S. scientists in international scientific organizations.
- To support studies and analyses related to participation of U.S. scientists in international scientific organizations and bilateral science activities.

The primary thrust of this program element is to ensure continued U.S. membership and involvement in international scientific organizations, primarily the International Institute for Applied Systems Analysis (IIASA), and the International Council of Scientific Unions (ICSU) and its member unions. Through participation in these organizations, U.S. scientists share in the planning and execution of major international research projects and in projects which address global problems. NSF provides support for U.S. membership in these organizations through the National Academy of Sciences, the U.S. national member of IIASA and ICSU.

A secondary activity under the Scientific Organizations and Resources program element consists of external and in-house studies, analyses, and assessments of cooperative scientific activities as well as certain international scientific organizations.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The budget request of $4,200,000 is $500,000 above the FY 1980 Current Plan. The FY 1981 program includes the following activities:

- Support for U.S. membership in IIASA and ICSU and its member unions ($4,100,000); an increase of $550,000 over FY 1980 to cover the higher costs of required dues and administrative expenses related to U.S. participation in these organizations due to dollar devaluation and inflation.
- Support of operational and analytical studies to provide program planning, design and assessment support for NSF international cooperative science activities ($100,000); a decrease of $50,000 from FY 1980.

International Travel Program Element $800,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$584,364	$700,000	$700,000	$800,000	$100,000

Objectives and Description

The objective of the International Travel program element is to enable U.S. scientists to participate in important international scientific meetings. By attending these meetings, U.S. scientists are able to acquire early scientific information concerning ongoing research by foreign colleagues in their fields and are able to establish a basis for future communication and collaboration. Group awards are primarily made to professional societies, universities, and other nonprofit organizations that support and coordinate participation by U.S. scientists. In addition, a few individual awards are made to U.S. scientists invited as organizers and lecturers to international meetings and to young scientists invited to participate in NATO Advanced Study Institutes. New management procedures were established in 1979 to centralize and consolidate international travel support. More travelers have been supported because the new procedures encourage group awards.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The requested increase of $100,000 over the FY 1980 plan is needed to raise the level of U.S. participation at international meetings and cover increased travel costs. The additional support and the continued emphasis on group awards under the new management procedures will boost U.S. representation at key scientific meetings by about 100 scientists and engineers and, at the same time, increase opportunities for the participation of younger scientists.

QUANTITATIVE PROGRAM DATA
INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES SUBACTIVITY

Proposals and Awards

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Proposals:			
Number—Total	377	400	430
Total Dollars Proposed	$22,166,242	$24,000,000	$26,200,000
International Travel Support Applications			
Number-Total	677	800	850
Total Dollar Support Requested	$1,616,100	$2,500,000	$2,800,000
Awards:[1]			
Number—Total	226	247	254
Dollars Awarded:			
Total Amount	$10,019,149	$11,314,000	$12,100,000
Average $ per Award	44,333	$45,806	$47,638
Average Award Duration (months)	18	18	18
International Travel Support:			
Total Number of Successful Applications	303	325	354
Dollar Support Provided:			
Total Amount	$584,364	$700,000	$800,000
Average $ per Successful Application	$1,929	$2,154	$2,600

Distribution of Funds Awarded by Performer

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Universities and Colleges	$3,500,270	$4,214,000	$4,600,000
Non-Profit Institutions	172,206	400,000	500,000
For-Profit Business and Industry	850,000	800,000	800,000
Federal Laboratories & Other USG Agencies	718,519	700,000	800,000
National Academy of Sciences & Professional Societies	5,362,518	5,900,000	6,200,000
Other[2]	—0—	—0—	—0—
Total	$10,603,513	$12,014,000	$12,900,000

Personnel and Other Factors

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Scientists:			
Number Supported	254	275	285
Amount of Support	$1,440,538	$1,750,000	$1,800,000
Other Professionals:			
Number Supported	36	45	50
Amount of Support	$517,702	$650,000	$750,000
Graduate Students:			
Number Supported	35	40	45
Amount of Support	$134,838	$175,000	$200,000
Other Personnel Costs	$385,865	$425,000	$500,000
Other Costs[3]	$7,161,176	$7,914,000	$8,300,000
Indirect Costs	$963,394	$1,100,000	$1,350,000
Total	$10,603,513	$12,014,000	$12,900,000

[1] Includes purchase orders and interagency agreements for programmatic work.
[2] State and Local Governments, individuals, FFRDC's managed by any performer listed.
[3] Expendable equipment, publication, computer and other direct costs.

POLICY RESEARCH AND ANALYSIS PROGRAM SUBACTIVITY $6,650,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Socioeconomic Effects of S&T	$1,112,225	$1,500,000	$1,400,000	$1,400,000	—0—
International Economic Policy	—0—	—0—	—0—	750,000	$750,000
Innovation Processes and Their Management	1,392,414	1,400,000	1,400,000	1,400,000	—0—
Environment, Energy, and Resources	1,087,467	900,000	1,100,000	1,100,000	—0—
Technology Assessment and Risk Analysis	1,452,112	1,300,000	1,249,000	1,400,000	151,000
Special Reports and Projects	414,815	700,000	600,000	600,000	—0—
Total	$5,459,033	$5,800,000	$5,749,000	$6,650,000	$901,000

Objectives and Description

The primary goal of the Policy Research and Analysis (PRA) subactivity is to increase knowledge for decisionmaking on public policy issues which have science and technology (S&T) content. The subactivity supports extramural policy research and analysis relevant to S&T and assists in the application and use of such information by S&T decisionmakers and institutions involved with S&T.

The activities of the Division are derived from the policy interests and needs of the National Science Foundation, the Executive Office of the President, and the Congress. They include:

- Synthesizing the available knowledge and data relevant to specific policy issues;
- Developing an improved S&T information base for public policy analysis;
- Conducting policy analyses and assessing alternative S&T policy options;
- Enhancing the Nation's S&T policy research capabilities; and
- Disseminating the information acquired and assimilated.

Significant Recent Achievements

The following are examples of recent achievements of the Policy Research and Analysis subactivity.

The International Spread of Innovations Via the Foreign Subsidiaries of U.S.-Based Enterprises

This project, directed by Raymond Vernon of Harvard University, reviewed the transfer and diffusion of 400 U.S. product innovations to overseas affiliates by U.S.

multinationals in the post-World War II period. The objective was to assess the rate, direction, and determinants of technology transfer and diffusion through foreign direct investment and foreign subsidiaries of U.S.-based firms. The project found that:

- R&D-intensive firms spread the production of innovations more quickly and widely in foreign locations than less R&D-intensive firms, and they use subsidiaries more frequently to produce the innovations than independent licensees.
- The number of new product lines produced abroad by subsidiaries increased in the 1970s, and the time between introduction of domestic production and foreign production has decreased.
- The diversification of products produced increased over time, with high-technology parent firms placing more emphasis on low-technology product lines (outside their principal activity) and other parent firms moving into technology-intensive lines.

Risks to Structures from Natural Hazards: A Technology Assessment

This recently completed technology assessment by the J.H. Wiggins Company of Los Angeles compiled, analyzed and evaluated information on hazard, exposure, and risk in order to develop a rational basis for hazard mitigation decisionmaking. Subjects treated in the report include urban construction, condemnation, and rehabilitation. The report also deals with practices and codes with regard to risks from: flooding, hurricane, tornado, wind, earthquake, tsunami, expansive soils, storm surge and landslide.

The study dealt with: risk determination, analysis of technological options to minimize damage, cost analysis (dollar estimates of damages, cost to loss ratios per county, cost-feasibility estimates for selected mitigation strategies) and examination of current and feasible policy options.

The chapter summarizing policy options and recommendations lists a total of 16 recommendations for implementation by the Federal Government and 14 recommendations for State actions.

The Future Regional Distribution of National Synthetic Fuel Facilities

In support of its mission to improve the S&T knowledge base for decisionmaking, PRA funded this study to assess factors relating to the geographic distribution of facilities for production of synthetic liquid and gaseous hydrocarbons from either coal or oil shale. The report reviews characteristics of current technologies and tradeoffs between them which influence siting decisions. Through surveys and interviews, the siting process is examined from the perspective of four functions that will be involved in the development of synthetic fuel capacity—oil production, interstate pipeline transmission, regional gas distribution, and major energy consumption facilities. The report suggests how the information developed could be used in improving future forecasting and modeling of regional energy development and facility siting.

Finally, it points out the difficulties in development of a long-range synthetic fuel capability in the face of constantly shifting regulatory restrictions.

Integration of NSF Funded Studies

During FY 1979, the PRA staff used the results of funded studies in several analytical papers requested by other agencies. Indicative of these efforts are the seven papers prepared for use by participants of the recent industrial innovation domestic policy review. Each paper reviewed major research findings, including those funded by this subactivity, relevant to important questions and raised issues essential to particular policy options. Titles of the seven papers are: Taxation and Investment in Industrial Innovation; Foreign Trade Policies and U.S. Industrial Innovation; Direct Federal R&D Support and Industrial Innovation; The Impact on Industrial Innovation of Environment, Health, and Safety (EHS) Regulations; Patents in the Private Sector; Scientific and Technical Information Policies for Industrial Innovation; and The Impact of Economic Regulation on Innovation by Firms in the Energy, Transportation, and Communication Sectors of the U.S. These papers were significant contributions to the final report which contributed to the President's recent efforts to encourage innovation.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

FY 1980 was the first year that funds were specifically identified for the Special Reports and Projects program element. Somewhat less ($-100,000) than the amount budgeted ($700,000) is expected to be spent in FY 1980. The program element of Environment, Energy, and Resources has a modest increase ($200,000) due to a substantial growth in relevant proposals from the academic community, as well as an increase in requests for studies from other organizations in the Executive Branch such as the Office of Management and Budget. The program element, Socioeconomic Effects of S&T, is reduced by $100,000 and Technology Assessment and Risk Analysis by $51,000 to provide the remainder of the increase.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$5,459,033
FY 1980 Program	$5,749,000
FY 1981 Request	$6,650,000
Difference—FY 1981/FY 1980	$901,000

The $6.6 million requested for this subactivity is about 16% greater than the FY 1980 program request of $5,749,000. This increase is to permit two major new thrusts in FY 1981: 1) a new program in international economic policy, an expansion of current ongoing work in international technology transfer ($750,000), and 2) the addition of a program in risk analysis to the ongoing technology assessment activities ($151,000).

Percentage changes between FY 1981 and FY 1980 for those program elements existing in FY 1980 are as follows:

Socioeconomic Effects of Science and Technology	0%
Innovation Processes and Their Management	0%
Environment, Energy, and Resources	0%
Technology Assessment and Risk Analysis	12%
Special Reports and Projects	0%

Highlights of the FY 1981 program include the following:

- A new program of research and analysis on issues in international economic policy will be initiated to enlarge the research and information base for decisions affecting domestic economic progress and the conduct of foreign relations. Of primary concern are the international monetary and trading system, coordination of domestic economic policy having international implications, and the role of industrial countries with respect to developing countries.
- A new thrust in risk analysis will be supported in which the primary purposes will be to support extramural research on risk analysis and to recognize the complementarity that exists between technology assessment and risk analysis.
- Support will be provided for the analysis of the interrelated environmental, economic, and social impacts of growth and economic change resulting from alternative technology choices in energy development.
- Further attention will be given to the influence of various government policy instruments (e.g., taxes, R&D spending, patents) on private sector activity and returns for R&D and to the analysis of technological innovation important to productivity growth and international competitiveness.
- Emphasis will be given to studies of the effects on innovation processes and decisions in and between firms and industries as influenced by government policy and action.

Coordination and Relationship to Other Efforts

A concerted effort is made to coordinate Policy Research and Analysis activities with relevant and interested individuals and organizations such as the Departments of Commerce, State, Treasury, Labor, Health and Human Services. Input is provided by the Office of Science and Technology Policy (OSTP) and by the Energy and Science Division of OMB. Specific examples of mechanisms employed in these efforts are the Domestic Policy Review Interagency Committees, the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), workshops, and informal working groups. In addition, staff from the Congressional Office of Technology Assessment and PRA review each other's proposals and plans.

The Foundation brings results of PRA studies and analyses to the attention of interested parties in all sectors by distributing copies and arranging colloquia for

decisionmakers and researchers. Final reports of all funded projects are available to the public through the National Technical Information Service (NTIS) of the Department of Commerce.

Socioeconomic Effects of Science and Technology Program Element $1,400,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$1,112,225	$1,500,000	$1,400,000	$1,400,000	—0—

Objectives and Description

This program element supplies analyses of the contribution of science and technology to the economy and to the quality of life, under both existing and alternate institutional conditions and policies. The main objective is to improve assessments of how Federal policies modify the rate, direction, and socioeconomic consequences of R&D and technological innovation. The objective is derived primarily from the expressed needs of the Executive Office of the President, the Congress, and the National Science Foundation.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

During FY 1981, one set of studies will attempt to provide new insights about the influence of government R&D spending on the outputs and returns from private sector technological innovation. Another group of studies will be initiated to examine more closely the alternative tax incentives available to stimulate industrial R&D and technological innovation. An additional set of studies will provide new empirical data and analyses about the contribution of scientific and technological results to regulatory decisionmaking and standard setting. Other research will improve information about the role of R&D in international competitiveness, and the influence of government policies in developing and commercializing technologies for foreign markets.

The following general questions will be addressed in FY 1981:

- What are the economic incentive and disincentive effects on R&D and technological innovation of four widely discussed types of government actions: tax policy, government R&D funding, intellectual property rights protection, and regulation?

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- How can the effects of new scientific findings and technological development on consumer and worker welfare, and on industrial growth be measured more precisely?
- What is the influence of foreign trade policy actions on the competitiveness of U.S. R&D-intensive products in international markets and the influence of these markets on U.S. industrial innovation?

There is no change in the budget from FY 1980 to FY 1981.

International Economic Policy Program Element $750,000

Obligations by Program Element

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
—0—	—0—	—0—	$750,000	$750,000

Objectives and Description

This new program element represents a natural expansion of the international technology transfer work of the previously described program element; consequently the two program elements will be administered jointly. The funds requested will make it possible for the Foundation to provide for programs of research, modelling, and policy analysis on issues of international economic policy which will affect domestic economic progress and the conduct of foreign relations. The need for a program to study such policy issues and to enlarge the research base for decisions on international economic policy has been expressed by decisionmakers in the legislative and executive branches. The program will provide a mechanism for transmitting valid and timely research findings to assist decisionmakers in dealing with specific problems as well as providing improved information to the research community about important issues facing decisionmakers.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The focus of the program will be on policy issues that are expected to require attention in the near- and medium-term future. These include: the international monetary and trading system; coordination of domestic economic policy having international implications; and the role of the industrial countries with respect to the less developed countries (LDCs).

Research questions to be addressed by this program include:

- In what directions might the international monetary system proceed to ensure a stable economic environment for international and domestic commerce and for long term economic growth?
- Is international coordination of domestic economic policy having major international repercussions feasible? If so, what incentives and procedures can be created to ensure that such coordination is implemented effectively? What can be learned from comparing the experience of the economic summits and the OECD about the desirability and feasibility of formal or informal coordination of domestic economic policies of the major industrial nations, given that the policies of one can be defeated by those of others?
- What forms of transfer from the industrial countries to the less developed countries has been most successful in the past and which are likely to be successful in the future? Are there other instruments, besides direct transfer of resources, which the industrial countries can use to assist the LDCs in pursuing their domestic, social, and economic policy objectives?
- What kinds of cooperation among the main industrial countries would be economically effective and politically feasible in dealing with the broader economic problems associated with scarce commodities of crucial importance to the industrial world? What can we learn from comparison of the experience of the International Energy Agency, the European Community, and the follow-up of the Tokyo summit?

Innovation Processes and Their Management
Program Element $1,400,000

Obligations by Program Element

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$1,392,414	$1,400,000	$1,400,000	$1,400,000	—0—

Objectives and Description

The principal objective of this program element is to improve understanding of the processes by which technological innovation occurs. Program activities seek improved understanding of the incentives and disincentives affecting these processes to identify potential leverage points for Federal action. This program element closely coordinates its activities with complementary efforts in the Directorate for Engineering and Applied Sciences.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

During FY 1981, the program will emphasize a greater conceptual and empirical integration of the innovation process field. High priority research issues will be identified, and addressed, through the extramural program.

Research will be encouraged on the following questions:

- What are the operational aspects of "smallness" that may account for the vigor of small, high-technology firms? How widespread, across various sectors of the economy, are the innovativeness and productivity of small businesses?
- What is the relationship between the availability of venture capital and technological innovation? What major policy actions seem to account most for the supply of venture capital for investment in innovation?
- How are decisions to innovate made in firms, or States or local agencies? How can these decisions be influenced by Federal actions or policies?
- Under what conditions (e.g., third parties or liaison agents) can the Federal Government improve communications and other relations between institutions involved in innovative activities? For example, can and do contract research institutes act as liaison agents between university and industrial research activities? Between Federal labs and State and local agencies? Between Federal labs and industries?

There is no change in the budget from FY 1980 to FY 1981.

Environment, Energy, and Resources Program Element $1,100,000

Obligations by Program Element

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$1,087,467	$900,000	$1,100,000	$1,100,000	—0—

Objectives and Description

The objective of this program element is to clarify the role of S&T in meeting national energy, environmental, and resource goals. Specific foci are: the tradeoffs between energy, environment, and resources; adequacy of the S&T information base for Federal decisionmaking in the environment, energy, and resources areas; and alternative Federal actions for achieving S&T goals.

Examples of research topics are:

- What effect does increasing Federal regulation of energy, environment and

resources (EER) have on the rate and direction of general industrial technological innovation?

- What alternatives are available for achieving the commercialization of new energy technologies? For instance, how effective are Federally-funded demonstration projects in promoting commercialization of new energy technologies compared to other means such as joint Federal-industrial funding of research and development?
- What kind of information is needed for decisionmaking in the areas where S&T and EER interact? For example, how can consistent and reliable data be obtained to track chemicals from the mining or production stage to the disposal stage, and how can the adequacy of such information be assessed for purposes of formulating related Federal policies? What alternative policies can be pursued in the face of uncertainty about scientific and technological data?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Topics to be pursued in the coming fiscal year include assessment of the data base for determining the effects of toxic chemicals on human health and the environment, evaluation of alternative compensation proposals for victims of pollutant-induced disease, and analysis of the effects of environmental regulations on industrial innovation.

There is no change in the budget from FY 1980 to FY 1981.

Technology Assessment and Risk Analysis Program Element $1,400,000

Obligations by Program Element

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$1,452,112	$1,300,000	$1,249,000	$1,400,000	$151,000

Objectives and Description

The objective of this program element is to determine the social, economic, and institutional consequences of the introduction of new technologies or expansion of existing technologies. Research supported seeks to define and explore the direct and indirect effects of technological change. Emphasis is placed on understanding long-term effects and comparative risks and benefits of alternative technological solutions to issues of national concern. The short-term goal of the program is to supply information that will help decisionmakers anticipate and plan for impacts and risks associated

with the implementation of new technologies. Long-term goals center on the improvement of the use of information about risks and impacts of technology in the science and technology policymaking process; on ways to enhance the data base for decision-making; and on improvements in the methods for evaluating long-term comparative risks of alternative technological solutions.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

In FY 1981, research will focus on the following questions:

- What are the implications for public policy that could result from the implementation of technologies which have been developed through government-sponsored research programs, e.g., in biomass utilization or in transportation?
- What are the consequences of new technologies developed from discoveries in the physical sciences, such as the micro-miniaturization of computer components or the possibility of generating nitrogen-fixing cereal strains through the application of recombinant DNA techniques?

In FY 1981, an additional $151,000 is requested to support increased studies in risk analysis. These studies will emphasize such questions as:

- How safe is safe enough?
- How adequate are the estimates of risks associated with different technologies?
- What strategies can be developed for coping with situations in which the degree of risk is either unknowable or unknown?
- What are the determinants of risk perception and preference as they affect public acceptability of technological risks?

The acceptability of a given risk is currently determined either by expressed preference or revealed preference as deduced from surveys. The results of either method are not always consistent. Methodological advances will be sought to put the determination of acceptable risk on a more solid footing.

Special Reports and Projects Program Element $600,000

Obligations by Program Element

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$414,815	$700,000	$600,000	$600,000	—0—

Objectives and Description

The major objectives of this program element are to respond to assignment of ad hoc and continuing policy reports. At present, most program resources are used for reports specifically requested by the Executive Branch or the Congress such as the Annual Science and Technology Report and the Five-Year Outlook on Science and Technology. Extramural support is also provided for special projects such as Domestic Policy Reviews (DPRs) involving science or technology requested by the Executive Office of the President.

The principal research topics in this program element come from legislation requiring the Annual and Five-Year Reports to the Congress and special requests from the Executive Office of the President. These reports analyze problems of national and international significance identified through scientific research or where scientific and technical concerns are substantial; and opportunities for constraints on scientific and technological capabilities which could contribute to the clarification and possible resolution of national issues.

There is no change in the budget requested for FY 1981.

QUANTITATIVE PROGRAM DATA
POLICY RESEARCH AND ANALYSIS SUBACTIVITY

Proposals and Awards

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number—Total	141	150	175
Total Dollars Proposed	$17,883,845	$19,000,000	$24,400,000
Awards:[1]			
Number—Total	137	100	103
Dollars Awarded:			
Total Amount	$5,459,033	$5,749,000	$6,650,000
Average $ per Award	39,847	57,490	64,563
Average Award Duration (Months)	16	16	16

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities & Colleges	$3,654,150	$3,379,000	$3,980,000
Non-profit Institutions	718,171	725,000	750,000
For-Profit Business and Industry	143,283	545,000	805,000
Federal Laboratories and Other USG Agencies	—0—	—0—	—0—
National Academy of Sciences and Professional Societies	570,646	600,000	600,000
Other[2]	372,783	500,000	515,000
Total	$5,459,033	$5,749,000	$6,650,000

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Scientists:			
Number supported	92	100	105
Amount of Support	$1,104,726	$1,195,000	$1,415,000
Other Professionals:			
Number Supported	68	70	78
Amount of Support	$228,840	$235,000	$310,000
Graduate Students:			
Number Supported	49	50	56
Amount of Support	$333,349	$345,000	$420,000
Other Personnel Costs	375,944	405,000	500,000
Other Costs[3]	2,015,427	2,074,000	2,340,000
Indirect Costs	1,400,747	1,495,000	1,665,000
Total	$5,459,033	$5,749,000	$6,650,000

[1] Includes purchase orders and interagency agreements for programmatic work.
[2] State and local governments, individuals, FFRDC's managed by any performer listed.
[3] Expendable equipment, publication, computer and other direct costs.

SCIENCE RESOURCES STUDIES SUBACTIVITY $3,400,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
S&T Personnel	$1,909,404	$1,775,000	$1,688,000	$1,700,000	$12,000
Funding of S&T	588,900	1,025,000	1,000,000	1,100,000	100,000
Modeling and Special S&T Indicators	573,303	400,000	500,000	600,000	100,000
Total	$3,071,607	$3,200,000	$3,188,000	$3,400,000	$212,000

Objectives and Descriptions

The objectives of this subactivity are the development, maintenance, and analysis of timely and comprehensive information on the Nation's human and financial resources for science and technology. Science Resources Studies meets one of the legislative mandates of the National Science Foundation Act of 1950. The Act authorizes and directs NSF to "...provide a central clearinghouse for the collection, interpretation, and analysis of data on the availability of, and the current and projected need for, scientific and technical resources in the United States, and to provide a source of information for policy formulation by other agencies of the Federal Government..."

Support is provided for an ongoing program of surveys and studies on science and technology resources that includes: 1) the collection, analysis, and interpretation of data; 2) identification of existing and emerging issues; 3) analysis of historical trends and forecasting of future trends; and 4) development of models for analytical and projection purposes. Results of these surveys and studies are disseminated through publication of a series of reports and summaries which make science resource data available to a wide audience.

The subactivity divides its efforts between 1) recurring studies and data collections, particularly those concerning R&D funding and the supply and utilization of S&T personnel, and 2) special analyses of data responsive to current science and technology policy issues. Though the issues and emphases vary, the surveys and studies cover a broad range of national resources for science and technology and provide factual and analytical information for the use of NSF managment, the National Science Board, the Congress, the Office of Science and Technology Policy, the Office of Management and Budget, and others engaged in science and technology policy formulation or evaluation.

Significant Recent Achievements

Science Indicators—1978

The eleventh annual report of the National Science Board, *Science Indicators—1978*, was transmitted by the President to the Congress in November 1979. Science Resources Studies provided the analysis and staff for its preparation. The report is the fourth in a series providing indices of science and technology performance in the United States. The present volume differs from previous reports in that it incorporates more interpretation and analysis of data presented, as well as new data. Primary policy questions illuminated by the data are identified, and increased emphasis is placed on alternative interpretations and the limitations of the data. This series of reports brings together a wide range of information depicting the current state of science and technology. The reports are extensively used by the Congress, the Executive Office of the President, and academic researchers and analysts.

Industrial R&D Expenditures

NSF has completed its 1978 survey of R&D expenditures by industry, the largest R&D performing sector in the United States. Data from this survey show an annual real growth in industrial R&D expenditures of 5 percent between 1975 and 1978. Based on analyses of the survey data, proposed R&D funding levels contained in recent Federal budgets, and information obtained in personal interviews with industrial R&D officials, the Foundation projects industrial R&D spending of $41 billion in 1980. Industrial R&D directors cite greater emphasis on research and development relative to new market opportunities and continued increases in R&D on energy and polution abatement as the primary reasons behind recent and expected future growth of R&D.

Scientific and Technical Personnel in Industry

The results of the first of a set of three surveys to collect data from individual firms on their employment of scientists and engineers were published in FY 1979. The data, collected from manufacturing industries, revealed that industries with higher than average concentrations of scientists and engineers had significantly greater growth in total employment than industries with below average concentrations. Additional data derived from surveys of firms in two sets of non-manufacturing industries are currently being collected and tabulated.

Changes Between the FY 1980 Budget Request and the FY 1980 Current Plan

The FY 1980 Current Plan differs from the FY 1980 Budget Request by only $12,000. There is also a small change in the distribution among the program elements. The Modeling and Special Science and Technology Indicators program element has been increased by $100,000 over the Budget Request to allow increased support for extramural analytical awards. The postponement until FY 1981 of the Survey of New

Entrants originally scheduled for FY 1980 and the reduced costs of another planned project have permitted offsetting reductions in the other two program elements.

FY 1981 Budget Highlights and Explanations of Increases and Decreases

Obligations

FY 1979 Actual	$3,071,607
FY 1980 Program	$3,188,000
FY 1981 Request	$3,400,000
Difference—FY 1981/FY 1980	$212,000

The $3,400,000 requested for the subactivity is 6.6 percent above the FY 1980 Current Plan of $3,188,000.

Percentage increases among program elements are as follows:

Scientific and Technical Personnel	1%
Funding of Science and Technology	10%
Modeling and Special S&T Indicators	20%

The FY 1981 program includes:

- Maintenance of the science resources information base through continuation of the periodic survey program at approximately its current level ($2,100,000).
- Continuation of work begun in FY 1979 on the development of modeling and simulation capabilities of the R&D funding and S&T personnel systems ($200,000).
- Continued support for the extramural analysis of science resources data. This program has been highly successful in creating interest among economists, statisticians, modelers, and policy analysts especially in the academic community. It provides potentially valuable inputs to S&T policy issues from extramural analysis of the extensive NSF data base ($600,000).
- Support of the Science Indicators effort at a level which should permit the development of new indicators, especially those concerned with outputs, and the exploration of more effective means to monitor and assess the status of science and technology ($500,000).

The amount requested for FY 1981 will allow:

- An increase of $285,000 over FY 1980 for a total of $500,000 for continuation of the design and planning of a key survey of scientists and engineers to be identified in the 1980 Decennial Census. The survey, to be carried out in 1982, will provide the comprehensive data base required for the development of the Scientific and Technical Personnel Data System for the 1980s. This effort will also furnish baseline data against which all S&T personnel studies in the next decade will be calibrated.

- Support of a survey of the R&D activities of independent nonprofit institutions. This periodic survey, last carried out in 1974, provides data used in the development of comprehensive national overviews of R&D funding. A new survey is badly needed for continued development of accurate national R&D funding total ($100,000).
- Net cyclical increases totalling $240,000 in several periodic studies and surveys. The largest single increases are expected in two components of the Scientific and Technical Personnel Data System. These components will be in the data collection phase of their biennial cycle at the same time requiring higher annual outlays than usual. These cyclical increases will be partially offset by a number of small cyclical decreases in other periodic surveys and studies carried out in abbreviated form in alternate years.
- The increases listed above are partially offset by the completion of the funding of several relatively large special studies totalling $413,000 which will be fully funded in FY 1980. These include: a study of how academic science and engineering faculty distribute their time among various professional activities, and in depth case studies of the effects of technological change on the utilization of scientists and engineers.

Coordination and Relationship to Other Efforts

This subactivity is the principal source of national statistics on resources for science and technology; it serves as the focal point within the Federal Government for the collection and analysis of data on science resources. Close and continuous interaction with other Federal agencies and with other public and private institutions is maintained to assemble and interpret information collected by them. Close and direct contact is also maintained with the Office of Management and Budget, the Office of Science and Technology Policy, and other NSF offices, especially the Division of Policy Research and Analysis, to provide data and analyses required for policy formulation and assessment.

Coordination is carried out through a variety of mechanisms: interagency agreements with the Bureau of the Census, the Bureau of Labor Statistics, the National Institutes of Health, the Office of Education, the National Endowment for the Humanities, and other Federal agencies; staff membership on interagency committees and task forces concerned with statistics and data collection; staff attendance at meetings and conferences; and informal contacts among the professional staff of NSF and other organizations. Periodic meetings and conferences are held with user groups to review the program,and surveys of users are conducted periodically to improve the usefulness of the outputs of the subactivity.

Scientific and Technical Personnel Program Element $1,700,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1980/81
$1,909,404	$1,775,000	$1,688,000	$1,700,000	$12,000

Objectives and Description

NSF has been charged by Executive Order to serve as the Federal Government's principal agency for the collection, coordination, and analysis of statistical information concerning scientific and technical personnel. This program element discharges this responsibility.

Studies are designed to provide the factual information essential to track the education and distribution of the Nation's scientists and engineers. Such information is used in appraising the adequacy of the Nation's scientists and engineers, in terms of their number and distribution; their quality as represented by educational attainment and other measures; and employment opportunities related to such factors as age, sex, and race. Specific objectives are the development and maintenance of:

- A comprehensive statistical picture of the current state of science and engineering in institutions of higher education, including current assessments of the ability of the higher education system to supply scientific and technical personnel;
- Timely and comprehensive statistical information on the current and future utilization of scientific and technical personnel; and
- Factual information on the characteristics of scientists and engineers, changes in characteristics, factors responsible for these changes, and their effects.

Examples of questions and issues addressed are:

- What are likely future supplies and needs for S&T personnel?
- Have there been significant shifts of doctoral employment by sector?
- What is the degree of change in field and activity, employment sector, and geographical distribution of scientists and engineers? What factors produce these mobility patterns?
- What is the impact of Federal policies and practices (e.g. funding priorities, new program initiatives) on current and anticipated S&T personnel supply and demand?

- How have the initial job patterns of new doctoral scientists and engineers changed in recent years?
- What have been the major changes in the financial support of science and engineering graduate students? What have been the effects of these support changes?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

In FY 1981 the program will include 1) maintenance of the S&T personnel data system through continuation of the periodic survey program; 2) continued work on the design and planning of the key survey of scientists and engineers to be identified in the 1980 Decennial Census; 3) support for extramural analysis of S&T personnel data.

There is a $12,000 increase in the FY 1981 budget above the FY 1980 Current Plan.

Funding of Science and Technology Program Element $1,100,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1980/81
$588,900	$1,025,000	$1,000,000	$1,100,000	$100,000

Objectives and Description

This program element includes the collection, analysis, and dissemination of information on the patterns and characteristics of funding for research and development and for other scientific and technological activities. The program includes a core of regular, periodic surveys. Data collected from government, industry, universities and colleges, and nonprofit institutions are integrated to establish national totals and trends. Special studies covering a wide range of topics related to the financing of science and technology are also carried out.

Examples of the questions and issues addressed are:

- What is the pattern of public and private R&D expenditures in relation to major functional areas?
- What is the impact of fluctuations in Federal R&D funding on the staffing patterns and general stability of universities and colleges?

- What is the current distribution of public R&D funds between large and small industrial firms?
- What role do various sectors play in the performance of R&D? In its funding?
- What is the impact of inflation on the Nation's R&D activities?
- What trends over time can be observed in R&D expenditures and in other economic variables? What data can best serve as bases for establishing the relationships between R&D expenditures and other economic variables?
- What is the geographic distribution of Federal R&D funds?
- How are Federal and private R&D expenditures distributed by sector and type of institutions?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

In FY 1981 the program will include 1) maintenance of the R&D funding data base through continuation of the periodic survey program and support for extramural analysis of R&D funding data.

The increase of $100,000 requested for this program in FY 1981 will permit a survey of R&D activities of independent nonprofit institutions. This survey, last carried out in 1974, will provide data needed for accurate national R&D funding totals.

Modeling and Special S&T Indicators Program Element $600,000

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1980/81*
$573,303	$400,000	$500,000	$600,000	$100,000

Objectives and Description

This program element supports studies of the dynamics of the science and technology resource allocation process. A major component of this undertaking involves the development of special science and technology indicators with emphasis on output indicators. This work and that of the other Science Resources Studies program elements provide the basis for the National Science Board's biennial *Science Indicators* publications prepared by SRS staff. Also included are modeling and simulation activities designed to lead to a better understanding of the factors responsible for changes in the distribution of science and technology resources.

Questions and issues examined include:

- What measures can serve as good indicators of the outputs and impacts of R&D?
- To what extent can modeling techniques be used to describe the key behavior and interactions related to R&D?
- What is the status of S&T resources in other countries?
- Are there fields of science in which the United States is becoming either more or less productive by comparison with other countries?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

In FY 1981 the program will include 1) support of extramural research for the development of new S&T indicators, especially those concerned with outputs; 2) work on the development of modeling and simulation capabilities for the science and technology resource system; 3) maintenance and updating of the S&T indicators data base.

The increase of $100,000 requested for this program in FY 1981 will be used to increase extramural research for the development of new S&T indicators.

SCIENCE RESOURCES STUDIES
FY 1981 BUDGET

DISCRETE ITEMS
(dollars in millions)

	FY 1979	FY 1980	FY 1981
Regular Periodic Studies			
S&T Personnel	$1.06	$1.06	$1.41
Funding of S&T	.41	.40	.62
Modeling and Special S&T Indicators	.28	.30	.30
Extramural Study Programs	.68	.60	.60
	$2.43	$2.36	$2.93

QUANTITATIVE PROGRAM DATA
SCIENCE RESOURCE STUDIES

Proposals and Awards

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number—Total	61	70	80
Total Dollars Proposed	$4,945,137	$5,750,000	$6,700,000
Awards:[1]			
Number—Total	52	48	48
Dollars Awarded:			
Total Amount	$3,071,607	$3,188,000	$3,400,000
Average $ per Award	59,069	66,417	70,833
Average Award Duration (months)	9	10	10

Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities & Colleges	$373,567	$375,000	$400,000
Non-Profit Institutions	283,965	275,000	300,000
For-Profit Business and Industry	1,140,453	1,188,000	1,250,000
Federal Laboratories and Other USG Agencies	860,051	700,000	750,000
National Academy of Sciences and Professional Societies	607,425	650,000	700,000
Other[2]	6,146	0	0
Total	$3,071,607	$3,188,000	$3,400,000

Personnel Support and Other Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Scientists:			
Number Supported	85	85	87
Amount of Support	$773,163	$800,000	$850,000
Other Professionals:			
Number Supported	30	31	32
Amount of Support	$191,637	$220,000	$240,000
Graduate Students			
Number Supported	1	4	4
Amount of Support	$2,165	$20,000	$20,000
Other Personnel Costs	555,961	575,000	610,000
Other Costs[3]	587,916	613,000	660,000
Indirect Costs	960,765	960,000	1,020,000
Total	$3,071,607	$3,188,000	$3,400,000

[1]Includes purchase orders and interagency agreements for programmatic work.
[2]State and local governments, individuals, FFRDC's managed by any performer listed.
[3]Expendable equipment, publication, computer and other direct costs.

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INFORMATION SCIENCE AND TECHNOLOGY SUBACTIVITY $5,900,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Standards & Measures	$1,004,576	$1,125,000	$1,100,000	$1,100,000	—0—
Structure of Information	1,028,637	1,650,000	1,500,000	1,500,000	—0—
Behavioral Aspects of Information Transfer	1,049,942	1,300,000	1,200,000	1,600,000	400,000
Infometrics	1,345,000	1,125,000	1,152,000	1,300,000	148,000
Information Technology	—0—	—0—	200,000	400,000	200,000
Total	$4,428,155	$5,200,000	$5,152,000	$5,900,000	$748,000

Objectives and Description

Information is a national resource like land, labor and capital. Sound national investments in this resource require an understanding of alternatives for its organization, access, and transfer. To further this understanding the Foundation supports basic and applied research on the properties, structure, flow, and utilization of information.

Four program elements of the subactivity support research on:

- Improved standards and measures through which the predictions of theory and the performance of information systems can be assessed.
- The structure of information.
- The behavioral aspects of information transfer.
- The development and use of models to understand the flows of information and its role in the economy (*infometrics*).

The fifth program element, Information Technology, was introduced in FY 1980 to support appropriate research activities related to emerging information technology.

Significant Recent Achievements

- An Experiment in Data Tagging in Information-Accessing Services Containing Energy-Related Data was completed by the American Chemical Society. The study, which was conducted in cooperation with the Department of Energy, examined the feasibility of coding numerical data in source documents with emphasis on cost and convenience. The results will permit the direct retrieval of this kind of information from automated systems.

- Research was supported at MIT to investigate a computer interface which would permit inexperienced end users to access automated information systems themselves rather than through professional intermediaries. The report defines two approaches which should be used in an integrated fashion to achieve the goal of improved access. The first emphasizes aids for human users and the second places the burden on the machine by applications of artificial intelligence techniques.
- A three volume work, by Machlup and Leeson at New York University, entitled "Information Through the Printed Word: The Dissemination of Scholarly, Scientific, and Intellectual Knowledge" was published. Derived from research supported by NSF and other agencies, its purpose is to provide a better understanding of the economics of disseminating scientific and intellectual information.
- In the context of a document retrieval system, a ranking algorithm defines an ordering on a set of documents in proportion to their degree of similarity to a user query. A ranking algorithm tries to present the most relevant information to the user first. A project at Syracuse University evaluated 504 different ranking algorithms to determine their relative effectiveness. A number of equally effective algorithms were discovered suggesting that significant cost reductions could be achieved by employing the least cost algorithm.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The major change in the Current Plan is the introduction of the Information Technology program element, for which $200,000 is allocated in FY 1980. The amounts allocated to three of the program elements have been reduced slightly from those in the FY 1980 budget request. Standards and Measures has been reduced by $25,000, and Structure of Information by $150,000. Behavioral Aspects of Information Transfer has been reduced by $100,000, and the Infometrics program element has been increased by $27,000. These adjustments provide funding for the new Information Technology program element and bring the allocation of funds into better alignment with anticipated research opportunities based on experience in FY 1979.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$4,428,155
FY 1980 Program	$5,152,000
FY 1981 Request	$5,900,000
Difference—FY 1981/FY 1980	$748,000

The percentage increases for program elements are as follows:

Standards and Measures	—0—
Structure of Information	—0—
Behavioral Aspects of Information Transfer	33%
Infometrics	13%
Information Technology	100%

The $5.9 million requested in FY 1981 for Information Science and Technology is 14.5% more than the FY 1980 program. The $748,000 increase requested will be used as follows:

- Support for research into the ways in which information can be transferred between information systems and their human users will be increased by $400,000, bringing the total to $1,600,000.
- Support for investigations of the information economy, including the development of predictive models of the scientific and technical communication system, will be increased by $148,000, bringing the total to $1,300,000.
- Support for research on information technology will be increased by $200,000, bringing the total to $400,000. The increase will be concentrated on projects assessing emerging new systems and for the design and use of more effective instrumentation in information science research.

Coordination and Relationship to Other Efforts

This subactivity is virtually the only U.S. source of support for information science research which is neither proprietary nor mission oriented. Related but mission-oriented research is supported by a number of agencies. Among these are the Library of Congress, the National Library of Medicine, the Office of Naval Research, and the Defense Advanced Research Projects Agency. Related research is also sponsored by other NSF programs, such as computer science, the behavioral sciences, and engineering. Coordination with allied programs in the Foundation and in other agencies is accomplished through such mechanisms as joint review of proposals, participation in advisory committee meetings, and liaison between the staffs of the coordinating programs. Coordination with the Executive Branch is effected through participation in the relevant activities of the Federal Coordinating Committee on Science, Engineering, and Technology.

Standards and Measures Program Element $1,100,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$1,004,576	$1,125,000	$1,100,000	$1,100,000	—0—

Objectives and Description

Progress in information science depends on improved measures and more accurate standards for assessing the predictions of theory and comparing the results of experiments. The continued development and refinement of such tools is, therefore, the first concern of this program element.

Major Research Questions

- How can the essential properties of information systems be formally characterized? Work that applies to combined human and machine-based systems is particularly encouraged.
- How can objective and quantitative measures of the attributes of information such as complexity, meaning, utility, and value be defined?
- How can measures of complexity, meaning, and utility be related to characteristics of information systems and to design for organization, transfer, interpretation, and utilization of information collections?
- How can standard experimental environments and test collections be designed to control variability and enhance the comparability of experimental results?

Explanation of FY 1981 Increases and Decreases

The FY 1981 estimate is $1,100,000, unchanged from the current plan for FY 1980.

Structure of Information Program Element $1,500,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$1,028,637	$1,650,000	$1,500,000	$1,500,000	—0—

Objectives and Description

Information systems involve (1) data files or other types of information stored in some physical form, and (2) users. This program element is primarily concerned with the physical and mathematical properties of information and information systems. Its major objectives are (1) characterizing information bearing structures, and (2) obtaining a better understanding of the relationship between form and content. The first of these two objectives is directed toward an understanding of those information structures that are most efficient in given circumstances; it may also suggest how human beings organize or should organize the information they use. The significance of the second objective is that computers and other information processing machines operate directly on the *form* of a statement, not on its content, or *meaning*. The extent to which meaning can be conveyed by form determines how effective a machine, or information system, can be in answering the more complicated kinds of questions people ask.

Major Research Questions

- How are existing collections of information organized and how should they be organized for maximum benefit?
- How are form and content (syntax and semantics) connected, and to what extent can the former determine or substitute for the latter?
- What relationships exist between information and the structure of language?
- What are the strengths and limitations of statistical theories of information?
- How can patterns of information in text, image, and numerical archives or files be identified and recognized automatically?

Explanation of FY 1981 Increases and Decreases

The FY 1981 estimate is $1,500,000, unchanged from the current plan for FY 1980.

Behavioral Aspects of Information Transfer Program Element $1,600,000

Obligations of Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$1,049,942	$1,300,000	$1,200,000	$1,600,000	$400,000

Objectives and Description

The effective application of information technology in the design of information systems depends upon a knowledge of human capabilities and limitations in processing information. Research in this program element contributes to that knowledge base.

Major Research Questions

The three main directions for research remain unchanged, although shifts in emphasis will be made to take current progress into account. The main questions are:

- What are the abilities and limitations of people transferring information to and from physical subsystems such as computer terminals, video displays, and printed materials?
- How do people form and recognize patterns in information systems and how do they systematically simplify complex information retrieval and processing problems?
- What are the properties specific to information systems which are intended for use by large numbers of people with varying requirements and capabilities? What tradeoffs have to be considered, e.g. between search time and cost, in the efficient design of information systems for highly different users?

Explanation of FY 1981 Increases and Decreases

The FY 1981 estimate is $1,600,000, which is $400,000 greater than currently planned for FY 1980. The increase will expand the FY 1980 level of effort in this program element to support the increasing interest in these problems among social and natural scientists.

Infometrics Program Element $1,300,000

Obligations by Program Element

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$1,345,000	$1,125,000	$1,152,000	$1,300,000	$148,000

Objectives and Description

National expenditures for the transfer of scientific and technical information have continued to grow considerably faster than those for research and development and

somewhat faster than the gross national product; they total more than $13 billion annually. In addition, the growing role of scientific and technical information in the economy, creates a requirement for better understanding of the role of information in the economy. The objective of this program element is to strengthen understanding of the role of information in the economy and to assess and predict the impact of technological, regulatory, and policy changes in the information system.

Major Research Questions

- What is the role of scientific and technical information as an input to production? What is the nature of information as a product? How can concepts such as complementarity and substitution, economies of scale, and public good, be applied to information goods and services?
- What is the comparative flexibility and substitutability of informational and non-informational parts of the workforce? What are the possible tradeoffs between the information labor force and information capital?
- How can one solve the aggregation problems encountered in modeling information flow? How can one relate information flow in firms to information flows in industries and to information flow in the economy as a whole?
- What criteria should be used in validating information models?

Explanation of FY 1981 Increases and Decreases

The FY 1981 estimate is $1,300,000, which is $148,000 greater than currently planned for FY 1980. The increase is responsive to the continued interest in this problem area shown by the research community.

Information Technology Program Element $400,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
—0—	—0—	$200,000	$400,000	$200,000

Objectives and Description

This program element is primarily concerned with two issues: (1) identifying and supporting research needed to utilize best the existing information technology and examining the potential use of promising new systems and ideas which are not being

pursued in the private sector; and (2) to promote the development and use of more effective instrumentation for information science research.

Regarding the second concern, special instruments such as microscopes and telescopes, which extend normal human abilities to observe and measure physical properties have been essential to the advancement of the physical and biological sciences. Information science is similarly dependent on instruments which make it possible to observe and measure properties of information and information transfer in a way that extends immediate individual perception. For example, structural analysis of language is almost impossible without an automatic parser, and acoustic analyzers and synthesizers are essential to research on the structure of vocal information. Further, there is a need for image processing instruments to efficiently gather data for use in research on accessing meaning from graphic information such as maps, engineering drawings, and patents. This program element will capitalize on the rapid advance of microelectronics, telecommunications, and other technological advances to promote the development of instrumentation for information science research.

Major Research Questions

- What instruments to assist information science research are now practical or feasible as a result of advances in technology?
- What advanced systems are technologically feasible over the next five to ten years? What are the social and economic implications of such technology?
- What is the impact of information technology advances on information science research? In particular, which research directions hold greater opportunity, and which are made less essential by technological change?

Explanation of FY 1981 Increases and Decreases

The FY 1981 estimate is $400,000, an increase of $200,000 above the Current Plan for FY 1980. This will support projects to conceptualize and analyze advanced information systems and to apply advanced information technology to instrumentation in information science.

QUANTITATIVE PROGRAM DATA
INFORMATION SCIENCE AND TECHNOLOGY SUBACTIVITY

Proposals and Awards

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number — Total	106	140	154
Total Dollars Proposed	$13,600,000	$18,000,000	$25,000,000
Awards:[1]			
Number — Total	40	43	46
Dollars Awarded:			
Total Amount	$4,428,155	$5,152,000	$5,900,000
Average $ Per Award	$110,704	$119,814	$128,261
Average Award Duration (Months)	19	19	19

Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities & Colleges	$3,664,542	$4,300,000	$5,000,000
Non-Profit Institutions	522,106	550,000	550,000
For-Profit Business & Industry	178,981	252,000	300,000
Federal Laboratories and Other USG Agencies	52,635	40,000	40,000
National Academy of Sciences and Professional Societies	—0—	—0—	—0—
Other[2]	9,891	10,000	10,000
Total	$4,428,155	$5,152,000	$5,900,000

Personnel Support and Other Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Scientists:			
Number supported	88	95	101
Amount of Support	$920,107	$1,050,000	$1,200,000
Other Professionals:			
Number Supported	14	15	16
Amount of Support	$144,871	$170,000	$190,000
Graduate Students:			
Number Supported	57	61	66
Amount of Support	$455,583	$530,000	$600,000
Other Personnel Costs	506,827	577,000	670,000
Other Costs[3]	1,180,346	1,395,000	1,590,000
Indirect Costs	1,220,421	1,430,000	1,650,000
Total	$4,428,155	$5,152,000	$5,900,000

[1] Includes purchase orders and interagency agreements for programmatic work.
[2] State and local governments, individuals, FFRDC's managed by any performer listed.
[3] Expendable equipment, publication, computer and direct costs.

CROSS-DIRECTORATE PROGRAMS

PROGRAM ACTIVITY SUMMARY

FY 1981 PROGRAM TOTAL $51,950,000

Obligations by Subactivity

Page	Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
H-2	Industry/University Cooperative Research	$5,445,929	$4,000,000	$7,050,000	$20,000,000	$12,950,000
H-5	Special Facilities and Instrumentation Programs	5,606,302	5,800,000	8,100,000	20,250,000	12,150,000
H-13	Cross-Directorate International Programs	3,387,484	3,200,000	4,200,000	5,200,000	1,000,000
H-20	Other Programs	2,423,171	4,300,000	6,175,348	6,500,000	324,652
	Total	$16,862,886	$17,300,000	$25,525,348	$51,950,000	$26,424,652

Goals and Description

The Cross-Directorate Programs Activity is new in the FY 1981 budget. The Foundation has grouped in this budget activity, for presentation purposes, a number of programs with special characteristics and goals. These programs mainly provide funds for purposes not related to any single field of science but to several scientific fields generally supported by the NSF. In some cases, these programs receive and review proposals in many areas aimed toward a specific objective other than advancing a particular field of science. One program, for example, provides equipment to researchers at small colleges and another experiments with building research linkage between academia and industry. Both programs support projects in many fields of science.

Some of the goals of individual programs included in the Cross-Directorate Program Activity are to:

- Encourage greater cooperation in research between universities and industry.
- Provide support for research equipment and improved research facilities to colleges and universities that have programs in the sciences and engineering.
- Maintain research cooperation between the U.S. and the U.S.S.R. and broaden opportunities between the U.S. and China.
- Help predominantly minority colleges and universities establish active research programs on their campuses thereby encouraging capable scientists at these institutions to compete for research support from all appropriate sources.

- Improve the quality of science by stimulating and increasing the competitiveness of scientists for Federal research support in States that are now relatively less able to compete successfully.
- Provide postdoctoral opportunities for recent doctoral graduates to pursue full-time basic research that enhances their ability to make significant contributions to the scientific world.
- Provide support for research in decision and management sciences aimed at the improvement of decision making in the public and private sectors.
- Continue support of efforts to plan and evaluate Foundation programs on the basis of established needs, goals, and objectives.

INDUSTRY/UNIVERSITY COOPERATIVE RESEARCH SUBACTIVITY $20,000,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Industry/University Cooperative Research Program	$5,445,929	$4,000,000	$7,050,000	$20,000,000	$12,950,000
Total	$5,445,929	$4,000,000	$7,050,000	$20,000,000	$12,950,000
Overall Program Level (see note)	$9,500,000	$6,000,000	$10,600,000	$30,000,000	$19,400,000

Note: This program shares funding of individual projects with many other NSF programs for FY 1980 and FY 1981 on a 67-33 basis; the true overall level of cooperative project funding is shown in the bottom line.

Objectives and Description

The purpose of the Industry/University Cooperative Research (IUCR) program is to encourage cooperative research projects in order to strengthen ties between universities and industry.

There is a continuing need for effective communication and cooperation between researchers in universities and researchers in industry. Universities produce knowledge and trained manpower. Industry translates knowledge into socially and economically useful developments. The ties should be strengthened between these two sectors of the Nation's scientific and technological system.

To encourage such ties, this program provides grants for the support of cooperative research projects involving both university and industrial scientists. Research is focused on fundamental scientific or engineering questions of a basic or applied nature. The work may be expected to make a long-term contribution toward product or process innovation, or to provide knowledge as a foundation for new or improved technologies. Technological development, classified and clinical research are not supported.

Criteria for project funding from the program include:

- quality of science proposed
- collaboration between industry/university researchers
- cost-sharing

Universities and colleges and established profit-making industrial firms, including small businesses, are eligible. A variety of arrangements have been supported. Cooperating entities must represent bona fide independent operations.

The distribution of IUCR funds among fields of science will follow the pattern of receipt of high-quality research proposals by NSF. All fields supported by NSF are eligible. Each IUCR proposal is first peer-reviewed in competition with other proposals in the same area of science, and then considered for IUCR funding. The review procedures are no different from those given to any scientific proposal received by NSF.

The administration of the program is designed to keep the peer review and technical decisions on awards decentralized in the standard programs of NSF organizational structure, while providing a central control for IUCR policies and allocation of IUCR funds. This provides the peer review quality control, minimizes administrative costs and avoids duplication of programs.

Major Research Questions

Research questions occur in all fields of science that have relevance to industrial technology. This includes understanding of physical, chemical, or electrical properties of matter and the exploration of engineering problems of important industrial processes and technologies. Research usually seeks to acquire new or more precise empirical data, to model or develop theories to explain phenomena, or to design new or improved devices and processes.

Significant Recent Achievements

An IUCR project funded in FY 1978 has been investigating basic mechanisms and structures for catalyzing the reduction of oxygen in electrochemical processes. In particular, an organometallic ion in a porphyrin structure has been constructed which shows remarkable catalytic activity in facilitating the electrochemical transformation of water to hydrogen and oxygen gases (or reversibly for producing electricity and water by electrochemically combining hydrogen and oxygen). Such catalysts may eventually contribute to the development of hydrogen fuel cells and of solar energy storage by hydrogen production.

Examples of IUCR awards made in FY 1979 are:

- Fundamental Study on Coextrusion of Polymeric Materials
- Characterization of Supported Metal and Metal Cluster Catalysts
- Thermal Convection in Cavities with Applications to Crystal Growth
- An Experimental Study for the Characterization of Defects and Imperfections in GA Field-Effect Transistors

- Fast Response Electron Spectroscopy
- Intercavity Laser Spectroscopy
- Design of Silicon Structures
- Study of the Limits of Applicability of Superposition in Electromagnetic Methods for Geophysical Prospecting

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

This program was begun as an experiment late in FY 1978. Eight proposals were funded in FY 1978 for a total of $1.7 million with $800,000 from the IUCR program.

In FY 1979, 57 IUCR awards were made for a total of $9.5 million, of which $5.4 million was funded from the IUCR program, as follows:

	FY 1979 IUCR Awards by Field	
Field	*Number*	*Percentage*
Engineering	29	51%
Materials Research	11	19%
Physics	5	9%
Chemistry	4	7%
Computer Science	4	7%
Applied Research	2	3.6%
Atmospheric Sciences	1	1.7%
Earth Sciences	1	1.7%
Total	57	100%

The high technical quality of these research proposals and the importance of strengthening the ties between universities and industry resulted in a decision to increase substantially the level of IUCR program activities. As a part of the President's innovation message to Congress in October 1979, the NSF IUCR program was identified for substantial growth. The rate of growth is scaled to fund the anticipated rate of receipt by NSF of high-quality industrial/university research proposals.

To encourage and maintain smooth progress of the program in response to the President's innovation message, the Current Plan for FY 1980 has been increased to $7.05 million from the FY 1980 Budget Request of $4.5 million.

FY 1981 Budget Highlights and Explanations of Increases and Decreases

	IUCR Program	*Support from other NSF Programs*	*Total IUCR Activity*
FY 1979 Actual	$5,445,929	$4,054,071	$9,500,000
FY 1980 Current Plan	7,050,000	3,550,000	10,600,000
FY 1981 Request	20,000,000	10,000,000	30,000,000
Difference—FY 1981/1980	$12,950,000	$6,450,000	$19,400,000

At the requested FY 1981 level of $20 million, the number of IUCR awards is expected to double in FY 1980 above FY 1979 and to double again in FY 1981.

SPECIAL FACILITIES AND INSTRUMENTATION PROGRAM SUBACTIVITY $20,250,000

Obligations by Program Element

Program Element	*Actual FY 1979*	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
University Research Facilities Improvement ...	—0—	—0—	—0—	$14,250,000	$14,250,000
2-Year and 4-Year College Instrumentation	606,302	1,000,000	3,300,000	3,000,000	-300,000
Regional Instrumentation Facilities	5,000,000	4,800,000	4,800,000	3,000,000	-1,800,000
Total	$5,606,302	$5,800,000	$8,100,000	$20,250,000	$12,150,000

Objectives and Description

The Special Facilities and Instrumentation Program subactivity provides support for instrumentation and facilities across several disciplines. The objectives of this subactivity are to:

- Provide support for essential research equipment to those 2-year and 4-year colleges that have only small or no doctoral programs in science and engineering.
- Increase the availability of highly specialized instrumentation and relevant personnel to researchers in various regions of the United States.
- Assist graduate level research laboratories at universities to upgrade their facilities.
- Maintain appropriate geographic distribution of basic research capability in the United States.

Many other Foundation programs provide support for specialized equipment and facilities through regular project grants.

University Research Facilities Improvement Program Element $14,250,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
—0—	—0—	—0—	$14,250,000	$14,250,000

Objectives and Description

A considerable amount of the research supported by the Federal government is conducted in university laboratories by faculty members and their graduate and post-doctoral students who work on independent research problems. The continuing need for scientific knowledge and research training of the highest quality is of utmost importance if this Nation is to maintain its leadership in science.

Many of the laboratories in operation for graduate-level research are simply outdated. Maintaining the high quality of research supported by the Federal Government through project awards requires that laboratory facilities be brought up-to-date.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The Foundation, through this new program, will provide $14,250,000 of support in FY 1981 to universities to upgrade research facilities. This support will include funds for the construction and renovation of graduate academic facilities for research in all fields of science and engineering, excluding the clinical areas. Federal funds will be provided on a one to one matching basis with university funds from non-Federal sources.

QUANTITATIVE PROGRAM DATA
UNIVERSITY RESEARCH FACILITIES IMPROVEMENT PROGRAM ELEMENT

Proposal and Award Summary

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Number of Proposals Received	—0—	—0—	200
Nunber of Awards	—0—	—0—	60
Dollars Proposed (Total)	—0—	—0—	$60,000,000
Dollars Proposed (Annual Rate)	—0—	—0—	30,000,000
Dollars Awarded (Total)	—0—	—0—	14,250,000
Dollars Awarded (Annual Rate)	—0—	—0—	7,125,000
Average $ per Award	—0—	—0—	237,500
Average Award Duration (Years)	—0—	—0—	2

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2-Year and 4-Year College Instrumentation Program Element $3,000,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$606,302	$1,000,000	$3,300,000	$3,000,000	$-300,000

Objectives and Description

The objective of the 2-Year and 4-Year College Instrumentation program element is to provide research equipment of moderate cost to colleges and universities lacking or having only very small doctoral programs in the sciences and engineering. Instrumentation and equipment awards make significant research investigations possible by qualified scientists who lack instruments or equipment essential for their experiments. The program is particularly concerned with the needs of well-trained recent Ph.D.'s, who are locating in these institutions more frequently than in the recent past. Being able to secure the necessary scientific equipment will enable these young scientists to maintain and improve their research capabilities, with measurable benefits to the Nation. In many cases, the availability of research equipment will permit the scientists to complete a sufficient amount of high-quality research to enable them to compete successfully for regular scientific research project support.

Significant Recent Achievements

The program made 44 grants in fiscal year 1979, totaling $606,302 during the program's first year. Research in chemistry and biology received the majority of the awards in FY 1979. However, physics, biophysics, computer science, atmospheric science, materials science, and oceanography are also represented in the award list.

Changes Between the FY 1980 Budget Request and FY 1980 Current Plan

The increase of $2,300,000 in the FY 1980 Current Plan for this program element, from $1,000,000 to $3,300,000, reflects Congressional action on the Foundation's FY 1980 Budget Request that provided for a prescribed increase.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$606,302
FY 1980 Program	$3,300,000
FY 1981 Request	$3,000,000
Difference—FY 1981/FY 1980	$-300,000

The program will continue at $300,000 below the FY 1980 level, which was a major increase over the FY 1979 rate of activity. The average size of awards is expected to increase to about $20,000, compared to $13,780 in FY 1979 and $16,500 in FY 1980 because of cost increases for equipment. The number of grants (150) is estimated to be 50 lower than the number estimated for FY 1980.

QUANTITATIVE PROGRAM DATA
2-YEAR AND 4-YEAR COLLEGE INSTRUMENTATION PROGRAM ELEMENT

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Number of Awards	44	200	150
Total Dollar Amount	$606,302	$3,300,000	$3,000,000
Average Dollar Amount	13,780	16,500	20,000
Average Award Duration (Months)	12	12	12

Percentage Distribution of Funds by Performer

All awards in this program element are made to colleges and universities.

Regional Instrumentation Facilities Program Element $3,000,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$5,000,000	$4,800,000	$4,800,000	$3,000,000	$-1,800,000

Objectives and Description

The objectives of this program element are to:

- Improve the quality and scope of research in various regions of the United States by increasing the availability of sophisticated instrumentation and trained personnel to researchers in these regions;
- Provide greater scientific opportunity by utilizing this instrumentation on a shared basis;
- Improve the geographic distribution of basic research capability in the U.S., and
- Enhance research interaction among university, industry, and government scientists and engineers.

The Foundation recognizes that research and instrumentation go hand in hand in the creation of new knowledge. Obsolescence of instrumentation in many of the Nation's research centers is becoming a serious problem exacerbated by the current revolution in instrumentation technology, which is producing instrumentation of a power unimagined only a few years ago. Regional facilities featuring such instrumentation offer an economical solution to the desire to make costly instrumentation widely available to qualified scientists, including those at smaller institutions.

To achieve these ends, it is also essential that highly qualified personnel be available to maintain and operate the instruments and often to help with interpretation of the results.

Funding History

In FY 1979, the following facilities were initiated:

University	*Facility*
Arizona State University	Scanning Electron Microscope
Montana State University	Surface Science and Submicron
California Institute of Technology	High Field Nuclear Magnetic Resonance
University of California-Berkeley	San Francisco Laser Center
Jointly With Stanford University	
University of Illinois	High Field Nuclear Magnetic Resonance

At the beginning of FY 1980, three additional facilities were established:

University	*Facility*
Massachusetts Institute of Technology	Laser Spectroscopy
University of Minnesota	Surface Science
Yale University	High Field Nuclear Magnetic Resonance

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The total number of facilities in operation in FY 1980 is 14, representing a broad cross-section of science and highly creative research opportunities. At present, it is envisioned that no additional facilities will be established during FY 1981, and the existing facilities will be subject to an intensive evaluation process. Thus, the Budget Request for FY 1981 of $3,000,000, which is $1,800,000 below the FY 1980 Current Plan of $4,800,000, will permit operational support, equipment purchases necessary to continue the operation of the existing facilities, and sufficient equipment support to maintain existing facilities at state-of-the-art.

QUANTITATIVE PROGRAM DATA
REGIONAL INSTRUMENTATION FACILITIES PROGRAM ELEMENT

Proposal and Award Summary

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Number of Proposals Received	164	14	14
Number of Awards	[1]11	[2]14	14
Dollars Proposed (Total)	$200,000,000	$6,000,000	$6,000,000
Dollars Proposed (Annual Rate)	50,000,000	1,500,000	1,500,000
Dollars Awarded (Total)	5,000,000	4,800,000	3,000,000
Dollars Awarded (Annual Rate)	1,250,000	1,200,000	750,000
Average $ Per Award	454,545	342,860	214,286
Average Award Duration (Years)	4	4	4

[1] Includes 5 new awards for FY 1979 and 6 continuing awards made in FY 1978.
[2] Includes 11 continuing awards made in FY 1978-FY 1979 and 3 new awards made in FY 1980.

Percentage Distribution of Funds Awarded by Performer

All funds are awarded to universities and colleges.

CROSS-DIRECTORATE INTERNATIONAL PROGRAMS SUBACTIVITY $5,200,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
US/USSR Cooperative Research Program	$3,387,484	$3,200,000	$3,200,000	$3,200,000	—0—
US/China Cooperation in Basic Sciences	—0—	—0—	1,000,000	2,000,000	$1,000,000
Total	$3,387,484	$3,200,000	$4,200,000	$5,200,000	$1,000,000

Objectives and Description

The objectives of the Cross-Directorate International Programs subactivity focus on promoting a more cost-effective U.S. scientific effort by exchanging research information with the U.S.S.R. and the Republic of China and by sharing costs and access to rare or unique research facilities, resources, and expertise through bilateral programs, joint commissions, and informal cooperation based upon mutual benefit.

U.S./U.S.S.R. Cooperative Research Program Element $3,200,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$3,387,484	$3,200,000	$3,200,000	$3,200,000	—0—

Objectives and Description

Cooperative scientific activities under the U.S./U.S.S.R. Agreement on Scientific and Technical Cooperation are directed towards acquiring new ideas and perspectives; providing the opportunity for U.S. researchers to have access to unique facilities and environment; sharing of research costs; and obtaining information on scientific activities and research and development in the Soviet Union. Equality of benefit and reciprocity are guiding criteria in the program.

Principal objectives of the cooperative program are to:

- Provide funding for U.S. scientists to work with Soviet scientists on cooperative activities which advance science and technology in the United States.

- Provide funding for joint exchanges, symposia, conferences, and research in the areas of science agreed to jointly between the United States and the Soviet Union.

This subactivity responds to NSF's statutory authority to "initiate and support specific scientific activities in connection with matters relating to international cooperation" and to support the scientific component of U.S. foreign policy initiatives. (P.L. 81-507).

The forms of cooperation under this agreement include: exchange of scientists and scientific and technical information; joint development of programs in both the basic and applied areas; joint research and testing; and joint conferences and symposia.

Cooperative areas currently include: Chemical Catalysis, Computer Applications in Management, Electrometallurgy and Materials, Corrosion, Physics, Microbiology, Science Policy, Scientific and Technical Information, Heat and Mass Transfer, Polymer Sciences, and Earth Sciences.

Significant Recent Achievements

Computer Applications in Management

U.S. and Soviet cooperative research activities include the development of high quality computer programs for numerical computations, a problem common to computer specialists in both countries. In this connection, U.S. and Soviet specialists have been cooperating in using computer programs for solving certain classes of matrix problems. Soviet expertise in the algorithmic solutions to these problems is unusually strong and has been extremely useful to U.S. researchers in this area. It is expected that a special users manual, which will be valuable to U.S. investigators in the computing community, will be developed from this cooperation.

Plasma Arc Remelting for Producing High Nitrogen Stainless Steels

The Soviet Union has invested extensive resources in techniques of plasma-arc remelting (PAR) for the production of high quality speciality steels and superalloys. There are now 20 PAR furnaces in the Soviet Union; none exist in the United States. It is estimated that the cost of building one would be approximately $500,000.

Under this cooperation, the Soviets will provide to the U.S. ingots prepared by stainless steel prepared by PAR process. The U.S. will furnish ingots prepared by electroslag and vacuum-arc remelting processes in U.S. furnaces. Joint testing will be conducted on composition, structure, hot-working response, and mechanical properties. Sharing of test results in this way will assist the United States in improving steel production processes.

Evaluation of Advanced Cutting Tool Systems

As part of US/USSR cooperation in electrometallurgy, joint testing has been underway to determine the benefits of hard refractory coatings on hard carbide and high speed cutting tools. Using a Soviet-developed electron beam gun, refractory

carbide, nitride and carbon nitride coatings of titanium and hafnium have been applied in the USSR to such tools, which were subsequently sent to the U.S. for testing. Excellent results have been achieved. Preliminary testing has shown increases in the range of 100%—700% in the lifetime of the coated hard carbides and 50%—250% in the lifetime of the coated high speed tool steels. In the future, it is planned to link the Soviet electron-beam gun with a U.S. developed evaporation chamber into a hybrid coating instrument which is expected to yield even more impressive results.

Heat and Mass Transfer

Fundamental research in heat and mass transfer is gaining importance in the U.S. as a result of the current energy crises. In both the U.S. and the Soviet Union, theoretical and experimental research in the field of heat and mass transfer has been actively pursued. The Soviets are especially strong in research on thermal radiation and convective heat and mass transfer, in which they are noted for advances in analytical development for prototype experimental investigations, and for the broad range of problems studied. Following several years of informal contact and cooperative research between the U.S. and the Soviet Union, plans for the current program of cooperation in heat and mass transfer under the S&T agreement were initiated in 1979. The planned program, which will cover the most important areas of heat and mass transfer research, will produce quantitative results beneficial to the U.S. in the design of more efficient industrial processes.

Changes Between FY 1980 Budget Request and the FY 1980 Current Plan

The FY 1980 Current Plan is the same as the FY 1980 Budget Request. Current activities and programs supported under this program were agreed to by both countries at the U.S./U.S.S.R. Joint Commission Meeting held in Moscow in February 1979.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$3,387,484
FY 1980 Program	$3,200,000
FY 1981 Request	$3,200,000
Difference—FY 1981/FY 1980	—0—

No increase is requested for the FY 1981 program. The program proposed for FY 1981, identical to that for FY 1980, is as follows: Chemical Catalysis ($350,000), Computer Applications in Management ($600,000), Electrometallurgy and Materials ($665,000), Corrosion ($250,000), Physics ($300,000), Microbiology ($250,000), Science Policy ($220,000), Scientific and Technical Information ($15,000), Heat and Mass Transfer ($250,000), Polymer Sciences ($150,000), and Earth Sciences ($150,000).

Coordination and Relationship to Other Efforts

NSF staff participates in an Interagency Coordinating Committee for U.S.-Soviet Affairs, chaired by the Department of State. This Committee is responsible for monitoring and coordinating U.S. Government activities with respect to the Soviet Union.

The NSF also provides staff support to Frank Press and the U.S. members of the Joint Commission.

NSF coordination with the Department of State, in connection with the US/USSR Cooperative Research Program, includes obtaining policy guidance in planning and carrying out cooperative S&T activities with the Soviet Union.

NSF program officers also coordinate with their counterparts in other technical agencies on various matters related to cooperative activities with the Soviet Union.

QUANTITATIVE PROGRAM DATA
U.S./U.S.S.R. COOPERATIVE RESEARCH PROGRAM

Proposal and Award Summary

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Awards:			
Number of Awards (Total)	44	41	41
Total Dollars Awarded:			
Total Amount	$3,387,484	$3,200,000	$3,200,000
Average $ Per Award	76,990	78,050	78,050
Average Award Duration (Months)	12	12	12

Distribution of Funds Awarded by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	$1,649,397	$1,915,300	$1,915,300
Non-Profit Institutions	277,159	545,000	545,000
For-Profit Business and Industry	430,200	49,700	49,700
Federal Laboratories	416,868	140,000	140,000
National Academy of Sciences	613,860	550,000	550,000
Other	—0—	—0—	—0—
Total	$3,387,484	$3,200,000	$3,200,000

Personnel Support and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Scientists:			
Number Supported	50	38	39
Amount of Support	$347,002	$234,558	$240,100
Other Professionals:			
Number Supported	33	31	31
Amount of Support	300,805	312,234	301,723
Graduate Students:			
Number of Supported	31	27	27
Amount of Support	272,957	202,574	207,641
Other Personnel Costs	276,587	225,500	228,945
Other Costs	1,319,693	1,398,918	1,410,015
Indirect Costs	870,440	826,216	811,576
Total	$3,387,484	$3,200,000	$3,200,000

U.S./China Cooperation in Basic Sciences
Program Element $2,000,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
—0—	—0—	$1,000,000	$2,000,000	$1,000,000

Objectives and Description

The funds requested for this new program element will make it possible for the Foundation to cooperate with Chinese scientists in a broad research program in the basic biological, social, mathematical, and physical sciences. This work is undertaken in accordance with the US-China Agreement for Cooperation in Science and Technology, which was signed on January 31, 1979. This cooperative research program is a natural follow-on and expansion of a series of exchanges of scientific delegations and individuals funded since 1972 under International Cooperative Scientific Activities. Other agreements have been signed which involve other agencies of the government. These agreements include the fields of energy, agriculture, high energy physics, and space technology, and the exchange of students and scholars.

Specific objectives of the NSF program are to:

- Encourage and assist the development of a broad range of cooperative scientific activities between the two countries which are based on mutual benefit, equality and reciprocity.
- Provide opportunities to U.S. scientists to cooperate with Chinese colleagues in scientific and technological fields of common interest.
- Maintain essential administrative support to program activities and operations, including travel and interpretation services.

Program activities will include cooperative research, symposia and scientific visits on topics of mutual scientific interest. Implementation of the program is dependent upon formal agreement on details with Chinese authorities.

Changes between FY 1980 Budget and FY 1980 Current Plan

The FY 1980 budget submission to Congress did not provide for this program. One million dollars was reprogrammed from other activities in order to cover the costs of program planning and the initial phase of program implementation during FY 1980.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	—0—
FY 1980 Program	$1,000,000
FY 1981 Request	$2,000,000
Difference—FY 1981/FY 1980	$1,000,000

NSF has recently conducted an inter-directorate review to identify the fields which offer the greatest potential scientific return in cooperation with China. The candidate fields are archaeology, anthropology, paleontology, linguistics, history of science, descriptive botany, descriptive zoology, natural products chemistry, and R&D management and science policy. The fields actually included in any accord with the Chinese, initially or over time, will depend upon perceived relative importance and the outcome of pending negotiations.

FY 1980 activities will focus on program development. Planning and implementing symposia or visits for the purpose of planning specific projects will be the principal activities supported. Some of these activities will be performed by the National Academy of Sciences.

The increase for FY 1981 will assure a program of significant scientific activity in each of the several additional fields which will be included in the final accord. A portion of the funds in this program may also be available to support the National Academy of Sciences' exchanges with its Chinese counterpart.

Coordination with and Relation to other Efforts

The Director of the National Science Foundation is an *ex officio* member for the U.S. on the US-China Joint Commission on Science and Technology, chaired by the President's Science Advisor. The Joint Commission is the coordinating body for the US-China Agreement on Science and Technology. NSF's planning activities are also coordinated with the Office of Science and Technology Policy, the Department of State, and other Federal agencies involved in agreements with China.

Internally, NSF coordinates its activities through a China Working Group reporting to the Assistant Director for Scientific, Technological and International Affairs. The China Working Group has members from each of NSF's line directorates. This new cooperative science activity will be carried out in addition to NSF support for exchanges of students and scientific delegations managed by the Committee for Scholarly Communication with the People's Republic of China, which were initiated before normalization of U.S.-China diplomatic relations.

OTHER PROGRAMS SUBACTIVITY $6,500,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Research Initiation in Minority Institutions	$425,944	$1,000,000	$1,000,000	$1,000,000	—0—
Experimental Program to Stimulate Competitive Research	875,310	2,700,000	3,850,000	2,700,000	-1,150,000
Postdoctoral Fellowships[1]	(1,774,251)	(900,000)	(900,000)	900,000	900,000
Decision and Management Sciences	—0—	—0—	—0—	1,000,000	1,000,000
Alan T. Waterman Award	150,000	[2](150,000)	150,000	150,000	—0—
NSF Planning and Evaluation	971,917	600,000	1,175,348	750,000	-425,348
Total	$2,423,171	$4,300,000	$6,175,348	$6,500,000	$324,652

[1] Postdoctoral Fellowship funds were included in Science Education prior to FY 1981.
[2] Alan T. Waterman Award funds were included in other NSF directorates for the FY 1980 Budget Request.

Objectives and Description

Program elements included in the Other Programs category focus on a wide range of support efforts that address specific needs and objectives rather than stressing any one particular scientific discipline.

Some of the objectives of this program subactivity are to:

- Help predominantly minority colleges and universities establish active research programs on their campuses, thereby encouraging capable scientists at these institutions to compete for research support from all appropriate sources.
- Strengthen the research base in eligible States that wish to increase the ability of scientists in these States to compete more successfully for Federal research funds.
- Provide support to allow young postdoctoral researchers to pursue full time work that will strengthen their ability to make significant contributions to the scientific community and to the world at large.
- Increase support for research, development, and testing methods to improve those activities common to decision and management sciences.
- Provide recognition to an outstanding young scientist based on his/her previous attainments.
- Develop more efficient techniques for reviewing and appraising the effectiveness of Foundation programs.

Research Initiation in Minority Institutions
Program Element $1,000,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$425,994	$1,000,000	$1,000,000	$1,000,000	—0—

Objectives and Description

The objectives of support for Research Initiation in Minority Institutions (RIMI) are to:

- Help establish active research programs on eligible campuses.
- Assist capable science faculty at participating institutions to begin independent research careers.
- Encourage scientists from participating colleges and universities to compete for research support from all appropriate sources.
- Provide necessary tools and time to carry on research at eligible institutions, where teaching loads tend to be heavy and quality research equipment is scarce.
- Reduce isolation of researchers at eligible institutions from the larger scientific community by providing travel support and opportunities to collaborate with scientists at major research institutions.
- Help eligible institutions retain faculty who wish to be active in research.

The Foundation has taken the role of catalyst for sustaining research support at predominantly minority institutions. Often, the most difficult part of a research project is getting it started. Given special help in getting necessary equipment and the time to exchange ideas with colleagues and try some approaches to see which may be most fruitful, those who are capable and continue to be interested in doing quality research will compete for research support from the Foundation and other agencies.

Support from the special funds earmarked for RIMI depends on the following criteria:

- The quality of the proposed research;
- Whether the institution has a student body which is predominantly minority; and
- Whether the investigator has had any Federal research support at that institution.

Proposals are accepted in all scientific disciplines supported by NSF including applied research. They are evaluated through the peer review process.

Significant Recent Achievements

Radiation Monitors for Nuclear Reactors

A crucial part of reactor safety systems are dosimeters which measure the amount of radiation received by workers. The neutron cross section excitation function is a measure of the sensitivity of the material in the dosimeter to neutrons. The data on which some of the cross sections are based are old and insufficiently accurate. With the aid of RIMI funds, S. K. Ghorai and students from Alabama State University have measured cross sections for isotopes of nickel and antimony, using research facilities at Auburn University. Their results have been requested by the International Nuclear Data Committee to fill out the body of information needed for nuclear technology.

Fossil Studies

S. Taseer Hussain of Howard University has collaborated with workers from the Geological Survey of Pakistan and others on the paleontology and biostratigraphy of northwestern Pakistan. Key fossil finds of rodents and large mammals, including whales, indicate respectively a revised timing for the arrival of rodents in the area and the presence of a sea, the western Tethys. Hussain has been highly productive in publications, and he plans to continue the search for fossils, begun with RIMI support, and the interpretation of the past history of the sea.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$425,944
FY 1980 Program	$1,000,000
FY 1981 Request	$1,000,000
Difference—FY 1981/FY 1980	—0—

No increase is requested in FY 1981 for this program element. This reflects our expectation that student bodies in the eligible institutions will not increase significantly, so that hiring of new faculty will be limited.

Coordination and Relation to Other Efforts

Although not previously identified as a budget program element, RIMI has been, for several years, an integral part of the Foundation's efforts to provide greater access to scientific careers by minorities. As the establishment of the Department of Education leads to changes in NSF's programs, internal coordination will be maintained both by interaction between program personnel in the Science Education Directorate and coordinators in the research directorates and through such media as the National Science Board Committee on Minorities and Women in Science. Ways of using the

capabilities of the Resource Centers for Science and Engineering to further RIMI objectives continue to be developed.

Coordination with other agencies include informal contacts with persons who have responsibility for minority activities, and more formal interactions such as their participation in a recent NSF-sponsored workshop on New Directions for Supporting Scientific Research in Black Institutions.

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QUANTITATIVE PROGRAM DATA
RESEARCH INITIATION IN MINORITY INSTITUTIONS PROGRAM ELEMENT

Proposal and Award Summary

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Number of Proposals Received	*	100	110
Number of Awards	9	30	28
Dollars Proposed (Total)	*	$5,000,000	$5,500,000
Dollars Proposed (Annual Rate)	*	2,000,000	2,000,000
Dollars Awarded (Total)	$425,944	1,000,000	1,000,000
Dollars Awarded (Annual Rate)	228,184	526,300	555,500
Average $ per Award	47,327	33,333	35,700
Average Award Duration (Months)	22.4	22.8	21.6

*Not available.

Percentage Distribution of Funds Awarded by Performer

All RIMI awards are made to colleges and universities.

Personnel and Other Factors

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Senior Scientists, Faculty			
Number of years supported	3	10	9
Amount of faculty support	$68,292	$250,000	$245,000
Postdoctoral Associates			
Number of years supported	—0—	—0—	—0—
Amount of faculty support	—0—	—0—	—0—
Graduate Students			
Number of supported per grant-year	2	10	10
Amount of graduate support	10,060	60,000	70,000
Undergraduate Students			
Number supported per grant-year	1	10	12
Amount of undergraduate support	6,175	30,000	40,000
Other Personnel Costs	49,971	150,000	150,000
Land, Buildings, and Fixed Equipment	—0—	—0—	—0—
Major Equipment (more than $200,000)	—0—	—0—	—0—
Other Equipment	111,760	200,000	180,000
Other Costs	81,242	110,000	115,000
Indirect Costs	98,444	200,000	200,000
Total	$425,944	$1,000,000	$1,000,000

Experimental Program to Stimulate Competitive Research Program Element $2,700,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$675,310	$2,700,000	$3,850,000	$2,700,000	$-1,150,000

Objectives and Description

The Experimental Program to Stimulate Competitive Research was established by the National Science Foundation in January 1978, in response to a recommendation from an NSF Task Force on Geographic Distribution of NSF Awards. Discussions leading to its establishment recognized the local, as well as national, importance of a strong science base, the benefits of a diversified and widespread performer pool, and the major contributions that a merit-based peer review system has made to the Nation. The Foundation adopted the program to ensure that no State need remain a non-participant in scientific research.

The program's objective centers on stimulating research competitiveness within the accepted peer review system. The program places responsibility for program design and execution upon academic scientists and industrial leaders within each State and requires substantial State and private sector cost sharing as well as plans for continuation of improvements after termination of NSF support. Projects will respond to specific scientific needs and circumstances and will build on existing areas of scientific strength to develop new areas of potential excellence.

The program is being conducted in two phases. During FY 1979, seven Phase A Planning awards of up to $125,000 were made to *ad hoc* committees in Arkansas, Maine, Montana, North Dakota, South Carolina, South Dakota and West Virginia. The *ad hoc* committees are composed of academic scientists and industrial leaders within each State. With the grant, each committee assessed current research activities within its State, identified resources and options for improvement, and created a five-year plan to improve the quantity and competitiveness of research within the State.

The seven eligible States were identified through the application of a set of objective criteria (such as the amount of scientific research project support received from NSF, the ratio of doctoral scientists and engineers per 1,000 population and Federal R&D dollars to universities and colleges in the State).

The seven plans that resulted from Phase A Awards will compete for Phase B Implementation Awards, to be made late in FY 1980.

During FY 1981, the Foundation plans to fund the second year of the Phase B Implementation Awards. The average annual rate per award in FY 1981 is estimated at $700,000. No State will be permitted to participate in Phase B for more than five years.

The Foundation plans to initiate Phase A planning activities in three additional

States during Fiscal Year 1980, with Phase A Awards to be made from FY 1981 funds. The three additional States, identified with the same criteria as used before, are expected to be Vermont, Idaho and Mississippi.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The increase of $1,150,000 for this program element in FY 1980, from a Budget Request of $2,700,000 to a Current Plan level of $3,850,000, reflects increased funding of Phase B implementation awards.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

	Obligations
FY 1979 Actual	$875,310
FY 1980 Program	$3,850,000
FY 1981 Request	$2,700,000
Difference—FY 1981/FY 1980	$-1,150,000

The National Science Foundation adopted the Experimental Program to Stimulate Competitive Research after the FY 1979 Budget had been submitted to Congress. During testimony before all four committees on the FY 1979 Budget Request, the NSF Director indicated that he intended to make $1,000,000 available for this program. House and Senate Authorization Committees and the House Appropriations Committee specifically endorsed the Director's intention.

The FY 1979 obligation of $1,000,000 carried out that stated intention by providing monies for planning and assessment in each of the seven States. The $3,850,000 provided in FY 1980 would implement the initial year of each State's five-year improvement program and permit a modest evaluation program to commence. At the FY 1981 request level of $2,700,000, the program will have available sufficient funds to make Phase A Awards in three additional states and provide 2nd year support for some of the Phase B Implementation Awards. Second year funds for the remaining Phase B Awards will be provided in FY 1982.

Significant Recent Achievements

- Basic science has been given increased visibility within each State and enthusiasm among science faculty is high.
- Many nationally prominent scientists have visited participant States and have assisted in the assessment activities.
- Detailed objective descriptions of science resources have been completed in each State.
- There have been improved interactions among academic institutions, State Government, and Industry, leading to an increase in co-operative activities.
- There has been an increase in communication and cooperation among academic institutions.
- There have been increases in long range science planning and in basic research proposals.

QUANTITATIVE PROGRAM DATA
EXPERIMENTAL PROGRAM TO STIMULATE COMPETITIVE RESEARCH PROGRAM ELEMENT

Number of Awards and Average Size

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Number of Awards	7	5-7	6-10
Total Dollar Amount	$875,000	$3,850,000	$2,700,000
Average Dollar Amount	125,000	600,000	360,000
Average Award Duration (Months)	12	12	12

Percentage Distribution of Funds by Performer

All awards in this program element are made to colleges and universities.

Postdoctoral Fellowship Program Element $900,000

Actual FY 1979[1]	Budget Request FY 1980[1]	Current Plan FY 1980[1]	Estimate FY 1981	Difference FY 1981/80
($1,774,251)	($900,000)	($900,000)	$900,000	$900,000

[1]These data which are included in Science Education are displayed for comparison purposes only.

Objectives and Description

A cadre of highly trained scientists is necessary for the soundness of the Nation's scientific and technological future. Although this Nation has a very strong and effective educational system, many promising new Ph.D. scientists can benefit greatly from additional training under the tutelage of leading experts in their own or related fields. Such training offers the opportunity for gaining new technical skills, new insights, and new perspectives on research problems. The Foundation supports such career-enhancement opportunities in all fields through the Postdoctoral Fellowship program.

The program element:

- Selects through national merit competition a limited number of the most promising individuals from all fields of science, mathematics, and engineering for one-year fellowships.
- Allows fellowship recipients to choose their senior scientific advisor in this country or abroad.
- Allows those with other demanding obligations to conduct their fellowship activities on a part-time basis over an extended period, thereby affording them access to a research career which might otherwise be delayed.

Significant Recent Achievements

As a result of the multidisciplinary nature of this program element, achievements are made in a broad variety of fields. One recently completed fellowship involved work with a Dutch group studying ways to produce more cost-effective solar cells for direct generation of electricity from sunlight. The Fellow's role in the group was the study of the electrical properties of materials used in such solar cells. Their efforts resulted in the design of new approaches to growing smaller and much cheaper silicon crystals which are very efficient in solar cells.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

There is no change between the amount in the FY 1980 Budget Request and the FY 1980 Current Plan. Funds for the program are included in the Science Education budget activity.

FY 1981 Budget Highlights and Explanations of Increases and Decreases

The amount requested for FY 1981 is the same as planned for FY 1980 and reflects a stable level of effort. However, funds for this program are requested in the Cross-Directorate Activity for FY 1981 to reflect the fact that postdoctoral stipends are offered in support of research.

Coordination and Relationship to Other Efforts

This program element is coordinated with similar support programs in other agencies especially the Department of Health and Human Services—National Institute of Health. Efforts are directed toward exchange of information and coordination of program direction to monitor both program equity and overlap among similar programs.

QUANTITATIVE PROGRAM DATA
POSTDOCTORAL FELLOWSHIP PROGRAM ELEMENT

Proposal and Award Summary

	*Estimate FY 1979***	*Estimate FY 1980*	*Estimate FY 1981*
Proposals:			
Number of Proposals	752	947	850
Total Amount Proposed	$10,377,600	$14,867,900	$13,345,000
Average Amount Per Proposal	13,800	15,700	15,700
Awards:			
Number of Awards	124	51	51
Total Amount Awarded	$1,774,251	$900,000	$900,000
Average Amount Per Award	14,308	17,650	17,650
Average Annual Amount	14,308	17,650	17,650
Average Award Duration (Months)	12	12	12
Total Number of Participants Supported*	123	50	50

Percentage Distribution of Funds Awarded by Performer

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Universities and Colleges	100	100	100
Other Non-Profit Organizations	—0—	—0—	—0—
Industry	—0—	—0—	—0—
Other	—0—	—0—	—0—

Personnel and Other Award Factors

	Estimate FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Professional Staff Costs	—0—	—0—	—0—
Other Staff Costs	—0—	—0—	—0—
Subtotal, Staff Costs	—0—	—0—	—0—
Expendable Supplies and Equipment	—0—	—0—	—0—
Permanent Equipment	—0—	—0—	—0—
Other Project Direct Costs	68,530	70,000	70,000
Subtotal, Non-Staff Project Costs	68,530	70,000	70,000
Total, Direct Costs	68,530	70,000	70,000
Indirect Costs	29,370	30,000	30,000
Participant Support Costs:			
Stipend & Other Personal Allowances	1,602,551	770,000	770,000
Cost-of-Education Allowances	73,800	30,000	30,000
Total, Participant Support Costs	1,676,351	800,000	800,000
Grand Total	$1,774,251	$900,000	$900,000

*Individual Awards. Does not include award for proposal evaluation support.
**This column of figures duplicates information incorporated in the quantitative data for Science Education.

Decision and Management Sciences Program Element $1,000,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
—0—	—0—	—0—	$1,000,000	$1,000,000

Objectives and Description

Improved management of complex economic, social, and technical organizations operating in risky and uncertain environments is one of the major challenges the nation faces in coming decades. Over the last forty years, the ability of scientists to address this challenge has been increasing. The branches of science that deal with improving organizational decisions, management, and operations are known variously as systems analysis, decision science, operation research, and operations management. The unifying theme in these sciences is the discovery of rational decision and management procedures. These are then applied to improve the operations of public and private enterprises, such as health systems, transporation systems, urban service systems, and business enterprises.

The objective of this subactivity is to provide a scientific knowledge base which can lead to the enhanced performance of organizations. The program will support interdisciplinary research on the development, testing, and evaluation of models which can be applied to the improvement of decisionmaking and the increased efficiency of public and private sector operations.

Examples of Major Research Questions

Major research questions include:

- How can real-time decisionmaking under uncertainty in large systems be improved?
- What are rules for rational decisionmaking when there is more than one decisionmaker and more than one objective in a given organization?
- What kind of general models for forecasting strategic environments can be developed?
- How can real-world uncertainty be measured and quantified?
- How can complex organizational preferences be modeled?
- How can mathematical decision theory be applied to investment and budgeting problems in public and private organizations?

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The Decision and Management Sciences program is being established as the result of a systematic review of NSF support for these fields. This review was undertaken by NSF management and program staff in conjunction with representatives from the relevant scientific communities. It revealed significant opportunities for research, including the development of information and analytical methods that will enhance the Nation's economic progress through improved planning and decisionmaking and through more effective designs for operations and procedures. In FY 1981, the program will emphasize pilot studies to test new methods.

Coordination and Relation to Other Efforts

In addition to providing direct support for research in the decision and management sciences, cross-directorate coordination is also maintained with other NSF programs that support research in the operational sciences and industrial engineering. These include related work conducted by the Mathematics and Computer Science Division of the Mathematical and Physical Sciences Directorate; the Engineering and Applied Research Divisions of the Engineering and Applied Sciences Directorate; the Social and Economic Science Division of the Biological, Behavioral and Social Sciences Directorate; and the Divisions of Policy Research and Analysis, International Programs, and Information Science of the Scientific, Technological, and International Affairs Directorate. Coordination is maintained by exchange of program plans, by joint review of proposals, and where appropriate, joint funding. Staff liaison is maintained with other agencies that are especially active in the mission related support of the decisions and management sciences, particularly the Department of Defense and the Department of Energy.

Alan T. Waterman Award $150,000

Actual FY 1979	*Budget Request FY 1980*	*Current Plan FY 1980*	*Estimate FY 1981*	*Difference FY 1981/80*
$150,000	([1])$150,000)	$150,000	$150,000	—0—

[1]Alan T. Waterman award funds were included in other Foundation programs for the FY 1980 Budget Request.

Objectives and Description

The annual Alan T. Waterman Award recognizes an outstanding young scientist in the forefront of science. In addition to a medal and other recognition, the recipient receives a grant of up to $50,000 per year for a period of up to three years for scientific

research or advanced study in the mathematical, physical, medical, biological, engineering, social, or other sciences at the institution of the recipient's choice.

In August 1975, the Congress established the Alan T. Waterman Award to mark the 25th Anniversary of the National Science Foundation and to honor the first Director of the Foundation, Dr. Alan T. Waterman.

Candidates for this award must be United States citizens and must be 35 years of age or younger by December 31 of the year in which nominated. Emphasis is given to a candidate's record of completed scientific or engineering research which has demonstrated an outstanding capability and exceptional promise for making significant achievements in the future. Efforts are made to assure that quality, innovation and potential for discovery are indicators for research performed by recipients of this award.

Significant Recent Achievements

There have been four recipients of the Waterman Award to date: two mathematicians, one paleogeologist and one physicist.

The first recipient, Charles L. Fefferman, received the Award in 1976 for his research in Fourier analysis, partial differential equations and several complex variables which have brought fresh insight and renewed vigor to classical areas of mathematics and contributed significantly to the advancement of modern mathematical analysis.

His outstanding achievements have been recognized by receipt, at the age of 22, of the Salem Prize; and in 1978, at the age of 29, receipt of the Fields Medal, which is awarded only once every four years and is the most sought after international prize among mathematicians. Further, in 1979, the National Academy of Sciences elected Fefferman to membership.

The second recipient, J. William Schopf, received the Award for his outstanding research on Precambrian biotas. His work on these delicate and ancient fossil microorganisms will contribute significantly to the knowledge of the origin of life and the evolution of the earliest known biotas of the world.

Schopf's outstanding research has been recognized by an Award given to him in 1966 by the Botanical Society of America and, in 1968 and 1971, by awards given by the Society of Economic Paleontologists and Mineralogists. He himself feels that his greatest honor was bestowed in the spring of 1978 when he was the first professor in his department to be named by the students as a "distinguished teacher."

The third recipient, Richard A. Muller, received the Award in 1978 for highly original and innovative research, which has led to important discoveries and inventions in diverse areas of physics, including astrophysics, radioisotope dating and optics.

It is believed that Muller's research will have a profound impact on several areas of science and, further, that his research on the measurement of cosmic velocity is one of the most significant achievements.

The fourth recipient, William P. Thurston, received the Award in 1979 in recognition of his achievements in introducing revolutionary new geometrical methods in the theory of foliations, function theory and topology.

His research is considered to have revolutionized his research discipline and to have solved several long-standing geometric problems.

Thurston's previous honors include an Alfred P. Sloan Fellowship and the American Mathematical Society's Oswald Veblen Prize in geometry for his contributions in that field.

NSF Planning and Evaluation Program Element $750,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Planning and Policy Studies	$908,733	$500,000	$825,348	$400,000	$-425,348
Evaluation Studies	63,184	100,000	350,000	350,000	—0—
Total	$971,917	$600,000	$1,175,348	$750,000	$-425,348

Objectives and Description

The objectives of the NSF Planning and Evaluation program element are:

- To provide planning and evaluation mechanisms that will strengthen the Foundation's capability to improve the overall quality of program management and oversight based upon appropriate data; and
- To support policy and program analysis activities that contribute to the Foundation's resolution of major issues regarding alternative methods of achieving scientific and educational research objectives.

Coordination and Relationship to Other Efforts

Information and data from all sections of the Foundation, other Federal agencies, and the academic and industrial research sectors are continually updated to ensure effective and meaningful input to strategic planning and policy issues of concern to the Director and the National Science Board. The program of extramural awards includes special studies by the National Academy of Sciences, industrial research associations, scientific/technical societies, and other Federal and non-Federal organizations. In particular, the Foundation is providing research support for data evaluation through the Standard Reference Data Program of the National Bureau of Standards.

Evaluation activities are coordinated with all NSF Program Activities. Other appropriate Federal agencies are informed of the plans and results of the evaluation activities.

PLANNING AND POLICY STUDIES PROGRAM SUBELEMENT $400,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$908,733	$500,000	$825,348	$400,000	$-425,348

Objectives and Description

The Planning and Policy Studies program subelement supports research and policy analysis designed to strengthen the Foundation's ability to plan for, and to improve the management of, its activities. The program focuses on strategic issues of concern to the Director of NSF and to the National Science Board. The requested funds provide for a program of extramural awards to:

- Provide information and analysis required by the NSF and the National Science Board in assessing problems, evaluating alternatives, establishing priorities, and developing recommendations regarding NSF activities.
- Identify potential problems and opportunities affecting the support of research and science education, and the Foundation's relationships with the scientific and industrial communities.
- Document scientific trends within disciplines and monitor directions in the capabilities of research performers.

Significant Recent Achievements

- The 1980 edition of Status of Science Reviews, more comprehensive than earlier editions, was issued. This publication has become a fundamental reference document for staff of the Foundation, the National Science Board, Executive offices, and Congressional committees.
- A final report was prepared, under contract, concerning "Trends in the Organization of Academic Research: The Role of Organized Research Units and Full-Time Researchers." The report looks at various aspects of the growth of institutes, centers and laboratories outside of regular academic departments, particularly the emergence of long-term career patterns for professional researchers outside the regular tenure-track faculty.
- "Interdisciplinary Research Management-Research Needs and Opportunities" is a status report providing twenty-one specific recommendations on this topic. The report is based to a considerable degree on findings from the several projects earlier supported by NSF's Research Management Improvement Program.
- A Final Staff Report "Regional Forums of the National Science Board" was prepared focusing on the last three forums in the initial series of six. These forums were designed to increase public awareness of issues affecting science and to facilitate public participation to the formulation and development of NSF policies and programs.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

Current funding for this program element in FY 1980 has been increased from $500,000 to $825,348 to provide for research on several specific issues not foreseen when the FY 1980 Budget Request was formulated. These issues include:

- Factors relating to the research capabilities and potential of historically minority academic institutions.
- The feasibility and usefulness of innovative financing mechanisms for supporting research.
- The value, significance, and social utility of basic research in the social sciences.
- Matters affecting the interests of several governmental agencies arising from sponsored basic research in the computer area and cryptology.
- Indicators of the instrumentation needs of the research community, and ways to improve the availability and use of instrumentation.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The decrease for this program subelement of $425,348, from $825,348 in FY 1980 to $400,000 in FY 1981, reflects the fact that the amount of work supported in planning and policy studies may vary from year to year and depends, in part, on short-term needs that cannot always be foreseen. This program supports research and analysis relating to policy issues of interest to decisionmakers and policy planners within, or having cognizance over, the Foundation. The focus is on high quality research that will contribute to the Foundatoin's efforts to properly plan and administer its programs. Frequently, topics supported have broader applicability as well.

Major Topics

Some of the major topics expected to be addressed in FY 1981 include:

- Determination of the effects of inflation on the conduct of research of interest to NSF.
- Development of indicators of the state of and needs for scientific instrumentation, particularly in university research activities.
- Analysis of innovative mechanisms to fund scientific activities.
- Elaboration of various policy aspects of industry-university cooperation.
- Examination of the degree to which emerging research topics can be determined from recent publications.
- Examination of factors influencing international cooperation and cost sharing in large-scale research efforts in both bilateral and multilateral modes.

EVALUATION STUDIES PROGRAM SUBELEMENT $350,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$63,184	$100,000	$350,000	$350,000	—0—

Objectives and Description

The goal of evaluation is to develop credible measures of scientific progress and the contribution or utility of NSF programs to this progress. More specifically, evaluation is concerned with oversight on the products or outputs of all NSF programs. Most of NSF programs are basic research and have as their objective the advancement of scientific knowledge. A principal justification for support of this objective is that knowledge gained will ultimately yield results which can be utilized in practical applications. However, utility in application is clear only after decades, and feedback on what is currently being produced is needed. Feedback consists of information on knowledge added or scientific progress.

The objectives of the Evaluation Studies program subelement are:

- To conduct evaluations of major programs chosen by the NSF Director and to develop data bases and preliminary analyses needed for design and testing of evaluations. These evaluations provide the Director with information on program results, impact, effectiveness, and conformance with legal authority for his use in oversight and subsequent budgeting decisions;
- To coordinate the evaluation activities of other parts of the Foundation; and
- To perform studies, as required, which utilize the data, experience and knowledge acquired in performing evaluations.
- To support efforts to evaluate and increase the reliability of data used by researchers and technologists.

Major Issues

The major research problem is to develop a systematic means for oversight on basic research program results. Since basic research does not typically yield outputs which have immediate technological utility, oversight in the short term will have to be on the scientific quality or merit of the immediate research outputs. However, the system must include a mechanism for assuring that assessments of the ultimate utility of the products or results of currently supported research will be provided. An experiment is currently in progress to assess the product of completed research projects. Basic questions addressed are: How does the quality of NSF supported research products compare with all contemporary research in the appropriate subfields? and, Is the assessment of the quality of the products from a completed project consistent with the award/decline decisions on subsequent proposals? The experiment will yield answers

to these questions for two major programs and information about validity and reliability of the methods used.

Significant Recent Achievements

- An evaluation of the Minority Institutions Science Improvement Program (MISIP) was completed. An important aspect of the study was the acquisition of baseline data.
- The experimental evaluation of completed research projects is nearing completion for one major NSF program (oceanographic science) and has started for another major program (chemistry).

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The Foundation has made $250,000 available in FY 1980 for utilization by the Office of Standard Reference Data, National Bureau of Standards, Department of Commerce, to fund a number of projects in the range of $10,000—$50,000 per year for data compilation and/or evaluation of physical and chemical data. This increases the Evaluation Studies program subelement's Current Plan in FY 1980 to $350,000, up from the FY 1980 Budget Request of $100,000. The products of these projects will be distributed to NSF and the research community.

QUANTITATIVE PROGRAM DATA
EVALUATION STUDIES PROGRAM SUBELEMENT

Proposals and Awards

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Number of Proposals Received	—0—	50	50
Number of Awards[1]	11	23	23
Dollars Proposed (Total)	—0—	$400,000	$400,000
Dollars Proposed (Annual Rate)	—0—	400,000	400,000
Dollars Awarded (Total)	$63,184	$350,000	$350,000
Dollars Awarded (Annual Rate)	63,184	350,000	350,000
Average $ per Award	5,744	15,200	15,200
Average Award Duration (Months)	5	12	12

Percentage Distribution of Funds by Performer

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	—0—	25	25
Industry	60	20	20
Federal Laboratories	—0—	40	40
Other Government Agencies	40	15	15

Personnel and Other Factors

	Estimate FY 1979	Estimate FY 1980	Estimate FY 1981
Senior Scientists, Faculty			
Number of years supported	—0—	—0—	—0—
Amount of faculty support	60	60	60
Postdoctoral Associates			
Number of years supported	—0—	—0—	—0—
Amount of postdoctoral support	—0—	—0—	—0—
Graduate Students			
Number of supported per award-year	—0—	—0—	—0—
Amount of graduate student support	—0—	—0—	—0—
Other Personnel Costs	$14,000	$97,000	$97,000
Land, Buildings, and Fixed Equipment	—0—	—0—	—0—
Major Equipment (more than $200,000)	—0—	—0—	—0—
Other Equipment	—0—	—0—	—0—
Other Costs[2]	41,684	191,000	191,000
Indirect Costs	7,500	62,000	62,000
Total	$63,184	$350,000	$350,000

[1] Includes awarded for supplements, purchase orders and interagency agreements.
[2] Fringe Benefits, expendable equipment travel, publication cost, computer costs, other direct costs.

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PROGRAM DEVELOPMENT AND MANAGEMENT

PROGRAM ACTIVITY SUMMARY

FY 1981 Program Total $60,800,000

Obligations by Subactivity

Page	Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
I-9	Mathematical and Physical Sciences	$4,154,420	$5,242,000	$4,755,000	$4,822,000	$67,000
I-10	Astronomical, Atmospheric, Earth and Ocean Sciences	4,911,017	5,538,000	5,787,000	5,987,000	200,000
I-12	Biological, Behavioral and Social Sciences	3,643,141	4,592,000	4,798,000	4,864,000	66,000
I-13	Science Education Programs	3,543,928	3,825,500	3,820,000	3,820,000	—0—
I-14	Engineering and Applied Science	5,151,927	5,463,500	5,864,000	5,964,000	100,000
I-16	Scientific, Technological and International Affairs	6,396,024	6,497,000	6,718,000	6,761,000	43,000
I-18	Executive Management	6,389,967	7,926,000	7,458,000	7,631,000	173,000
I-20	Central Support Services and Administration	20,575,474	20,516,000	21,363,762	20,951,000	-412,762
	Total	$54,765,898	$59,600,000	[2,3]$60,563,762	$60,800,000	$236,238
	Full Time Permanent Positions[1]	1,260	1,280	[4]1,274	1,293	19

[1] Includes 12 reimbursible positions.
[2] Includes $2,547,762 FY 1979 PDM carryover funds.
[3] Excludes $84,000 transferred to Department of Education.
[4] Excludes 6 positions transferred to Department of Education.

Organization and Objectives

The goal of the Program Development Activity and Management is to achieve the most effective management of the National Science Foundation. Major objectives of this activity are to:

- operate a system of impartial evaluation and selection of proposals to ensure support of research and science education projects on the basis of scientific merit;
- provide a sufficient staff of well-trained and highly qualified scientists, educators, administrators, and support personnel;
- supply support services to provide staff an environment conducive to effective program and management operations;
- ensure proper accountability and oversight of Federal funds through effective management policies, procedures, and techniques;
- maintain an in-house capability for high quality analysis of science and technology policy;

- identify issues and develop long-range plans for effective and responsive NSF programs; and
- obtain oversight by outside experts and in-house staff to ensure vitality and responsiveness of NSF programs.

NSF is organized into six program directorates, an administration directorate, and six staff offices reporting to the Director. Within this structure, the six program directorates operate and manage the major discrete parts of the Foundation's efforts in science research.

Three of the directorates, each composed of related groups of scientific disciplines, strongly represent basic research programs in the top management level. These directorates are Mathematical and Physical Sciences; Astronomical, Atmospheric, Earth, and Ocean Sciences; and Biological, Behavioral, and Social Sciences.

The other directorates manage research in applied science and engineering; science education; and a consolidation of international science programs, science information activities, science resources studies, and science policy analysis. These directorates are Engineering and Applied Science, Science Education, and Scientific, Technological, and International Affairs.

The staff offices reporting to the Director are Planning and Resources Management, Equal Employment Opportunity, Government and Public Programs, General Counsel, Small Business Research and Development, and Audit and Oversight.

In addition to managing and operating science research programs through grants and contracts, the NSF staff conducts in-house efforts related to:

- studies of science resources, including scientific manpower;
- evaluation of science policy issues and alternatives in support of the National Science Board and the Office of Science and Technology Policy;
- coordination of national and international scientific activities;
- planning and management of a complex logistic support for the U.S. Antarctic Research Program;
- planning and managing the expanded ocean drilling programs; and
- a science liaison staff maintained at Tokyo, Japan, to assist coordination of science programs involving Far Eastern countries.

Significant Recent Achievements

- Directorate for Engineering and Applied Science—Effective July 1, 1979, the Engineering Division of the Mathematical, and Physical and Engineering Directorate and the Applied Science Divisions of the Applied Science and Research Applications Directorate were merged, forming the new Directorate for Engineering and Applied Science. This merger was designed to:

- strengthen NSF's engineering programs by giving engineering a single, more visible place in the organization;
- enhance NSF's programs of applied and problem-focused research by providing a broader base of science and engineering to build upon; and
- recognize the key role of engineering in the transfer of science into technology and the importance of engineering in NSF's industry-related and problem-oriented research programs.

- Cross-Directorate Programs Activity—In recent years, several programs have been mandated by the Congress or have been developed by NSF in response to specific scientific needs. For the most part, these initiatives did not fit comfortably within the programs of a single directorate or they required special management and administration.

  Under a new Cross-Directorate Programs Activity, these programs are set forth separately in NSF's budget. Among these programs are the US/USSR Cooperative Research Program, the Two and Four-Year College Science Instrumentation Program, the Experimental Program to Stimulate Competitive Research and the University Research Facilities Improvement Program.

  The Cross-Directorate Programs Activity not only identifies these special programs; it also assists NSF to establish budgetary requirements and measure accomplishments. Under current planning, management of the cross-directorate programs is to be continued within NSF's existing organizational structure.

- Master Grant—An experiment in simplified research grant administration was begun in January, 1979, with the chemistry department of the University of Florida. Since then, the chemistry departments of eight other universities have joined the experiment. The institutions are the University of California at Los Angeles, the University of California at San Diego, California Institute of technology, the University of Wisconsin at Madison, the Massachusetts Institute of Technology, Columbia University, the State University of New York at Stony Brook, and the University of Illinois at Urbana.

  The experiment employs a concept known as the master grant; i.e., NSF treats research projects approved not as individual grants to the institution but as sub-elements of a single grant. Such grouping of projects permits a substantial simplification of recordkeeping and a sharing of resources.

  NSF also is placing increased emphasis upon the use of continuing grants and multiple-year awards to reduce the numbers of proposals, peer reviews, and NSF processing and grants awarded. In this connection, NSF now automates most of the more than 11,000 award letters, about 11,000 declination letters, and 35,000 letters soliciting ad hoc proposal reviews or selecting reviewers each year. The automated production results in sizable savings of clerical staff time.

- Senior Executive Service—Title IV of the Civil Service Reform Act established the Senior Executive Service, a separate personnel system for senior executives and managers in the Federal government. The SES was designed primarily to

provide greater flexibility among the senior staff and thereby to assist the achievement of program and agency goals.

NSF has established its Senior Executive Service cadre based on an allocation of 129 positions approved by the Office of Personnel Management. The SES Performance Appraisal System in NSF has also been established and is now being implemented.

- Staffing Study—An agency staffing study, completed during the early fall of 1979, was used to determine staffing requirement for the FY 1981 budget. Procedures and data were developed to estimate the personnel requirements for proposal workload and sizes of program budgets in each directorate. The study also assists managers in achieving the following objectives:
  - — Improving the ability to compare the distribution of workloads within the Foundation;
  - — Improving the integration of PD&M budget requests with program requirements;
  - — Improving the ability to estimate changes in workloads from trends noted in the inputs of each directorate; and
  - — Establishing analytical models for future staff planning.

NATIONAL SCIENCE FOUNDATION
Analysis of Appropriation Limitations for Program Development and Management

Fiscal Year Appropriated	PD & M Limitation	Fiscal year in which limitation is obligated		
		Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Prior Years Recoveries and Available Balances	$3,138,660	$3,138,660	—0—	—0—
FY 1979:				
P.L. 95-392	54,800,000	52,252,238	2,547,762	—0—
(Reallocated to U.S. Antarctic Program for military payraise)		(625,000)		
FY 1980:				
P.L. 96-103	58,100,000	—0—	58,100,000	—0—
(Transferred to the Department of Education)			(84,000)	
FY 1981 Estimate:				
Annual Appropriation	60,800,000	—0—	—0—	60,800,000
Total Obligated		54,765,898	$60,563,762	$60,800,000

Changes Between the FY 1980 Budget Request and the FY 1980 Current Plan

The current plan for FY 1980 provides a total of $60,563,762 for the Foundation's program development and management expenses. This level of funding will allow NSF to operate with a staffing plan of 1,274 full-time positions. The average salary will be about $30,250.

The FY 1980 plan includes $58,100,000 appropriated in FY 1980 and $2,547,762 carryover balance from FY 1979. It excludes $84,000 to be transferred during FY 1980 to the new Department of Education for the part year salaries of 6 positions transferred. Of the FY 1979 carryovers, $2,500,000 resulted from the House Appropriations Subcommittee recommendation that the FY 1980 costs of the October 1979 Federal pay increase be at least partially absorbed by the Foundation in lieu of proposing a supplemental appropriation request for the purpose. It is estimated that the total cost will be approximately $2,700,000.

Other significant changes in the FY 1980 plan, compared to the FY 1980 budget request, include:

- An increase of $397,000 resulting from provisions of the Civil Service Reform Act establishing the Senior Executive Service.
- An increase of $225,000 for additional part-time employment, in response to P.L. 95-437, the Federal Employees Part-time Career Employment Act of 1978.
- An increase of $200,000 for additional shared costs of the overseas office personnel and services provided by the Department of State to NSF employees assigned overseas or traveling abroad on official business. This increase reults from a change in billing procedure by the Department of State and the declining value of the dollars to foreign currencies.

- An increase of $90,000 for supplies $50,000 for printing and $40,000 for miscellaneous office equipment due to price increases.
- Offsetting these increases are:
  - — a decrease of $286,000 in travel of persons and transportation of things as required by P.L. 96-86 and administration guidelines requiring agencies to reduce their estimates of the two categories by 8%.
- A decrease of $685,000 in rents and communications, primarily related to equipment rentals and communications, and
- Decreases of $400,000 in equipment procurement primarily related to office automation.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The FY 1981 estimate of $60,800,000 for Program Development and Management is an increase of $236,238 over the estimate for FY 1980.

A total staff of 1,293 positions is planned for FY 1981, an increase of 19 positions. Six of the new positions were identified for support of basic and applied research efforts by the NSF staffing study completed in the fall of 1979. Eight are needed in connection with the expanded program of ocean drilling. Of the remaining five positions, three are allocated to the expanded program for research facilities, one to the small business research program, and one for the Five-Year Outlook in Science report authorized by the Science and Technology Policy Act of 1976.

FY 1981 increases and decreases are:

- An increase of $456,000 for permanent personnel compensation for salary costs of the additional 19 positions. This initial funding is approximately two-thirds of the annual cost of these positions and the balance will be annualized in FY 1982;
- An increase of $25,000 for consultant compensation to fund about 250 more consultant days performed by outside experts to provide oversight and advice concerning NSF programs;
- An additional $63,000 for personnel benefits as the employer's contributions to retirement and insurance for the additional 19 positions and for increased costs of benefit payments for the existing staff.
- A total increase of $146,000 is provided for travel. This item covers additional site visits for monitoring and oversight of program awards by existing staff, and 19 new employees, advisory committees, and consultants for new programs.
- An increase of $50,000 for transportation of things for household moves of new employees.

- A net decrease of $235,000 in rents and communications, resulting from an increase of $200,000 in space rental rates assessed to NSF by the General Services Administration and a decrease of $435,000 in rental costs for data processing equipment previously leased but now purchased.
- An increase of $50,000 for printing and reproduction due to increased costs of paper, printing supplies, and printing by the Government Printing Office and private contractors.
- A decrease of $108,762 in administrative services contracts previously budgeted for software development.
- A net decrease of $210,000 resulting from reduced purchases of special purpose equipment and computer hardware.

PROGRAM DEVELOPMENT AND MANAGEMENT
Summary of Obligations by Object

Object	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Full-time Permanent Positions[1]	1,260	1,280	[2]1,274	1,293	19
Average Salary	$28,070	$27,500	$30,250	$30,300	$50
Personnel Compensation:					
Full-time Permanent Staff	$33,255,107	$35,160,000	$37,413,000	$37,869,000	$456,000
Other than Full-time Staff	504,513	650,000	765,000	765,000	—0—
Other Personnel Compensation	502,946	650,000	872,000	872,000	—0—
NSB, Advisory Committees & Consultants	442,864	850,000	550,000	575,000	25,000
Subtotal, Personnel Compensation	34,705,430	37,310,000	39,600,000	40,081,000	481,000
Personnel Benefits:					
Employer Contribution to Retirement, Life & Health Insurance, FICA, etc.	2,975,302	3,435,000	3,424,000	3,469,000	45,000
Other Personnel Benefit Payments	79,550	125,000	70,000	88,000	18,000
Subtotal, Personnel Benefits	3,054,852	3,560,000	3,494,000	3,557,000	-63,000
Subtotal, Personnel Compensation and Benefits	37,760,282	40,870,000	43,094,000	43,638,000	544,000
Travel:					
Staff Travel	1,731,278	2,055,000	1,902,000	1,960,000	58,000
NSB, Advisory Committees & Consultants	778,132	1,095,000	1,035,000	1,120,000	85,000
Other Travel Expenses	46,286	85,000	62,000	65,000	3,000
Subtotal, Travel	2,555,696	3,235,000	2,999,000	3,145,000	146,000
Transportation of Things	207,159	300,000	250,000	300,000	50,000
Rental & Communications:					
Office Space Rental	3,280,508	3,400,000	3,360,000	3,560,000	200,000
Data Processing & Office Automation Equipment Rentals	1,422,388	1,260,000	1,075,000	640,000	-435,000
Other Rentals	351,807	575,000	400,000	400,000	—0—
Telephone, Telegraph, Cable & Postage	1,956,479	2,350,000	2,065,000	2,065,000	—0—
Subtotal, Rental & Communications	7,011,182	7,585,000	6,900,000	6,665,000	-235,000
Printing & Reproduction	430,334	500,000	550,000	600,000	50,000
Other Contractual Services:					
Administrative Contracts	1,425,165	1,625,000	1,450,000	1,450,000	—0—
Audit Services	756,361	940,000	850,000	850,000	—0—
Data Processing Contracts	1,170,689	1,600,000	1,755,762	1,647,000	-108,762
Operations & Maintenance	(620,689)	(688,000)	(875,000)	(875,000)	(—0—)
Software Development	(550,000)	(912,000)	(880,762)	(772,000)	(-108,762)
Employee Training	314,748	350,000	430,000	430,000	—0—
Subtotal, Other Contractual Services	3,666,963	4,515,000	4,485,762	4,377,000	-108,762
Supplies & Materials:					
Office Supplies, Printing Supplies, etc.	541,612	500,000	600,000	600,000	—0—
Data Processing Supplies	109,952	120,000	110,000	110,000	—0—
Subtotal, Supplies & Materials	651,564	620,000	710,000	710,000	—0—
Equipment:					
Office, Furniture & Special Purpose Equipment	630,585	550,000	585,000	510,000	-75,000
Data Processing Equipment:					
Computer Hardware	1,103,545	700,000	700,000	565,000	-135,000
Office Automation Equipment	743,884	700,000	265,000	265,000	—0—
Subtotal, Equipment	2,478,014	1,950,000	1,550,000	1,340,000	-210,000
Grants, Subsidies & Contributions:					
Award Recipients Expenses	4,704	25,000	25,000	25,000	—0—
TOTAL	$54,765,898	$59,600,000	[2,4]$60,563,762	$60,800,000	$236,238

[1]Includes 12 reimbursable positions.
[2]Includes $2,547,762 in FY 1979 carryover funds for PD&M.
[3]Excludes 8 positions transferred to the Department of Education.
[4]Excludes $84,000 transferred to the Department of Education.

Mathematical and Physical Sciences $4,822,000

Summary of Obligations by Object

Object	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Full-Time Permanent Positions	116	118	119	120	1
Personnel Compensation and Benefits:					
Full-Time Permanent Positions	$3,358,766	$4,054,000	$3,815,000	$3,840,000	$25,000
Other Than Full-Time Staff	16,945	27,000	25,000	25,000	—0—
Other Personnel Compensation	107,255	89,000	120,000	120,000	—0—
Advisory Committees and Consultants	26,928	80,000	40,000	45,000	5,000
Benefits	292,758	408,000	350,000	352,000	2,000
Travel:					
Staff Travel	260,851	306,000	285,000	300,000	15,000
Advisory Committees and Consultants	90,817	122,000	120,000	140,000	20,000
Office Automation Equipment	—0—	158,000	—0—	—0—	—0—
Total	$4,154,420	$5,242,000	$4,755,000	$4,822,000	$67,000

Functional Subactivity Description and Objectives

This functional subactivity is organized on a disciplinary basis and in addition to the Office of the Assistant Director for Mathematical and Physical Sciences consists of the following divisions:

- Division of Mathematical and Computer Sciences
- Division of Physics
- Division of Chemistry
- Division of Materials Research

The Division of Mathematical and Computer Sciences provides support for these two scientific disciplines, including providing Federal leadership in exploring and developing the uses of computers in research.

The Division of Physics is responsible for carrying out a major portion of the Foundation's program for support of basic research in physics which has the objective of increasing knowledge and understanding of the basic properties of the fundamental forces and elementary constituents of matter.

The Division of Chemistry provides support for research in chemistry which promotes the understanding of the structures, properties and chemical transformation of matter.

Support of fundamental studies in the optical, electrical, magnetic, structural, thermal and chemical properties of materials is provided through the Division of Materials Research. The objective of such studies is to increase our basic knowlege of materials and to utilize this knowledge in contributing to the solution of national problems.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The cost of permanent positions is increased by $27,000 for part salary costs and benefits of an additional associate program manager in the field of mathematics, a position identified by the NSF staffing study during 1979. Staff travel is increased by $15,000 to provide additional site visits for monitoring and oversight of program awards. An additional $25,000 is provided for the increased costs of compensating advisory committees and consultants and their related travel.

Astonomical, Atmospheric, Earth and Ocean Sciences $5,987,000

Summary of Obligations by Object

Object	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Full-Time Permanent Positions	148	151	150	156	6
Personnel Compensation and Benefits:					
Full-Time Permanent Positions	$4,020,542	$4,430,000	$4,675,000	$4,820,000	$145,000
Other Than Full-Time Staff	10,809	35,000	15,000	15,000	—0—
Other Personnel Compensation	48,249	40,000	102,000	102,000	—0—
Advisory Committees and Consultants	31,642	55,000	45,000	50,000	5,000
Benefits	351,113	434,000	430,000	445,000	15,000
Travel:					
Staff Travel	327,276	375,000	365,000	380,000	15,000
Advisory Committees and Consultants	121,386	95,000	155,000	175,000	20,000
Office Automation Equipment	—0—	74,000	—0—	—0—	—0—
Total	$4,911,017	$5,538,000	$5,787,000	$5,987,000	$200,000

Functional Subactivity Description and Objectives

The organizational structure of the Astronomical, Atmospheric, Earth and Ocean Sciences functional subactivity consists, in addition to the Office of the Assistant Director, of the following components:

- Division of Astronomical Sciences
- Division of Atmospheric Sciences
- Division of Earth Sciences
- Division of Ocean Sciences
- Division of Polar Programs
- Division of Ocean Drilling Programs

The Foundation's support of research in optical and radio astronomy is accomplished through the Division of Astronomical Sciences. This support includes grants to individual astronomers and the funding for five national centers for astronomical

research. The objective of this research is to increase the understanding of the physical nature of the universe, the structure and behavior of stars, objects and phenomena observed in deep space, and the makeup of the interstellar medium.

The Division of Atmospheric Sciences supports research across the entire range of atmospheric phenomena. Included in the Division are the Climate Dynamics Program, Atmospheric Sciences Project Support, the Global Atmospheric Research Program, and the National Center for Atmospheric Research.

The Division of Earth Sciences supports basic research in geology, geophysics, and geochemistry with the objective of providing knowledge of the structure and composition of the rocks that comprise the earth's crust and the processes that form and modify them.

The Division of Ocean Sciences supports research in oceanography, the evolution of ocean basins, and marine life. Support is also provided for the construction and operation of research ships and shore facilities essential to the conduct of marine research. The Division is responsible for the planning, management, and support of U.S. participation in the International Decade of Ocean Exploration.

The Division of Polar Programs has lead agency responsibilities for the U.S. Antarctic Program and the Arctic Research Program. For the USAP, DPP manages the entire U.S. program with the Departments of Defense and Transportation providing operational support on a cost reimbursable basis. In the Arctic, NSF is one of the major agency supporters of basic research.

The Division of Ocean Drilling Programs includes two subactivities: the Deep Sea Drilling Project (DSDP) and the Ocean Margin Drilling Project (OMDP). NSF has overall management responsibility for these programs.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Funding for personnel compensation is increased by $160,000 to cover the part-year salary costs and benefits six additional positions in the new Division of Ocean Drilling Programs. These positions are a division director, a chief scientist, an ocean drilling section manager, an ocean drilling engineer, and support staff. Staff travel for this new program will require $15,000. Consultant compensation and associated travel will require a total of $25,000.

Biological, Behavioral and Social Sciences $4,864,000

Summary of Obligations by Object

Object	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Full-Time Permanent Positions	114	119	120	122	2
Personnel Compensation and Benefits:					
Full-Time Permanent Positions	$2,776,801	$3,375,000	$3,630,000	$3,690,000	$60,000
Other Than Full-Time Staff	86,207	95,000	159,000	159,000	—0—
Other Personnel Compensation	36,730	35,000	74,000	74,000	—0—
Advisory Committees and Consultants	102,983	130,000	130,000	130,000	—0—
Benefits	250,841	325,000	330,000	336,000	6,000
Travel:					
Staff Travel	165,780	250,000	185,000	185,000	—0—
Advisory Committees and Consultants	223,799	240,000	290,000	290,000	—0—
Office Automation Equipment	—0—	142,000	—0—	—0—	—0—
Total	$3,643,141	$4,592,000	$4,798,000	$4,864,000	$66,000

Functional Subactivity Description and Objectives

The Biological, Behavioral and Social Sciences functional subactivity consists, in addition to the Office of the Assistant Director, of the following divisions:

- Division of Physiology, Cellular and Molecular Biology
- Division of Behavioral and Neural Sciences
- Division of Environmental Biology
- Division of Social and Economic Sciences

The Division of Physiology, Cellular and Molecular Biology supports research to understand the molecular basis of cellular structure and the physiochemical basis of biological functions in cells, organ systems, and whole organisms.

The Division of Behavioral and Neural Sciences supports research to advance the understanding of the behavior of humans and lower animals and the biological, psychological, and cultural factors that underlie behavior.

The Division of Environmental Biology supports research to understand the ecological interrelationships in terrestrial and freshwater ecosystems and the evolutionary relationships among the several million species of plants, animals, and microorganisms.

The Division of Social and Economic Sciences supports research to advance understanding of the processes underlying the structure and operation of social institutions and to elucidate the principles underlying their stability and change.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Personnel compensation and benefits are increased by a total of $66,000 to fund two additional program directors, one each in population biology and in cellular biology. Both positions were identified by the NSF staffing study.

Science Education Programs $3,820,000

Summary of Obligations by Object

Object	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Full-Time Permanent Positions	110	112	[1]106	106	—0—
Personnel Compensation and Benefits:					
Full-Time Permanent Positions	$2,926,449	$3,060,000	$3,145,000	$3,145,000	—0—
Other Than Full-Time Staff	39,987	55,000	76,000	76,000	—0—
Other Personnel Compensation	43,200	35,000	67,000	67,000	—0—
Advisory Committees and Consultants	20,593	45,000	30,000	30,000	—0—
Benefits	263,088	293,500	290,000	290,000	—0—
Travel:					
Staff Travel	131,463	135,000	142,000	142,000	—0—
Advisory Committees and Consultants	56,360	95,000	70,000	70,000	—0—
Administrative Contracts	62,788	—0—	—0—	—0—	—0—
Office Automation Equipment	—0—	107,000	—0—	—0—	—0—
Total	$3,543,928	$3,825,500	$3,820,000	$3,820,000	—0—

[1] Excludes 6 positions transferred to the Department of Education.

Functional Subactivity Description and Objectives

The Science Education Program functional subactivity is composed of the Office of the Assistant Director for Science Education and the following units: Division of Scientific Personnel Improvement, Division of Science Education Resources Improvement, Division of Science Education Development and Research, Office of Science and Society, and Office of Program Integration.

The overall objective of the functional subactivity is to initiate and support programs which will strengthen science education programs at all levels, assure high standards and quality in the training of all students and professionals in the sciences, and raise the general level of science literacy in the Nation.

The Division of Scientific Personnel Improvement is responsible for fellowships and traineeships, programs to provide experience in independent study and research, programs to assist the professional development of science faculty, and a program to encourage greater participation in the sciences by minorities, women and the handicapped.

The Division of Science Education Resources Improvement is responsible for the improvement of pre-college instruction and programs to improve the science education capabilities of 2-year and 4-year institutions of higher education, including those institutions providing undergraduate and graduate training in the sciences for minority students.

The Division of Science Education Development and Research is responsible for programs to advance our knowledge of how scientific concepts, processes and skills are learned and to encourage the development of materials and instructional techniques by which the quality, relevance and efficacy of the learning processes in science can be improved.

The Office of Science and Society is responsible for programs to improve the

public understanding of science, including how science works and what are its uses and limitations. The program also provides citizens with access to scientific information related to important public issues, which includes ethics and values in science and technology.

The Office of Program Integration provides support services to the Assistant Director for Science Education. These services include integrating and comparing programs across divisions, including program evaluation and needs assessment in science education.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Funding for program development and management in Science Education is held level for FY 1981, partly as a result of the transfer of six positions and $84,000 to the new Department of Education during FY 1980.

Engineering and Applied Science $5,964,000

Summary of Obligations by Object

Object	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Full-Time Permanent Positions	149	155	150	152	2
Personnel Compensation and Benefits:					
Full-Time Permanent Positions	$4,193,469	$4,241,000	$4,715,000	$4,770,000	$55,000
Other Than Full-Time Staff	61,616	68,000	83,000	83,000	—0—
Other Personnel Compensation	25,045	51,000	76,000	76,000	—0—
Advisory Committees and Consultants	42,418	75,000	60,000	65,000	5,000
Benefits	363,897	407,500	430,000	435,000	5,000
Travel:					
Staff Travel	386,173	394,000	400,000	415,000	15,000
Advisory Committees and Consultants	79,309	128,000	100,000	120,000	20,000
Office Automation Equipment	—0—	99,000	—0—	—0—	—0—
Total	$5,151,927	$5,463,500	$5,864,000	$5,964,000	$100,000

Functional Subactivity Description and Objectives

The Foundation's program of Engineering and Applied Science seeks to strengthen the research base of U.S. engineering and applied science and to enhance the links between research and applications for greater contributions to the understanding and resolution of significant societal problems.

In addition to the Office of the Assistant Director for Engineering and Applied Science, the activity is organized into six divisions:

- The Division of Electrical, Computer, and Systems Engineering provides support for basic research in the three related disciplines of electrical, computer, and systems engineering.

- The Division of Chemical and Process Engineering sponsors basic research relevant to the entire range of chemical, petrochemical, biochemical, food, mineral, and other process industries.
- The Division of Civil and Mechanical Engineering supports a broad array of research efforts involving mechanical and thermal phenomena important to engineering applications.
- The Division of Applied Research considers unsolicited, applied research proposals growing out of basic discoveries in various fields of science and engineering with high potential for technical application or for use in public policy.
- The Division of Problem-Focused Research concentrates upon selected problems of society where science and technology can make significant contributions to timely, practical solutions.
- The Division of Intergovernmental Science and Public Technology supports efforts to increase the capability of state and local governments to use science and technology in public policy, tests incentives to increase R&D investment in the private sector, conducts experiments to increase the ability of scientists in selected states to compete successfully for Federal research funds, and supports research in appropriate technologies. Foundation efforts to increase the participation of small business in research and applied science are primarily directed in this division.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Personnel compensation funding is increased by $60,000 to cover the part-year salary and benefits of two additional program directors, one in the small business innovative research program, the other in separation process engineering. The latter position was identified by the NSF staffing study. Staff travel is increased by $15,000 to provide additional site visits for monitoring and oversight of program awards by the existing and new staff. An additional $25,000 is provided for the increased costs of advisory committees and consultants.

Scientific, Technological and International Affairs $6,761,000

Summary of Obligations by Object

Object	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Full-Time Permanent Positions	182	183	182	183	1
Personnel Compensation and Benefits:					
Full-Time Permanent Positions	$5,237,679	$5,130,000	$5,350,000	$5,380,000	$30,000
Other Than Full-Time Staff	49,222	65,000	94,000	94,000	—0—
Other Personnel Compensation	29,756	115,000	108,000	108,000	—0—
Advisory Committees and Consultants	33,538	60,000	45,000	45,000	—0—
Benefits	532,655	596,000	550,000	563,000	13,000
Travel:					
Staff Travel	228,011	310,000	250,000	250,000	—0—
Advisory Committees and Consultants	41,863	75,000	55,000	55,000	—0—
Transportation of things	11,500	20,000	10,000	10,000	—0—
Administrative Contracts	226,090	50,000	250,000	250,000	—0—
Supplies and Materials	5,700	5,000	6,000	6,000	—0—
Office Automation Equipment	—0—	71,000	—0—	—0—	—0—
Total	$6,396,024	$6,497,000	$6,718,000	$6,761,000	$43,000

[1]Includes 11 reimbursable positions.

Functional Subactivity Description and Objectives

This functional subactivity is composed of the Office of the Assistant Director for Scientific, Technological and International Affairs and the following components:

- Division of International Programs
- Division of Policy Research and Analysis
- Division of Science Resources Studies
- Division of Information Science and Technology

The Division of International Programs funds and manages international cooperative research and exchange of scientists and NSF participation in Joint Commissions for Scientific and Technical Cooperation; and sponsors U.S. participation in nongovernmental international scientific organizations. The Division also manages the Foundation's Special Foreign Currency program which uses U.S. owned excess currencies in certain countries to carry out research and related activities, including the translation of foreign scientific literature into English. The objectives are to strengthen U.S. science by acquiring scientific information abroad, foster close working relationships between U.S. and foreign scientists and thereby share facilities and costs. These programs also support U.S. foreign policy objectives related to science and technology. The Division maintains liaision with the Department of State, other Federal agencies, and the National Academy of Sciences on matters affecting the Foundation's international programs. It promotes and supports effective U.S. scientific representation in international organizations and at international scientific conferences and provides advice and guidance to units of the Foundation on international scientific matters.

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The Division of Policy Research and Analysis carries out and supports science and technology policy research and analysis. The Division provides policy research and assessment for existing and emerging science and technology issues and is the Foundation's focal point for investigating and analyzing the effects of Federal policy options on R&D, technological developments, and the costs and benefits from such activities. Also, the Division helps support the analytical needs of various groups within the Executive Office of the President such as the Office of Science and Technology Policy and the Office of Management and Budget.

The Division of Science Resources Studies is responsible for collecting and interpretating data on national resources in science and technology. In carrying out this responsibility the Division collects, analyzes and publishes statistical data obtained directly from surveys conducted by the Division or by other Federal agencies. The subjects covered by these surveys include research and development in industry, universities, and nonprofit institutions, and other science and technology indicators.

The Division of Information Science and Technology funds basic and applied research proposals to advance the understanding of the properties and structure of information and how it is organized, transferred, and used.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Funding for personnel compensation is increased by $33,000 for the part year salary costs and benefits of an additional policy analyst who will have responsibility for preparation of the Five-Year Outlook on Science report prepared for the Office of Science and Technology Policy. This position was identified by the NSF staffing study. An additional $10,000 is included for benefits to NSF employees stationed at Tokyo due to higher cost of living in Japan.

Executive Management $7,631,000

Summary of Obligations by Object

Object	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Full-Time Permanent Positions	135	135	141	146	5
Personnel Compensation and Benefits:					
Full-Time Permanent Positions	$4,136,936	$4,400,000	$4,683,000	$4,794,000	$111,000
Other Than Full-Time Staff	62,197	130,000	98,000	98,000	—0—
Other Personnel Compensation	43,069	65,000	111,000	111,000	—0—
NSB, Advisory Committees and Consultants	184,312	400,000	195,000	205,000	10,000
Benefits	371,998	437,000	429,000	440,000	11,000
Travel:					
Staff Travel	144,811	210,000	185,000	198,000	13,000
NSB, Advisory Committees and Consultants	163,978	335,000	245,000	270,000	25,000
Other Travel Expenses	4,719	20,000	12,000	15,000	3,000
Telegraph and Cable	35,000	40,000	35,000	35,000	—0—
Administrative Contracts	481,882	875,000	590,000	590,000	—0—
Audit Service	756,361	940,000	850,000	850,000	—0—
Award Recipients Expenses	4,704	25,000	25,000	25,000	—0—
Office Automation Equipment	—0—	49,000	—0—	—0—	—0—
Total	$6,389,967	$7,926,000	$7,458,000	$7,631,000	$173,000

Functional Subactivity Description and Objectives

Policy direction, top management of the NSF and support for the Director are included in this functional area. In addition to the Office of the Director and the National Science Board, Executive Management consists of the following NSF offices:

- Office of the General Counsel
- Office of Governmental and Public Programs
- Office of Planning and Resources Management
- Office of Equal Employment Opportunity
- Office of Small Business Research and Development
- Office of Audit and Oversight

The National Science Board, which consists of 24 leading scientists and educators, appointed by the President, and the Director of NSF, develops the broad policy guidelines under which Foundation activities are carried out within the framework of the National Science Foundation Act. Public members of the Board are compensated for their attendance at meetings of the NSB and its committees and for travel costs incurred in carrying out their responsibilities. Duties of the NSB are specified in the National Science Foundation Act.

The Director is the chief executive officer of the Foundation and is responsible for the execution of the Foundation's program in accordance with the National Science Foundation Act and the broad policy guidelines of the Board.

The Office of the General Counsel provides legal advice and counsel to the Board, the Director, and the staff on all aspects of the agency's operation.

The Office of Government and Public Programs advises and assists the Director and coordinates the Foundation's liaison with Congress, as well as with professional societies and other nongovernmental organizations; informs the public of NSF activities through the general and specialized media, both printed and electronic; and edits or prepares official publications of NSF.

The Office of Planning and Resources Management provides for planning, policy, and program analysis on a Foundation-wide basis with special emphasis on coordination and information exchange of activities that cut across directorates or which involve major Foundation policies. Development of the Foundation budget, its justification to the Office of Management and Budget and to the Congress and implementation of financial operating plans consistent with authorization and appropriation legislation are major functions of this Office. The Office includes the Foundation's program review capability which assists with periodic reviews of agency programs by NSF management, program administrators and to the National Science Board.

The Office of Equal Employment Opportunity administers the NSF Equal Employment Opportunity Program, including the Federal Women's Program and Opportunities for Spanish Speaking People and also serves as the principal advisor to the Director on equal employment opportunity matters.

The Office of Small Business Research and Development, assists the Director in fostering communications between NSF and the small business community related to research and development. The Office assists individual small businesses in obtaining information on programs, policies and procedures of NSF, as well as other possible sources of support and information outside NSF, and recommends changes in NSF procedures so as to draw more fully on resources of the small business community. The Office collects, analyzes, compiles, and publishes information on grants and contracts awarded to small businesses and submits quarterly reports to Congress on NSF small business activities. The Office represents the NSF on the Interagency Committee on Women's Business Enterprise.

The Office of Audit and Oversight has responsibility for: sampling proposal actions and post-award administration to evaluate documentation and adherence to stated procedures; assessing overall system performance and recommending improved and simplified procedures; investigating charges of improper actions by NSF staff and monitoring the decision reconsideration system; performing financial audits, monitoring and coordinating procedures for scientific oversight undertaken by disciplinary panels; and performing evaluation and program audit. The Office reports directly to the Director.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

An increase of $122,000 will fund the part-year salary costs and benefits of five additional positions for the expanded industry/university cooperative research pro-

gram, and the new program of instrumentation and research facilities, Staff travel is increased by $13,000 to fund higher costs and travel by new employees. The National Science Board, advisory committees, and consultants are increased $35,000 to cover higher costs of operation. Funding for the costs associated with the presentation of the National Medal of Science is increased by $3,000.

Central Support Services and Administration $20,951,000

Summary of Obligations by Object

Object	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Administration:					
Full-Time Permanent Positions[1]	308	307	306	308	2
Personnel Compensation and Benefits:					
Full-Time Permanent Positions	$6,604,465	$6,470,000	$7,400,000	$7,430,000	$30,000
Other Than Full-Time Staff	177,530	175,000	215,000	215,000	—0—
Other Personnel Compensation	169,532	220,000	214,000	214,000	—0—
Advisory Committees and Consultants	450	5,000	5,000	5,000	—0—
Benefits	628,502	661,000	685,000	696,000	11,000
Travel:					
Staff Travel	86,913	75,000	90,000	90,000	—0—
Advisory Committees and Consultants	620	5,000	—0—	—0—	—0—
Administration, Subtotal	$7,668,012	$7,611,000	$8,609,000	$8,650,000	$41,000
Central Support Services:					
Other Travel Expenses	41,567	65,000	50,000	50,000	—0—
Transportation of Things	195,659	280,000	240,000	290,000	50,000
Office Space Rental	3,280,508	3,400,000	3,360,000	3,560,000	200,000
Data Processing and Office Automation Equipment Rentals	1,422,388	1,260,000	1,075,000	640,000	-435,000
Other Rentals	351,807	575,000	400,000	400,000	—0—
Telephone, Telegraph, Cable and Postage	1,921,479	2,310,000	2,030,000	2,030,000	—0—
Printing and Reproduction	430,334	500,000	550,000	600,000	50,000
Administrative Contracts	654,405	700,000	610,000	610,000	—0—
Data Processing Contracts	1,170,689	1,600,000	1,755,762	1,647,000	-108,762
Operations and Maintenance	(620,689)	(688,000)	(875,000)	(875,000)	(—0—)
Software Development	(550,000)	(912,000)	(880,762)	(772,000)	(-108,762
Employee Training	314,748	350,000	430,000	430,000	—0—
Supplies and Materials:					
Office Supplies, Printing Supplies, etc.	535,912	495,000	594,000	594,000	—0—
Data Processing Supplies	109,952	120,000	110,000	110,000	—0—
Equipment:					
Office, Furniture & Special Purpose Equipment	630,585	550,000	585,000	510,000	-75,000
Data Processing Equipment: Computer Hardware and Office Automation	1,847,429	700,000	965,000	830,000	-135,000
Central Support Services, Subtotal	$12,907,462	$12,905,000	$12,754,762	$12,301,000	$-453,762
Total	$20,575,474	$20,516,000	$21,363,762	$20,951,000	$-412,762

[1] Includes one reimbursable position.

Functional Subactivity Description and Objectives

The Assistant Director for Administration manages the Central Support Services and Administration area which encompasses those agency-wide administrative and

support services best provided on a centralized basis and those costs which cannot be directly associated with the operation of any one Directorate.

The Administration area includes salaries and travel costs associated with the development, coordination and accomplishment of agency-wide administrative, personnel, accounting, contracting, and data processing activities. There are five staff units reporting to the Assistant Director for Administration. The Division of Financial and Administrative Management is responsible for logistics and housekeeping for the NSF and for accounting services. Employee oriented functions are assigned to the Division of Personnel and Management and Health Services Unit. The Division of Personnel and Management also provides management services. The Division of Grants and Contracts is responsible for reviewing and approving the business aspects of all proposed grants and contracts and for receiving and follow-up on final grant fiscal and technical reports. Both the Division of Grants and Contracts and the Division of Financial and Administrative Management work closely with the business offices of universities and institutions performing the research supported by NSF. Data processing support is provided by the Division of Information Systems.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

An increase of $41,000 is provided for part year salaries and benefits of two additional positions in the Division of Grants and Contracts. These positions are associated with the expanded Ocean Drilling Program in the Directorate for Astronomical, Atmospheric, Earth and Ocean Sciences.

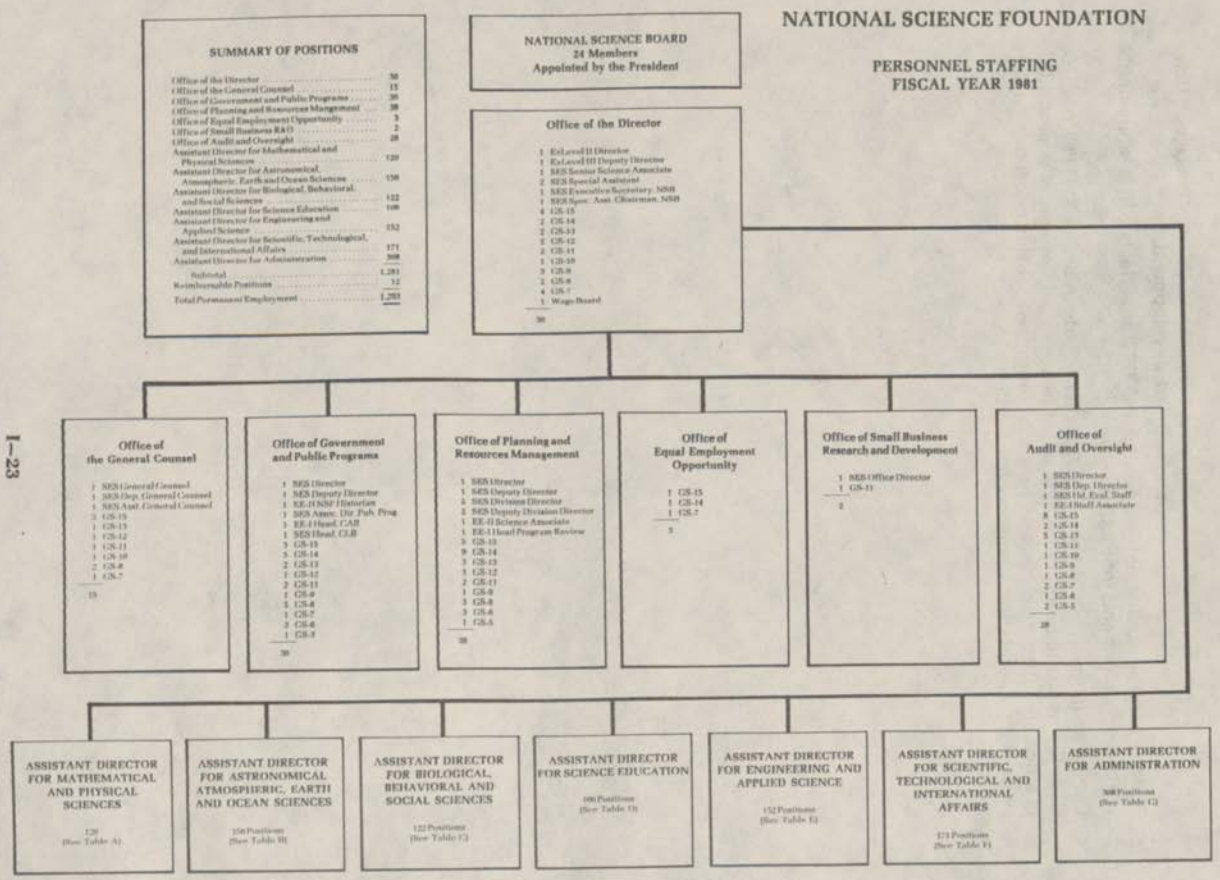
Other increases and decreases by line item are as follows:

- Transportation of Things—An increase of $50,000 takes into acount higher labor charges and higher average costs of household and equipment moves. This item includes the cost of moving household goods of eligible new employees, truck rental for use in transporting supplies and equipment between the NSF warehouse and various office locations in Washington, freight cost on equipment where the cost is not included in the purchase price, and transportation and installation costs of NSF scientific exhibits at scientific conventions and meetings.
- Space Rental—An increase of $200,000 results from adjustments in the standard level user charge assessed by the General Services Administration for leased space occupied by the Foundation's Washington offices.
- Data Processing and Office Equipment Rentals—A decrease of $435,000 results from NSF's near complete purchase of its central computer system and significant progress towards automating office procedures in the Foundation. Equipment formerly leased or rented is now owned by the Foundation.
- Printing and Reproduction—An increase of $50,000 covers price increases imposed by the Government Printing Office and private vendors and provides for a limited increase in the volume of program related material to be printed.

- Data Processing Contracts—A decrease of $108,762 results from the completion of several major projects in computer software development.
- Special purpose equipment—A decrease of $75,000 reflects NSF's equipment purchase requirements for FY 1981.
- Computer hardware and Office Automation—A decrease of $135,000 results from the near-completion of NSF's effort to acquire its computer system and to automate office procedures. The amount required for this effort in FY 1981 reflects the Foundation's progress toward these goals.

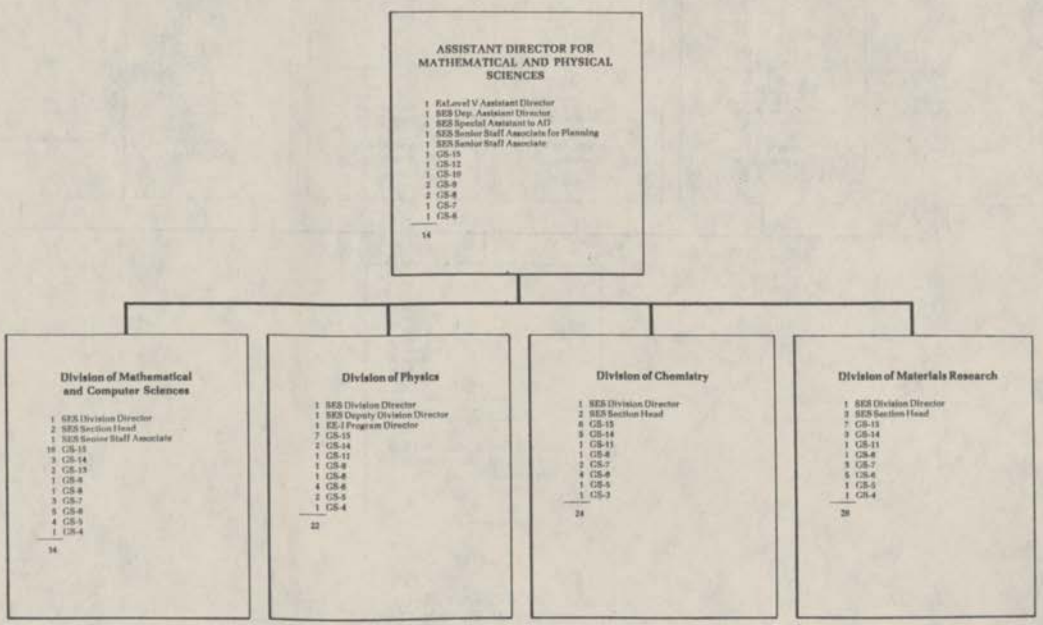
NATIONAL SCIENCE FOUNDATION

PERSONNEL STAFFING
FISCAL YEAR 1981



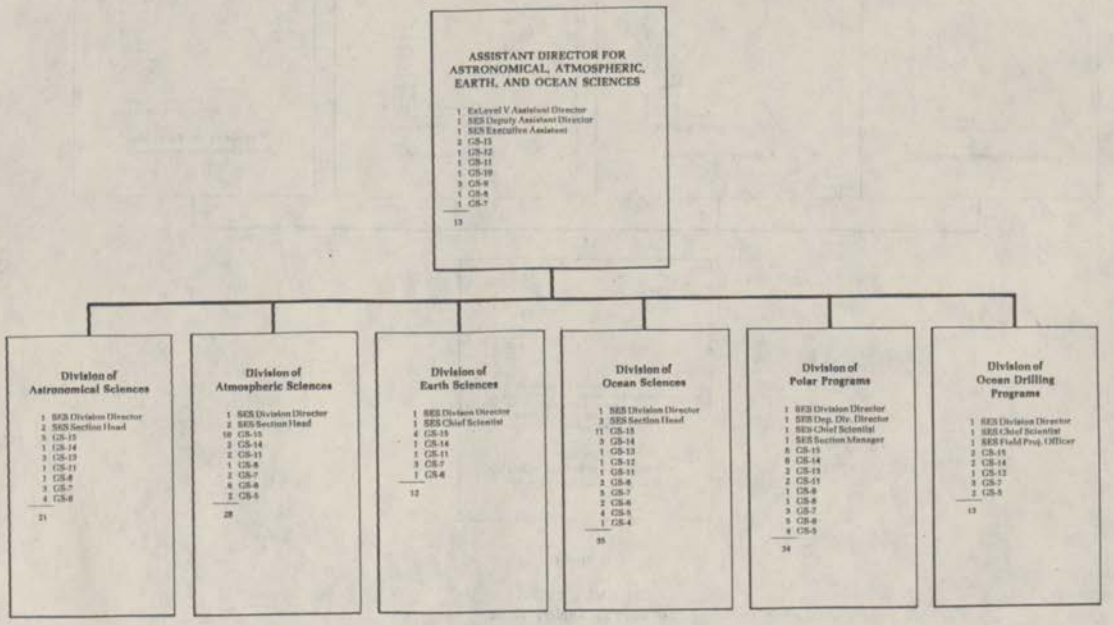
PERSONNEL STAFFING
FISCAL YEAR 1981

Table A



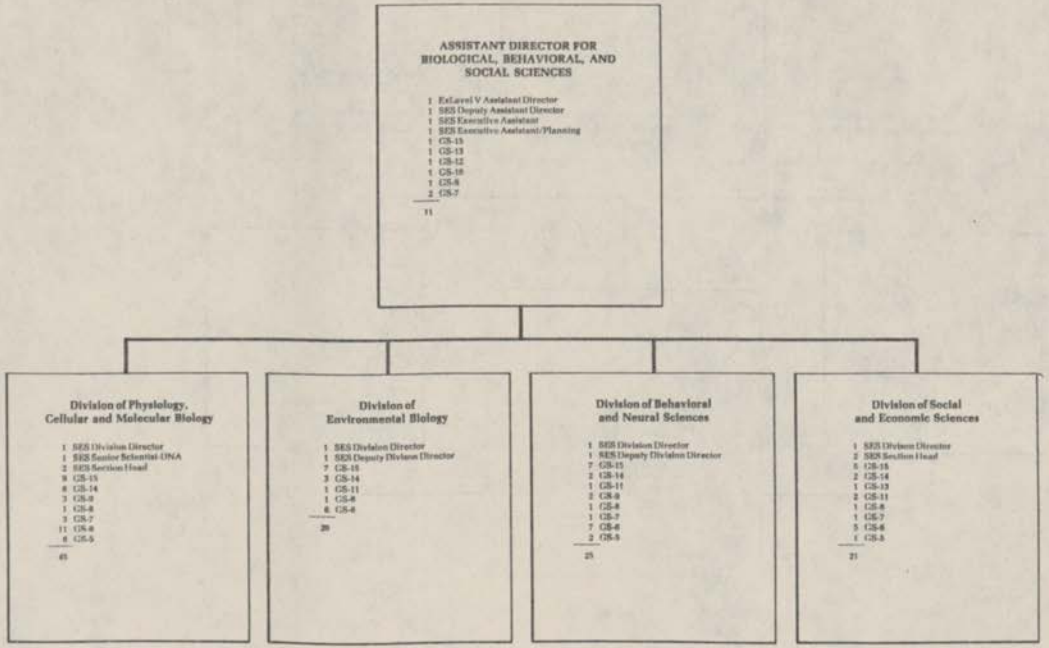
PERSONNEL STAFFING
FISCAL YEAR 1981

Table B



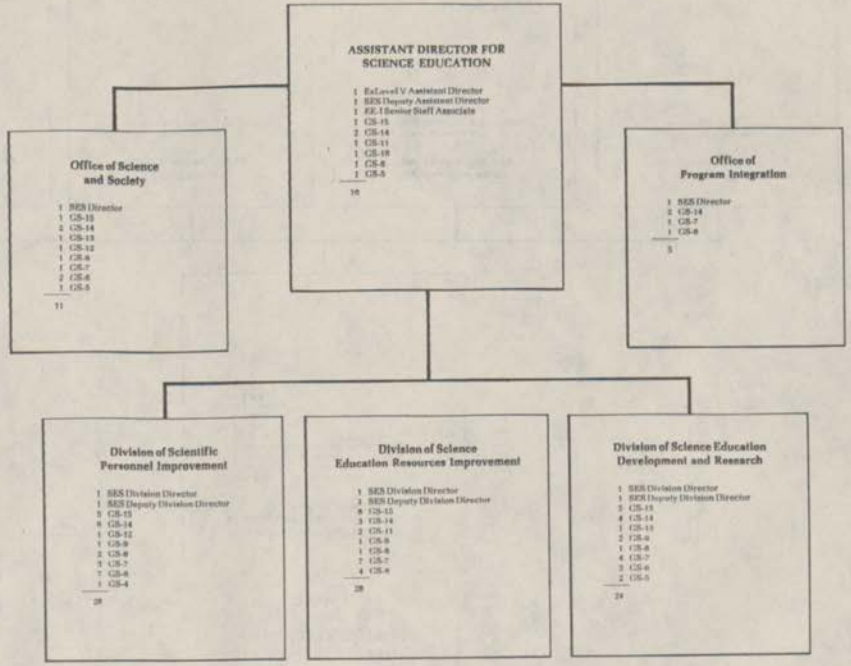
PERSONNEL STAFFING
FISCAL YEAR 1981

Table C



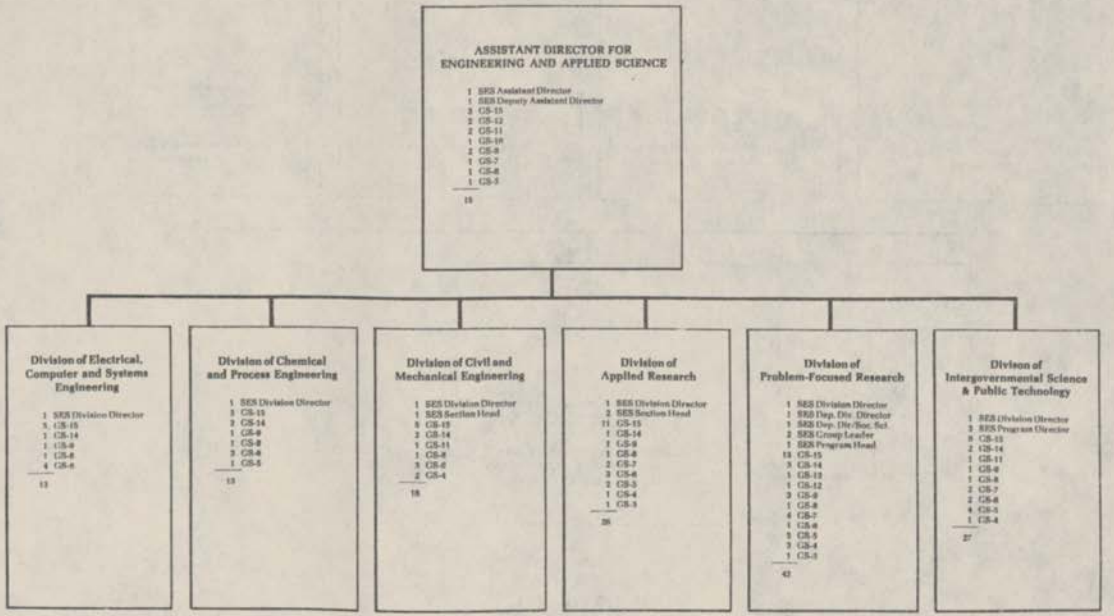
PERSONNEL STAFFING
FISCAL YEAR 1981

Table D



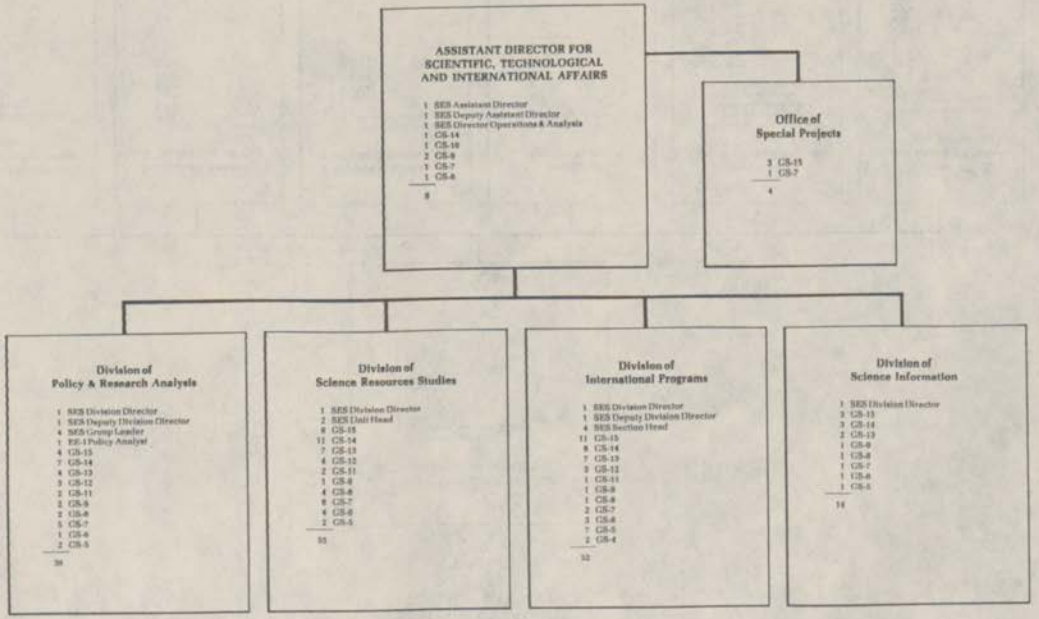
PERSONNEL STAFFING
FISCAL YEAR 1981

Table E



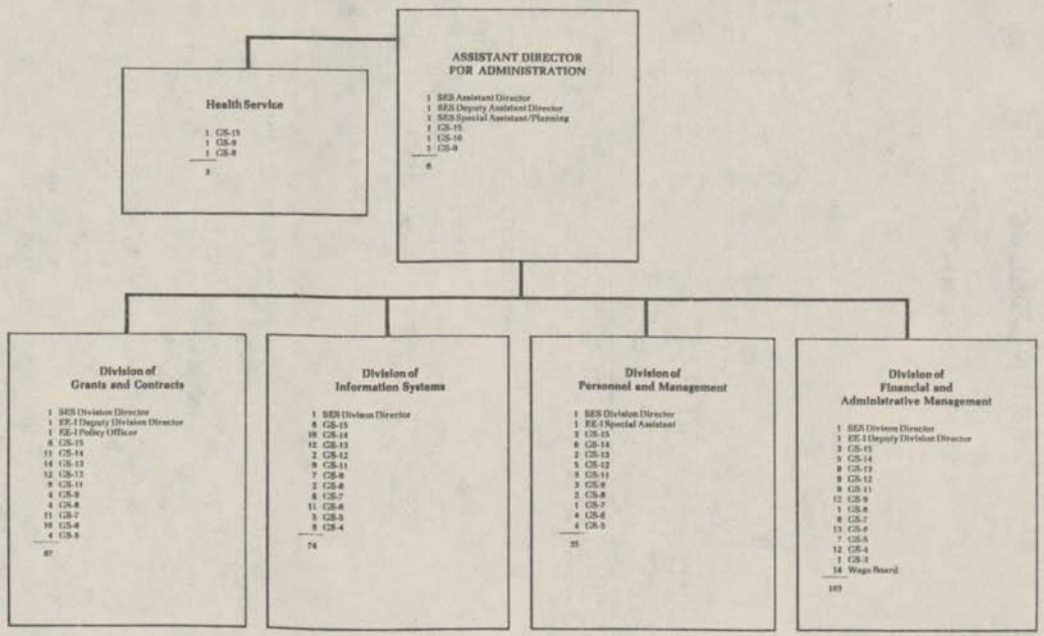
PERSONNEL STAFFING
FISCAL YEAR 1981

Table F



PERSONNEL STAFFING
FISCAL YEAR 1981

Table G



SCIENCE EDUCATION

PROGRAM ACTIVITY SUMMARY

FY 1981 PROGRAM TOTAL $85,700,000

Obligations by Subactivity

Page	Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
J-I	Scientific Personnel Improvement	$33,071,847	$32,900,000	[1]$31,600,000	$35,200,000	$3,600,000
J-II	Science Education Resources Improvement	28,605,692	29,100,000	[2]24,000,000	24,200,000	200,000
J-III	Science Education Development & Research	12,014,423	15,300,000	14,950,000	17,500,000	2,550,000
J-IV	Science & Society	6,287,455	7,400,000	7,650,000	8,800,000	1,150,000
	Total	$79,979,417	$84,700,000	[1,2]$78,200,000	$85,700,000	$7,500,000

[1]Includes $1.0M to be obligated by the Pre-College Teacher Development in Science Program in January 1980 for summer projects for teachers in Grades K-4, but excludes $1.5M for academic year projects scheduled for obligation after April 1, 1980, the date for establishment of the Department of Education. This latter amount will at that time be transferred to the new Department.
[2]Excludes $5.0M which is being transferred to the Department of Education as of April 1, 1980.

Goals and Description

The National Science Foundation Act of 1950 (P.L. 81-507, as amended) directs the Foundation to ". . .initiate and support. . .programs to strengthen. . .science education programs at all levels. . ." From this mission flow two continuing goals for the Science Education Program in FY 1981:

- To help all citizens increase their basic understanding of science and its contributions to the quality of life; and
- To assure a stable flow of the most talented students into careers in the sciences, with particular reference to increasing the participation of minorities and women.

To implement these goals the Science Education staff, working closely with the Congress, the National Science Board and the scientific community, has developed a balanced and carefully integrated set of program mechanisms. The objectives of these programs are to:

- Support research on how science and mathematics are learned and development of more effective instructional techniques and materials for use at all levels of education;
- Provide high quality training in science for specially selected students in programs ranging from the junior high school through the graduate levels;

- Provide for subject-matter revitalization of both pre-college teachers of science and undergraduate science faculty;
- Assist in the improvement of undergraduate science instruction at 2-year and 4-year colleges and universities; and
- Improve the public's understanding of science and how it affects their daily lives thus increasing the ability of citizens to participate knowledgeably in the resolution of science-related public policy issues.

In pursuing these objectives the Foundation will place special emphasis on four priority thrusts. Two of the four thrusts were initiated in FY 1979. The first of these is the improvement of science education for the early adolescent. This entails focussing continued effort at a point of high opportunity, the junior high/middle school years. What we know about this age group tells us that many choose not to study science and mathematics beyond this age and that this is particularly true of minorities and girls. We need to know more about why this phenomenon occurs at this age level and what needs to be done to alter the situation so that these students have a broadened understanding of science and that they do not preclude themselves from possible preparation for future science and technology-related careers.

The second of the thrusts initiated in FY 1979 is that of improved access of under represented minorities and women to careers in science and engineering. The matter of career access, while related to the early adolescence thrust, is of sufficient importance to continue to set this subject forward as a particular science education concern.

The third priority thrust, initiated in FY 1980, relates to out-of-classroom or informal science learning experiences. This is an important factor in the general development of the public's understanding of science, and is of great importance in interesting and motivating children to study science. Elementary school enrollments are shrinking drastically. Yet within this reduced school enrollment are the scientists who will be entering the scientific labor force at the turn of the century. With a smaller pool to draw from, science must command a greater proportion of talented young students to assure an adequate labor force two decades hence. The motivational aspects of informal, out-of-classroom science learning in the current decade is expected to play an important role in the development of the cadre of scientists of the future.

This year a fourth priority thrust is added to the above continuing concerns—revitalization of college science teaching. For the past several years, higher education (undergraduate institutions in particular) has been affected by a series of events which have, in a cumulative way, affected the quality and currentness of college teaching of science. Declining student enrollments due primarily to birthrate changes have affected faculty mobility and reduced the need for new faculty. This, in conjunction with tenure, has brought about a consequent aging of faculty. In addition, the changing character of the student body and changing patterns in the job market have made the content of many course offerings obsolete. Because of these factors the Foundation is proposing to give priority, as a new major thrust for FY 1981, to the updating of the subject-matter competence of college science faculty.

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The program structure necessary to achieve this plan is already in place. It consists of four program subactivities, which are administrative groupings of program elements having similar objectives. They are:

Scientific Personnel Improvement—Programs in this subactivity are designed to improve subject-matter competence of pre-college and college science teachers and students; and to identify and encourage the talented, particularly minorities, women and the physically handicapped, to participate more fully in the study of the sciences, mathematics and engineering.

Science Education Resources Improvement—This group of programs is designed to bring about the improvement of instruction in the sciences in schools, 2-year and 4-year colleges, and universities and provide validated knowledge concerning effective instructional strategies and research results in education in the sciences for use by decisionmakers in science education.

Science Education Development and Research—These two programs support scientists and practitioners who are trying to advance our basic knowledge of how the concepts, processes and skills of science are learned and encourage the development of new, more effective materials and methods of instruction, without which the improvement of science education cannot proceed in an orderly fashion.

Science and Society—The programs in this subactivity seek to bring about greater general understanding of science and technology, the connections between them, and the human value implications of both for contemporary life.

Within this program structure the Foundation plans to implement its four priority thrusts. In the accomplishment of this, the strategy initiated in FY 1979 will be continued. This strategy requires that, wherever appropriate in the several science education program mechanisms, special efforts will be made to allocate regular program resources to the furtherance of these priority thrusts. The importance of these priorities in the achievement of the two major goals stated above demands that they be incorporated into each applicable program rather than being isolated as separate or discrete functions.

In addition to these priority concerns, the Foundation's traditional concerns for the support of those students having the greatest talent for study and research in science and for improving the quality of science instruction in junior/community colleges and in 4-year colleges will be continued in FY 1981. The effectiveness of our Nation's leaders—scientists and non-scientist—is directly dependent upon the quality of instruction provided in our institutions of higher eduction.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The differences between the FY 1980 Budget Request and the FY 1980 Current Plan are related to: 1) actions taken by the Congress during the FY 1980 Authorization process; 2) an earlier-than-originally-planned increase of fellowship and traineeship stipends; and 3) the establishment of the Department of Education.

Direction from the Congress resulted in an increase in two program elements over the amount included in the FY 1980 Budget Request. First, Minorities, Women and

the Physically Handicapped in Science Program in the Scientific Personnel Improvement Subactivity has been increased from a requested $2,000,000 to the current plan of $2,240,000. Second, Ethics and Values in Science and Technology Program in the Science and Society Subactivity has been increased from a request of $1,300,000 to a current plan of $1,693,000.

The Foundation last increased its Fellowship and Traineeship stipend rates in FY 1976. At that time the rates were $3,900 and $3,600 respectively on a 12 month basis. The typical fellow therefore received $2,925 for personal expenses for a 9 month school year. Similarly, the typical trainee received $2,700 for a school year. The effects of inflation since 1976 on these low levels of support need not be documented here. The Foundation had planned a stipend increase for FY 1981. Because of the recent rapid increase in the inflation rate, this planned increase was changed to a two-phase plan to be initiated in FY 1979 to bring some relief sooner to fellows and trainees. The first phase, a $420 per annum increase for each fellow and trainee, was accomplished by a pro-rata reprogramming of FY 1979 funds from each Science Education program. To carry this increase forward required a similar pro-rata reprogramming of FY 1980 funds. The second phase adds an increment of $480 per annum in FY 1981.

Subsequent to the passage of the Foundation's FY 1980 Appropriation, the Department of Education Organization Act of 1979, P.L. 96-88, was signed by the President. This act required that there be transferred to the new Department of Education the Foundation's Minority Institutions Science Improvement Program (described in the Science Education Resources Improvement Subactivity, below) and that portion of the Pre-College Teacher Development in Science Program (described in the Scientific Personnel Improvement Subactivity, below) which provides for the upgrading of the science subject-matter backgrounds of practicing teachers of the primary grades (K-4). The estimate of FY 1980 funds available for the Minority Institutions Science Improvement Program is $5,000,000. The preliminary estimate of FY 1980 funds in the Pre-College Teacher Development in Science Program which will be used to fund projects for primary grade teachers is $2,500,000.

The Administration's plan for establishment of the Department of Education requires that of these estimates, that portion not yet obligated as of April 1, 1980 shall be transferred to the Department. Because of predetermined proposal receipt dates, and peer review and award schedules, it is estimated that the following amounts will be available for transfer as of April 1, 1980:

Minority Institutions Science Improvement Program	$5,000,000
Pre-College Teacher Development (K-4) Program	$1,500,000
Total Estimated Transfer, FY 1980	$6,500,000

These amounts have therefore been excluded from the FY 1980 Current Plan as displayed in this document. In addition, no funds for these two activities are included in the FY 1981 Budget Request.

FY 1981 Budget Highlights and Explantion of Increases and Decreases

Obligations

FY 1979 Actual	$79,979,417
FY 1980 Program	$78,200,000
FY 1981 Request	$85,700,000
Difference—FY 1981/FY 1980	$7,500,000

The amount requested for the FY 1981 Science Education Program Activity is $85,700,000. This represents a 9.6 percent increase over the adjusted Current Plan for FY 1980, $78,200,000.

Given the adjustments in the Science Education Current Plan caused by the transfers to the Department of Education, the percent change between FY 1980 and FY 1981 for the four Science Education Subactivities are:

Scientific Personnel Improvement	11.4%
Science Education Resources Improvement	0.8%
Science Education Development & Research	17.1%
Science and Society	15.0%

Program areas increased in FY 1981 include:

- $425,000 for Graduate Fellowships and Traineeships to provide for increased stipend support.
- $820,000 for Student-Oriented Programs to increase support for special education opportunities in science for middle-school and high school students and for Undergraduate Research Participation.
- $1,011,000 to increase support for improvement of undergraduate instruction in science through the upgrading of subject-matter backgrounds of science faculty.
- $1,359,000 to increase support for minority high school students and for women to increase the access of these underrepresented groups in the scientific and technological labor force.
- $522,000 for improving undergraduate instruction in science through Local Course Improvement.
- $404,000 for Information Dissemination in Science Education to increase the support of activities designed to bring to education decisionmakers information about new instructional materials and techniques and the results of research into the learning of science which can be utilized to improve education in science, including a new emphasis on the dissemination of information on instruction in science in 2- and 4-year colleges.
- $523,000 to increase the Research in Science Education Program for developing new knowlege about the processes by which science is learned and the motivational factors involved in pursuing science as a career.
- $2,035,000 for Development in Science Education to create new instructional materials and techniques primarily to be applied to the furtherance of the Foundation's four Science Education priority thrusts—improvement of educational

opportunities for early adolescents, career access for minorities, and women, informal out-of-classroom instructional materials and systems, and the quality of science teaching in higher education.

- $1,080,000 to increase utilization of museums and similar community resources in improving the public's understanding of science and its role in their daily lives.

Programs or projects reduced or eliminated:

- Postdoctoral Fellowships have been transferred to the Cross-Directorate Program section of this budget document.
- The Student-Originated Studies Program has been combined with the Undergraduate Research Participation Program with no loss of support for the group served, undergraduate students.
- The Minority Institutions Science Improvement Program is transferred pursuant to P.L. 96-88, the Department of Education Organization Act of 1979, as well as that portion of the Pre-College Teacher Development in Science Program which involved primary grade (K-4) teachers.
- $448,000 decrease in the Comprehensive Assistance to Undergraduate Science Education Program and a $286,000 decrease in the Instructional Scientific Equipment Program. These decreases are more than offset by increases in other programs which focus directly on the improvement of undergraduate science education.

Thus, the highlight of the FY 1981 Science Education Program activity is its emphasis on increasing those resources allocated to the support of a broad spectrum of activities which will:

- Improve the science instruction of early adolescents, and in particular minorities and girls, to equip them better to appreciate how science affects their daily lives and motivate them to continue the study of science so as not to preclude possible career choices in science and technology;
- Improve study and research opportunities for minorities and women and identify the social, psychological and instructional barriers which these groups face in pursuing careers in science; and, further, to explore and develop the means to alleviate those barriers;
- Increase the number and kind of informal out-of-classroom learning experiences in science, particularly for children, to improve their understanding of science and technology as it touches their lives and to encourage them to delve deeper into the study of science for their personal edfication and possible career utilization; and
- Increase opportunities for college science faculty to upgrade their science backgrounds and to make their course offerings more effective and relevant to the scientific manpower requirements of the future.

In implementing these emphases the Science Education Program will focus on individuals by: 1) identifying talented students at the junior high through graduate school levels and providing special opportunities for extending their education in science; 2) supporting faculty members who wish to update their science subject-matter competencies and improve the quality and relevance of the courses they teach; 3) seeking out and supporting the most talented of those working in the area of science education research and development; and 4) bringing to all citizens an understanding of science through use of the informal education mechanisms with which they interact on a day-to-day basis.

Coordination and Relationship to Other Efforts

The Science Education Program activity is coordinated with the benefit of government-wide formal and informal efforts. In 1964, the Federal Interagency Committee on Education was established by Executive Order. This effective coordination mechanism has been continued under P.L. 96-88, The Department of Education Organization Act of 1979. Section 214 of this Act directs that, "The Committee shall assist the Secretary in providing a mechanism to assure that the procedures and actions of the Department and other Federal departments and agencies are fully coordinated." The Committee is composed of the Secretary of Education as chairperson and senior policymaking officials of Federal agencies, commissions and boards having an interest and/or responsibility in education. The Committee also includes policy level representation from the Office of Management and Budget, the Council of Economic Advisors, the Office of Science and Technology Policy, and the Domestic Policy Staff. The Assistant Director for Science Education has served as the Foundation's representative on this important coordination mechanism since its inception.

The Assistant Director for Science Education also serves as the Foundation's representative on the National Council for Educational Research, a statutory advisory council to the Director of the National Institute for Education. This body, which was transferred to the Department of Education under Section 301 (b) (7) of P.L. 96-88, meets regularly and is composed of both governmental and nongovernmental members who advise on Federal research, development and dissemination policy.

The Assistant Director for Science Education has been intimately involved in the legislative development of the Department of Education. At the present time the Assistant Director and senior members of the staff of the Office of the Assistant Director for Science Education are consulted regularly by those staff members responsible for the transition effort. The Foundation looks forward to continuing consultation and coordination with the new Department as required by Section 304 (b) and the development of coordinated planning and operation of science education programs as required by Section 304 (c) of the Department of Education Organization Act.

In addition to these formal coordination efforts, the Office of the Assistant Director for Science Education is in contact with the top management of agencies such as the Department of Energy, the National Endowment for the Humanities, and the National Endowment for the Arts. These contacts are primarily in the area of program planning

and policy. Other more specific examples of coordination will be provided at the Subactivity level where they are more conveniently addressed.

Changes in Budget Structure

The structure of the FY 1981 Science Education Program activity is the same as that authorized by the Congress in FY 1980, with the exception of the program transfers required by legislation creating the Department of Education. The emphases on career access for minorities and women, on education in science at the junior high school level, on informal out-of-classroom educational experiences, and on improvement of undergraduate instruction in science, can be readily accommodated within the current program structure.

Evaluation and Oversight

The evaluation and oversight aspect of the Science Education program activity involves input from the National Science Board, the Advisory Committee for Science Education, representatives of the scientific and educational community, and the public. It includes special activities responsive to expressed Congressional intent. An example of such special activities is the evaluation of the Resource Centers for Science and Engineering called for in House Report No. 96-321, the Conference Report on the National Science Foundation Authorization Act for FY 1980. Another is a study of several activities designed to improve the quality of undergraduate science teaching. This study was also called for in House Report No. 96-321. Both of these studies will be transmitted to the Congress in January 1980.

The Advisory Committee for Science Education is specifically charged with the primary responsibility for external oversight of the Science Education Program Activity. This group, whose membership includes representatives of all levels of education and professional scientists from both industry and academia, performs this function through a system of subcommittees augmented by consultants from outside the Foundation when special expertise is required. These subcommittees report their program oversight findings to the Director of the Foundation via the Assistant Director for Science Education. In addition, the Advisory Committee makes a formal report annually to the Foundation's Director and the National Science Board.

The Office of Program Integration (OPI) for Science Education was established in FY 1976. This office, which reports directly to the Assistant Director for Science Education, is responsible for integrating, comparing, and evaluating programs across divisions. It has also been responsible for broad needs assessments at all levels of science education. As an example, OPI has arranged, through the U.S. Government Printing Office, for publication of *Early Adolescence: Perspectives and Recommendations.* This planning effort in science education for early adolescents follows on an earlier OPI-developed series on the *Status of Pre-College Science, Mathematics and Social Studies Educational Practices in U.S. Schools.*

In addition to formal evaluations of program areas, the Foundation has increased requirements for evaluation of awarded projects. Program officers are responsible for insuring that all projects include appropriate plans for evaluation. Where appropriate, funds are included in the project budgets specifically for this purpose.

QUANTITATIVE PROGRAM DATA
SCIENCE EDUCATION ACTIVITY

Proposals and Awards

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	10,899	10,360	10,896
Total Amount Proposed	$277,461,543	$402,989,900	$373,888,800
Average Amount Per Proposal	25,457	38,898	34,314
Awards:			
Number of Awards	3,660	3,590	3,214
Total Amount Awarded	$79,979,417	$78,200,000	$85,700,000
Average Amount Per Award	21,840	21,800	26,700
Average Annual Amount	13,794	13,100	16,000
Average Award Duration (Months)	19	20	20
Total Number of Participants Supported	34,192	33,125	37,842

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities & Colleges	75	74	75
Other Nonprofit Organizations	17	18	17
Industry	1	1	1
Other*	7	7	7

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$18,540,818	$19,254,400	$21,256,000
Other Staff Costs	7,044,241	7,291,000	8,152,000
Subtotal, Staff Costs	25,585,059	26,545,400	29,408,000
Expendable Supplies & Equipment	3,033,579	2,851,100	3,355,000
Permanent Equipment	9,160,047	7,403,300	7,328,000
Other Project Direct Costs	9,854,719	9,767,000	11,287,000
Subtotal, Nonstaff Project Costs	22,048,345	20,021,400	21,970,000
Total, Direct Costs	47,633,404	46,566,800	51,378,000
Indirect Costs	11,275,303	11,979,700	13,246,000
Participant Support Costs:			
Stipend & Other Personal Allowances	15,045,776	13,861,300	15,092,000
Cost-of-Education Allowances	6,024,934	5,792,200	5,984,000
Total, Participant Support Costs	21,070,710	19,653,500	21,076,000
Grand Total	$79,979,417	$78,200,000	$85,700,000

*Individual Awards.

SCIENTIFIC PERSONNEL IMPROVEMENT SUBACTIVITY $35,200,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Fellowships and Traineeships	$15,262,154	$13,700,000	$13,975,000	$14,400,000	$425,000
Minorities, Women & the Physically Handicapped in Science	2,361,832	2,000,000	2,240,000	3,600,000	1,360,000
Student-Oriented Programs	5,417,635	5,200,000	5,180,000	6,000,000	820,000
Faculty Improvement	[1]10,030,226	12,000,000	[2]10,205,000	[3]11,200,000	995,000
Total	[1]$33,071,847	$32,900,000	[2]$31,600,000	[3]$35,200,000	$3,600,000

[1] Includes $1,200,000 for projects for teachers in grades K-4 comparable to activities scheduled to be transferred to the Department of Education for FY 1980.

[2] Includes $1,000,000 to be expended in January 1980 for summer projects for teachers in grades K-4, but excludes $1,500,000 for academic year projects scheduled for awards in May 1980.

[3] Excludes $2,500,000 being requested as part of the Department of Education budget for teachers in grades K-4.

Objectives and Description

An adequate cadre of scientific personnel is an important national asset. Increasingly, the application of science to the solution of societal problems depends upon people well trained in the sciences. Thus, the objectives of the Scientific Personnel Improvement subactivity are: to identify and encourage scientific talent; to assist in maintaining high standards and quality training of students and professionals in the sciences; and to stimulate more participation in the sciences by underrepresented groups such as minorities, women and the physically handicapped. This subactivity addresses these objectives through the following strategies:

- Support faculty improvement in all fields of science through continuing education activities for pre-college and undergraduate teachers of science, and thereby foster the improvement of basic understanding of science by all citizens;
- Provide support for study to a limited number of the Nation s most able graduate students in science and engineering;
- Increase the number of underrepresented minorities in science careers through assistance for meritorious minority graduate students;
- Develop and test methods to attract, encourage and motivate minorities, women, and the physically handicapped to pursue science careers, and to provide them with special training opportunities beyond those available in formal science education programs; and
- Identify and encourage science and engineering students in the early stages of educational development and provide talented students with specialized science learning opportunities of immediate relevance to their needs and interests.

Four elements contribute to these objectives: (1) Fellowships and Traineeships at the graduate level; (2) Minorities, Women and the Physically Handicapped at the junior high school level and above; (3) Student-Oriented Programs at the high school and undergraduate levels; and (4) Faculty Improvement at the pre-college (grades 5-12) and college levels. The focus of the first three elements is students, while the fourth is aimed at the teachers of science.

The Scientific Personnel Improvement subactivity contributes to the major thrusts of the Science Education activity as follows:

- *Fellowships and Traineeships* assure the flow of able science graduate students into the advanced science talent pool, thereby developing careers and increasing the access of underrepresented groups to careers in science.
- *Minorities, Women and the Physically Handicapped* projects develop and test ways to attract, encourage, and motivate under represented groups into careers in science.
- *Student-Oriented Programs* support projects for the development of careers in science; in addition these programs enhance the access of underrepresented groups to careers in science. These projects also provide talented early adolescents unusual opportunities for enrichment in science and mathematics.
- *The Faculty Improvement* projects, through teacher development programs, facilitate the preparation of students to function effectively in an increasingly science and technologically oriented society. All subelements of Faculty Improvement contribute to the faculty development thrust and combat faculty obsolescence. In addition to this primary thrust the Pre-College Teacher Development in Science subelement contributes to the early adolescence and career access thrusts by improving the subject matter knowledge and teaching strategies of science teachers of pre-college students.

Significant Recent Achievements

- Through a Minorities in Science project at the Illinois Institute of Technology, 125 minority high school students are engaged in small team projects in mechanical design, solar energy, or electrical engineering. These projects are designed to give them direct experience in applying scientific principles to the solution of engineering problems and first hand information on careers and academic requirements for the study of engineering.
- In another Minorities in Science project, Rockwell International Corporation Science Center developed a comprehensive plan to increase the number of Hispanics and Native Americans entering scientific and engineering careers. Based on a state-wide model to be implemented in New Mexico, the plan entails collaborative efforts of the Federal government, the State government (both executive and legislative branches), industries, universities and other educational units, professional societies, and minority organizations.

- Through the Women in Science subelement a roster of approximately 1,300 women scientists was prepared by the Research Triangle Institute (RTI). The list contains the names of women who are interested in visiting junior and senior high schools to encourage women to consider science careers. This roster, together with a *Manual for Program Operations*, also prepared by RTI, is expected to aid in the conduct of future projects at the local level and not only motivates, but assists young women to prepare for careers in science.
- In the states of Washington and Oregon, a visiting scientist program for physically handicapped students entitled "Expanding Career Options in Science" has been nitiated by Portland State University. Handicapped scientists are visiting rural and small town schools and meeting with handicapped students, their counselors, teachers and parents. In addition to providing role models, the scientists explain how they work, how one becomes a scientist, and describe career prospects.
- In a Student Science Training project, Texas Women's University conducted a summer program which acquainted students with the analysis of such societal problems in the forefront of chemical research as water pollution, the photochemistry of smog, and photosynthesis. Participating were highly talented students from high schools having deficient science programs.
- Through a Science Faculty Professional Development grant Shannon O'Dunn of Grossmont Community College plans to study the natural and artificial changes which took place in the coastal zones including surf zones, beaches, beach cliffs and selected adjacent terraces of southern California, northern Baja California, and Mexico in the last 100 years. Based on this study he will develop teaching aids for lower division college students and interested laymen.
- Through the Undergraduate Research Participation project at Creighton University in Omaha, Nebraska, seven undergraduate students carried out research on population dynamics, animal behavior, hibernation, physiology, and genetics. These studies aid the student in gaining an understanding of how living organisms respond to stresses and genetic abnormalities. The studies also give the participant first-hand research experience.
- Through a Pre-College Teacher Development in Science project at Oklahoma State University a series of three Saturday workshops were held for middle school and secondary school mathematics and science teachers. The topics were (1) *Mathematical Explorations for Gifted Students*; (2) *Make It and Take It With You Workshops*; and (3) *The use of Microcomputers in the Classroom*.
- In a Chautauqua-Type Faculty Short Course on Risk-Benefit Analysis, Chris Whipple of the Electric Power Research Institute, Palo Alto, California presented the issues involved in determining the acceptability of risk. The course covered three broad categories: (1) technical and economic factors relevant to the determination of risks, benefits, and their distribution; (2) psychological and

social considerations which influence the perception of risks and benefits, and the social values underlying public risk taking; and (3) the political and regulatory practices which have developed to make risk acceptability evaluations.

- In an Industrial Research Participation project, four academic physicists and electrical engineers at General Telephone and Electronics Corporation's Waltham, Massachusetts laboratories are learning about the employment of industrial robots for the handling and assembly of materials, two-way transmission over a single optical fiber, and the use of digital technology in speech analysis and synthesis to better prepare their students for future industrial employment.

Changes Between the FY 1980 Budget Request and FY 1980 Current Plan

The net decrease of $1,300,000 in the FY 1980 Current Plan over the Budget Request for FY 1980, from $32,900,000 to $31,600,000 reflects the following changes:

- Fellowships and Traineeships were increased $275,000 to cover stipend raises initiated in FY 1979; this partially offsets the effects of inflation. The stipend increases originally planned for FY 1981 were moved up two years on an emergency basis. Thus, the FY 1979 annual stipends of $3,900 for fellowships and $3,600 for traineeships were increased $420 to $4,320 and $4,020, respectively; FY 1980 stipends remain at these levels.
- The Minorities, Women, and Physically Handicapped element was increased $240,000 (from $2,000,000 to $2,240,000) reflecting Congressional interest in this program as expressed in P.L. 96-44, the Foundation's FY 1980 Authorization legislation.
- The Faculty Improvement element was decreased $1,795,000 (from $12,000,000 to $10,205,000) as follows:
  - A portion of this decrease ($295,000) was required to compensate for the increases reflected above; it was absorbed primarily by the Pre-College Teacher Development in Science subelement.
  - The remaining decrease ($1,500,000) reflects the transfer of funds to the Department of Education for the support of academic year projects for teachers in grades K-4.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$33,071,847
FY 1980 Program	$31,600,000
FY 1981 Request	$35,200,000
Difference—FY 1981/FY 1980	$3,600,000

The increase of $3,600,000 to a total Budget request of $35,200,000 for the Scientific Personnel Improvement subactivity is 11.4 percent more than the $31,600,000 available in FY 1980.

The increases/decreases are as follows:

- The Fellowships and Traineeships element is increased $425,000 (from $13,975,000 to $14,400,000) to implement the second phase of stipend adjustments. The stipends have been steadily eroded by inflation and remain below the poverty level for a single person. The number of students supported in FY 1981 will return to the FY 1979 level of approximately 550 new fellowship and traineeship starts and a total support level of 1,700 individuals (1,550 Fellows and 150 Trainees).
- The Minorities, Women and Physically Handicapped element is increased $1,360,000 (from $2,240,000 to $3,600,000). The increase will be used primarily for Minority Student Apprenticeships at the senior high school level and for opportunities for women in science. The apprenticeships give these students an opportunity to participate in scientific research and improve the access of this underrepresented group to careers in science.
- The Student-Oriented Programs element is increased $820,000 (from $5,180,000 to $6,000,000) to give additional junior high school students opportunities to learn firsthand about research through working with research scientists in universities and industry. The Student-Originated Studies and Undergraduate Research Participation subelements, which both focus on research experiences for undergraduates, are combined in FY 1981 for more efficient programmatic operation.
- The Faculty Improvement element is increased $995,000 (from $10,205,000 to $11,200,000). This increase reflects the following changes:
  - An increase of $1,011,000 (from $2,989,000 to $4,000,000) for Science Faculty Programs subelement to facilitate the acquisition of new scientific knowledge by faculty in two-year and four-year colleges and the undergraduate divisions of universities.
  - A decrease of $16,000 (from $7,216,000 to $7,200,000) in the Pre-College Teacher Development in Science subelement is caused by two factors:
    - A decrease of $1,000,000 below FY 1980 Current Plan through the transfer of the remaining teacher development for kindergarten through fourth grade to the new Department of Education; and
    - An increase of $984,000 to strengthen the development of teachers of grades 5-12, particularly the early adolescence grades, as part of the Science Education activity's special thrust.

Percentage changes for Scientific Personnel Improvement elements between the FY 1981 Budget Request and the FY 1980 Current Plan are as follows:

Fellowships and Traineeships	3.0%
Minorities, Women and Physically Handicapped	60.7%
Student-Oriented Programs	15.8%
Faculty Improvement	9.8%

Coordination and Relationship to Other Efforts

Fellowships and Traineeships—Coordination of NSF Graduate Fellowships with other similar Federal programs is achieved in broad scope through the Federal Interagency Committee on Education. Beyond this, informational contracts are maintained with selected agencies having specific training missions which may overlap with areas supported by the Foundation. Among these agencies are the Department of Energy; the Environmental Protection Agency; the U.S. Office of Education—now the Department of Education—; the National Institutes of Health—particularly the National Institute of Mental Health; and the National Institute of General Medical Sciences—; and the National Academy of Sciences.

Fellowships offered by the Foundation are based on a national merit competition and the Fellows may use the fellowship at an institution of their choice. Thus, NSF fellowships differ from most other Federal support programs which are usually local competitions and limited to use at a single institution. In many instances, final decisions regarding awardees in other programs are made following announcement of the Foundation's awards. In all cases, provisions are made by NSF to prohibit dual support in those limited cases where this might occur.

In contrast to individual portable awards, Minority Institution Graduate Traineeships operate more like other Federal support programs, relying on the local administration of funds awarded to the institution. Special efforts are given to definition of fields of support and program requirements in order to minimize potential duplication of other Federal efforts, particularly the Graduate and Professional Opportunities Program of the Office of Education and the Minority Access to Research Career program of NIH.

Minorities, Women and the Physically Handicapped in Science—A new research apprenticeship program for minority high school students is being coordinated through the Office of Science and Technology Policy with the Department of Defense, Department of Energy, National Institutes of Health, Department of Agriculture, and other governmental agencies. The Physically Handicapped in Science staff coordinates its activities with the Bureau of Education for the Handicapped. Other avenues for information exchange include the American Association for the Advancement of Science, National Science Teachers Association, and the Association of American Colleges. The Women in Science Program is coordinated with the Education and Work Group in the National Institute of Education. In addition, components of the minorities and women programs are coordinated within the NSF through the National Science

Boards's Committee on Minorities and Women, the Advisory Committee for Science Education and the Advisory Committee for Minority Programs in Science Education.

Student-Oriented Programs—Information about student programs is exchanged between the staff of NSF and their counterparts at the Department of Energy, National Endowment for the Humanities, and the National Aeronautics and Space Administration. NSF staff will also participate in the NASA sponsored "Workshop to Develop a National College Student Experiment Competition for the Space Shuttle."

Working together, the Foundation and national Hispanic organizations are cooperating to increase Hispanic high school student participation in the Student Science Training subelement.

Faculty Improvement—Several agencies, such as the Department of Energy (energy education), the U.S. Office of Education (environmental,Indian and bilingual education) and the Bureau of Indian Affairs (Indian education), assist NSF pre-college teacher education projects in the process of carrying out their missions. The staff of the Pre-college Teacher Development in Science subelement meets periodically with cognizant staff members in such agencies to prevent any duplication of effort in science-related areas of overlapping responsibility.

In the Chautauqua-Type Faculty Short Courses NSF selects the courses to be offered and the instructors to be appointed with the assistance of the American Association for the Advancement of Science which coordinates suggestions provided by the academic community, industry, and professional scientific societies.

QUANTITATIVE PROGRAM DATA
SCIENTIFIC PERSONNEL IMPROVEMENT SUBACTIVITY

Proposal and Award Summary

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Proposals:			
Number of Proposals	7,667	7,040	7,340
Total Amount Proposed	$99,973,882	$101,389,900	$113,638,800
Average Amount Per Proposal	13,039	14,440	15,480
Awards:			
Number of Awards	2,531	2,405	2,390
Total Amount Awarded	$33,071,847	$31,600,000	$35,200,000
Average Amount Per Award	13,065	13,140	14,728
Average Annual Amount	10,452	10,950	11,850
Average Award Duration (Months)	15	15	15
Total Number of Participants Supported	34,166	33,120	38,210

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Universities and Colleges	49	53	54
Other Non-Profit Organizations	3	3	4
Industry	1	—0—	1
Other*	47	44	41

Personnel and Other Award Factors

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Professional Staff Costs	$6,063,297	$6,338,200	$7,379,000
Other Staff Costs	909,575	921,800	1,119,000
Subtotal, Staff Costs	6,972,872	7,260,000	8,498,000
Expendable Supplies and Equipment	917,319	938,160	1,093,000
Permanent Equipment	54,226	52,000	60,000
Other Project Direct Costs	1,949,573	1,849,600	2,151,000
Subtotal, Non-Staff Project Costs	2,921,118	2,839,760	3,304,000
Total, Direct Costs	9,893,990	10,099,760	11,802,000
Indirect Costs	2,655,628	2,727,689	3,158,000
Participant Support Costs:			
Stipend & Other Personal Allowances	14,494,466	12,981,350	14,256,000
Cost-of-Education Allowances	6,024,934	5,792,200	5,984,000
Total, Participant Support Costs	20,519,400	18,773,550	20,240,000
Grand Total	$33,071,847	$31,600,000	$35,200,000

*Individual Awards.

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Fellowships and Traineeships Element $14,400,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Graduate Fellowships	$11,405,576	$10,800,000	$10,900,000	$11,800,000	$900,000
Minority Institution Graduate Fellowships and Traineeships	2,082,327	2,000,000	2,175,000	2,600,000	425,000
Postdoctoral Fellowships	1,774,251	900,000	900,000	[1]—0—	-900,000
Total	$15,262,154	$13,700,000	$13,975,000	$14,400,000	$425,000

[1]Postdoctoral fellowships funded under Cross-Directorate Programs Activity.

Objectives and Descriptions

The objectives of the Fellowships and Traineeships element are to:

- Provide support for study to a limited number of the Nation's most able graduate students in science and engineering; and
- Increase the number of underrepresented minorities in science through assistance for minority graduate students.

The Graduate and Minority Graduate Fellowships subelements will support a limited number of highly talented individuals for awards through national competitions. The access of under represented groups to careers in science is facilitated not only through fellowships, but also through graduate traineeship awards to minority institutions, which select the Trainees to be supported. Both graduate fellowships and traineeships support up to 3 years of work or study toward advanced degrees in science.

In FY 1979, 576 new graduate Fellows and Trainees were supported in addition to 1,211 continuing graduate students for a total of 1,787. These plus 123 postdoctoral Fellows bring the total to 1,910 as follows:

Graduate Fellowships Program—Four hundred fifty-one new fellowships were awarded from a pool of 3,768 applicants. Another 1,312 applicants were judged highly meritorious and were accorded "Honorable Mention." This citation enables many of the applicants to acquire other sources of support. The new Fellows joined 1,064 continuing Fellows (for a total of 1,515) whose course of study is already underway at the institutions of their choice.

Minority Graduate Fellowships—More than 520 individuals who are American Indian, Alaskan Native, Black, Mexican American or Puerto Rican competed nationally for 65 fellowships, which were awarded on the basis of merit. In addition, 163 individuals judged deserving of support were accorded "Honorable Mention." It is expected that many of of these Honorable Mention students will be supported via non-federal funds, thus enhancing the flow of highly talented minorities into the Nation's scientific pool. The new Fellows joined 27 continuing Fellows (for a total of 92). These continuing

Fellows started with the FY 1978 experimental program and planned to utilize the second year of their three-year award during the 1979-80 school year.

Minority Institution Graduate Traineeships—Graduate students were supported in 19 departments at 10 institutions which have over 50% minority enrollment. A steady state was achieved with the award of 60 new 3-year, fully funded traineeships. Thus, support was provided for a total of 180 traineeship-years in FY 1979.

National Needs Postdoctoral Fellowships—In FY 1979 123 Fellows were supported; in FY 1981, Postdoctoral Fellowships will be offered through a Cross-Directorate subactivity.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

- A total of about 1,700 graduate science students (1,550 Fellows and 50 three-year trainees—150 Traineeship years) will be supported through Graduate Fellowships, Minority Graduate Fellowships and Minority Institutions Graduate Traineeships.
- In FY 1981, these subelements continue at the same level of new starts (550) as were made in FY 1979.
- The Minority Graduate Fellowships will reach a steady state of 150 Fellows supported in FY 1981 when the third year of national competition is completed.
- At the FY 1981 request level, the Foundation will achieve its target of having approximately 20 percent of its graduate student support going to minorities through the collective efforts of the Minority Graduate Fellowships and Minority Institution Graduate Traineeships.
- The increase of $425,000 (from $13,975,000 to $14,400,000) for Fellowships and Traineeships will be used to make the second phase of the planned adjustments initiated in FY 1979 for stipend increases; however, cost-of-education allowances, which have remained at $3,400/year since 1976, are still in need of adjustment. Annual stipends for all graduate Fellows will be increased $480 from $4,320 to $4,800 and for Graduate Trainees from $4,020 to $4,500. Although these amounts remain well below the stipend levels provided by many other fellowship and training grants, these increases significantly reduce the differential which has existed in recent years.
- Postdoctoral Fellowship funds are not requested under this program element, but appear in this budget under the Cross-Directorate Programs Activity.

QUANTITATIVE PROGRAM DATA
FELLOWSHIPS AND TRAINEESHIPS ELEMENT

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	5,144	4,360	4,360
Total Amount Proposed	$45,030,600	$38,081,900	$40,242,800
Average Amount Per Proposal	8,754	8,735	9,230
Awards:			
Number of Awards	1,744	1,650	1,560
Total Amount Awarded	$15,262,154	$13,975,000	$14,400,000
Average Amount Per Award	8,751	8,470	9,230
Average Annual Amount	8,751	8,470	9,230
Average Award Duration (Months)	12	12	12
Total Number of Participant—Years Supported	[1]1,910	[1]1,790	[2]1,700

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	9	6	9
Other Non-Profit Organizations	—0—	—0—	—0—
Industry	—0—	—0—	—0—
Other*	91	94	91

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	—0—	—0—	—0—
Other Staff Costs	—0—	—0—	—0—
Subtotal, Staff Costs	—0—	—0—	—0—
Expendable Supplies and Equipment	—0—	—0—	—0—
Permanent Equipment	—0—	—0—	—0—
Other Project Direct Costs	$382,300	$350,000	$350,000
Subtotal, Non-Staff Project Costs	382,300	350,000	350,000
Total, Direct Costs	382,300	350,000	350,000
Indirect Costs	185,936	150,000	150,000
Participant Support Costs:			
Stipend & Other Personal Allowances	8,900,918	7,820,800	8,120,000
Cost-of-Education Allowances	5,813,000	5,654,200	5,780,000
Total, Particiant Support Costs	14,713,918	13,475,000	13,900,000
Grand Total	$15,262,154	$13,975,000	$14,400,000

*Individual Awards.
[1]Includes 123 Postdoctoral Fellowships in FY 1979 & 50 in FY 1980.
[2]Postdoctoral Fellowships not included.

Minorities, Women and Physically Handicapped in Science Element $3,600,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$2,361,832	$2,000,000	$2,240,000	$3,600,000	$1,360,000

Objectives and Description

The objectives of Minorities, Women, and the Physically Handicapped in Science projects are to:

- Determine ways of increasing the entry or re-entry into scientific careers of women, minorities, and the physically handicapped;
- Provide these groups with special science learning experiences beyond those available in formal science education programs; and
- Develop and test new methods to attract, encourage, and motivate minorities, women, and the physically handicapped to consider careers in science.

Strategies to accomplish these objectives include workshops which furnish career information; facilitation projects which update knowledge; development of career information; modifications of existing science courses; and special training opportunities beyond those available in existing formal science education programs.

Minorities in Science—In addition to experimental activities such as the Rockwell International Corporation project cited earlier, this subelement has used the student participant models of the Student-Oriented Programs element to improve the flow of minorities into science careers. In FY 1979 the Foundation supported 20 projects to provide nearly 1,650 minority students with the opportunity to study or conduct research in a variety of science disciplines. However, in FY 1980 at the President's request, $500,000 of the funds available are being reprogrammed exclusively to provide summer and academic year apprenticeship opportunities for 200 minority high school students. In FY 1981 the number of minority students in this activity will be doubled, and $1,000,000 will be used for high school apprenticeships.

Women in Science—In FY 1979 the Science Workshops, serving approximately 7,200 women at the undergraduate and graduate levels, provide objective information on possible careers in science. The Facilitation Projects, serving approximately 350 women, are for individuals who have received degrees in science, but who are not presently employed in the fields in which they were trained. The educational experiences provided by these projects update their knowledge to that expected of current college graduates. About 20 Workshop and 10 Facilitation Projects will be supported in FY 1981. Special emphasis will be given to workshops to meet the needs of women

who have a bachelor's degree in science but are unemployed or underemployed and are seeking to reenter science or change careers. The Current Plan for FY 1980 and the Budget Request for FY 1981 are $1,041,000 and $1,400,000 respectively, for the Women in Science subelement.

Physically Handicapped in Science—In FY 1979, 16 projects were supported; approximately 12 awards will be made in FY 1980 and FY 1981 to develop and disseminate career information and materials. These projects also field test and assess the value of fundamental science courses adapted for handicapped students at the junior high school, high school and college student levels. The Current Plan and the Budget Request both remain at $500,000 per year for the Physically Handicapped in Science subelement.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

- The increases of $1,360,000 (from $2,240,000 to $3,600,000) for Minorities, Women and the Physically Handicapped will be used principally to expand the Minorities in Science and the Women in Science subelements as follows:
  - The increase of $1,000,000 (from $700,000 to $1,700,000) will support 400 research apprenticeships for talented minority high school students in grades 10-12. These apprenticeships stimulate broader interest in careers in science and engineering and establish individual working relationships between high school students and active researchers who may become helpful mentors as the students advance.
  - The increase of $360,000 (from $1,040,000 to $1,400,000) for the Women in Science subelement is to initiate program efforts (career workshops) and other activities at the pre-college level in place of the visiting women scientist activities.

QUANTITATIVE PROGRAM DATA
MINORITIES, WOMEN AND PHYSICALLY HANDICAPPED ELEMENT

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	185	200	210
Total Amount Proposed	$4,950,000	$6,000,000	$6,300,000
Average Amount Per Proposal	26,756	30,000	30,000
Awards:			
Number of Awards	81	75	120
Total Amount Awarded	$2,361,832	$2,240,000	$3,600,000
Average Amount Per Award	29,259	30,000	30,000
Average Annual Amount	29,259	30,000	30,000
Average Award Duration (Months)	12	12	12
Total Number of Participants Supported	9,280	8,630	13,700

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	80	80	80
Other Non-Profit Organizations	20	20	20
Industry	—0—	—0—	—0—
Other	—0—	—0—	—0—

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$1,017,100	$964,500	$1,548,000
Other Staff Costs	212,300	201,000	324,000
Subtotal, Staff Costs	1,229,400	1,165,500	1,872,000
Expendable Supplies and Equipment	142,000	134,460	216,000
Permanent Equipment	—0—	—0—	—0—
Other Project Direct Costs	236,000	224,100	360,000
Subtotal, Non-Staff Project Costs	378,000	358,560	576,000
Total, Direct Costs	1,607,400	1,524,060	2,448,000
Indirect Costs	400,675	379,790	612,000
Participant Support Costs:			
Stipend & Other Personal Allowances	353,757	336,150	540,000
Cost-of-Education Allowances	—0—	—0—	—0—
Total, Participant Support Costs	353,757	336,150	540,000
Grand Total	$2,361,832	$2,240,000	$3,600,000

Student-Oriented Program Element $6,000,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Student Science Training	$2,481,797	$2,300,000	$2,291,000	$3,000,000	$709,000
Student-Originated Studies	977,209	900,000	897,000	—0—	-897,000
Undergraduate Research Participation	1,958,629	2,000,000	1,992,000	3,000,000	1,008,000
Total	$5,417,635	$5,200,000	$5,180,000	$6,000,000	$820,000

Objectives and Description

To help assure the continued scientific strength of the Nation, the objectives of the Student-Oriented Programs are to provide support to:

- Train a modest number of the most talented students in the sciences;
- Identify and encourage science and engineering students in the early stages of educational development;
- Offer talented students science learning opportunities beyond those normally available in formal science programs in schools and colleges; and
- Make available to students firsthand experiences in the research process by working directly with science faculty and industrial scientists on a one-to-one basis.

Secondary School Student Science Training—This subelement aids in the identification of talented high school students with an interest in science and enables them to gain experience in research and independent study and to assess career choices at an early stage of development. In FY 1979, of the 116 projects (more than 4,300 participants) nearly one-half were with high ability students with excellent science backgrounds. The remainder dealt with students of demonstrated high potential but of limited science backgrounds. The projects involving the latter students focused on students from the inner cities, isolated rural areas and educationally disadvantaged populations.

As part of the Foundation's efforts to find new ways to improve science education and to motivate early adolescents, the experimental effort with talented junior high students initiated in FY 1980 will be continued in FY 1981.

Undergraduate Research Participation—Talented undergraduate science majors, who have demonstrated ability in science careers are identified and provided opportunities to participate in on-going research activities with university science faculty or industrial scientists. Students devote full-time to the research activity for a period of 10-12 weeks in the summer months, normally between their junior and senior years. This experience contributes to the scientific preparation of these students who are committed to a science career.

In FY 1979, 1,160 talented undergraduates worked on 127 projects with scientists to gain an insight into how research is conducted. Through professional contacts the students can evaluate their career options well in advance of making graduate school decisions. Opportunities for undergraduate science majors to work with industrial research scientists have the additional advantage of exposing the participants to the nature of industrial science careers.

The Student-Originated Studies and Undergraduate Research Participation subelements taken together continue in FY 1980 at their FY 1979 levels. In FY 1981 the two are combined into a single Undergraduate Research Participation program to achieve greater operational efficiency. The FY 1981 Budget Request for Undergraduate Research Participation ($3,000,000) is slightly above the FY 1980 Current Plan total for the two subelements ($2,889,000).

FY 1981 Budget Highlights and Explanation of Increases and Decreases

- The increase of $709,000 in the Student Science Training subelement (from $2,291,000 to $3,000,000) will be used to support 37 additional projects involving about 1,000 junior and senior high student participants. Projects designed for junior high school students were initiated as part of Science Education's early adolescence thrust and will receive increased emphasis at this funding level. This Budget Request will provide experiences for approximately 5,500 students in about 186 projects with most operating in the summer for an average period of 6 weeks.
- The decrease of $897,000 (from $897,000 to zero) for Student-Originated Studies terminates this subelement. However, the Undergraduate Research Participation mode is augmented in order not to reduce the support of highly talented undergraduate students receiving summer research experience.
- The increase of $1,008,000 (from $1,992,000 to $3,000,000) in the Undergraduate Research Participation subelement will allow participation of 500 additional students to make a total of approximately 1,500 students in about 190 projects.

QUANTITATIVE PROGRAM DATA
STUDENT-ORIENTED PROGRAMS ELEMENT

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	940	1,000	1,200
Total Amount Proposed	$15,500,000	$17,500,000	$21,600,000
Average Amount Per Proposal	16,489	17,500	18,000
Awards:			
Number of Awards	319	300	330
Total Amount Awarded	$5,417,635	$5,180,000	$6,000,000
Average Amount Per Award	16,983	17,266	18,181
Average Annual Amount	16,983	17,266	18,181
Average Award Duration (Months)	12	12	12
Total Number of Participants Supported	6,240	5,920	7,000

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	96	96	96
Other Non-Profit Organizations	4	4	4
Industry	—0—	—0—	—0—
Other	—0—	—0—	—0—

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$1,464,105	$1,400,000	$1,620,000
Other Staff Costs	162,678	154,000	180,000
Subtotal, Staff Costs	1,626,783	1,554,000	1,800,000
Expendable Supplies and Equipment	379,582	364,000	420,000
Permanent Equipment	54,226	52,000	60,000
Other Project Direct Costs	542,261	515,000	600,000
Subtotal, Non-Staff Project Costs	976,069	931,000	1,080,000
Total, Direct Costs	2,602,852	2,485,000	2,880,000
Indirect Costs	591,510	570,000	660,000
Participant Support Costs:			
Stipend & Other Personal Allowances	2,223,273	2,125,000	2,460,000
Cost-of-Education Allowances	—0—	—0—	—0—
Total, Participant Support Costs	2,223,273	2,125,000	2,460,000
Grand Total	$5,417,635	$5,180,000	$6,000,000

Faculty Improvement Element $11,200,000

Obligations by Program Subelement

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Pre-College Teacher Development	[1]$6,996,074	$9,000,000	[2]$7,216,000	[3]$7,200,000	$-16,000
Science Faculty Programs	3,034,152	3,000,000	2,989,000	4,000,000	1,011,000
Total	[1]$10,030,226	$12,000,000	[2]$10,205,000	[3]$11,200,000	$995,000

[1]Includes $1,200,000 for projects for teachers in grades K-4 comparable to activities scheduled to be transferred to the Department of Education for FY 1981.

[2]Includes $1,000,000 to be expended in January 1980 for summer projects for teachers in grades K-4, but excludes $1,500,000 for academic year projects scheduled for awards in May 1980.

[3]Excludes $2,500,000 being requested as part of the Department of Education budget for teachers in grades K-4.

Pre-college Teacher Development in Science—This subelement is designed to assist teachers in grades 5-12 to strengthen their subject matter competency in mathematics and the natural and social sciences. With the transfer to the Department of Education of activities for teachers in the primary grades (K-4), an increasing emphasis on the middle and junior high school teacher (grades 5-9) will be undertaken as a natural consequence of the Foundation's early adolescence thrust. Insufficient attention to the quality of instruction in science and mathematics in these grades has been shown to close out later career options in science and technology for many students, particularly women and minorities. Further, we believe NSF, in cooperation with academic scientists, is in an unique position to offer education opportunities for the specialists in science and mathematics at these grade levels.

Awards for the support of group teacher education activities are made on a competitive basis to colleges and universities and closely allied institutions having particular scientific expertise and facilities, such as museums and planetariums. Participants are provided training during the academic year, the summer, or both. These activities stress the integration of the subject matter of science with the development of teaching strategies appropriate to the grade level of the student involved. In many cases, societal issues such as pollution, ecology, and bioethics are included in the subject content of the project. These are often treated from the perspective gained through the joint application of physical science principles and social science insights to an understanding of the problem.

It is anticipated that up to 60 percent of the approximately 12,500 participants in the projects will be middle and junior high school teachers (grades 5-9).

Science Faculty Programs—This subelement uses four components: (1) Faculty Short Courses; (2) Industrial Research Participation; (3) Institutes and Conferences; and (4) Science Faculty Fellowships. The Faculty Short Courses component makes it possible for about 2,700 college and university science faculty members to undertake two two-day periods of intensive study designed to update their subject matter backgrounds and to provide new perspectives in their undergraduate teaching fields. The sessions are conducted by recognized experts at locations widely dispersed

across the country, thus providing convenient access at modest travel cost to the participants.

The use of modern technology for reaching a larger number of teachers in a more cost-effective manner will be explored in FY 1981. This effort will include, but is not limited to, a feasibility study on the use of telecommunications for the presentation of course materials simultaneously at two or more field centers.

The Industrial Research Participation component is designed to provide 2- and 4-year college and university science faculty having little or no industrial experience with an opportunity to undertake a 10-week summer research program at a non-academic laboratory. Such an experience permits faculty members to re-evaluate their teaching from the standpoint of the needs and requirements of their students. It benefits their undergraduate students, most of whom will be pursuing careers outside of academia, in that the faculty participants are able to provide:

- Better career counseling;
- More up-to-date and relevant instructional materials; and
- Excellent research projects.

The component aims to develop and maintain communication and collaboration among scientists in industry and in colleges and universities. About 20 industrial and government research facilities, selected on a competitive basis, will provide research opportunities for about 65 participants.

The Foundation is currently conducting a study to determine the optimum distribution of support between intensive study opportunities of the institute-type and fellowship-like activities. A pilot set of eight Institutes and Conferences is to be conducted in the summer of 1980. In addition about 70 individual salary matching fellowship-like awards were made available in FY 1980 to science faculty wishing to pursue advanced study or research for periods of up to 12 months at academic or nonacademic facilities, including government laboratories.

1981 Explanation of Budget Highlights and Increases and Decreases

- The net $16,000 decrease (from $7,216,000 to $7,200,000) for the Pre-College Teacher Development in Science subelement reflects the following:
  - An increase of $984,000 to achieve a total of 250 projects for activities in grades 5-12. This will maintain the momentum of the middle school thrust initiated in FY 1979;
  - The FY 1980 Current Plan is $1,500,000 below appropriation level from transfers implemented in FY 1980;
  - A decrease of $1,000,000 from FY 1980 Current Plan through the transfer of kindergarten through fourth grade teacher training activities to the Department of Education. Thus the total being requested as part of the Department of education budget for teachers in grades K-4, is $2,500,000 in FY 1981.

- The increase of $1,011,000 (from $2,989,000 to $4,000,000) for Science Faculty Programs will provide an increase of about 1,000 faculty development opportunities (from approximately 2,900 to 3,900). This number of opportunities for faculty development in FY 1981 can vary from 3,900 to 4,200 depending on the outcome of the projected study mentioned earlier.

QUANTITATIVE PROGRAM DATA
FACULTY IMPROVEMENT ELEMENT

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	1,398	1,480	1,570
Total Amount Proposed	$34,493,282	$39,808,000	$45,406,000
Average Amount Per Proposal	24,673	26,897	28,980
Awards:			
Number of Awards	387	380	380
Total Amount Awarded	$10,030,226	$10,205,000	$11,200,000
Average Amount Per Award	25,917	28,860	29,470
Average Annual Amount	14,800	14,850	16,840
Average Award Duration (Months)	21	22	21
Total Number of Participants Supported	16,316	16,780	15,810

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	79	83	80
Other Non-Profit Organizations	3	3	4
Industry	2	—0—	3
Other*	16	14	13

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$3,582,092	$3,973,700	$4,211,000
Other Staff Costs	534,597	566,800	615,000
Subtotal, Staff Costs	4,116,689	4,540,500	4,826,000
Expendable Supplies and Equipment	395,737	439,700	457,000
Permanent Equipment	—0—	—0—	—0—
Other Project Direct Costs	789,012	760,500	841,000
Subtotal, Non-Staff Project Costs	1,184,749	1,200,200	1,298,000
Total, Direct Costs	5,301,438	5,740,700	6,124,000
Indirect Costs	1,500,336	1,626,900	1,736,000
Participant Support Costs:			
Stipend & Other Personal Allowances	3,016,518	2,699,400	3,136,000
Cost-of-Education Allowances	211,934	138,000	204,000
Total, Participant Support Costs	3,228,452	2,837,400	3,340,000
Grand Total	$10,030,226	$10,205,000	$11,200,000

*Individual Awards.

SCIENCE EDUCATION RESOURCES IMPROVEMENT PROGRAM SUBACTIVITY $24,200,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Comprehensive Assistance to Undergraduate Science Education	$13,518,541	$13,500,000	$13,441,000	$13,000,000	$-441,000
Undergraduate Instructional Improvement	6,402,566	6,500,000	6,474,000	6,700,000	226,000
Minority Institutions Science Improvement	4,909,749	5,000,000	[1]—0—	[2]—0—	—0—
Resource Centers for Science and Engineering	2,743,871	2,800,000	2,789,000	2,800,000	11,000
Information Dissemination	1,030,965	1,300,000	1,296,000	1,700,000	404,000
Total	$28,605,692	$29,100,000	$24,000,000	$24,200,000	$200,000

[1] $4,980,000 of the amount appropriated for FY 1980 is being transferred to the Department of Education as of April 1, 1980.
[2] $5,000,000 for this program element is being requested as part of the FY 1981 Department of Education budget.

Objectives and Description

The overarching goal of the Science Education Resources Improvement Subactivity (SERI) is to strengthen the quality of education in science and engineering available in the Nation's schools. The United States depends heavily on its elementary and secondary schools and its 2-year and 4-year colleges and universities to provide education in science and engineering that will:

- Fill the Nation's need for highly trained scientists, engineers and technologists;
- Develop a scientifically literate citizenry.

By fulfilling the Nation's continuing need for highly trained personnel in science and technology, the United States' strength and leadership in innovation and productivity are more secure. By developing science literacy in our people, through the educational process, each individual gains the opportunity to understand, make better use of, and be knowledgeable of scientific and technological advances in this country and in the world.

The Foundation's current thrusts in science education are:

- Improving science education at the early adolescent level;
- Strengthening the teaching of undergraduate science, engineering and mathematics; and
- Providing increased access to careers in science for women and minorities.

Five strategic approaches are used in pursuing this goal of improved science and engineering education. These include:

- Assisting undergraduate institutions, including two-year colleges, in implementing comprehensive improvements in the science education programs offered;

- Assisting colleges and universities in the improvement of instructional materials for specific undergraduate science courses or programs;
- Assisting colleges and universities in equipping their laboratories for more effective science instruction;
- Establishing academic centers that will foster the flow into the sciences of talented persons from under represented ethnic minority groups and from low-income families;
- Informing decisionmakers, primarily those in elementary and secondary schools, about recent developments in instructional materials, educational practices, and research findings related to science education.

At the pre-college and college levels the Information Dissemination for Science Education program element provides information on new developments and improvements in science education to key personnel at regional, state and local levels. At the undergraduate level, science education development plans that combine a coherent array of activities are funded through the Comprehensive Assistance to Undergraduate Science Education program element. The Resource Centers for Science and Engineering span an even broader spectrum of activities as programs and resources are marshaled to bring opportunities for academic training and careers to minority and low income students through access strategies employed in the community, schools, undergraduate and graduate institutions of a region. The Local Course Improvement sub-element encourages rapid movement into the undergraduate classroom of (a) new disciplinary and interdisciplinary knowledge developed through scientific research, (b) improved instructional strategies based on increased knowledge of pedagogy developed through educational research, and (c) improved techniques for developing instructional materials and other products of curriculum development. The rapidly advancing revolution in instrumentation for instruction and in computer technology is addressed through the Instructional Scientific Equipment sub-element which assists undergraduate institutions in their efforts to equip their laboratories with modern up-to-date apparatus and equipment.

Significant Recent Achievements

- In FY 1979 the second Resource Center for Science and Engineering was funded as the University of New Mexico and New Mexico State University cooperated in the establishment of a Resource Center in the Southwest to increase both science awareness and the number of scientists and engineers among the Hispanic, Native American and other minority communities in the Southwest region. Joining these two institutions are 15 educational institutions and two research laboratories. Activities within the Southwest Resource Center include student and faculty internships, student and faculty research projects, minority recruitment efforts, teacher/counselor workshops, traveling demonstrations, science fairs, educational television programs and tutorial services.

- North Carolina State University at Raleigh conducted a three-day seminar in which faculty from area institutions provided program managers with first-hand information on institutional science education needs and requirements. The project was supported by the Comprehensive Assistance to Undergraduate Science Education program as part of its efforts to understand better the needs of the colleges and universities it serves and thus to establish a firm basis for designing the program.
- The Local Course Improvement and Instructional Scientific Equipment programs have published a key word index covering all projects in both programs for several years up to the summer of 1978. The publication provides ready identification of hundreds of science course improvement projects whose directors have volunteered to provide advice concerning their experience with particular scientific equipment and various approaches to curriculum development.
- Under an Instructional Scientific Equipment project, the University of Rhode Island is establishing a modern plant cell biology teaching laboratory, shared by the Departments of Botany and Plant Soil Science. The laboratory will be equipped with specialized microscopes and a spectrophotometer to allow students to learn those new techniques of cell study that form the basis of research in agricultural productivity.
- Under an Information Dissemination award the Wisconsin Academy of Sciences, Arts and Letters, working with state science supervisors and university personnel, is conducting regional conferences in Iowa, Minnesota and Wisconsin. The conferences will acquaint secondary school leaders with recently formulated ideas about intellectual development and their implications for helping students to develop reasoning ability while learning science.
- A Local Course Improvement project at Southern Methodist University focuses on a two-semester course sequence in software engineering in response to student and industry demands in an area of the country where high technology prevails. The first course will provide a senior Computer Science major with experience in the guided development of a proposal for a medium sized software system. The second course will provide the student with experience on a software development project team.
- Supported by a Comprehensive Assistance award six small public and private liberal arts colleges in North Dakota are integrating computer learning modules into freshman and sophomore-level science courses. Seventy-two science faculty members in ten major science areas are involved in this effort.
- A Minority Institutions Curriculum Exchange Conference for participants from 215 institutions of higher education was convened in Washington, D.C. in January, 1979. The goals of the conference were to facilitate contact and the exchange of ideas and information among faculty members concerning advances in curriculum development and instructional techniques which may enhance the quality and effectiveness of science education at minority institu-

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tions. The proceedings of the conference have been published and widely disseminated.

Changes Between FY 1980 Budget and FY 1980 Current Plan

The major portion ($5,000,000) of the decrease from the FY 1980 budget request is due to the transfer during FY 1980 of the Minority Institutions Science Improvement Program to the Department of Education.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$28,605,692
FY 1980 Program	$24,000,000
FY 1981 Request	$24,200,000
Difference—FY 1981/FY 1980	$200,000

The $24,200,000 requested for the Science Education Resources Improvement (SERI) subactivity is essentially unchanged from the FY 1980 program amount. By program element the percentage changes for FY 1981 are:

Information Dissemination	31.2%
Undergraduate Instructional Improvement	3.5%
Comprehensive Assistance to Undergraduate Science Education	-3.3%
Minority Institutions Science Improvement	Transferred prior to FY 1980 Awards
Resource Centers for Science and Engineering	0.4%

An increase of $404,000 in the Information Dissemination program element will raise the total request to $1,700,000 from $1,296,000. This will permit the Foundation to increase its emphasis on the priority assigned to the improvement of science instruction for early adolescents, minorities, women and the physically handicapped, and to begin dissemination of ideas and results from undergraduate projects.

The FY 1981 budget request for the Undergraduate Instructional Improvement program element will permit approximately 450 awards to colleges and universities to support highly-focused curriculum improvement projects distributed between the two subelements, Local Course Improvement and Instructional Scientific Equipment. This will result in 200 awards for Local Course Improvement, an increase of 49 over FY 1980, and 250 awards for Instructional Scientific Equipment, a decrease of 35 from FY 1980, reflecting a small shift in priority toward Local Course Improvement projects to increase opportunities for flexibility and innovation in response to local academic needs.

The decrease of $441,000 in the Comprehensive Assistance to Undergraduate Science Education (CAUSE) program request, from $13,441,000 in FY 1980 to $13,000,000

in FY 1981 will result in a decrease from 69 to 65 awards from FY 1980 to FY 1981.

Areas of continued emphasis for the FY 1981 CAUSE program are:

- Assistance to 2-year and 4-year colleges;
- Assistance to institutions serving minority students;
- Assistance to institutions providing training for teachers for early adolescents;
- Exploration of new ideas and additional mechanisms for improving undergraduate science education.

In each of these program elements special efforts will continue during FY 1981 to encourage local innovation in developing cost effective and scientifically sound approaches to improving institutional capabilities for science education.

As a result of the Department of Education Reorganization Act (P.L. 96-88), the Minority Institutions Science Improvement Program element will be transfered during FY 1980, taking with it FY 1980 funds in the amount of $5,000,000. Funds for the continuation of this program are included in the FY 1981 budget request for the new Department of Education.

The Resource Centers for Science and Engineering program element will be continued during FY 1981 at the $2,800,000 level, enabling the establishment of one additional resource center. This will bring the total number of centers established from FY 1978 through FY 1981 to four.

Coordination and Relationship to Other Efforts

In discharging its responsibility for strengthening science education in the Nation, the Foundation interacts with other Federal agencies also concerned with education in schools, colleges, and universities. The staff maintains a variety of contacts through both formal and informal associations with their counterparts in such agencies. For example, the Division staff utilizes the formal channels for information exchange established by the Federal Interagency Committee on Education (FICE) and its various subcommittees. These channels, together with informal, personal interactions, continue to produce effective exchange of information and ideas.

The guidelines for the Local Course Improvement subelement call attention to a parallel program in the National Endowment for the Humanities and hold open the possibility of joint funding of projects. The Local Course Improvement staff continues its effective interaction with the Department of Energy in seeking proposal reviewers and exchanging information about energy-related course improvement.

Staff members of the Comprehensive Assistance to Undergraduate Science Education and Minority Institutions Science Improvement programs have consulted frequently with the Office of Education's Strengthening Developing Institutions program to insure that funding of requests is complementary and not overlapping. Tentative award lists are exchanged prior to making final recommendations for funding. The staff maintains a similar cooperative relationship with the Fund for the Improvement of Postsecondary Education.

The Information Dissemination for Science Education staff continues its ties with the Office of Education's National Diffusion Network program staff and the National Institute of Education's Dissemination and Improvement of Practice group.

With the establishment of the Department of Education, the Foundation expects to develop a close mutual consultantship and information exchange relationship with the new Department in areas affecting the strengthening of science education in minority institutions.

QUANTITATIVE PROGRAM DATA
SCIENCE EDUCATION RESOURCES IMPROVEMENT SUBACTIVITY

Proposals and Awards

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Proposals:			
Number of Proposals	2,460	2,335	2,400
Total Amount Proposed	$89,543,181	$123,715,497	$137,100,000
Average Amount Per Proposal	40,500	53,000	57,000
Awards:			
Number of Awards	583	565	550
Total Amount Awarded	$28,605,692	$24,000,000	$24,200,000
Average Amount Per Award	49,000	42,500	44,000
Average Annual Amount	19,600	17,000	17,600
Average Award Duration (Months)	30	30	30

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Universities and Colleges	99	99	99
Other Non-Profit Organizations	1	1	1
Industry	—0—	—0—	—0—
Other	—0—	—0—	—0—

Personnel and Other Award Factors

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Professional Staff Costs	$7,533,000	$6,944,000	$6,990,000
Other Staff Costs	3,193,000	2,705,000	2,790,000
Subtotal, Staff Costs	10,726,000	9,649,000	9,780,000
Expendable Supplies & Equipment	1,323,800	1,049,800	1,130,000
Permanent Equipment	9,032,300	7,242,300	7,150,000
Other Project Direct Costs	3,178,202	2,260,500	2,266,000
Subtotal, Non-Staff Project Costs	13,534,302	10,552,600	10,546,000
Total, Direct Costs	24,260,302	20,201,600	20,326,000
Indirect Costs	4,345,390	3,798,400	3,874,000
Grand Total	$28,605,692	$24,000,000	$24,200,000

Comprehensive Assistance to Undergraduate Science Education Program Element $13,000,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$13,518,541	$13,500,000	$13,441,000	$13,000,000	$-441,000

Objectives and Description

The Comprehensive Assistance to Undergraduate Science Education (CAUSE) program is designed to encourage improvement in the quality and effectiveness of undergraduate science education in the Nation's colleges and universities.

The program's primary objectives are to:

- Strengthen and improve the quality of undergraduate science instruction in 2-year and 4-year colleges and universities; and
- Enhance institutional capability for self-assessment and updating of their science programs.

The Foundation provides grants of up to $250,000 to be expended during a period of one to three years in support of locally developed undergraduate science improvement plans. Each plan must include evidence of a review of local needs in science education, a set of attainable goals, and an evaluation plan to measure progress and results. It also must be so structured that its benefits will continue beyond the granting period.

Needs for instructional assistance in improving the quality of undergraduate science education continue because of increasing costs, declining student enrollments, with the increase in the average age of the faculty, changing character of the student body, changing patterns in the job market, and advances in knowledge of the learning process, make many current course offerings and certain instructional equipment obsolete. In addition, colleges must respond to an expanding need for science knowledge from both science and nonscience majors. NSF funds, are a necessary and important catalyst for stimulating institutions to address their science education problems in responsible and creative ways.

In its first four years of operation, the CAUSE program received about 1,900 proposals from over 1,000 different institutions. This represented approximately one-third of the total target population.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The FY 1981 requested funding level of $13,000,000 for the Comprehensive Assistance to Undergraduate Science Education program represents a decrease of $441,000 from the level of FY 1980, and will support approximately 65 projects, a decrease of four from the number supported in FY 1980.

Project directors have reported to the Foundation that an estimated 58,000 students per year will benefit from improvements in science instruction implemented through projects funded in FY 1979. The projected figures for FY 1981 awards is 55,000 students per year.

QUANTITATIVE PROGRAM DATA
COMPREHENSIVE ASSISTANCE TO UNDERGRADUATE SCIENCE EDUCATION PROGRAM ELEMENT

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980/79	Estimate FY 1981
Proposals:			
Number of Proposals	311	303	300
Total Amount Proposed	$55,600,000	$63,000,000	$63,000,000
Average Amount Per Proposal	178,800	207,900	210,000
Awards:			
Number of Awards	72	69	65
Total Amount Awarded	$13,518,541	$13,441,000	$13,000,000
Average Amount Per Award	187,800	194,900	200,000
Average Annual Amount	62,600	65,000	66,700
Average Award Duration (Months)	36	36	36

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	100	100	100
Other Non-Profit Organizations	—0—	—0—	—0—
Industry	—0—	—0—	—0—
Other	—0—	—0—	—0—

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$4,100,000	$4,100,000	$3,960,000
Other Staff Costs	1,580,000	1,580,000	1,500,000
Subtotal, Staff Costs	5,680,000	5,680,000	5,460,000
Expendable Supplies & Equipment	648,800	648,800	650,000
Permanent Equipment	3,342,300	3,342,300	3,350,000
Other Project Direct Costs	1,721,221	1,645,500	1,440,000
Subtotal, Non-Staff Project Costs	5,712,321	5,636,600	5,440,000
Total, Direct Costs	11,392,321	11,316,600	10,900,000
Indirect Costs	2,126,220	2,124,400	2,100,000
Grand Total	$13,518,541	$13,441,000	$13,000,000

Undergraduate Instructional Improvement Program Element $6,700,000

Obligations by Program Element

Program Subelement	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Local Course Improvement	$2,954,529	$3,000,000	$2,988,000	$3,500,000	$512,000
Instructional Scientific Equipment	3,448,037	3,500,000	3,486,000	3,200,000	-286,000
Total	$6,402,566	$6,500,000	$6,474,000	$6,700,000	$226,000

Objectives and Description

Colleges and universities must continually revise their instruction in science to keep pace with developments flowing from research laboratories. Many of the new findings affect what is being taught, but improvements in the techniques of teaching science also continue to appear. Institutions of higher learning must be capable of responding rapidly to both of these kinds of change. Typically these changes are focused in single courses whose mode of instruction is largely determined by individual faculty members.

The Local Course Improvement program subelement is designed to help individual college-level science departments incorporate scientific and educational advances, usually through the efforts of only one or two faculty members. The need for Foundation assistance is growing because local resources are diminishing at the same time that science and technology knowledge is increasing.

The specific objectives of the Local Course Improvement program are:

- To provide institutions with the capacity for introducing scientific or technological developments in their courses, and for preparing improved approaches to the presentation of scientific concepts.
- To improve the pre-service training of prospective teachers of science and mathematics through the modification of specific courses.
- To provide an incentive for individual faculty to try something new and different.

The Local Course Improvement Program makes small, matching awards ($25,000 maximum) in support of specific, short-term local projects. In FY 1979, 151 projects were supported in 43 states and Puerto Rico, out of 514 proposals received. Projects involved a wide range of activities. Typically they include the design, preparation and implementation of specific new course materials or teaching strategies. Student audiences range from individuals who are very weak in science to those capable of advanced independent study. Many grants involve the use of computers, ranging from large time-sharing systems to relatively inexpensive microcomputers.

Through the Instructional Scientific Equipment program subelement, the Foundation assists undergraduate institutions to keep pace with changes in teaching requirements imposed by developments in scientific research. What is considered to be the best in research today must be a regular part of undergraduate instruction tomorrow. Thus, needs for instructional equipment continually change in kind and increase in sophistication.

The specific objectives of the Instructional Scientific Equipment Program are:

- To encourage and support the introduction of modern equipment to improve science and engineering laboratory instruction;
- To encourage and support incorporation of current educational technology into undergraduate science instruction; and
- To focus these efforts at the level of individual or small groups of well-defined courses, having specific improvement plans and lacking the appropriate instructional equipment to effect desired improvements.

This program helps provide laboratory equipment to encourage introduction of new scientific material and improved teaching strategies. The awards are limited to a maximum of $20,000 and must be matched by the grantee institution. In FY 1979, there were 284 awards made in response to 1459 proposals received. A total of nearly $18,000,000 was requested compared to the $3,450,000 which was obligated.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Local Course Improvement

The FY 1981 funding level of $3,500,000 for the Local Course Improvement program represents an increase of $512,000 over FY 1980. This increment will:

- Permit funding of a small number of projects to facilitate communication among the science education community of significant achievements of projects supported through this program.
- Allow consideration and possible implementation of a revision in the matching provision for grantees. Evidence indicates that uniform application of the current "one-third of total costs" requirement under all circumstances may be detrimental to program objectives, and a variety of alternatives are currently being studied.

Instructional Scientific Equipment

The requested FY 1981 funding level of $3,200,000 for the Instructional Scientific Equipment program represents a decrease of $286,000 from the funding level for FY 1980 and will support approximately 250 projects.

The shift in emphases, from the support of purchase of instructional equipment to local course improvement, reflects a desire to motivate a greater number of individual science faculty members to upgrade the courses they teach in terms of:

- The most recent advances in subject-matter;
- The application of the results of recent research on how science is learned and applied to the manner in which they conduct their courses.

QUANTITATIVE PROGRAM DATA
UNDERGRADUATE INSTRUCTIONAL IMPROVEMENT PROGRAM ELEMENT

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	1,971	1,830	1,900
Total Amount Proposed	$27,550,000	$25,620,000	$26,600,000
Average Amount Per Proposal	14,000	14,000	14,000
Awards:			
Number of Awards	435	495	450
Total Amount Awarded	$6,402,566	$6,474,000	$6,700,000
Average Amount Per Award	14,719	13,100	15,000
Average Annual Amount	6,100	6,100	6,900
Average Award Duration (Months)	26	26	26

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	100	100	100
Other Non-Profit Organizations	—0—	—0—	—0—
Industry	—0—	—0—	—0—
Other	—0—	—0—	—0—

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$1,300,000	$1,300,000	$1,500,000
Other Staff Costs	350,000	400,000	400,000
Subtotal, Staff Costs	1,650,000	1,700,000	1,900,000
Expendable Supplies and Equipment	200,000	200,000	200,000
Permanent Equipment	3,500,000	3,500,000	3,400,000
Other Project Direct Costs	240,000	274,000	300,000
Subtotal, Non-Staff Project Costs	3,940,000	3,974,000	3,900,000
Total, Direct Costs	5,590,000	5,674,000	5,800,000
Indirect Costs	812,566	800,000	900,000
Grand Total	$6,402,566	$6,474,000	$6,700,000

Minority Institutions Science Improvement Program Element .... —0—

Obligations by Program Element

	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981
To be Transferred to Department of Education	$4,909,749	$5,000,000	—0—	—0—

This program has assisted 2-year and 4-year institutions whose enrollments are predominantly (more than 50 percent) Alaskan Native, American Indian, Black, Mexican American, Puerto Rican or other ethnic minority groups underrepresented in science to improve the quality of their science education programs and to increase the flow of ethnic minority students into science careers. Pursuant to the Department of Education Organization Act (P.L. 96-88), this program element has been transferred to the new Department.

The Administration's plan establishing the new Department of Education requires that all funds in programs subject to transfer which are not obligated as of April 1, 1980 shall be transferred as of that date. The predetermined schedule for proposal submission, peer review and awards precluded the obligation of any significant fraction of FY 1980 funds before April 1, 1980. Therefore, all FY 1980 funds allocated to this program are being transfered and no funds are requested for FY 1981.

Funds are being requested in the amount of $5,000,000 by the Department of Education to continue the Minority Institutions Science Improvement Program in FY 1981.

QUANTITATIVE PROGRAM DATA
MINORITY INSTITUTIONS SCIENCE IMPROVEMENT PROGRAM

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	61	—0—	—0—
Total Amount Proposed	$10,208,995	—0—	—0—
Average Amount Per Proposal	167,360	—0—	—0—
Awards:			
Number of Awards	39	—0—	—0—
Total Amount Awarded	$4,909,749	—0—	—0—
Average Amount Per Award	125,891	—0—	—0—
Average Annual Amount	62,945	—0—	—0—
Average Award Duration (Months)	24	—0—	—0—

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	100	—0—	—0—
Other Non-Profit Organizations	—0—	—0—	—0—
Industry	—0—	—0—	—0—
Other	—0—	—0—	—0—

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$900,000	—0—	—0—
Other Staff Costs	700,000	—0—	—0—
Subtotal, Staff Costs	1,600,000		—0—
Expendable Supplies and Equipment	350,000	—0—	—0—
Permanent Equipment	2,110,000	—0—	—0—
Other Project Direct Costs	250,000	—0—	—0—
Subtotal, Non-Staff Project Costs	2,710,000	—0—	—0—
Total, Direct Costs	4,310,000	—0—	—0—
Indirect Costs	599,749	—0—	—0—
Grand Total	$4,909,749	—0—	—0—

Resource Centers for Science and Engineering $2,800,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$2,743,871	$2,800,000	$2,789,000	$2,800,000	$11,000

The Resource Centers for Science and Engineering program promotes increased participation in science and engineering by minorities and persons from low-income families through the establishment of geographically dispersed Resource Centers.

Specifically, the program seeks to expand options in science and engineering by assisting eligible institutions in their efforts:

- To increase the interest in science and engineering studies of these students;
- To increase the number of doctorates in science received by these students;
- To provide such students with role models in science and research opportunities with established scientists;
- To provide faculty members with academic research options and to increase their scholarly productivity.

The activities and influence of the established Centers is reaching out to institutions at all educational levels as well as to the minority and low-income community in the surrounding area. Centers are located near concentrations of minority groups or low-income families and are geographically dispersed in order to serve different minority groups.

A Resource Center established through this program serves a variety of functions for the various constituent groups in the region in which it is located. Some of the functions are as follows:

- For its minority students or students from low-income families, the Center (a) provides access to established scientists, (b) offers a variety of quality science programs, (c) has faculty and programs reflecting sensitivity to the special needs of these students, and (d) has visible and functional minority faculty to serve as role models for these students.
- For its minority faculty, the institution at which the Center is located has a record of demonstrated commitment as reflected in its history of promotion and tenure with respect to this group and it provides them with professional development and research opportunities.
- For neighboring undergraduate and pre-college institutions enrolling substantial numbers of minority students or students from low-income families, the

Center develops joint education programs designed to increase the flow of talented students from these groups into science.

- For the nearby minority community, the Center engages in activities designed to facilitate (a) the dissemination and interpretation of scientific information to the lay community and (b) an exchange of views regarding local scientific needs and interests between members of the lay and academic communities.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The Resource Centers for Science and Engineering program element will be funded in FY 1981 at the level of $2,800,000, approximately the same as in FY 1980, and permit the establishment of the 4th Resource Center. As they are established, these Centers not only individually serve their respective regions, but also support and complement each other in a growing network that creates its own effect on the capability of the Foundation to address the needs of minority students and students from low-income families.

QUANTITATIVE PROGRAM DATA
RESOURCE CENTERS FOR SCIENCE AND ENGINEERING

Proposal and Award Summary

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Proposals:			
Number of Proposals	1	12	15
Total Amount Proposed	$2,994,186	$30,970,479	$42,000,000
Average Amount Per Proposal	2,994,186	2,580,873	2,800,000
Awards:			
Number of Awards	1	1	1
Total Amount Awarded	$2,743,871	$2,789,000	$2,800,000
Average Amount Per Award	2,743,871	2,789,000	2,800,000
Average Annual Amount	685,968	697,250	700,000
Average Award Duration (Months)	48	48	48

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Universities and Colleges	100	100	100
Other Non-Profit Organizations	—0—	—0—	—0—
Industry	—0—	—0—	—0—
Other	—0—	—0—	—0—

Personnel and Other Award Factors

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Professional Staff Costs	$913,000	$1,128,000	$1,000,000
Other Staff Costs	263,000	335,000	400,000
Subtotal, Staff Costs	1,176,000	1,463,000	1,400,000
Expendable Supplies and Equipment	75,000	136,000	200,000
Permanent Equipment	80,000	400,000	400,000
Other Project Direct Costs	835,871	215,000	300,000
Subtotal, Non-Staff Project Costs	990,871	751,000	900,000
Total, Direct Costs	2,166,871	2,214,000	2,300,000
Indirect Costs	577,000	575,000	500,000
Grand Total	$2,743,871	$2,789,000	$2,800,000

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Information Dissemination for Science Education Program Element $1,700,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$1,030,965	$1,300,000	$1,296,000	$1,700,000	$404,000

Objectives and Description

The purpose of this program element is to disseminate information on alternative instructional materials and practices and on research findings related to classroom instruction in the sciences and mathematics. To maximize impact, this activity has in the past focused on science supervisors and other decision makers at the state and local level. It has become increasingly apparent that decision makers in higher education are also in great need of the kinds of information made available under Information Dissemination for Science Education funding. While the present emphasis on improvement of science education for early adolescents and minorities (especially those attending junior high schools in urban settings) will continue, dissemination of findings from research and development on undergraduate instructional problems will be encouraged at the higher education levels. Support will be allocated to achieve more rapid and efficient dissemination of information on new teaching materials and techniques to benefit the physically handicapped, minorities and women and on current developments flowing from research and development activities at all levels in science education. This information will be dispersed and exchanged in working seminars and conferences, through professional journals, in professional meetings and through computerized systems.

FY 1981 Budget Highlights and Explanations of Increases and Decreases

In addition to traditional Information Dissemination for Science Education projects, including the urban junior high school emphasis, the increase of $404,000 over the current FY 1980 plan will allow the Information Dissemination program to support a limited number of projects aimed at:

- Providing decision makers at all educational levels who are responsible for selecting curricula and course plans with information on alternative instructional materials and techniques designed for teaching minorities, women and the physically handicapped; and

- Motivating individual faculty members in higher education who are in a position to minimize the lag between results from research and development in science education and their application in the education system.

These activities will help ensure that tested techniques and ideas flowing from the research and development efforts in science education supported by the Foundation and other agencies will reach the classroom in a timely fashion.

QUANTITATIVE PROGRAM DATA
INFORMATION DISSEMINATION FOR SCIENCE EDUCATION PROGRAM ELEMENT

Proposal and Award Summary

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Proposals:			
Number of Proposals	116	150	200
Total Amount Proposed	$3,190,000	$4,125,000	$5,500,000
Average Amount Per Proposal	27,500	27,500	27,500
Awards:			
Number of Awards	36	50	63
Total Amount Awarded	$1,030,965	$1,296,000	$1,700,000
Average Amount Per Award	28,640	25,920	27,000
Average Annual Amount	21,480	19,440	20,200
Average Award Duration (Months)	16	16	16

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Universities and Colleges	85	85	85
Other Non-Profit Organizations	15	15	15
Industry	—0—	—0—	—0—
Other	—0—	—0—	—0—

Personnel and Other Award Factors

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Professional Staff Costs	$320,000	$416,000	$530,000
Other Staff Costs	300,000	390,000	490,000
Subtotal, Staff Costs	620,000	806,000	1,020,000
Expendable Supplies and Equipment	50,000	65,000	80,000
Permanent Equipment	—0—	—0—	—0—
Other Project Direct Costs	131,110	126,000	226,000
Subtotal, Non-Staff Project Costs	181,110	191,000	306,000
Total, Direct Costs	801,110	997,000	1,326,000
Indirect Costs	229,855	299,000	374,000
Grand Total	$1,030,965	$1,296,000	$1,700,000

SCIENCE EDUCATION DEVELOPMENT AND RESEARCH SUBACTIVITY.....$17,500,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Development in Science Education*	$8,184,741	$9,000,000	$8,965,000	$11,000,000	$2,035,000
Research in Science Education	3,829,682	6,300,000	5,985,000	6,500,000	515,000
Total	$12,014,423	$15,300,000	$14,950,000	$17,500,000	$2,550,000

Objectives and Description

The objectives of the Science Education Development and Research (SEDR) subactivity are to develop new means for improving science education at all levels, and to further the basic understanding of science teaching and learning. Progress is sought by:

- Developing innovative technologies, instructional materials, methods of instruction, and ways to increase participation in science, and
- Generating new knowledge and theory as a basis for improvements in science education.

The quality of life is increasingly affected by science and its related technology. The health of science, in turn, is influenced by the quality of science education. Due to rapid changes in science and society, science education must be continually modified through development and research. Both are needed to introduce new knowledge into the educational process, to prepare people for new science-related tasks and problems, to translate scientific knowledge into a form that can be understood and learned, and to capitalize upon new insights into the way we learn. Both development and research in science education are needed to assure that people will be able to cope with and enjoy the benefits of our technologically based society.

The kind of investment needed to improve science education through research and development clearly warrants Federal funding. All the challenges cannot be met by individual institutions. The Foundation thus has an important role to play in helping schools, colleges, museums and other institutions, as well as individual citizens, to meet science education challenges.

The Science Education Development and Research Subactivity has specifically targeted several areas of emphasis which relate directly to the goals and objectives stated for the Foundation's science education activity as a whole.

For *both* development and research these areas of emphasis include:

- *Science Literacy and the Relation of Science to Society*—To assist all citizens in coping with and enjoying both our technological society and the natural world, and to understand the relationships at the interface of science and society.

- *Career Access*—With special concern for participation of minorities, women and the physically handicapped, to assure a stable flow of talented individuals into science careers, and to maintain their effectiveness through continuing education.
- *Early Adolescence*—This age group is also highlighted because of the importance and past neglect of junior high school science instruction. It is at this age that most U.S. children receive their *last* formal science instruction.
- *Technology in Science Education*—To exploit the potential of the rapidly advancing information technologies for improving science (especially mathematics) learning, and to help people use these technologies effectively.

Also pervading both development and research activities is an increasing concern with efforts to disseminate knowledge generated by these activities to those responsible for science education.

Significant Recent Achievements

- *Science Literacy*—With funds from the National Science Foundation a political science course has been developed at Indiana University to teach high school juniors and seniors the principles of political processes that operate at all levels of government. A new text was published in November 1978 and has already been adopted voluntarily at the State level in nine states with indications for further adoptions. In many places, the course is replacing one in use since 1913.
- *Career Access for Minorities*—At the University of Washington, a physicist is developing a set of undergraduate instructional units particularly aimed at minority and other students who need help in the study of science and mathematics. The approach emphasizes both concept learning and reasoning skills.
- *National Productivity*—Computer-aided design (CAD) speeds the creation of complex engineering structures such as energy-efficient cars, computers on a chip, and the wings of supersonic planes. To facilitate the use of this important new design tool, a project at Rensselaer Polytechnic Institute is surveying the best current practice and exploring ways to share software and curriculum materials in this field.
- *Technology in Science Education*—Parallel developments in computer and videodisc technologies appear to have reached a stage where the two technologies can be combined into one low-cost system. Such systems will bring together the power and logic of the computer with the visual capabilities of color television. The combination will produce a versatile learning device that permits interaction with the student. Two proof-of-concept demonstrations are being supported to pursue the potential these combined technologies hold for improving the productivity and cost effectiveness of science education.

- *Hand-Held Calculators in the Math Class*—There has been considerable ferment around the question of whether hand-held calculators help or hinder children's progress in mathematics. A 5-state team of investigators has studied the impact of calculator use by 1,500 elementary students. The team finds (1) no measurable detrimental effects from using calculators, (2) children learn to use calculators quickly and perform computations much more successfully than their non-user counterparts and (3) children develop highly positive attitudes toward calculator use.
- *Improving Math Problem Solving*—There is considerable evidence that basic skills in mathematics among U.S. students have steadily improved over the past 30 years but that more complex problem solving skills have declined in the last ten to fifteen years. Research on the processes used by students in solving non-routine problems shows, for example, that students rarely check to see if their answers make sense.

  Research on ways to improve performance on problem solving tasks is continuing at a number of sites at several universities. In a 2-year study conducted by the National Council of Teachers of Mathematics, a sample of school board members, parents, school administrators, mathematicians and mathematics educators have identified the improvement of problem solving abilities as the number one priority for school mathematics.
- *Math Course Selection by Junior High School Girls*—A research team at the Denver Research Institute of the University of Denver has been interested in the pervasive belief that mathematics acts as a selective barrier to science careers for women and that early decisions to avoid mathematics courses foreclose later opportunities. In a project comparing junior high school level males and females, influences on student choices in taking (or not taking) the first optional courses in mathematics are being studied. Thus far their results show the dominant influences to be: (1) utilitarian concerns—usefulness to further education or careers, (2) liking for and confidence in mathematics, and (3) the views of other persons of significance to the student (especially parents). When a student decides about enrolling in his/her *first* optional mathematics course, sex is not an important variable.
- *Report on Technology in Science Education*—As part of the long-range planning process, a series of reports were commissioned in 1978 to assist the Directorate in formulating a broad, comprehensive research and development agenda. The first report, *Early Adolescence* (SE 78-75), includes perspectives and recommendations regarding science and mathematics education for the early adolescent. The second in the series, *Technology in Science Education: The Next Ten Years* (SE 79-57), was published in July 1979. This document contains analyses and recommendations concerning technology and science education for the decade ahead.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The budget for this subactivity is reduced by $350,000 in the current plan from the budget request. This is due to a reprogramming of $300,000 from the Research in Science Education Program to the Ethics and Values in Science and Technology Program in response to Congressional interest in this latter program and a small pro-rata reprogramming of funds to increase the fellowship and traineeship stipend level.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$12,014,423
FY 1980 Program	$14,950,000
FY 1981 Request	$17,500,000
Difference—FY 1981/FY 1980	$2,550,000

The $17.5 million requested for the Science Education Development and Research subactivity is 17.0 percent above the FY 1980 program of $14,950,000. The $11 million requested for Development in Science Education is $2,035,000 more than the FY 1980 budget of $8,965,000. The $6,500,000 requested for the Research in Science Education program is $515,000 more than the FY 1980 budget of $5,985,000.

Percentage changes between FY 1981 and the FY 1980 Current Plan for the Science Education Development and Research program elements are as follows:

Development in Science Education	23%
Research in Science Education	9%

The distribution of the FY 1981 Budget Request in the development and research components reflects the Foundation's continued emphasis on updating science education instructional materials for early adolescence, improving the quality of formal and informal systems of science education for all citizens, and generating new knowledge and theory through basic research which can serve as the foundation for improvements in science education.

Coordination and Relationship to Other Efforts

Liaison is maintained, through both formal and informal mechanisms, with staff counterparts in the Office of Education, the Educational Planning and Evaluation Office of HEW, the National Institute of Education, the Fund for the Improvement of Postsecondary Education, the Department of Defense Advanced Research Projects Administration, and the National Endowment for the Humanities. Extensive efforts are made by the National Institute of Education (NIE) and the Foundation to coordinate their complementary efforts in research and development in the teaching and learning of science and mathematics. One major outcome is the establishment in FY 1980 of a cooperative effort between the Foundation and the NIE for development and

research in mathematics. Foundation staff members serve on subcommittees on the Federal Interagency Committee on Education in areas of Research, Development, Dissemination and Evaluation; Educational Technology; Environmental Education; and Population Education. They are also members of Subcommittees of the Federal Council on Educational Research and Development. To insure nonduplication, there is frequent checking between agencies either when multiple funding is sought or when there is a possibility of overlap.

Contact has been made with individuals engaged in planning for the new Department of Education in order to help assure that there is a strong commitment to science and mathematics education in the plans and structure of the new department.

QUANTITATIVE PROGRAM DATA
SCIENCE EDUCATION DEVELOPMENT AND RESEARCH SUBACTIVITY

Proposals and Awards

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	319	435	480
Total Amount Proposed	$50,400,000	$66,500,000	$74,900,000
Average Amount Per Proposal	157,994	153,000	156,000
Awards:			
Number of Awards	93	120	137
Total Amount Awarded	$12,014,423	$14,950,000	$17,500,000
Average Amount Per Award	129,187	124,500	128,000
Average Annual Amount	81,592	74,700	76,800
Average Award Duration (Months)	19	20	20

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities & Colleges	68	71	70
Other Nonprofit Organizations	24	22	23
Industry	7	6	5
Other	1	1	2

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$3,996,541	$4,954,000	$5,750,000
Other Staff Costs	1,827,686	2,460,000	2,831,000
Subtotal, Staff Costs	5,824,227	7,414,000	8,581,000
Expendable Supplies & Equipment	325,166	295,000	463,000
Permanent Equipment	73,521	109,000	118,000
Other Project Direct Costs	2,456,633	2,801,000	3,438,000
Subtotal, Nonstaff Project Costs	2,855,320	3,205,000	4,019,000
Total, Direct Costs	8,679,547	10,619,000	12,600,000
Indirect Costs	3,334,876	4,331,000	4,900,000
Grand Total	$12,014,423	$14,950,000	$17,500,000

Development in Science Education Program Element $11,000,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$8,184,741	$9,000,000	$8,965,000	$11,000,000	$2,035,000

Objectives and Description

The objectives of the Development in Science Education (DISE) program are to:

- Develop and evaluate course materials and curricula, delivery modes, and technologies that can improve science instruction at all levels;
- Experiment with out-of-school methods for delivering science education; and
- Develop methods for keeping science education current.

Schools, colleges and universities must deal with new scientific career patterns, changing student characteristics, rapid knowledge production, increasing costs, and a need for a deeper understanding of the implications of science by the public. New instructional materials and methods of teaching science will be needed to help us meet the requirements of the next 10 years. Many of the needed improvements will be facilitated through the materials and models that will be generated under this program element. Audiences range from the elementary school student to the mid-career scientist and engineer and cover all science disciplines.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

To implement the objectives described above, the following emphases will be pursued in 1981:

- Science for the Early Adolescent: In FY 1981, significant attention will continue to be given to junior high school science education. The improvement of junior high school education in science and mathematics is essential if we are to raise the level of the general public's understanding of science and increase the access of women and minorities to scientific careers. Although adolescents in this age group have the intellectual development necessary to handle scientific ideas, large numbers of youngsters including a disproportionate number of minorities and girls, drop out of science after the eighth, ninth, or tenth grades. This not only forecloses many career lines but also hinders later functioning in a world in which science and technology play a major role.
- Improving Access to Careers in Science: The professional cadre of scientists and engineers in this country continues to reflect inadequate participation by women and some of the minorities. These imbalances run counter to the known distri-

bution of talent and thus represent lost opportunities to individuals and a waste of scientific potential. The Development in Science Education program will consider projects at all educational levels designed to overcome barriers to science careers for these groups.

- Science Literacy and the Relation of Science to Society: The impact and consequences of science and technology can be understood and evaluated only in the context of the larger society in which they exist. However, the education of scientists and engineers often fails to deal in any depth with the humanistic aspects of their work or to raise the difficult issue of the social implications of science. Similarly, education in the non-scientific professions is deficient in its neglect of science. Furthermore, the general education of most citizens poorly prepares them to deal with the science-related social issues of the day. The Development in Science Education program will provide support for projects that address the need for improved education in these areas.
- Education for Productivity: National productivity and economic progress depend on the ability of a society to capitalize upon new and appropriate technological opportunities. To help society respond to changing conditions, the educational system must reduce the time lag between the discovery of new principles and practices and their appearance in curricula and instructional materials. This applies both to the training of new applied scientists and engineers and to the continuing education of practicing professionals. The Development in Science Education program expects to support proposals aimed at the rapid infusion of the results of scientific research and invention into higher education.
- Technology as Applied to Learning: Recent technological achievements offer increased opportunities for improved learning at all levels. The power and diversity of computers and other electronic technology have already been widely demonstrated, but the implications of their decreasing cost and of the development and availability of other new information devices continue to invite educational exploitation. Improvement of cost and educational effectiveness, creation of new instructional materials or methodologies, and stimulation of a more positive student attitude toward science are some of the generally recognized educational benefits that may be realized through the application of new technologies to education. The support of novel applications of technology to improve science education at any level will constitute another emphasis of the Development in Science Education program in FY 1981.

The current FY 1980 budget of $8,965,000 will permit funding of about 60 projects. The amount requested for FY 1981, $11,000,000, will permit the funding of approximately 75 projects. The increase will permit a continuation and extension of the strong emphases begun in FY 1979 in the areas of early adolescence, science literacy, career access, productivity, and technology as applied to learning.

QUANTITATIVE PROGRAM DATA
DEVELOPMENT IN SCIENCE EDUCATION PROGRAM ELEMENT

Proposals and Awards

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Proposals:			
Number of Proposals	152	165	200
Total Amount Proposed	$30,780,000	$34,000,000	$41,400,000
Average Amount Per Proposal	202,500	206,000	207,000
Awards:			
Number of Awards	53	60	75
Total Amount Awarded	$8,184,741	$8,965,000	$11,000,000
Average Amount Per Award	154,429	149,400	146,700
Average Annual Amount	88,245	94,400	92,600
Average Award Duration (Months)	21	19	19

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Universities & Colleges	59	63	65
Other Nonprofit Organizations	32	30	29
Industry	8	7	5
Other	1	0	1

Personnel and Other Award Factors

	Actual FY 1979	*Estimate FY 1980*	*Estimate FY 1981*
Professional Staff Costs	$3,034,426	$3,348,000	$4,092,000
Other Staff Costs	619,936	684,000	836,000
Subtotal, Staff Costs	3,654,362	4,032,000	4,928,000
Expendable Supplies & Equipment	261,768	288,000	352,000
Permanent Equipment	24,472	27,000	33,000
Other Project Direct Costs	2,138,836	2,305,000	2,860,000
Subtotal, Nonstaff Project Costs	2,425,076	2,620,000	3,245,000
Total, Direct Costs	6,079,438	6,652,000	8,173,000
Indirect Costs	2,105,303	2,313,000	2,827,000
Grand Total	$8,184,741	$8,965,000	$11,000,000

Research in Science Education Program Element $6,500,000

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$3,829,682	$6,300,000	$5,985,000	$6,500,000	$515,000

Objectives and Description

The objectives of the Research in Science Education (RISE) program element are to:

- Provide a better base of knowledge for future activities in science education;
- Integrate and synthesize results of existing research to make them more accessible and useful to policymakers and others involved in science education; and
- Encourage coordination of science education research efforts so that results are focused and cumulative.

Experience from the science education reforms of the 1950's and 1960's demonstrates that a valid and coherent research base is needed in carrying out educational change. At present, the science education system is seeking ways to meet demands such as controlling the costs of education; increasing participation by women, minorities, and physically handicapped individuals; and improving the ability of the public to deal with science-based instruction. By building a community of scholars, research can be coordinated and focused on fruitful lines of work. By helping to aggregate a coherent knowledge base, this program facilitates the development of innovative and practical solutions to problems in science and mathematics education.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Major Research Emphasis:

- Science education for the early adolescent: For many students the last opportunity to learn science in school occurs during the period of early adolescence. This is also a key period in which to stimulate continuing interest in science. However, early adolescence is also a period characterized by rapid changes in attitude as well as in biological, social, and intellectual development. Research is encouraged that elaborates biological, social, intellectual, motivational, and instructional factors that may specifically influence the learning of science and mathematics during adolescence.
- Science for women, minorities, and the physically handicapped: No group should be exempted from the opportunity to learn science and mathematics and to participate in science-related careers. The RISE program has a particular interest in the development of new knowledge that will assist educators in understanding

those psychological, social, economic, intellectual, and instructional factors that facilitate greater participation in science-related activities by women, minorities, and the physically handicapped.

- Technology in science education: Costs of technologies are dropping so rapidly that their general use in the service of science education is becoming increasingly feasible. There is a need for development of theory and research to guide us in making effective applications of these technologies to problems of science and mathematics education, such as those in continuing education of scientists and engineers.
- Science literacy: We live in a world built on the findings of science and the fruits of technology. It is a world in which the nature and quality of life may rest in part on the ability of people to maintain useful, current levels of science enlightenment. RISE seeks research that has implications for science literacy. Research covers learning in and out of school and among adults as well as young students.
- Cognitive Processes and the Structure of Knowledge: Research focuses on the relationship between learning processes and the structure of knowledge in a scientific and mathematical discipline. There is need for this research for a range of science disciplines.

Within the above areas of emphasis, the continuing education of scientists and engineers employed in industry is a special concern. Research on conditions that facilitate continuous learning by specialists is encouraged.

In FY 1981, continued emphasis will be given to basic research emerging from earlier projects and directed toward answering questions about science learning, the use of ideas, motivation to learn science, and career choices. Continued efforts will be directed toward understanding the conditions that facilitate the learning of new science and technology by scientists and engineers. Efforts to evaluate and synthesize existing research will be continued.

The Current Plan FY 1980 budget of $5,985,000 will permit funding about 60 projects. The $6,500,000 request for FY 1981 will permit funding a slightly higher number. This budget request will allow continued attention to the major emphasis identified above.

QUANTITATIVE PROGRAM DATA
RESEARCH IN SCIENCE EDUCATION PROGRAM ELEMENT

Proposals and Awards

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number of Proposals	167	270	280
Total Amount Proposed	$19,620,000	$32,500,000	$33,500,000
Average Amount Per Proposal	117,485	120,000	120,000
Awards:			
Number of Awards	40	60	62
Total Amount Awarded	$3,829,682	$5,985,000	$6,500,000
Average Amount Per Award	95,742	99,750	104,800
Average Annual Amount	76,594	59,800	57,200
Average Award Duration (Months)	15	20	22

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities & Colleges	89	85	82
Other Nonprofit Organizations	7	9	9
Industry	3	4	5
Other	1	2	4

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$962,715	$1,606,000	$1,658,000
Other Staff Costs	1,158,311	1,711,000	1,995,000
Subtotal, Staff Costs	2,121,026	3,317,000	3,653,000
Expendable Supplies & Equipment	84,141	107,000	111,000
Permanent Equipment	59,145	82,000	85,000
Other Project Direct Costs	335,797	461,000	578,000
Subtotal, Nonstaff Project Costs	479,083	650,000	774,000
Total, Direct Costs	2,600,109	3,967,000	4,427,000
Indirect Costs	1,229,573	2,018,000	2,073,000
Grand Total	$3,829,682	$5,985,000	$6,500,000

SCIENCE AND SOCIETY SUBACTIVITY $8,800,000

Obligations by Program Element

Program Element	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
Public Understanding of Science	$3,435,088	$4,000,000	$3,900,000	$5,000,000	$1,100,000
Ethics and Values in Science and Technology	1,259,144	1,300,000	1,693,000	1,700,000	7,000
Science for Citizens	1,593,223	2,100,000	2,057,000	2,100,000	43,000
Total	$6,287,455	$7,400,000	$7,650,000	$8,800,000	$1,150,000

Objectives and Description

The Science and Society subactivity is intended to bring about greater understanding of science and technology and their role in modern life, to improve the relationship between the scientific and technological community and the larger society, and to help in solving important ethical and social issues associated with science and technology. The specific objectives of the subactivity are to:

- Improve the content and processes of communication between the scientific and the nonscientific communities;
- Identify, analyze, and help to resolve the ethical and social dilemmas that arise in the work of scientists and engineers and in their interaction with citizens affected by their work;
- Encourage and facilitate the participation of scientists and engineers in activities aimed at increasing the public understanding of science and the resolution of policy issues with significant scientific and technological aspects; and
- Encourage new and improved ways of providing scientific and technical expertise to citizens and their organizations and representatives, so they can better understand and participate in decisions on policy issues involving science and technology.

In pursuing these objectives the Foundation attempts to respond to such questions as:

- How can the work of scientists and engineers, and the implications and consequences of their work, be clarified for the public?
- How can citizens who are not themselves scientists participate effectively in deciding science-related issues of public policy?
- How can scientists and engineers participate most effectively in sharing their expertise with the public and in contributing to the resolution of issues of public policy?

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- How and by whom are decisions made about the conduct of scientific activities, and how should these decisions be made in a democratic society? Against what ethical and social standards can and should such decisions be judged?

All Science and Society programs address a central goal of the Science Education Program Activity as a whole: to develop effective means, both formal and informal, of providing scientific information and experience to all citizens, of all ages and at all levels of education and interest. The Science and Society subactivity will also play an important part in achieving other current Science Education priority thrusts, namely:

- Special emphasis will be placed in all Science and Society programs on meeting the needs of women, minorities, and other groups that have lacked access to scientific and technical understanding and experience; and
- Special emphasis will be placed on the support of informal education in science addressed to pre-adolescent and early adolescent youth, as part of a general thrust directed toward this important age group.

Significant Recent Achievements

- The Public Understanding of Science program has continued as the primary source of funding for further planning and development of "3-2-1 Contact", a major new children's television series about science. The series began daily half-hour broadcasts over public television stations in January, 1980 and is expected to reach a significant portion of 8- 12-year old U.S. children. The series is based on research into the preferences, knowledge and understanding of some 7,000 pupils throughout the U.S. The program seeks to help children experience the joy of scientific exploration as well as motivate them to pursue an interest in science.
- Science museums attract a large and motivated audience that is eager to learn more about science and technology. To broaden this audience still further and reach persons who might not otherwise attend science museums, the Public Understanding of Science program is supporting the development of a mini-museum in a large inner-city urban shopping mall in Philadelphia. This Franklin Institute project will combine exhibits, workshops and demonstrations in an environment where the audience has a high proportion of teen-agers and adults who have had little contact with the programs and activities of science centers, and will serve as a prototype for other museum outreach activities.
- Support of science programming on radio has been increased by the Public Understanding of Science program. This medium has proved to be especially effective in reaching new audiences. A notable example is STAR-DATE, a new series of nightly radio vignettes about astronomy, which is being aired by 306 radio stations and (in Spanish) as ASTROFECHA by another 26 stations. Trans World Airlines has recently begun including STAR-DATE as part of its in-

flight program for passengers, reaching another estimated 1.5 million listeners. The program is produced by the McDonald Observatory of the University of Texas, and includes suggestions for sky-watching, history of astronomy, skylore and news about astronomy research.

- To encourage more and better coverage of science by the daily and weekly press, the Public Understanding of Science program has supported a number of projects designed to provide scientific background information to journalists and editors. For example, the American Psychiatric Association conducted a briefing on new developments in mental health research for newspaper and magazine personnel. The briefings resulted in cover stories in both TIME and NEWSWEEK, as well as many newspaper articles throughout the country.
- The Ethics and Values in Science and Technology program supported several projects to analyze the ethical and value content and implications of techniques and procedures that are now widely used in attempting to deal with policy issues that involve scientific uncertainty and problems of estimating risk. For example, an interdisciplinary group at Clark University studies how equity issues enter into public decisions about technological developments, focusing on radioactive waste management. Interim and final results of this study have been shared with state and Federal agencies, legislative committees, and concerned citizen organizations, in addition to publication in the professional literature.
- Several projects to explore ethical issues in research on human subjects are being supported by the Ethics and Values in Science and Technology program. A group at Washington University (St. Louis) is conducting a study of the ethical problems encountered in the course of fieldwork in the social sciences, particularly anthropology. In a related context, Georgetown University sponsored a conference to examine approaches for resolving the ethical dilemmas found in biomedical research projects involving human subjects. The Federation of Organizations for Professional Women conducted a workshop to explore the ethical issues associated with the determination of priorities for research on human reproduction and to women in that determination.
- Public Service Science Residents supported by grants from the Science for Citizens program contributed their scientific and technical expertise to projects involving a wide diversity of host organizations, target audiences, and local and regional policy issues. These included a study of residential heating and energy conservation in New Hampshire, a mineral resources inventory of the Ft. Belknap Indian Reservation, research on urbanization and storm runoff drainage in San Antonio, and an analysis of Washington State tax policies.
- Forums, conferences, workshops, and planning studies supported by the Science for Citizens program have resulted in the contribution of scientific and technical understanding to the constructive analysis and discussion of important local and regional policy issues in a similarly wide range of communities and

on a diversity of topics. These include, for example, forestry management in Indiana, North Dakota, and Oregon; water and sewage management in Illinois and Washington; land use planning in New York; and alternative energy development in California, Hawaii, Maine and New Hampshire. Many of these activities also resulted in handbooks and other publications designed to assist citizens facing similar problems in other communities; for example, the Foundation for Urban and Neighborhood Development in Colorado prepared a booklet on *Citizen Participation in Mineral Development*, and the University of Illinois at Urbana published *A Handbook for Planning Community Education Programs* that is being used as a resource by comparable projects elsewhere.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The NSF Authorization Act for 1980 (P.L. 96-44) earmarked an amount, for the Ethics and Values in Science and Technology program, which was in excess of the budget request. Since additional funds over the budget request were not appropriated, adjustments were made to be responsive to Congressional intent. An additional $400,000 was allocated to this program with corresponding reductions made in the Science Education Development and Research subactivity ($300,000) and the Science and Society subactivity ($100,000).

FY 1981 Budget Highlights: Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$6,287,455
FY 1980 Program	$7,650,000
FY 1981 Request	$8,800,000
Difference—FY 1981/FY 1980	$1,150,000

Percentage changes between FY 1980 and FY 1981 for the Science and Society subactivity as a whole and for its constituent program elements are as follows.

Science and Society	15.0%
Public Understanding of Science	28.2%
Ethics & Values in Science and Technology	0.4%
Science for Citizens	2.1%

Almost all of the increase ($1,100,000) is requested for the Public Understanding of Science Program. This amount will be used primarily to augment support for science museums, and in particular for projects designed to strengthen outreach activities addressed to youth, minorities, amateur scientists, and other groups presently outside the regular flow of scientific and technical information. These activities will play an important part in the general thrust of the Science Education Directorate toward pro-

viding richer and more diverse experiences of science and technology for all citizens.

The remainder of the requested increase ($50,000) will be used to maintain the other two program activities at their FY 1980 levels.

Coordination and Relation to Other Federal Efforts

All three of the Science and Society programs use long-standing and increasingly successful mechanisms for relating their activities to those of other Federal agencies.

- The NSF's Ethics and Values in Science and Technology program and the Science, Technology and Human Values program of the National Endowment for the Humanities work in close collaboration on projects of interest to both agencies. This cooperation, which includes joint peer review and joint support for many projects, has been extended to the new individual awards suggested by the FY 1980 Senate Authorization Report No. 96-106.
- The Public Understanding of Science (PUOS) program works closely with comparable public education programs in such agencies as the Department of Energy, the Office of Education, the Smithsonian Institution, and the Corporation for Public Broadcasting. On the initiative of PUOS, an Important Notice was recently issued by the NSF and the National Endowments for the Arts and the Humanities announcing the inauguration of joint review arrangements and possible joint funding of projects of interest to all three agencies.
- The Science for Citizens program seeks to avoid duplication and to achieve reinforcement of its efforts by maintaining close liaison with a variety of other agencies also interested in community-based activities. These include, for example, the Department of Energy, the Department of Housing and Urban Development, the Department of Agriculture, the Environmental Protection Agency, and the Community Services Agency.

QUANTITATIVE PROGRAM DATA
OFFICE OF SCIENCE AND SOCIETY SUBACTIVITY

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Preliminary Proposals:			
Number of Proposals	783	865	965
Total Amount Proposed	$69,000,000	$93,000,000	$113,000,000
Average Amount Per Proposal	88,123	108,000	117,000
Formal Proposals:			
Number of Proposals	453	550	661
Total Amount Proposed	$27,544,480	$37,650,000	$48,250,000
Average Amount Per Proposal	60,805	68,000	73,000
Awards:			
Number of Awards	105	139	136
Total Amount Awarded	$6,287,455	$7,650,000	$8,800,000
Average Amount Per Award	59,883	55,000	65,000
Average Annual Amount	55,000	39,000	46,000
Average Award Duration (Months)	13	17	17
Total Number of Participants Supported	26	55	52

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	40	36	36
Other Non-Profit Organizations	42	47	47
Other	18	17	17

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$947,980	$1,018,200	$1,137,000
Other Staff Costs	1,113,980	1,204,200	1,412,000
Subtotal, Staff Costs	2,061,960	2,222,400	2,549,000
Expendable Supplies and Equipment	467,294	568,000	669,000
Other Project Direct Costs	2,270,311	2,855,900	3,432,000
Subtotal, Non-Staff Project Costs	2,737,605	3,423,900	$4,101,000
Total, Direct Costs	4,799,565	5,646,300	6,650,000
Indirect Costs	936,580	1,123,700	1,314,000
Participant Support Costs:			
Stipends and Other Personal Allowances	551,310	880,000	836,000
Total, Participant Support Costs	551,310	880,000	836,000
Grand Total	$6,287,455	$7,650,000	$8,800,000

Public Understanding of Science Program Element $5,000,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$3,435,088	$4,000,000	$3,900,000	$5,000,000	$1,100,000

Objectives and Description

The objectives of the Public Understanding of Science program are:

- To improve the scope and quality of public information about the scientific and technological content of major issues of public policy;
- To improve the quality and extent of the informal scientific experience of citizens (including children and adults), in order to provide greater public understanding of the principles and processes of science and technology and the ways in which they affect contemporary life;
- To improve the techniques of distribution and dissemination of information about science and technology to citizens; and
- To develop a better base of knowledge about public audiences and their needs for scientific information, and about the processes of public communication of science.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The Public Understanding of Science program supports projects that make use of the most cost-effective means of communication, particularly television and radio, the daily and weekly press, and museums of science and technology. Special emphasis is placed on reaching audiences that do not ordinarily have access to scientific and technical information, including minority groups, the rural population, senior citizens and the urban and rural poor.

The proposed increase of $1,100,000 (28.2%) over the current plan of $3,900,000 for the Public Understanding of Science program will permit greatly increased support for the activities of science museums. These institutions have grown rapidly in recent years in number, attendance, and importance in achieving the goals of the Science Education Directorate in the field of informal science education. However, their resources have not grown to a comparable extent, and the Foundation is the only agency with specific responsibility for assisting them to develop new programmatic activities. The proposed increase will be used in particular to support museum outreach projects focused on the needs and interests of early adolescents, minorities, women and other groups outside the normal flow of scientific and technical information.

QUANTITATIVE PROGRAM DATA
PUBLIC UNDERSTANDING OF SCIENCE PROGRAM ELEMENT

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Preliminary Proposals:			
Numbers of Proposals	231	265	340
Total Amount Proposed	$41,897,000	$50,350,000	$68,000,000
Average Amount Per Proposal	181,372	190,000	200,000
Formal Proposals:			
Number of Proposals	79	90	116
Total Amount Proposed	$9,320,000	$11,250,000	$17,400,000
Average Amount Per Proposal	117,974	125,000	150,000
Awards:			
Number of Awards	30	30	35
Total Amount Awarded	$3,435,088	$3,900,000	$5,000,000
Average Amount Per Award	114,503	130,000	142,857
Average Annual Amount	114,503	130,000	142,857
Average Award Duration (Months)	12	12	12
Total Number of Participants Supported	—0—	—0—	—0—

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	10	10	10
Other Non-Profit Organizations	90	90	90

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$298,000	$340,000	$433,000
Other Staff Costs	613,000	699,000	892,000
Subtotal, Staff Costs	911,000	1,039,000	1,325,000
Expendable Supplies and Equipment	285,000	325,000	414,000
Other Project Direct Costs	1,740,000	1,985,000	2,533,000
Subtotal, Non-Staff Project Costs	2,025,000	2,310,000	2,947,000
Total, Direct Costs	2,936,000	3,349,000	4,272,000
Indirect Costs	499,088	551,000	728,000
Grand Total	*$3,435,088	$3,900,000	$5,000,000

*In FY 1979 the Office of Education transferred an additional $1,500,000 and the National Library Information Service an additional $50,000 to supplement NSF awards. The total amount awarded, including these transfers, was $4,985,088, and the average annual amount per award was $166,000.

Ethics and Values in Science and Technology Program Element $1,700,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$1,259,144	$1,300,000	$1,693,000	$1,700,000	$7,000

Objectives and Description

The central objective of the Ethics and Values in Science and Technology program is to explore and analyze the ethical rules and social values that govern the conduct of science and technology, including the ethics and values that govern the selection of research priorities and the utilization of research results. Specific areas of concern to the program include ethical issues and value assumptions associated with:

- The education and professional conduct of scientists and engineers;
- The obligations and constraints imposed upon scientists and engineers and their organizations and institutions;
- New developments in science and technology and their utilization and applications; and
- Public and institutional decisionmaking processes involving science and technology.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The program supports: (a) research on ethical and value issues associated with current developments in science and technology; (b) projects to elucidate social processes that influence the conduct of science and technology; (c) national and international workshops and symposia, particularly those organized by professional scientific and engineering societies; and (d) activities to integrate ethical and value issues into the professional education of scientists and engineers.

As suggested in the FY 1980 Senate Authorization Report No. 96-106, a new activity was initiated in which the National Science Foundation and the National Endowment for the Humanities will give a number of awards to individual researchers for cross-disciplinary activities in these areas and to establish new bases for sustained activities in this field. The $400,000 increase in the Ethics and Values in Science and Technology budget for FY 1980 was allocated to these awards, which will be continued at the same level in FY 1981.

No significant change is requested in the Ethics and Values in Science and Technology budget estimates for FY 1981.

QUANTITATIVE PROGRAM DATA
ETHICS AND VALUES IN SCIENCE AND TECHNOLOGY PROGRAM ELEMENT

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Preliminary Proposals:			
Number of Proposals	200	250	275
Total Amount Proposed	$15,000,000	$20,000,000	$22,000,000
Average Amount Per Proposal	75,000	80,000	80,000
Formal Proposals:			
Number of standard proposals	87	90	100
Number of proposals for Interdisciplinary Incentive Awards and Sustained Development Awards	—0—	75	125
Total Number of Proposals	87	165	225
Total Amount Proposed	$6,986,000	$10,100,000	$13,800,000
Average Amount Per Proposal	80,299	61,000	61,000
Awards:			
Number of Awards	23	53	53
Total Amount Awarded	*$1,259,144	*$1,693,000	*$1,700,000
Average Amount Per Award	54,744	32,000	32,000
Average Annual Amount	44,000	15,000	15,000
Average Award Duration (Months)	15	26	26
Total Number of Participants Supported	—0—	30	30

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	96	78	78
Other Non-Profit Organizations	4	3	3
Other	—0—	19	19

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$324,980	$249,980	$250,000
Other Staff Costs	324,980	249,980	250,000
Subtotal, Staff Costs	649,960	499,960	499,960
Expendable Supplies and Equipment	42,294	40,000	40,000
Other Project Direct Costs	264,169	446,040	452,000
Subtotal, Non-Staff Project Costs	306,463	486,040	492,000
Total, Direct Costs	956,423	986,000	992,000
Indirect Costs	302,721	377,000	378,000
Participant Support Costs	—0—	—0—	—0—
Stipends and Other Personal Allowances	—0—	330,000	330,000
Total, Participant Support Costs	—0—	330,000	330,000
Grand Total	*$1,259,144	*$1,693,000	*$1,700,000

* In FY 1979 the National Endowment for the Humanities transferred approximately $460,000 to supplement NSF awards and it is expected that NEH will transfer approximately $800,000 during Fiscal Years 1980 and 1981. The total amount awarded, including these transfers, was approximately $1,719,000 in FY 1979 and is expected to be approximately $2,493,000 in FY 1980 and FY 1981; the average annual amount per award was $75,000 in FY 1979 and is expected to be approximately $47,000 in FY 1980 and FY 1981.

Science for Citizens Program Element $2,100,000

Obligations by Program Element

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$1,593,223	$2,100,000	$2,057,000	$2,100,000	$43,000

Objectives and Description

The Science for Citizens program (SFC) provides support for activities which

- encourage scientists to participate in public activities aimed at the resolution of local or regional policy issues with significant scientific and technological aspects, and
- provide scientific and technical expertise to citizens and citizen groups so they can better understand and participate in decisions on local or regional policy issues involving science and technology.

To develop these activities, SFC supports two kinds of efforts: those directed at considering specific problems and those directed at encouraging long-term, self-sustaining programs of activity. Support for the first kind of effort provides useful background and impetus for groups to go on to develop long-term programs. SFC currently supports four types of activities designed to achieve these goals:

- Public Service Science Residencies enable scientists and engineers to undertake applied research and public education projects in association with citizens groups, units of state and local government, and other non-profit community organizations.
- Forums, Conferences, and Workshops support community-based efforts to improve the scientific content and level of community discussion about particular issues of policy that involve science and technology.
- Planning Studies support community-based efforts to devise public service science centers, where on-going programs can be responsive to community needs for scientific information and advice on policy issues.
- Public Service Science Centers provide three years of support, on a continuing and matching basis, for community-based and community-wide mechanisms to initiate, expand, or coordinate public service science activities.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

The budget request of $2,100,000, unchanged from FY 1980, will maintain the program's shift in emphasis from supporting projects directed toward specific problems and short-term objectives to encouraging long-term self-sustaining programs. This strategy has greater potential for long-term impact and will provide models for other communities. To achieve this goal, SFC plans to support several new projects to establish Public Service Science Centers in FY 1981, as well the second year of activities of the Centers to which awards were made in FY 1980. This plan will necessitate decreasing the program's budgetary allocation to Public Service Science Residencies by about 17 percent, and to Forums, Conferences, Workshops and Planning Studies by about 11 percent, apart from the effect of inflation.

QUANTITATIVE PROGRAM DATA
SCIENCE FOR CITIZENS PROGRAM ELEMENT

Proposal and Award Summary

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Preliminary Proposals:			
Number of Proposals	352	350	350
Total Amount Proposed	$12,500,000	$22,500,000	$22,500,000
Average Amount Per Proposal	35,511	64,000	64,000
Formal Proposals:			
Number of Proposals for Forums, Conferences Workshops, and Planning Studies	94	70	70
Number of proposals for Public Service Science Centers	14	25	25
Number of Proposals for Public Service Science Residencies	179	200	225
Total Number of Proposals	287	295	320
Total Amount Proposed	$11,238,480	$16,300,000	$17,050,000
Average Amount Per Proposal	39,158	55,000	53,000
Awards:			
Number of Awards	52	56	48
Total Amount Awarded	$1,593,223	$2,057,000	$2,100,000
Average Amount Per Award	30,639	37,000	44,000
Average Annual Amount	34,000	32,000	38,000
Average Award Duration (Months)	11	14	14
Total Number of Participants Supported	26	25	22

Percentage Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	14	21	21
Other Non-Profit Organizations	34	49	49
Other	52	30	30

Personnel and Other Award Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Professional Staff Costs	$325,000	$428,250	$453,900
Other Staff Costs	176,000	255,200	270,500
Subtotal, Staff Costs	501,000	683,450	724,400
Expendable Supplies and Equipment	140,000	203,000	215,200
Other Project Direct Costs	266,142	424,900	446,900
Subtotal, Non-Staff Project Costs	406,142	627,900	662,100
Total, Direct Costs	907,142	1,311,350	1,386,500
Indirect Costs	134,771	195,650	207,500
Participant Support Costs:			
Stipends and Other Personal Allowances	551,310	550,000	506,000
Total Support Costs	551,310	550,000	506,000
Grand Total	$1,593,223	$2,057,000	$2,100,000

SPECIAL FOREIGN CURRENCY

PROGRAM ACTIVITY SUMMARY

FY 1981 PROGRAM TOTAL $5,500,000

Obligations by Subactivity

Page	Subactivity	Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
K-I	Research & Related Activities	$3,836,241	$4,900,000	$4,903,374	$4,400,000	$-503,374
K-II	Science Information	165,000	1,100,000	600,000	1,100,000	500,000
	Total	$4,001,241	$6,000,000	$5,503,374	$5,500,000	$-3,374

Goals and Description

The National Science Foundation supports science activities in Egypt, India and Pakistan utilizing U.S.-owned foreign currencies designated by the Department of the Treasury as excess to the requirements of the U.S. Government. In this way the National Science Foundation is able to support scientific activities of benefit to the United States and participating foreign countries without exporting dollars. The objectives of the overall activity are pursued chiefly through grants for research and related activities and contracts for the translation into English of technical literature from foreign languages. This activity supports:

- Participation by U.S. scientists and institutions in international cooperative science projects.
- Translations of scientific and technical literature.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The difference between the FY 1980 Budget Request and the FY 1980 Current Plan reflects a reduction of $500,000 made by the Congress in the FY 1980 NSF Appropriation Act. This reduction will be taken in the Science Information subactivity to phase out contract translation activities in Egypt where SFC reserves are being depleted. By FY 1981, it is expected that translation resources (current and new contract capabilities) in India and Pakistan will have been developed to handle the volume normally accommodated by the Egyptian contractors. In addition to the $5,500,000 appropriated in FY 1980 there is a carryover from FY 1979 in the amount of $3,374 to be used in the Research and Related Activities subactivity.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

Obligations

FY 1979 Actual	$4,001,241
FY 1980 Program	$5,503,374
FY 1981 Request	$5,500,000
Difference—FY 1981/FY 1980	$-3,374

The $5,500,000 requested for the Special Foreign Currency Program Activities is slightly less than the FY 1980 program of $5,503,374.

Percentage Changes in Subactivities

Research and Related Activities	-10%
Science Information	83%

In FY 1981, the Special Foreign Currency Program activities will provide excess currencies in the following dollar equivalents:

- Research and related activites in India and Pakistan ($4,200,000). This total will provide support for new and continuing cooperative research activities and travel for U.S. scientists to attend important scientific meetings abroad.
- Support of cooperative research activities in Egypt ($200,000). This amount representing a reduction of $500,000 from the FY 1980 level, is due to the depletion of SFC reserves in Egypt. Funds will be used to complete existing projects.
- Translations into English from foreign language scientific publications by contractors in India and Pakistan ($1,100,000); an increase of $500,000 to restore the overall program to the annual level of previous years. This is consistent with the recent White House initiatives on innovation highlighting enhancement of the transfer of information from other countries.

Coordination and Relationship to Other Efforts

NSF participates in an interagency working group on special foreign currency (SFC) matters and in the activities of Joint Commissions for Economic Cooperation, both coordinated by the Department of State. NSF has been assigned by Executive Order the responsibility for coordination and for meeting SFC translation requirements of all U.S. Government agencies and making those translations available through the National Technical Information Service of the Department of Commerce.

Evaluation and Oversight

The Research and Related Activities subactivity supports basic and applied research projects. Through peer review, joint meetings and editorial referees in the open literature, the mutuality of benefits and the quality of research are addressed on a continuing basis. Under the Science Information subactivity user scientists are sampled on a regular basis to assess the quality of the translations.

QUANTITATIVE PROGRAM DATA
SPECIAL FOREIGN CURRENCY ACTIVITY

Proposals and Awards

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Proposals:			
Number—Total	42	55	50
Total Dollars Proposed	$4,745,583	$6,225,000	$5,675,000
International Travel Support Applications:			
Number-Total	274	425	425
Total Dollar Support Requested	$568,885	$900,000	$900,000
Awards:[1]			
Number—Total	39	50	45
Dollars Awarded:			
Total Amount	$3,737,432	$5,023,374	$5,020,000
Average $ per Award	95,832	$100,467	$111,556
Average Award Duration (months)	18	18	18
International Travel Support:			
Total Number of Successful Applications	122	213	208
Dollar Support Provided:			
Total Amount	$263,809	$480,000	$480,000
Average $ per Successful Application	$2,162	$2,254	$2,308

Distribution of Funds Awarded by Performer

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Universities and Colleges	$1,591,492	$1,828,374	$2,600,000
Non-Profit Institutions	224,263	1,275,000	750,000
For-Profit Business and Industry	—0—	—0—	—0—
Federal Laboratories & Other USG Agencies	1,513,774	550,000	150,000
National Academy of Sciences & Professional Societies	37,250	850,000	500,000
Other[2]	634,462	1,000,000	1,500,000
Total	$4,001,241	$5,503,374	$5,500,000

Personnel and Other Factors

	Actual FY 1979	Estimate FY 1980	Estimate FY 1981
Scientists:			
Number Supported	41	55	45
Amount of Support	$199,155	$275,000	$225,000
Other Professionals:			
Number Supported	21	26	21
Amount of Support	$81,624	$105,000	$85,000
Graduate Students:			
Number Supported	37	48	43
Amount of Support	$61,145	$83,000	$75,000
Other Personnel Costs	87,690	115,000	95,000
Other Costs[3]	3,554,215	4,903,374	5,000,000
Indirect Costs	17,412	22,000	20,000
Total	$4,001,241	$5,503,374	$5,500,000

[1] Includes purchase orders and interagency agreements for programmatic work.
State and Local Governments, individuals, FFRDC's managed by any performer listed.
[3] Expendable equipment, publication, computer and other direct costs.

RESEARCH AND RELATED ACTIVITIES PROGRAM SUBACTIVITY $4,400,000

Obligations by Program Subactivity

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$3,836,241	$4,900,000	$4,903,374	$4,400,000	$-503,374

Objectives and Description

By using U.S.-owned excess foreign currency, the Research and Related Activities program supports performance of high quality scientific research and assists U.S. scientists and institutions in obtaining the benefits of participation in joint projects with scientists in Egypt, India, and Pakistan. In addition, the program supports foreign policy initiatives of the U.S. Government by financing activities conducted under the Joint Economic Commissions (for Egypt and India). Recent grants have supported collaborative scientific activities in chemistry, atmospheric sciences, remote sensing, engineering, physics, the social sciences, oceanography, and the life sciences. Several binational workshops have also been supported to examine specific areas of mutual research interest.

Significant Recent Achievements

- U.S. and Indian scientists have met in a binational workshop on oceanography, and have identified areas of research of mutual interest to both countries. These include the interaction between the monsoon and ocean circulation, biological productivity, material resources, and geo-oceanography. A number of joint research activities are being planned to broaden significantly U.S.-Indo scientific interaction in this important field.
- U.S. and Indian scientists participated in a major international study of the summer monsoon under the MONEX experiment. The U.S. effort included data collection from research aircraft, ocean vessels and a geostationary satellite positioned over the Indian Ocean. The data will extend scientific knowledge of the summer monsoon which affects weather and climate on a global scale. Several major reports are now in progress.
- U.S. and Pakistani scientists are collaborating on a study of enzymes responsible for DNA repair in various types of cell damage. The work has resulted in identification and isolation of two enzymes for such repair which may lead to improved understanding and control of the repair of damaged cells.

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Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The Current Plan is $3,374 more than the FY 1980 Budget Request of $4,900,000, due to a carryover from FY 1979.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

In FY 1981, the Research and Related Activities include:

- Support for joint activities in India ($3,200,000) to include cooperative research activities in oceanography, remote sensing, and earthquake engineering, and support for binational workshops and research in the basic science areas of physical, biological, mathematical and social sciences. Also included is support of attendance of U.S. scientists at significant scientific meetings in that country. These activities will be supported at essentially the same level as in FY 1980.
- Support of cooperative research projects in Egypt ($200,000). This is a reduction of $500,000 from the FY 1980 level due to the depletion of SFC reserves in Egypt. These minimal funds will be used exclusively to complete existing projects.
- Support for activities in Pakistan ($1,000,000), no increase over FY 1980 funds. This will provide support for new and continuing projects in water resources, geology, and biological sciences, and travel by U.S. scientists to attend important scientific meetings.

Coordination and Relationship to Other Efforts

NSF participates in several Joint Commission activities with Egypt and India to support U.S. foreign policy objectives and to enhance U.S. scientific opportunities. Excess currencies are utilized in support of overseas activities. Other NSF programs often provide dollars for those components of the joint projects which are to be performed in the United States. The Department of State coordinates overall U.S. Government SFC-funded science activities through an SFC interagency working group. NSF participates actively in this group and maintains contacts with other agencies to share information and avoid duplication of effort.

SCIENCE INFORMATION PROGRAM SUBACTIVITY $1,100,000

Obligations by Program Subactivity

Actual FY 1979	Budget Request FY 1980	Current Plan FY 1980	Estimate FY 1981	Difference FY 1981/80
$165,000	$1,100,000	$600,000	$1,100,000	$500,000

Objectives and Description

This subactivity provides translations of the results of foreign research and development which otherwise would not be available to the U.S. scientific and technical community. By Executive Order, the NSF has been assigned overall U.S. Government responsibility for the translation of scientific information. These translations are provided to some 30 participating U.S. Government agencies and the U.S. scientific community through the National Technical Information Service. The translations are primarily full-text translations of foreign scientific books and articles and compilations of specialized bibliographies and abstracts.

During FY 1979, a total of about 40,000 pages of original language material were translated, mainly from publications and reports in the life and engineering sciences. Almost half of the total was from Russian language scientific and technical information sources. The remaining material was mainly from German, French, Polish, Dutch, Japanese, Arabic and Italian sources.

Significant Recent Achievements

In addition to producing a number of works in physics, biology, chemistry and other basic sciences, a significantly expanded and revised edition of a major encyclopedia of antibiotics, *Antibiotics: Origin, Nature, and Properties*, was translated from Polish. This monumental work presents comprehensive information and data on over 1,300 groups of antibiotic substances, including their pharmacological and biological activity and physical and chemical structure. The work is of practical utility to chemists, biochemists, pharmacologists, and others engaged in research on antibiotics. The U.S. distributor of this work is the American Society for Microbiology.

Changes Between FY 1980 Budget Request and FY 1980 Current Plan

The Current Plan is $500,000 less than the FY 1980 Budget Request. Contract translation activities are being phased out in Egypt where special foreign currency reserves are being depleted. By FY 1981, it is expected that translation resources (current and new contract capabilities) in India and Pakistan will have been developed to handle the U.S. demand normally accommodated by the Egyptian contractors.

FY 1981 Budget Highlights and Explanation of Increases and Decreases

In FY 1981 the Science Information subactivity will include $1,100,000 to support the translation into Engligh of foreign language scientific publications. This increase of $500,000 will restore the translation program to the level of FY 1978, judged by NSF and other Federal agencies to provide a satisfactory level of translated scientific and technical publications, producing about 50,000 pages of translations.

Coordination and Relationship to Other Efforts

By Executive Order, NSF is responsibe for coordinating the use of special foreign currency for translation programs by all U.S. Government agencies. The funds requested support translation requirements of NSF and other U.S. agencies whose translation costs are paid by NSF. In addition, a few U.S. Government agencies transfer special foreign currency funds to NSF to pay for their own translations.

Support under this program complements translating activities conducted by commercial organizations and professional societies in the United States. Products of this program are made available to all U.S. agencies and the general public through the National Technical Information Service of the Department of Commerce.

INTRODUCTION

This report is produced annually to accompany the annual budget submission to the Congress and is reconciled with the official accounting records of the Foundation. The report reflects the number and dollar value of NSF program grants and contracts made in Fiscal Year 1979.

The report is divided into three principal sections, NSF Salaries and Expense, Research and Related Activities and Science Education Activities Appropriations, the NSF Special Foreign Currency Appropriations, and Fellowships. For the first section and Special Foreign Currency section, four subsections are provided: State, Federal Government, U.S. Possessions, and Foreign Countries. The detail in these sections and subsections is sequenced alphabetically by grantee or contractor name. A summary report also precedes each of the three sections.

The total number of awards and the total dollar amounts for each grantee or contractor are displayed, followed by a breakdown of these totals into groupings of NSF program activities. Fellowships are treated separately and the data reflect the total number of total dollar amounts awarded to institutions under this program, followed by the amounts payable to the individual Fellows for stipends or other allowances.

DEFINITIONS, EXCLUSIONS, AND INCLUSIONS

- Institutions listed in this report are "Parent" institutions as defined in the Federal institutional classification structure. Data pertaining to subordinate branches, campuses, or components (such as medical schools) are accumulated under the single parent institution total.

- "Other Grants and Contracts" refers to miscellaneous award such as purchase orders, travel authorizations, and grants to individuals (including International Travel Grants).

- This report excludes:

    - Transactions funded from Program Development and Management Funds.

    - Awards (or portions of awards) using funds transferred to NSF by other Federal agencies and Foreign Countries.

    - Administrative transactions such as extensions of project duration or amendments to modify grant or contract terms, which do not involve the obligations of FY79 funds.

FISCAL YEAR 1979

PROGRAM GRANTS AND CONTRACTS AWARDED

FROM

NSF SALARIES AND EXPENSES APPROPRIATION
RESEARCH AND RELATED ACTIVITIES APPROPRIATION
SCIENCE EDUCATION ACTIVITIES APPROPRIATION

SUMMARY (Amount in Thousands of Dollars)	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
ALABAMA	59	2,966	7	251			18	899	2	23	3	229	29	1,544
ALASKA	52	5,032			41	3,830	6	971				15	3	216
ARIZONA	188	22,798	45	2,796	64	16,943	48	1,640	8	103	10	669	13	647
ARKANSAS	31	1,496	6	307	1	123	7	218	1	1	4	390	12	457
CALIFORNIA	1,829	141,006	625	48,672	534	45,461	497	25,223	81	2,073	126	13,885	166	5,692
COLORADO	266	42,860	69	4,181	65	31,343	56	3,025	17	421	21	1,412	38	2,478
CONNECTICUT	254	11,326	74	3,559	34	1,495	93	4,306	15	580	9	689	29	696
DELAWARE	52	2,636	22	1,330	11	574	7	300	3	12	3	290	6	131
DISTRICT OF COLUMBIA	630	21,676	60	1,918	97	1,952	32	1,572	171	9,469	103	3,600	167	3,164
FLORIDA	286	17,784	66	3,331	88	9,369	65	2,678	10	436	10	887	27	1,102
GEORGIA	181	8,370	47	1,760	26	1,352	43	2,731	10	257	7	787	48	1,483
HAWAII	101	5,579	16	448	50	3,868	28	1,098	1	16	1	65	5	104
IDAHO	16	480	2	65			4	253			1	62	9	99
ILLINOIS	738	42,652	310	22,173	89	5,154	192	8,099	34	885	32	3,011	81	3,331
INDIANA	315	18,179	155	11,713	14	542	68	2,993	17	216	12	1,149	49	1,568
IOWA	118	5,021	45	1,767	9	370	31	1,387	0	38	2	234	25	1,225
KANSAS	90	2,903	29	1,138	8	241	21	735	7	18	2	152	23	619
KENTUCKY	71	2,643	18	640	1	8	10	614	3	3	11	924	28	454

SUMMARY (Amount in Thousands of Dollars)	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
LOUISIANA	96	3,069	39	1,277	7	196	9	317	10	139	3	136	28	1,003
MAINE	46	2,012	4	199	12	620	13	787	1	60	3	156	13	190
MARYLAND	455	16,004	108	6,430	51	2,556	60	2,960	77	1,206	44	1,483	115	1,368
MASSACHUSETTS	963	70,389	296	24,287	218	20,362	287	15,190	30	1,045	68	6,800	64	2,705
MICHIGAN	430	24,272	160	11,049	39	1,870	140	7,483	16	412	13	1,177	62	2,281
MINNESOTA	202	9,103	79	3,453	25	1,354	49	2,312	8	34	6	661	35	1,289
MISSISSIPPI	44	1,629	6	206	1	31	4	270	1	2			32	1,119
MISSOURI	186	8,134	65	2,251	24	1,242	73	2,996	10	101	6	463	28	1,082
MONTANA	30	1,619	8	931	1	23	7	290	1	1	3	209	10	166
NEBRASKA	54	3,302	15	1,229	6	1,201	10	331	2	36	2	179	19	327
NEVADA	19	1,176	5	153	8	673	4	267				30	2	53
NEW HAMPSHIRE	55	1,942	13	533	16	566	9	513	1	1	2	75	14	255
NEW JERSEY	256	14,807	136	9,257	22	870	37	2,155	8	340	6	601	47	1,584
NEW MEXICO	67	7,113	9	339	19	2,154	18	859	2	3	7	804	12	2,954
NEW YORK	1,335	91,994	464	41,351	189	17,494	373	17,161	74	1,880	60	6,435	175	7,672
NORTH CAROLINA	263	12,029	77	3,291	20	1,414	89	4,334	13	337	13	870	51	1,763
NORTH DAKOTA	24	668	5	121	1	39	3	235	5	5	2	163	8	104
OHIO	365	14,318	136	6,448	33	1,134	80	3,366	24	709	14	1,262	78	1,400
OKLAHOMA	68	2,380	17	499	12	482	14	501	2	71	3	328	20	499

SUMMARY (Amount in Thousands of Dollars)	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
OREGON	199	11,859	48	2,110	60	5,138	51	2,889	4	145	4	400	32	1,157
PENNSYLVANIA	650	34,769	239	17,501	61	2,845	157	7,021	58	1,754	38	2,927	97	2,719
RHODE ISLAND	167	12,134	73	4,896	46	5,310	22	1,028	6	22	5	625	15	253
SOUTH CAROLINA	76	2,854	20	805	12	322	16	808	2	129	4	273	22	517
SOUTH DAKOTA	14	597	2	63	2	213	1	50	1	27	1	125	7	119
TENNESSEE	120	5,758	32	1,799	6	110	34	2,623	4	103		75	44	1,028
TEXAS	463	22,549	138	6,616	87	6,080	139	5,006	27	405	17	1,174	85	3,269
UTAH	129	6,284	46	2,523	14	705	22	1,495	7	58	7	766	13	736
VERMONT	22	717	3	116	3	75	5	148					11	378
VIRGINIA	378	9,822	85	3,536	33	1,187	59	2,174	70	252	57	1,137	74	1,535
WASHINGTON	302	16,922	74	4,149	88	6,359	76	3,708	14	72	16	1,304	34	1,330
WEST VIRGINIA	29	23,678	5	147	7	22,756	2	125	1	23	5	217	9	410
WISCONSIN	318	18,074	110	6,494	43	2,477	105	6,661	10	64	9	1,241	41	1,137
WYOMING	27	1,455			16	1,000	5	262	1		1	116	4	76
UNITED STATES TOTAL	5,089	838,779	4,093	270,113	2,114	231,443	3,171	155,087	876	23,989	776	60,663	2,059	67,485
FEDERAL GOVERNMENT TOTAL	93	41,567	7	647	47	37,650	5	150	23	1,482	11	1,639		
U.S. POSSESSIONS TOTAL	40	6,215	5	210	4	4,801							31	1,203
FOREIGN COUNTRIES TOTAL	18	652			13	610	2	37	2	1			1	4
GRAND TOTAL	5,240	857,213	4,105	270,970	2,178	274,505	3,178	155,274	901	25,472	787	62,302	2,091	68,692

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
ALABAMA														
ALABAMA A & M UNIVERSITY	5	394,784											5	394,784
AUBURN UNIVERSITY	7	260,940	4	149,281						15,000	1	64,459	2	32,200
BIRMINGHAM SOUTHERN COL	1	22,329											1	22,329
JEFFERSON ST JR COL	1	5,000											1	5,000
JOHN C CALHOUN ST CMTY C	1	242,346											1	242,346
NORTHWEST ALA ST JR COL	1	5,169											1	5,169
S D BISHOP ST JR COLLEGE	2	153,983											2	153,983
SELMA UNIV	1	21,500											1	21,500
SOUTHERN RESEARCH INST	1	105,819									1	105,819		
TALLADEGA COL	5	280,709											5	280,709
TROY ST U AT MONTGOMERY	1	176,731											1	176,731
TUSKEGEE INSTITUTE	3	90,179					1	79,099					2	11,080
U OF ALA IN HUNTSVILLE	2	37,389							1	7,394			1	29,995
UNIV OF MONTEVALLO	1	31,850											1	31,850
UNIV OF SOUTH ALA	3	108,552					3	108,552						
UNIVERSITY OF ALABAMA	23	965,349	3	102,185			14	711,075			1	58,788	5	93,301
OTHER GRANTS & CONTRACTS	5	43,650							1	1,053			2	42,577
STATE TOTAL		2,948,259		251,466				898,726		23,447		229,066		1,545,554
		59		7				18		2		3		29
ALASKA														
UNIV OF ALASKA ANCHORAGE	1	44,500											1	44,500
UNIV OF ALASKA FAIRBANKS	51	4,987,183			41	3,829,795	6	971,243				15,000	2	171,147
STATE TOTAL		5,031,683				3,829,795		971,243				15,000		215,647
		52				41		6						3

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
ARIZONA														
AMERIND FOUND INC	1	69,698					1	69,698						
ARIZONA STATE UNIVERSITY	37	1,864,258	12	856,310	7	409,074	13	392,171	2	27,790	1	148,866	2	30,045
CERRO TOLOLO INT-AM OBSER	3	4,350,000			3	4,350,000								
COLLEGE OF GANADO	1	10,219											1	10,219
GREAT WESTERN RES INC	1	22,991									1	22,991		
KITT PEAK NAT OBSERVATORY	4	9,701,200			4	9,701,200								
LOWELL OBSERVATORY	6	266,400			6	266,400								
MOHAVE COMMUNITY COLLEGE	1	4,260											1	4,260
MUSEUM OF NORTHERN ARIZ	6	94,423			1	12,764	5	81,659						
NORTHERN ARIZ UNIV	5	501,659	1	12,451			1	26,351					3	262,857
PIMA COMMUNITY COLLEGE	2	233,655											2	233,655
SCOTTSDALE CMTY COLLEGE	1	23,800											1	23,800
SPIN & SPACE SYSTEMS INC	1	24,225									1	24,225		
UNIVERSITY OF ARIZONA	110	5,826,737	32	1,927,384	38	2,202,396	28	1,069,910	2	71,990	7	473,379	3	81,678
OTHER GRANTS & CONTRACTS	9	4,475			5	1,347			4	3,128				
STATE TOTAL		22,798,000		2,796,145		16,943,181		1,639,789		102,908		669,463		646,514
		188		45		64		48		8		10		13
ARKANSAS														
ARKANSAS GENERAL ASSEMBLY	1	61,000									1	61,000		
ARKANSAS OFF OF ATTY GEN	1	54,000									1	54,000		
HENDERSON STATE UNIV	1	8,870											1	8,870
U-ARKANSAS FAYETTEVILLE	17	683,642	6	307,448	1	123,000	4	104,484			2	274,982	4	71,498
U-ARKANSAS LITTLE ROCK	5	111,054											5	111,054
U-ARKANSAS MED SCIS CAM	4	130,495					3	113,395					1	17,100
U-ARKANSAS MONTICELLO	1	248,712											1	248,712
OTHER GRANTS & CONTRACTS	1	646							1	646				

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
ARKANSAS														
STATE TOTAL		1,496,191		307,446		123,000		217,879		648		389,962		457,254
		31		6		1		7		1		4		12
CALIFORNIA														
AIDC	1	462,786									1	462,786		
ADVANCED RES &APPLIC CORP	1	24,993									1	24,993		
AEROSPACE CORPORATION	4	236,346	2	99,946	2	136,400								
AGHAJANIAN ASSOCIATES	2	228,235									2	228,235		
AMER SOC OF ZOOLOGISTS	6	31,963					6	31,963						
AMFX SYSTEMS INC	1	24,031									1	24,031		
AVCO ENGINEERS INC	2	286,685									2	286,685		
AVER BIOSCIENCE DESIGN	1	123,371									1	123,371		
APPLIED TECHNOLOGY COUNCL	1	88,532									1	88,532		
ASSN OF BAY AREA GOVT	1	50,000									1	50,000		
BOTANICAL SOC OF AMERICA	1	26,440					1	26,440						
BUILDING SYSTEMS DEV INC	1	187,304									1	187,304		
CA ST U-DOMINGUEZ HILLS	3	12,828					1	8,200					2	4,628
CAL ACAD OF SCIENCES	7	235,917					7	235,917						
CAL ARBORETUM FDN	2	209,881									2	209,881		
CAL PUB INTEREST RES GRP	1	73,410											1	73,410
CAL RECOVERY SYSTEMS INC	1	19,599									1	19,599		
CAL ST COL AT BAKERSFIELD	2	19,406											2	19,406
CAL ST COL SAN BERNARDINO	1	10,507											1	10,507
CAL ST U SAN LUIS OBISPO	5	77,834			1	28,800					1	30,000	1	19,034
CALIF ST POLY UNIV POMONA	3	48,581											3	48,581
CALIF ST UNIV CHICO	5	94,490			1	18,130	1	21,000				10,000	3	45,360
CALIF ST UNIV FULLERTON	9	219,142	1	42,400	1	7,000	1	52,720			1	25,580	4	91,442

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
CALIFORNIA														
CALIF ST UNIV HAYWARD	1	49,975					1	49,975						
CALIF ST UNIV LONG BEACH	6	131,286	1	19,400		18,809	2	48,810					3	44,269
CALIF ST UNIV LOS ANGELES	3	125,553	2	96,100			1	29,453						
CALIF ST UNIV NORTHRIDGE	4	222,246											4	222,246
CALIF ST UNIV SACRAMENTO	1	19,395											1	19,395
CALIFORNIA INST OF TECH	115	11,802,085	51	5,532,740	34	4,119,645	24	1,184,591			5	945,109	1	20,000
CITY OF HOPE NATL MED CTR	3	164,999					2	75,000			1	89,999		
CLAREMONT GRADUATE SCHOOL	2	25,587	2	25,587										
COMPASS SYSTEMS INC	1	156,600			1	156,600								
COMPUTECH	1	104,598									1	104,598		
CTR ADV STUDY BEHAV SCI	1	500,000					1	500,000						
CTR FOR STUDY COMM COLLS	1	10,000											1	10,000
DALE R HEIEN CO	1	31,678									1	31,678		
DYNAMICS TECHNOLOGY INC	1	125,719									1	125,719		
EARTHQUAKE ENG RES INST	3	224,945									3	224,945		
ECOENERGETICS INC	1	24,696									1	24,696		
ECONOMICS RES ASSOCIATES	1	12,969									1	12,969		
EDP AUDITORS FND EDUCRES	1	12,061	1	12,061										
EMTECH ENGINEERING INC	1	24,691									1	24,691		
ESTELLE DOHENY EYE FDN	1	11,225					1	11,225						
FAR WEST LAB ED RES & DEV	1	764											1	764
FIELDING INSTITUTE	1	7,720											1	7,720
FOOTHILL COL	1	24,966											1	24,966
FRESNO CITY COL	1	84,087											1	84,087
FUGRO INC	1	169,554									1	169,554		
GLASS & CERAMICS INTL INC	1	24,996									1	24,996		
GOLDEN WEST COLLEGE	1	11,344											1	11,344

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
CALIFORNIA														
HARVEY MUDD COL	6	400,754					1	35,300	1	51,623	1	30,351	3	283,480
HIGHER EDUC RES INST INC	1	123,093							1	123,093				
HOLMES AND NARVER INC	6	9,048,385			6	9,048,385								
HOPKINS-SEA WORLD RES INST	1	38,413			1	38,413								
HUGHES RES LABORATORIES	1	2,600	1	2,600										
HUMBOLDT STATE UNIVERSITY	6	150,336			2	25,290	1	74,264	2	18,232			1	32,550
INFOMEDIA CORPORATION	1	41,704	1	41,704										
INSTS OF MEDICAL SCIENCES	3	306,204	1	83,996			1	38,000			1	184,208		
INTEGRATED SCIENCES CORP	1	118,801									1	118,801		
J G BOUWKAMP INC	1	106,339									1	106,339		
JACK R BENJAMIN ASSOC INC	1	34,886									1	34,886		
JET PROPULSION LABORATORY	2	23,262	1	20,262	1	3,000								
JOHN A. BLUME & ASSOCIATES	2	203,790									2	203,790		
K M NURSERY INC	1	24,724									1	24,724		
KQED/COMM TELEV OF SO CAL	1	14,438											1	14,438
L A CNTY MUS NAT HIST	3	103,620					3	103,620						
LAWRENCE BERKLEY LAB	3	747,346	3	747,346										
LIQUID CHEMICAL CO INC	1	25,000									1	25,000		
LOCKHEED MIS & SPA CO INC	3	292,909	1	96,530	2	196,379								
LOS ANGELES CITY COL	2	38,217											2	38,217
LOS ANGELES PIERCE COL	1	4,946											1	4,946
LUTECH INC	1	25,000									1	25,000		
MACHINE INTELLIGENCE CORP	1	25,000									1	25,000		
MERRITT COL	1	20,000											1	20,000
MILLS COL	1	24,731											1	24,731
MT ST MARYS COL	1	58,080											1	58,080
NAVAL POSTGRADUATE SCHOOL	8	197,151	6	124,651	2	72,500								

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GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
CALIFORNIA														
NEUSHUL MARICULTURE INC	1	335,207									1	335,207		
OCCIDENTAL COL	3	27,066	1	4,000									2	23,066
PITZER COL	1	32,460					1	32,460						
POINT LOMA College	1	7,079											1	7,079
POINT REYES BIRD OBSERV	2	36,860			2	36,860								
POMONA COL	5	41,978	1	25,529							1	4,500	1	11,950
RANCHO SANTA ANA DOT GDN	1	10,065					1	10,065						
RANCHO SANTIAGO CC SYS OF	1	45,493											1	45,493
RAND CORPORATION	1	54,262					1	54,262						
ROCKWELL INTERNATIONAL	4	345,761	3	285,861	1	59,900								
S BARBARA MUS OF NAT HIST	1	5,065					1	5,065						
SADDLEBACK COMM COLLEGE	1	2,700											1	2,700
SALK INST FOR BIOL STUD	3	237,409					3	237,409						
SAN DIEGO SOC NAT HISTORY	3	85,578			1	28,438	2	57,140						
SAN DIEGO ST UNIVERSITY	14	746,707			3	120,038	6	441,910		10,220			5	174,539
SAN FRANCISCO STATE U	9	584,922			2	118,900	4	147,304					3	318,718
SAN JOSE STATE UNIVERSITY	7	271,470	2	11,746	3	177,797					1	30,000	1	31,927
SCIENCE APPLICATIONS INC	2	104,910			1	65,100							1	39,810
SCIENCE ENG ASSOCIATES	1	198,360									1	198,360		
SCRIPPS CLINIC & RES FDN	4	138,081					4	138,081						
SIERRA GEOPHYSICS INC	1	39,939			1	39,939								
SNAZELLE FILMS INC	1	50,968									1	50,968		
SO CAL COASTAL WATER RES	1	165,100									1	165,100		
SOUTHWEST INNOVATION GRP	1	250,000									1	250,000		
SPEECH COMMUN RES LAB INC	1	69,137					1	69,137						
SRI INTERNATIONAL	30	3,277,531	11	820,245	7	1,029,245			4	558,391	7	850,450	1	19,200
STANFORD UNIV	184	22,006,130	111	16,386,765	19	1,340,375	45	2,991,302	2	210,217	2	462,000	5	615,499

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
CALIFORNIA														
STEARNS, COVRAD & SCHMIDT	1	1,542									1	1,542		
SYSTEMS CONTROL INC	2	86,203	1	84,344					1	1,859				
TELESENSORY SYSTEMS INC	2	180,760									2	180,760		
THE EXPLORATORIUM	1	366,409											1	366,409
THE WRIGHT INSTITUTE	2	67,097					2	67,097						
TYMSHARE	1	84,484							1	84,484				
UNIV OF CAL SANTA BARBARA	81	3,468,466	37	1,789,810	22	979,771	18	616,609			2	32,817	2	49,459
UNIV OF CAL-SAN FRANCISCO	29	1,640,977	2	134,050	1	61,708	24	1,297,681	1	39,988	1	107,550		
UNIV OF CALIF-BERKELEY	270	18,606,316	124	7,879,624	24	2,360,300	92	4,549,121	3	165,735	17	2,625,247	10	1,026,291
UNIV OF CALIF-DAVIS	89	4,921,268	26	1,221,565	7	335,866	46	2,435,617	2	18,106	4	830,122	4	79,992
UNIV OF CALIF-IRVINE	60	3,657,039	25	1,618,899	4	168,849	24	1,307,396	1	13,860	5	291,585	5	256,450
UNIV OF CALIF-LOS ANGELES	191	10,716,725	83	4,738,023	34	2,217,415	58	2,402,290	7	543,875	6	744,546	3	70,576
UNIV OF CALIF-RIVERSIDE	42	2,311,955	13	349,957	2	157,589	20	1,164,851	1	5,985	4	594,693	2	38,900
UNIV OF CALIF-SAN DIEGO	219	27,704,246	51	3,357,214	4	20,231,035	56	2,923,142	1	8,844	4	1,093,921	3	90,090
UNIV OF CALIF-SANTA CRUZ	37	1,917,199	7	346,532	16	804,886	10	532,035				20,000	4	213,746
UNIV OF SAN FRANCISCO	2	51,773					2	51,773						
UNIV OF SOUTHERN CALIF	90	5,522,746	44	2,508,082	14	1,154,955	20	1,062,895	1	93,176	4	555,160	7	148,480
UNIVERSITY OF SAN DIEGO	1	12,000											1	12,000
UNIVERSITY OF SANTA CLARA	4	60,030							1	29,833			3	30,197
WILLIAM SPANGLE & ASSOC	1	21,300									1	21,300		
WOODWARD-CLYDE CONSULTS	3	125,356			2	65,741					1	59,615		
ZOECON CORPORATION	1	102,000					1	102,000						
OTHER GRANTS & CONTRACTS	146	1,111,640	11	144,053	10	37,012			31	95,397	16	46,821	58	788,357
STATE TOTAL		141,006,296		48,671,563		45,461,086		25,223,120		2,072,918		13,885,110		5,692,499
		1,829		625		334		497		81		126		166

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
COLORADO														
ARAPAHOE COMMUNITY COLL	1	24,322											1	24,322
ASPEN CENTER FOR PHYSICS	3	92,350	3	92,350										
ASPEN INST OF HUM STUDIES	1	161,500											1	161,500
BIOL SCI CURICULM STDY CO	2	730,649											2	730,649
COLO COALITN FULL EMPLMT	1	51,410											1	51,410
COLORADO COLLEGE	2	31,740			2	31,740								
COLORADO SCHOOL OF MINES	9	321,811	4	218,395	3	67,700	1	15,722					1	19,994
COLORADO STATE UNIVERSITY	70	5,113,827	23	1,148,899	17	1,353,255	11	1,301,796	6	225,722	4	617,767	9	463,388
COLORADO, OFFICE OF GOV	1	82,504									1	82,504		
HAZEN RESEARCH INC	1	24,600									1	24,600		
NAT CTR FOR ATMOS RES	6	28,039,579			6	28,039,579								
NAT JEWISH HOSP & RES CTR	1	90,000					1	90,000						
NATL CTR HI EDUC MGMT SYS	1	73,664							1	73,664				
ROCKY MTN BIOL LAB	3	138,438					3	138,438						
ROCKY MTN MATH CONSORTIUM	1	12,115	1	12,115										
SOC SCI EDUC CONSORTIUM	2	274,963											2	274,963
TRINIDAD STATE JR COL	1	1,200											1	1,200
UNIV COLORADO AT BOULDER	105	5,459,094	35	2,419,010	25	1,181,984	31	1,067,783	2	112,531	5	415,145	7	262,641
UNIV OF COLO AT DENVER	6	320,561			1	20,000					1	29,960	4	270,601
UNIV OF COLO HLTH SCI CTR	6	341,673					6	341,673						
UNIV OF NORTHERN COLORADO	5	31,153					1	1,293					2	29,860
UNIVERSITY OF DENVER	18	1,145,506	3	290,596	10	648,262	2	68,666			1	37,811	2	100,173
VIBRASOUND RESEARCH CORP	1	24,815									1	24,815		
WASTE & LAND SYSTEMS INC	1	25,000									1	25,000		
YEGGE, HALL & EVANS	1	150,345									1	150,345		
OTHER GRANTS & CONTRACTS	19	100,276			1	260			4	9,291	5	5,834	5	86,891
STATE TOTAL		42,660,097		4,181,365		31,342,780		3,025,371		421,208		1,411,781		2,477,592
		266		69		65		56		17		21		38

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
CONNECTICUT														
ARI COOP EDUC SERVICES	1	20,900											1	20,900
CENTRAL CONN ST COL	1	92,870											1	92,870
CONN AGR EXP STATION	1	35,400					1	35,400						
CONNECTICUT COLLEGE	1	3,603											1	3,603
COOPER AND COMPANY	1	98,700											1	98,700
CTR FOR ENVIRNMENT & MAN	7	404,816			7	404,816								
EASTERN CONN STATE COL	1	3,000					1	3,000						
FAIRFIELD UNIV	1	6,257											1	6,257
FUTURES GROUP	2	266,485							1	76,975	1	189,510		
HARTFORD PUBLIC SCHOOLS	1	25,770											1	25,770
HASKINS LABORATORIES INC	2	307,124					2	197,649		109,475				
INSTITUTE FOR THE FUTURE	2	175,174	2	175,174										
JOINT COMM ON LEGIS MGMT	1	25,000									1	25,000		
NEIGHBORHOOD HOUSING INC	1	47,200											1	47,200
SOC OF GENERAL PHYSIOL	1	4,500					1	4,500						
ST JOSEPH COL	2	23,773											2	20,773
TRINITY COL	2	47,867	1	29,960									1	17,907
UNIVERSITY OF BRIDGEPORT	1	20,239											1	20,239
UNIVERSITY OF CONNECTICUT	44	1,381,202	16	645,455	2	56,382	22	1,033,664	3	50,746		75,000	1	19,957
UNIVERSITY OF HARTFORD	3	91,943											3	91,943
UNIVERSITY OF NEW HAVEN	1	31,920											1	31,920
WESLEYAN UNIV	13	404,562	4	173,971	2	56,100	3	85,584	1	50,812			3	58,095
YALE UNIVERSITY	143	7,182,901	51	2,534,325	23	977,842	63	2,946,182	1	291,988	4	399,391	1	33,173
OTHER GRANTS & CONTRACTS	21	127,894							9	20,492	3	357	9	107,045
STATE TOTAL		11,326,102		3,558,883		1,495,142		4,305,979		580,488		689,258		696,352
		254		74		34		93		15		9		29

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
DELAWARE														
DELAWARE GEVERAL ASSEMBLY	1	30,000									1	30,000		
H F DUPONT WINTERTHUR MUS	1	70,653									1	70,653		
SYM ENVIR BIOGEOCHEM INC	1	10,700							1	10,700				
UNIVERSITY OF DELAWARE	46	2,509,817	22	1,329,629	11	573,598	7	299,859			1	189,661	5	117,070
OTHER GRANTS & CONTRACTS	3	14,911							2	1,351			1	13,560
STATE TOTAL		2,636,081		1,329,629		573,598		299,859		12,051		290,314		130,630
		52		22		11		7		3		3		6
DISTRICT OF COLUMBIA														
AMER ANTHROPOL ASSOC	1	10,000							1	10,000				
AMER ASSN COMM & JR COLS	1	800											1	800
AMER ASSOC FOR ADVT SCI	7	371,806							2	35,240	2	182,409	3	154,157
AMER COUNCIL ON EDUCATION	2	177,911							1	77,275			1	100,636
AMER GEOPHYSICAL UNION	6	167,093	1	15,093	4	89,000			1	63,000				
AMER INST OF ARCHITECTS	1	194,696									1	194,696		
AMER POLITICAL SCI ASSOC	2	17,132					1	332	1	16,800				
AMER PSYCHOLOGICAL ASSOC	1	10,800							1	10,800				
AMER SOC FOR ENG ED	1	226,200											1	226,200
AMER SOC FOR MICROBIOLOGY	1	250,000							1	250,000				
AMER STATISTICAL ASSOC	2	433,045					1	420,445	1	12,600				
AMERICAN CHEMICAL SOC	2	195,571							1	165,310			1	30,261
AMERICAN ENTERPRISE INST	1	70,891					1	70,891						
AMERICAN UNIVERSITY	5	349,221	3	253,774			1	75,757					1	19,690
ASSN OF SCI TECH CTRS	3	156,510											3	156,510
ASSOC OF AMER GEOGRAPHERS	4	111,215					3	72,881	1	26,820		11,514		
ASSOC OF AMERICAN UNIV	2	151,684							2	151,684				
ASSOC SUPVSCURRICULUM DEV	1	29,491											1	29,491

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GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
DISTRICT OF COLUMBIA														
ASSOC UNIV INC	1	19,684											1	19,684
BROOKINGS INSTITUTION	1	258,513					1	63,580				194,933		
CARNEGIE INST OF WASH	16	860,503			13	692,800	3	167,703						
CATHOLIC UNIV OF AMERICA	12	380,189	9	292,650	1	30,500	1	8,034					1	49,005
CITIZENS COMMUNCTNS CTR	1	15,000									1	15,000		
CONEG POLICY RES CTR INC	1	109,200									1	109,200		
CONF BD OF THE MATH SCI	2	116,085	1	98,285					1	17,800				
COUNCIL INTL URBN LIAISON	1	37,500									1	37,500		
COURTESY TRAVEL SERVICE	2	900,000							2	900,000				
ECONOMIC ASSOCIATES INC	1	54,500							1	54,500				
FED OF ORGAN-PROF WOMEN	1	38,253											1	38,253
GALLAUDET COL	2	38,384					2	38,384						
GEORGE WASHINGTON UNIV	22	1,037,830	7	382,642	1	13,100	5	201,262	4	190,225	2	183,608	3	66,993
GEORGETOWN UNIVERSITY	11	420,990	2	110,666			7	281,464					2	28,860
HAROLD F WISE, OFFICE OF	1	195,974									1	195,974		
HOWARD UNIVERSITY	13	529,250	3	101,000	1	49,900	2	86,417			1	18,501	6	273,432
IMAGE ASSOCIATES	1	3,000									1	3,000		
INST LOCAL SELF-RELIANCE	1	45,945									1	45,945		
INTL CITY MANAGEMENT ASSN	3	288,185									3	288,185		
LABOR INST HUMAN ENRICH	1	59,110											1	59,110
MATH ASSOC OF AMER	1	133,186											1	133,186
MOSHMAN ASSOCIATES INC	3	215,891							3	215,891				
MUNICIPAL FIN OFF ASSN	1	30,655									1	30,655		
NAT ACAD OF SCIENCES	56	8,615,509	9	607,479	16	972,090	1	20,000	23	6,685,202	4	195,250	3	135,488
NAT PLANNING ASSOC	1	58,466							1	58,466				
NAT SCIENCE TCHRS ASSOC	1	2,205											1	2,205
NATIONAL GOVERNORS' ASSN	3	245,250									3	245,250		

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
DISTRICT OF COLUMBIA														
NATL ASSN ED OPPOR HI ED	1	9,964											1	9,964
NATL ASSN OF COUNTIES	1	74,375									1	74,375		
NATL CEN FOR RESRC RC INC	1	19,200											1	19,200
NATL WILDLIFE FEDERATION	1	286,200											1	286,200
NTL ASSOC EDUC BRDCASTRS	1	9,250											1	9,250
PUBLIC BROADCASTING SERV	1	200,000											1	200,000
PUBLIC INTEREST EC CENTER	1	6,170											1	6,170
PUBLIC TECHNOLOGY INC	4	901,393									4	901,393		
RESOURCES FOR FUTURE INC	3	219,882					2	64,470					1	155,412
SCIENCE PROGRAM GROUP INC	2	83,987							1	66,666			1	17,321
SCIENTIFIC MANPOWER COMM	1	38,825											1	38,825
SCRIPTA TECHNICA INC	1	4,800			1	4,800								
STERLING MOSE CORP	1	38,487							1	38,487				
U OF DC-MT VERNON SQ CAMP	2	37,000											2	37,000
U S CONFERENCE OF MAYORS	2	149,563									2	149,563		
URBAN INSTITUTE	4	335,844									4	335,844		
OTHER GRANTS & CONTRACTS	400	1,627,302	25	56,470	60	99,574	1	675	21	422,567	69	187,704	24	860,312
STATE TOTAL		21,675,565		1,918,059		1,951,764		1,572,295		9,469,333		3,600,499		3,163,615
		630		60		97		32		171		103		167
FLORIDA														
BETHUNE-COOKMAN COL	2	111,383											2	111,383
BISCAYNE COLLEGE	1	19,943											1	19,943
ECKERD COLLEGE	1	37,201					1	37,201						
EDWARD WATERS COL	1	243,766											1	243,766
FAIRCHILD TROPICAL GARDEN	3	82,392					3	82,392						
FLA INTERNATIONAL UNIV	1	18,518	1	18,518										

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
FLORIDA														
FLORIDA A&M UNIVERSITY	2	46,680	1	45,000									1	1,680
FLORIDA ATLANTIC UNIV	4	106,788	1	38,964	1	35,500	1	9,395					1	22,929
FLORIDA INST OF TECH	4	314,915			1	23,800	1	21,600			1	43,350	1	226,165
FLORIDA STATE UNIV	58	3,198,982	16	922,916	17	1,139,823	22	952,514					3	183,729
HILLSBOROUGH CNTY COLLEGE	1	6,900											1	6,900
JACKSONVILLE UNIV	1	35,642											1	35,642
MARIE SELBY BOTAN GARDENS	1	40,600							1	40,600				
MOTE MARINE LAB	1	11,000					1	11,000						
NOVA UNIVERSITY	8	320,749			8	320,749								
PAPANICOLAOU CAN RES INST	1	35,000					1	35,000						
TALL TIMBERS RES INC	2	136,024					2	136,024						
TAMPA CHAMBER OF COMMERCE	1	39,975									1	39,975		
THOMAS HERBERT RESRC CONS	1	24,915									1	24,915		
UNIV OF CENTRAL FLORIDA	5	80,613					1	14,900					4	65,713
UNIV OF NORTH FLORIDA	1	40,892											1	40,892
UNIV OF SOUTH FLORIDA	10	294,621	3	74,325	2	59,600	3	121,473					2	39,223
UNIV OF WEST FLORIDA	4	36,019											4	36,019
UNIVERSITY OF FLORIDA	76	4,115,528	39	2,089,454	6	231,984	21	917,180	4	391,772	4	447,916	2	37,222
UNIVERSITY OF MIAMI	68	8,357,347	4	125,196	52	7,536,668	8	339,230			3	331,253	1	25,000
OTHER GRANTS & CONTRACTS	8	27,463	1	17,000	1	645			5	4,110			1	5,688
STATE TOTAL		17,783,836		3,331,573		9,348,769		2,677,909		436,482		887,409		1,101,894
		266		66		88		65		10		10		27
GEORGIA														
AGNES SCOTT COL	1	6,486											1	6,486
ALBANY STATE COL	1	24,080											1	24,080
ASSN MEDIA-BASED CONT ED	2	233,000											2	233,000

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
GEORGIA														
ATLANTA JUNIOR COLLEGE	1	50,000											1	50,000
ATLANTA UNIV	9	270,630			1	19,466							8	251,124
ATLANTA UNIV CENTER INC	1	20,330											1	20,330
AUGUSTA COL	1	36,589											1	36,589
CLARK COL	4	189,962											4	189,962
COLUMBUS COL	1	15,626											1	15,626
EMORY UNIVERSITY	12	426,411	3	97,089			6	256,850					3	82,472
GA DEPT OF COMM AFFAIRS	1	130,000									1	130,000		
GAINESVILLE JR COL	1	1,000											1	1,000
GEORGIA COLLEGE	1	14,937											1	14,937
GEORGIA INST OF TECH	50	3,023,988	31	1,399,750	10	729,736	3	183,674	1	220,239	4	461,269	1	29,320
GEORGIA SOLAR COALITION	1	30,713											1	30,713
GEORGIA SOUTHERN COLLEGE	3	32,310											3	32,310
GEORGIA STATE UNIVERSITY	5	96,806			1	16,200	1	26,047					3	54,559
LOCKHEED-GEORGIA COMPANY	1	19,200											1	19,200
MEDICAL COL OF GEORGIA	1	140,000					1	140,000						
MOREHOUSE COL	2	97,285					2	97,285						
SKIDAWAY INST OF OCEANOGRY	7	328,446			7	328,446								
SOUTH GEORGIA COLLEGE	1	184,623											1	184,623
UNIVERSITY OF GEORGIA	55	2,881,632	12	262,911	5	208,272	10	2,037,547		25,000	1	191,677	7	156,225
VALDOSTA ST COL	1	7,750											1	7,750
WEST GEORGIA COLLEGE	2	50,100			2	50,100								
OTHER GRANTS & CONTRACTS	16	58,368	1	535					9	11,538	1	4,000	5	42,295
STATE TOTAL		8,370,252		1,760,285		1,352,240		2,731,403		256,777		786,946		1,482,601
		161		47		26		43		10		7		48

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
HAWAII														
BERNICE P BISHOP MUSEUM	3	159,696					3	159,696						
OCEANIC INSTITUTE	1	82,344			1	82,344								
RES CORP OF UNIV OF HAWA	1	46,000			1	46,000								
UNIV OF HAWAII AT HILO	1	24,550											1	24,550
UNIV OF HAWAII SYSTEM OFF	2	81,743			1	65,800							1	15,943
UNIV OF HAWAII-MANOA	93	5,185,079	16	448,199	47	3,653,733	25	938,513	1	15,939	1	64,786	3	63,909
STATE TOTAL		5,579,412		448,199		3,847,877		1,098,209		15,939		64,786		104,402
		101		16		50		28		1		1		5
IDAHO														
IDAHO STATE UNIVERSITY	7	258,194					3	221,347					4	36,847
NORTHWEST NAZARENE COL	1	3,685											1	3,685
UNIVERSITY OF IDAHO	7	209,116	1	56,581			1	31,970			1	61,680	4	58,885
OTHER GRANTS & CONTRACTS	1	8,800	1	8,800										
STATE TOTAL		479,795		65,381				253,317				61,680		99,417
		16		2				4				1		9
ILLINOIS														
ANGONNE NATIONAL LAB	5	179,625	2	77,500	1	54,000							2	48,125
ASSOC COL OF THE MIDWEST	1	25,000											1	25,000
BRADLEY UNIVERSITY	2	37,187											2	37,187
CHICAGO STATE UNIVERSITY	5	212,633					1	43,822					4	168,811
CITY COLLEGES OF CHICAGO	2	218,225											2	218,225
COLUMBIA COL	1	24,775											1	24,775
CONSULTING ENGRS GROUP	1	111,374									1	111,374		
DEPAUL UNIV	4	303,544	1	18,761	2	109,600			1	174,983				
EAST ASIAN RES OF SCI INC	1	41,500					1	41,500						

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
ILLINOIS														
ELGIN COMM COL	1	12,000											1	12,000
ELMHURST COL	1	20,000	1	20,000										
FIELD MUSEUM OF NAT HIST	14	635,555				5,000	13	619,945					1	10,610
GEORGE WILLIAMS COL	1	13,937											1	13,937
GOULD INC	1	19,200											1	19,200
GOVERNORS STATE UNIV	2	95,828			1	36,000						30,000	1	29,828
GRAVI-MECHANICS CO	1	24,970									1	24,970		
IIT RESEARCH INSTITUTE	1	25,007									1	25,007		
ILL COMM ON INTERGOV COOP	1	51,615									1	51,615		
ILL ST MUSEUM	2	89,965			1	41,914	1	48,051						
ILLIANA AVIATION SCIS LTD	1	93,098									1	93,098		
ILLINOIS BENEDICTINE COL	1	16,970											1	16,970
ILLINOIS CENTRAL COL	1	19,390											1	19,390
ILLINOIS INST OF TECH	23	1,201,921	14	657,194			1	8,800	1	43,575	3	160,306	4	332,046
ILLINOIS STATE UNIV	5	131,665					3	77,066					2	54,599
INST OF GAS TECHNOLOGY	2	2,429									2	2,429		
KNOX COL	1	14,640											1	14,640
LAKE FOREST COL	2	59,403					1	40,641					1	18,762
LEWIS UNIVERSITY	1	8,230											1	8,230
LOYOLA UNIV OF CHICAGO	6	182,230	2	31,996			4	150,234						
MILLIKIN UNIVERSITY	2	29,844											2	29,844
MONMOUTH COL	1	11,467											1	11,467
MUSEUM OF SCI & IND	1	113,600											1	113,600
NAT OPINION RESEARCH CTR	2	159,019					2	159,019						
NORTHEASTRN ILLINOIS UNIV	1	11,300											1	11,300
NORTHERN ILLINOIS UNIV	25	837,019	10	300,060	8	173,193	2	51,500					5	312,266
NORTHWESTERN UNIVERSITY	115	7,542,947	67	4,573,593	5	506,642	33	1,369,199	4	239,735	3	578,244	3	275,534

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GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
ILLINOIS														
PORTLAND CEMENT ASSOC	1	499,566									1	499,566		
SANGAMON STATE UNIVERSITY	1	9,793											1	9,793
SOUTHERN ILL RES INST	1	70,000	1	70,000										
SOUTHERN ILL U-CARBONDALE	6	130,401	2	77,406	1	850	1	6,084					2	46,061
SOUTHN ILL U-EDWARDSVILLE	1	9,440	1	9,440										
ST XAVIER COL	1	17,022					1	17,022						
TRITON COL	2	38,498											2	38,498
UNIV OF ILL MED CTR CHCGO	4	287,448					3	135,730			1	151,718		
UNIV OF ILLINOIS-CHGO CIR	56	2,271,637	34	1,385,600			15	398,702	1	47,760	2	89,348	4	350,227
UNIV OF ILLINOIS-URBANA	242	16,001,190	120	9,858,582	40	2,074,040	66	2,846,215	3	317,182	4	435,484	9	469,687
UNIVERSITY OF CHICAGO	130	10,255,070	53	5,058,962	25	2,095,147	44	2,085,144	1	24,310	4	732,233	3	259,274
WESTERN ILLINOIS UNIV	2	26,388											2	26,388
XYTEL CORPORATION	1	23,625									1	23,625		
OTHER GRANTS & CONTRACTS	53	435,063	2	34,000	5	57,481			23	37,552	6	1,560	17	304,470
STATE TOTAL		42,652,053		22,173,094		5,153,867		8,098,674		885,097		3,010,577		3,330,744
		738		310		89		192		34		32		81
INDIANA														
ANDERSON CO.	1	9,490											1	9,490
BALL STATE UNIV	5	96,758											5	96,758
BUTLER UNIV	1	8,153									1	8,153		
CABOT CORPORATION	1	202,382	1	202,382										
EARLHAM COL	1	10,300											1	10,300
IND CEN FOR ADV RES INC	1	202,000									1	202,000		
IND U-PURDUE U FT WAYNE	1	35,338					1	35,338						
IND U-PURDUE U-INDNPLS	12	365,213	1	11,371			6	253,078					5	100,764
INDIANA STATE UNIVERSITY	4	103,327					2	79,665					2	23,662

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
INDIANA														
INDIANA U CENTRAL SYS OFF	2	87,705							1	35,505			1	52,200
INDIANA UNIV-BLOOMINGTON	88	7,433,330	35	4,857,798	9	280,948	30	1,401,221	3	147,442	1	82,865	10	663,058
INDIANAPOLIS, CITY OF	1	45,000									1	45,000		
PURDUE UNIVERSITY	140	7,427,005	91	4,803,153	5	260,600	26	1,167,817	1	9,664	6	780,219	11	405,552
ROSE-HULMAN INST OF TECH	1	31,665	1	31,665										
ST MARY-OF-THE-WOODS COL	1	2,093											1	2,093
ST MARYS COL	1	19,726					1	19,726						
ST MEINRAD COL	1	7,288											1	7,288
UNIVERSITY OF NOTRE DAME	34	1,993,744	26	1,806,553			2	35,697	1	10,452	1	29,881	4	111,161
OTHER GRANTS & CONTRACTS	19	98,954							11	13,212	1	450	7	85,292
STATE TOTAL		18,179,471		11,712,922		541,548		2,992,542		216,275		1,148,566		1,567,618
		315		155		14		68		17		12		49
IOWA														
COE COL	1	3,800											1	3,800
DRAKE UNIV	1	17,070											1	17,070
GRINNELL COL	3	150,626											3	150,626
IOWA ST U OF SCIENCE&TECH	48	1,832,165	22	740,314	5	161,260	12	576,939	3	34,780	2	234,295	4	84,577
LORAS COL	1	243,900											1	243,900
LUTHER COL	2	153,533											2	153,533
UNIV OF NORTHERN IOWA	2	38,850											2	38,850
UNIVERSITY OF IOWA	53	2,507,423	23	1,026,779	4	208,400	19	809,665					7	462,579
WARTHURG COLLEGE	1	21,000											1	21,000
OTHER GRANTS & CONTRACTS	6	52,655							3	3,445			3	49,210
STATE TOTAL		5,021,022		1,767,093		369,660		1,386,604		38,225		234,295		1,225,145
		118		45		9		31		6		2		25

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
KANSAS														
DONNELLY COL	1	82,962											1	82,962
EMPORIA STATE UNIVERSITY	1	14,877											1	14,877
KANSAS STATE UNIVERSITY	34	1,180,335	19	659,975			6	250,414	1	3,600	1	127,000	7	139,346
MENNINGER FOUNDATION	1	94,452					1	94,452						
PITTSBURG STATE UNIV	1	11,651											1	11,651
PRATT COMM JR COL	1	20,134											1	20,134
RICKEL MANUFACTURING CORP	1	25,000									1	25,000		
U OF KANSAS MAIN CAMPUS	34	1,248,697	9	444,098	7	226,357	11	362,381	2	10,540			5	205,321
UNIV OF KANSAS MED CTR	2	20,161					2	20,161						
WICHITA STATE UNIVERSITY	6	131,712	1	34,000	1	15,033	1	8,000					3	74,679
OTHER GRANTS & CONTRACTS	8	73,374							4	3,603			4	69,771
STATE TOTAL		2,903,355		1,138,073		241,390		735,408		17,743		152,000		618,741
		90		29		8		21		7		2		23
KENTUCKY														
AM PRNTG HOUSE FOR BLIND	1	35,884											1	35,884
BEREA COLLEGE	1	13,470											1	13,470
CENTRE COL OF KENTUCKY	1	8,700											1	8,700
COUNCIL OF STATE GOVTS	8	762,357									8	762,357		
GEORGETOWN COL	1	7,698											1	7,698
KENTUCKY WESLEYAN COL	1	2,600											1	2,600
MOREHEAD STATE UNIV	2	35,335											2	35,335
MURRAY STATE UNIV	3	62,083											3	62,083
ST CATHERINE COL	1	13,538					1	13,538						
THOMAS MORE COL	1	8,000											1	8,000
UNIV OF KENTUCKY	28	1,289,675	16	572,266			7	538,450			2	131,842	3	47,117
UNIV OF LOUISVILLE	9	247,379	2	68,100			2	61,729			1	30,000	4	87,550

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS												SCIENCE EDUCATION	
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications			
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
KENTUCKY														
WESTERN KENTUCKY UNIV	7	114,169			1	7,700							6	106,469
OTHER GRANTS & CONTRACTS	7	41,424							3	2,905			4	38,519
STATE TOTAL		2,642,512		640,366		7,700		613,217		2,905		924,199		453,625
		71		18		1		10		3		11		28
LOUISIANA														
GRAMBLING STATE UNIV	2	51,773											2	51,773
LA ST UNIV BATON ROUGE	34	1,134,802	18	566,775	7	196,337	4	139,855	2	25,129			3	206,706
LA ST UNIV MEDICAL CTR	1	27,400					1	27,400						
LOUISIANA STATE U SYS OFF	2	101,400	1	80,000									1	21,400
LOUISIANA TECH UNIVERSITY	3	67,925	1	31,996									2	35,929
LOYOLA UNIV-NEW ORLEANS	1	50,000											1	50,000
MCNEESE STATE UNIVERSITY	1	7,680											1	7,680
NORTHEAST LOUISIANA UNIV	1	58,437											1	58,437
NORTHWESTERN ST UNIV-LA	1	12,538											1	12,538
SONIC-CLEAN INC	1	25,000									1	25,000		
SOUTHEASTERN LA UNIV	1	99,402							1	99,402				
SOUTHERN UNIV	4	315,747											4	315,747
ST MARYS DOMINICAN COL	1	15,594											1	15,594
TULANE UNIV	22	734,033	16	554,634			4	149,763	1	7,514			1	22,142
UNIV OF NEW ORLEANS	3	152,300	1	41,300							2	111,000		
UNIV OF SOUTHWESTERN LA	3	45,637											3	45,637
XAVIER U OF LOUISIANA	2	95,737											2	95,737
OTHER GRANTS & CONTRACTS	15	73,861	2	2,527					6	7,412			5	63,922
STATE TOTAL		3,069,286		1,277,232		196,337		317,018		139,457		136,000		1,033,242
		96		39		7		9		10		3		28

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
MAINE														
BATES COL	1	5,013											1	5,013
BOWDOIN COL	2	87,599					1	72,914					1	14,685
COLBY COL	2	42,755											2	42,755
COLLEGE OF THE ATLANTIC	1	9,458											1	9,458
JACKSON LAB	5	293,550					4	280,000					1	13,550
MT DESERT ISLAND BIOL LAB	1	167,602					1	167,602						
NORTHEASTERN RESEARCH FDN	7	364,346			6	349,346	1	15,000						
UNITY COLLEGE	1	5,765											1	5,765
UNIV OF MAINE ORONO	23	1,010,049	4	198,787	6	270,520	6	251,558	1	60,218	2	155,999	4	72,967
OTHER GRANTS & CONTRACTS	3	26,083									1	125	2	25,958
STATE TOTAL		2,012,220		198,787		619,866		787,074		60,218		156,124		190,151
		46		4		12		13		1		3		13
MARYLAND														
AMER INST OF NUTRITION	1	49,694									1	49,694		
AMER TYPE CULTURE COLLECT	3	242,502					3	242,502						
BETHESDA CORPORATION	1	25,000									1	25,000		
CAPITAL SYSTEMS GROUP INC	2	314,391									2	314,391		
CAPITOL INST OF TECH	1	10,200											1	10,200
CHESAPEAKE BIS CONSORTIUM	1	149,698					1	149,698						
COMM COL OF BALTIMORE	1	249,884											1	249,884
COPPIN STATE COL	1	106,652											1	106,652
ENVIRONMENTAL QUALITY SYS	2	322,382									2	322,382		
GOUCHER COLLEGE	1	7,467											1	7,467
INFO COMMUNIC APPLIC INC	3	82,130							3	82,130				
JOHNS HOPKINS UNIVERSITY	44	5,305,577	29	2,145,521	18	1,224,457	30	1,401,621	1	195,841	1	30,000	5	306,737
KING RESEARCH INC	1	143,864							1	143,864				

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
MARYLAND														
L N K CORPORATION	1	25,000									1	25,000		
MARTIN MARIETTA CORP	4	411,304	2	122,170			1	91,300			1	197,834		
MORGAN STATE UNIVERSITY	2	25,482											2	25,482
MT ST MARYS COL	2	85,028											2	85,028
OCEAN DATA SYSTEMS INC	1	1,890			1	1,890								
SOIL & LAND USE TECH INC	1	236,265									1	236,265		
ST MARYS COL OF MD	1	25,000											1	25,000
TERRASPACE INC	1	136,852									1	136,852		
TOWSON STATE UNIV	1	13,712											1	13,712
U S NAVAL ACADEMY	1	12,600	1	12,600										
UNIV OF MARYLAND SYS OFF	3	84,808	2	79,800	1	5,008								
UNIV OF MD BALT CNTY	6	294,626					5	270,071					1	24,555
UNIV OF MD BALT PROF SCHS	3	106,536					3	106,536						
UNIV OF MD COLLEGE PARK	113	6,417,866	65	4,020,377	22	1,282,770	15	698,744	4	210,535	1	61,364	6	144,076
UNIV OF MD EASTERN SHORE	1	209,407											1	209,407
UNIV OF MD UNIV COLLEGE	1	10,950							1	10,950				
WESTAT INC	2	399,139							2	399,139				
OTHER GRANTS & CONTRACTS	209	500,208	9	49,960	9	42,230	2	460	65	163,803	32	84,084	92	159,671
STATE TOTAL		16,004,114		6,430,423		2,556,355		2,960,332		1,206,262		1,482,866		1,367,871
		455		108		51		60		77		44		115
MASSACHUSETTS														
ABT ASSOCIATES INC	2	53,175							1	1,317	1	51,858		
ADVANCED MECH TECH INC	1	186,408									1	186,408		
ADVANCED MECHANICAL TECH	2	50,000									2	50,000		
AMER ACAD OF ARTS AND SCI	4	109,812					4	109,812						
AMER SCIENCE & ENGRG INC	2	96,500			2	96,500								

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
MASSACHUSETTS														
AMHERST COL	5	204,127			1	40,000	3	156,127					1	8,000
AMPEC CORPORATION	1	20,475									1	20,475		
ARTHUR D LITTLE INC	2	18,349							2	18,349				
ATMOS & ENVIRON RES INC	1	63,700			1	63,700								
BETH ISRAEL HOSPITAL	2	82,792					2	82,792						
BOSTON BIOMED RES INST	4	163,000					4	163,000						
BOSTON COL	10	338,039	1	26,000	5	158,220	3	129,531				10,000	1	14,288
BOSTON STATE COLLEGE	1	43,541											1	43,541
BOSTON UNIV	31	1,312,037	5	291,205	5	121,840	16	775,765					5	123,227
BRANDEIS UNIV	41	1,948,495	20	956,192			16	660,350	1	162,923	1	100,000	3	69,030
CACHE CORPORATION	1	298,500											1	298,500
CHARLES RIVER ASSOC, INC	1	29,851					1	29,851						
CHARLES S DRAPER LAB INC	1	122,149									1	122,149		
CHILDRENS HOSP MED CTR	4	224,912					4	224,912						
CLARK UNIV	6	647,403	2	123,800	1	60,000	2	83,025	1	350,578		30,000		
CNTR-STUDY OF PUB POLICY	1	143,590					1	143,590						
COL OF OUR LADY OF ELMS	1	3,940											1	3,940
COL OF THE HOLY CROSS	1	206,025											1	206,025
CRYSTAL SYSTEMS INC	1	25,000									1	25,000		
DYNATECH CORPORATION	1	166,706									1	166,706		
EASTERN NAZARENE COLLEGE	1	10,107											1	10,107
EDUCATION DEVELOPMENT CTR	2	138,000											2	138,000
EIC CORPORATION	4	112,165	1	40,844							3	71,321		
EIKONIX CORPORATION	1	24,987									1	24,987		
EMMANUEL COL	1	80,000			1	80,000								
ENVRNMTL RES & TECH INC	1	120,000			1	120,000								
FEDERAL RESERVE BANK BOST	1	15,600									1	15,600		

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
MASSACHUSETTS														
GTE LABORATORIES INC	1	19,200											1	19,200
HAMPSHIRE COLLEGE	2	80,362											2	80,362
HARBRIDGE HOUSE, INC	1	63,606			1	63,606								
HARVARD UNIVERSITY	173	10,811,412	46	4,141,137	24	1,421,802	96	4,763,923	1	11,169	4	398,761	2	74,620
IONOMET COMPANY	3	169,311									3	169,311		
JOSLIN DIABETES FDN INC	1	60,000					1	60,000						
LASER ANALYTICS INC	1	76,018									1	76,018		
LIFESYSTEMS COMPANY	1	25,000									1	25,000		
LINCOLN LABORATORY	3	395,081			2	345,100					1	49,981		
MANLAUS INC	2	148,400	2	148,400										
MARIA MITCHELL OBSERV	1	8,800			1	8,800								
MARINE BIOLOGICAL LAB	6	477,809			2	57,216	3	252,685			1	167,908		
MASS GENERAL HOSPITAL	4	204,856					4	204,856						
MASS INST OF TECH	260	24,491,562	118	14,374,450	51	3,757,220	48	3,297,455	2	126,415	18	2,682,520	3	253,502
MASS ST LEGIS STATE HOUSE	1	39,000									1	39,000		
MCLEAN HOSPITAL	2	78,433					2	78,433						
MOLECULON RESEARCH CORP	1	106,822									1	106,822		
MT HOLYOKE COL	1	2,500	1	2,500										
NATL BUREAU OF ECON RES	22	2,319,129					17	1,463,149	1	155,838	4	700,142		
NEW ALCHEMY INSTITUTE	1	84,002									1	84,002		
NEW ENG INST LIFE SCI INC	1	199,474									1	199,474		
NORTHEAST RADIO OBS CORP	2	948,700			2	948,700								
NORTHEASTERN UNIV	31	1,723,342	22	1,274,106			4	129,500			1	29,451	4	290,285
R S PEABODY FDN ARCH	1	10,278					1	10,278						
RADIATION MON DEVICES INC	1	25,000									1	25,000		
RETINA FDN	1	64,005					1	64,005						
SALEM STATE COLLEGE	1	50,000											1	50,000

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
MASSACHUSETTS														
SCIENTIFIC SYSTEMS	1	94,886									1	94,886		
SHRIVER CTR MENTAL RETARD	1	12,599					1	12,599						
SIDNEY FARBER CANCER INST	2	182,000					2	182,000						
SIMMONS COL	1	71,439									1	71,439		
SISA INCORPORATED	1	188,640									1	188,640		
SMITH COL	2	35,561	1	15,561									1	20,000
SOUTHEASTERN MASS UNIV	3	101,008	3	101,008										
SPIRE CORPORATION	2	50,000									2	50,000		
SUFFOLK UNIV	1	37,807											1	37,807
TECHNICAL ED RES CTR, INC	1	254,040											1	254,040
TUFTS UNIV	17	641,152	5	121,186			11	501,276					1	18,690
U MASS MED SCH-WORCESTER	6	236,578					6	236,578						
UNIV-MASS AMHERST CAMPUS	81	4,853,472	39	2,347,489	12	1,309,004	22	800,620	2	24,702	5	300,817	3	70,840
UNIV-MASS BOSTON CAMPUS	4	81,535			2	22,339	1	48,446					1	10,750
UNIVERSAL TEXTILE MACHINE	1	25,000									1	25,000		
UNIVERSITY OF LOWELL	5	189,172	3	157,682					1	9,031			1	22,459
W J SCHAFER ASSOCIATES	1	23,350									1	23,350		
WATER PURIFICATION ASSOC	1	130,102									1	130,102		
WELLESLEY COL	4	276,751					2	114,514			1	150,262	1	11,975
WGBH EDUCATIONAL FOUND	1	79,000											1	79,000
WHEATON COL	1	150,450											1	150,450
WILLIAMS COL	2	21,657	1	9,657									1	12,000
WOODS HOLE OCEAN INST	93	11,848,795	27	11,683,193	1	40,600						125,000		
WORCESTER FDN EXP BIO	8	370,389					5	370,389						
WORCESTER POLYTECH INST	5	322,543	3	120,834						147,255			2	34,454
WORCESTER STATE COLLEGE	1	19,044											1	18,048
OTHER GRANTS & CONTRACTS	49	571,928	1	35,362	7	4,957			16	37,157	3	12,309	18	282,043

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS												SCIENCE EDUCATION	
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications			
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
MASSACHUSETTS														
STATE TOTAL		70,389,092		24,287,413		20,362,002		15,190,061		1,044,734		6,799,699		2,705,183
		963		296		218		287		30		68		64
MICHIGAN														
ALBION COL	1	14,934											1	14,934
ALMA COL	4	30,459											4	30,459
ANDREWS UNIV	1	4,494											1	4,494
CALVIN COL	1	33,317	2	26,900									1	6,417
CENTRAL MICH UNIV	2	157,806											2	157,806
CONCORDIA COLLEGE	1	16,526											1	16,526
EASTERN MICHIGAN UNIV	1	46,744											1	46,744
GRAND VALLEY ST COLLEGES	1	11,842											1	11,842
HENRY FORD HOSPITAL	1	40,000					1	40,000						
HOPE COL	8	146,894	1	35,200									7	111,694
KALAMAZOO COL	2	25,686											2	25,686
MICH TECHNOLOGICAL UNIV	14	796,852	5	518,756	3	128,500	2	63,825					4	85,771
MICHIGAN CHRISTIAN COL	1	2,000											1	2,000
MICHIGAN STATE UNIVERSITY	103	8,117,603	54	5,355,872	5	219,690	30	1,476,004	1	17,215	4	403,602	9	645,220
NORTHERN MICHIGAN UNIV	1	28,769											1	28,769
OAKLAND UNIV	5	294,842	5	294,842										
SHAW COLLEGE AT DETROIT	1	24,454											1	24,454
SOUTHWESTERN MICH COL	1	83,209											1	83,209
UNIV OF DETROIT	2	98,215	1	88,054									1	10,161
UNIVERSITY OF MICHIGAN	211	12,340,126	72	4,072,416	27	1,425,215	96	5,398,920	5	258,356	6	689,924	5	495,294
WAYNE COUNTY CMTY COLLGE	1	192,682											1	192,682
WAYNE STATE UNIV	17	1,383,342	19	640,258	1	29,894	11	503,953	2	123,034	1	30,000	3	56,199
WESTERN MICH UNIV	5	151,765	1	17,009	2	65,344					1	45,876	1	25,536

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
MICHIGAN														
OTHER GRANTS & CONTRACTS	23	228,974			1	1,397			8	13,363	1	9,325	13	204,889
STATE TOTAL		24,271,537		11,049,307		1,870,047		7,482,702		411,968		1,176,727		2,280,786
		430		160		39		140		16		13		62
MINNESOTA														
BEMIDJI STATE UNIVERSITY	1	31,634											1	31,634
BIO-METRIC SYSTEMS INC	1	24,989									1	24,989		
CARLETON COL	4	45,354											4	45,354
COL OF ST BENEDICT	1	3,985											1	3,985
COL OF ST CATHERINE	1	21,000	1	10,500										10,500
COL OF ST SCHOLASTICA	1	10,438											1	10,438
GUSTAVUS ADOLPHUS COL	2	17,724											2	17,724
HAMLINE UNIV	1	20,000											1	20,000
MACALESTER COL	5	491,877			1	171,545							4	320,334
MANKATO STATE UNIVERSITY	3	31,075											3	11,075
MAYO FOUNDATION	1	80,000					1	80,000						
MINN ED COMPUT CONSORTIUM	2	109,398											2	109,398
ST CLOUD STATE UNIV	1	18,110											1	18,110
ST MARYS COL	1	17,600											1	17,600
ST OLAF COL	3	265,463	2	15,500									1	249,963
UNIV OF MINN AT DULUTH	6	224,665			1	12,449							5	212,216
UNIV OF MINNESOTA	138	6,815,826	70	5,201,500	20	1,110,348	39	1,807,939	2	20,762	4	578,897	5	96,374
UNIVERSITY OF MINNESOTA	19	752,885	5	208,460	3	59,350	9	423,575	1	4,035	1	57,463		
WINONA STATE UNIV	1	27,669											1	27,669
OTHER GRANTS & CONTRACTS	13	93,145	1	17,000					3	9,301			4	66,844
STATE TOTAL		9,102,911		5,452,960		1,353,692		2,311,514		54,098		661,349		1,289,214
		202		79		25		49		8		6		35

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
MISSISSIPPI														
ALCORN STATE UNIVERSITY	4	43,226											4	43,226
COAHOMA JR COL	1	97,250											1	97,250
DELTA STATE UNIVERSITY	1	14,126											1	14,126
ITAWAMBA JR COL	1	1,500											1	1,500
JACKSON STATE UNIVERSITY	8	199,598			1	31,260							7	168,338
MINISTERIAL INST & COLL	1	88,910											1	88,910
MISSISSIPPI COLLEGE	3	36,771											3	36,771
MISSISSIPPI INDUS COL	1	180,993											1	180,993
MISSISSIPPI STATE UNIV	4	78,120	2	63,000									2	15,120
TOUGALOO COL	2	47,557											2	47,557
UNIV OF SOUTHERN MISS	4	71,217	1	26,300									3	44,917
UNIVERSITY OF MISSISSIPPI	11	465,267	3	116,645			4	269,893					4	78,729
UTICA JR COL	1	285,087											1	285,087
OTHER GRANTS & CONTRACTS	2	18,949							1	2,000			1	16,949
STATE TOTAL		1,628,571		205,945		31,260		269,893		2,000				1,119,473
		44		6		1		4		1				32
MISSOURI														
CENTRAL METHODIST COL	1	10,450											1	10,450
ENVIRONMETRICS-ST LOUIS	1	24,973									1	24,973		
JEWISH HOSP OF ST LOUIS	1	55,000					1	55,000						
MARYVILLE COL-ST LOUIS	1	41,597											1	41,597
MCDONNELL DOUGLAS CORP	1	19,200											1	19,200
MISSOURI WESTERN STATE C	1	13,420											1	13,420
MO BOTANICAL GARDEN	10	404,707					9	393,707	1	11,000				
MO HOUSE OF REPRESENTS	1	154,000									1	154,000		
NORTHEAST MO STATE UNIV	1	8,014											1	8,014

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
MISSOURI														
SOUTHEAST MO STATE UNIV	2	21,340											2	21,340
SOUTHWEST MO STATE UNIV	1	40,857											3	40,857
ST LOUIS UNIVERSITY	9	384,251			5	264,300	3	117,426					1	2,525
UNIV OF MISSOURI COLUMBIA	40	1,693,599	13	427,196	4	239,652	17	665,885	2	17,551	1	39,425	3	303,890
UNIV OF MISSOURI KAN CITY	6	604,081					4	219,287					2	384,794
UNIV OF MISSOURI ROLLA	21	1,061,578	11	667,829	4	174,000			1	51,721	1	85,179	4	82,849
UNIV OF MISSOURI ST LOUIS	5	169,326			2	31,860	2	75,543					2	61,923
WASHINGTON UNIVERSITY	72	3,380,118	21	1,155,583	9	532,126	37	1,469,123	2	17,401	1	149,300	2	56,578
OTHER GRANTS & CONTRACTS	9	47,881							4	3,528	1	9,818	4	34,535
STATE TOTAL		8,134,392		2,250,613		1,241,940		2,995,971		101,201		462,695		1,081,972
		186		45		24		73		10		6		28
MONTANA														
MONTANA COL MINERAL SCI	1	5,342											1	5,342
MONTANA STATE UNIVERSITY	12	1,151,936	7	916,982			3	101,699			1	125,000	1	7,955
NORTHERN MONTANA COL	2	36,309											2	36,309
UNIVERSITY OF MONTANA	11	395,683	1	13,932	1	22,600	4	187,922			1	83,521	4	85,708
OTHER GRANTS & CONTRACTS	4	31,638							1	896	1	75	2	30,667
STATE TOTAL		1,618,908		930,914		22,600		289,921		896		208,596		165,981
		30		8		1		7		1		3		10
NEBRASKA														
CREIGHTON UNIV	3	53,615					1	28,368					2	25,247
DOANE COL	1	13,602											1	13,602
KEARNEY STATE COL	1	58,986											3	58,986
MED ST LEGIS EXEC BOARD	1	57,789									1	69,789		
NEBRASKA WESLEYAN UNIV	1	7,128											1	7,128

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
NEBRASKA														
U OF NEB MED CTR AT OMAHA	2	40,565					2	40,565						
UNIV OF NEBRASKA-LINCOLN	35	2,940,488	15	1,228,939	6	1,201,000	6	226,970	1	34,672	1	109,003	6	139,904
UNIV OF NEBRASKA-OMAHA	6	103,218					1	35,000					5	68,218
OTHER GRANTS & CONTRACTS	2	14,602							1	1,017			1	13,585
STATE TOTAL		3,301,993		1,228,939		1,201,000		330,903		35,689		178,792		326,670
		54		15		6		10		2		2		19
NEVADA														
DESERT RESEARCH INSTITUTE	8	673,051			8	673,051								
UNIVERSITY OF NEVADA-RENO	11	503,100	5	153,059			4	267,300				30,000	2	52,742
STATE TOTAL		1,176,151		153,059		673,051		267,300				30,000		52,742
		19		5		8		4						2
NEW HAMPSHIRE														
BROWNING ENGINEERING CORP	1	25,000									1	25,000		
DARTMOUTH COL	23	1,006,849	8	316,321	4	105,239	8	474,823				20,000	3	90,466
FRANKLIN PIERCE LAW CTR	1	12,000											1	12,000
LAKES REGION PLANNG CMSN	1	26,416											1	26,416
N H CULL AND UNIV COUNCIL	1	14,963											1	14,963
NEW HAMPSHIRE COLLEGE	1	19,774											1	19,774
UNIV N H KEENE ST COLLEGE	1	15,865											1	15,865
UNIV N H PLYMOUTH ST COL	1	4,802											1	4,802
UNIV OF N H DURHAM	21	775,926	5	216,899	11	421,752	1	38,000			1	29,660	3	69,615
OTHER GRANTS & CONTRACTS	4	40,685			1	39,300			1	745			2	640
STATE TOTAL		1,942,280		533,220		566,291		512,823		745		74,660		254,541
		55		13		16		9		1		2		14

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
(CONTINUED) NEW JERSEY														
AEROCHEM RESEARCH LABS	1	99,937									1	99,937		
AM FED OF INV PROCESS SOC	1	34,970	1	34,970										
BURLINGTON COUNTY COL	2	171,159											2	171,159
COL OF MED & DENT OF N J	5	390,801					5	390,801						
COL OF ST ELIZABETH	1	12,000											1	12,000
COMPUTER HORIZONS INC	2	153,966							2	153,966				
EXXON RES & ENGR COMPANY	1	4,800											1	4,800
FAIRLEIGH DICKINSON UNIV	2	278,441											2	278,441
GEORGIAN COURT COL	1	17,924											1	17,924
GLASSBORO STATE COL	1	9,310											1	9,310
INNOVATIVE SYSTEMS RES	1	31,816									1	31,816		
INST FOR ADVANCED STUDY	3	881,800	3	881,800										
MONTCLAIR STATE COL	1	58,211					1	58,211						
NEW JERSEY INST OF TECH	5	351,227	2	248,962									3	102,265
OCEAN COUNTY COL	1	19,000											1	19,000
PRINCETON UNIV	96	6,354,585	56	4,012,151	16	728,939	20	1,158,885	1	149,620		173,568	3	131,622
RAMSEY HIGH SCHOOL FLOA	1	29,660											1	29,660
RIDER COL	1	13,623											1	13,623
RUTGERS UNIVERSITY	83	4,490,123	63	3,649,415	6	140,700	11	547,268	2	35,000		16,000	6	101,760
SCIENT PROCESS & RES INC	2	224,985									2	224,985		
SETON HALL UNIV	1	14,624											1	14,624
STEVENS INST OF TECH	11	425,321	6	313,700							1	30,000	4	81,621
STOCKTON STATE COLLEGE	2	28,023											2	28,023
TEXTILE RESEARCH INST	1	53,100	1	53,100										
THRESHOLD TECHNOLOGY INC	1	25,000									1	25,000		
TRENTON STATE COL	2	38,035	1	14,765									1	23,530
UPSALA COL	1	170,910											1	170,910

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
NEW JERSEY														
WILLIAM PATERSON COLLEGE	3	219,188											3	219,188
OTHER GRANTS & CONTRACTS	18	204,605	3	48,300					3	2,007			12	154,298
STATE TOTAL		14,807,202		9,257,161		869,639		2,155,143		340,393		601,306		1,583,556
		256		136		22		37		8		6		47
NEW MEXICO														
COL OF SANTA FE	1	5,604											1	5,604
EASTERN NEW MEXICO UNIV	1	40,000					1	40,000						
LOVELACE MEDICAL FOUNDATI	1	123,335									1	123,335		
NEW MEX INST MINING & TEC	15	662,672	1	25,700	10	492,200	1	21,191			2	117,379	1	6,202
NEW MEXICO STATE UNIV	15	570,080	4	111,300	2	38,000	2	50,000			2	75,701	5	95,079
SACRAMENTO PEAK OBSERV	5	1,495,581			3	1,495,581								
SCH OF AMER RESEARCH	1	31,165					1	31,165						
UNIVERSITY OF NEW MEXICO	25	4,357,985	4	202,218	2	123,394	13	716,623			2	487,994	4	2,827,756
WESTERN NEW MEXICO UNIV	1	19,085											1	19,085
OTHER GRANTS & CONTRACTS	4	7,416			2	4,418			2	2,998				
STATE TOTAL		7,112,923		339,218		2,153,593		858,979		2,998		804,409		2,953,726
		67		9		19		18		2		7		12
NEW YORK														
ADELPHI UNIV	2	66,689	1	48,000									1	18,689
ALBANY MEDICAL COL	1	27,750					1	27,750						
ALFRED UNIV	1	30,635	1	30,635										
AMER ASSOC OF PHYS TCHRS	2	47,900											2	47,900
AMER COUNC OF LEARNED SOC	1	16,455					1	16,455						
AMER INST OF CHEM ENG	1	20,000	1	20,000										
AMER INST OF PHYSICS	3	155,155					2	14,055					1	141,100

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
NEW YORK														
AMER MUSEUM OF NAT HIST	6	284,660					6	284,660						
AMER PHYSICAL SOC	1	15,000							1	15,000				
ASSOC FOR TROPICAL BIOL	1	6,123							1	6,123				
B THOMPSON INST PLANT RES	3	247,980					2	133,000			1	114,980		
BARNARD COL	1	77,248					1	77,248						
BROOKHAVEN LAB	10	661,134			5	349,975	3	253,000	1	21,700	1	36,459		
BUFFALO ORG FOR SOC & T I	1	89,693									1	89,693		
CANISIUS COL	2	27,877											2	27,877
CENTER FOR ENVIR INFORM	1	5,383											1	5,383
CHILDREN'S TELEV WORKSHOP	1	1,180,000											1	1,180,000
CLARKSON COL OF TECH	26	904,648	23	833,848					1	10,800		40,000	2	20,000
CNTR FOR POLICY RESEARCH	1	71,102					1	71,102						
COL OF MOUNT ST VINCENT	1	129,832											1	129,832
COLD SPRING HARBOR LAB	11	410,706					11	410,706						
COLGATE UNIV	5	92,646	1	38,900			1	24,000					3	29,746
COLUMBIA UNIV	178	17,622,481	54	6,546,660	76	7,942,671	38	1,682,641	2	372,837	4	672,665	4	405,007
CONS CMSN ACCRE HLTH SERV	1	7,333											1	7,333
COOPER UNION	1	116,900											1	116,900
CORNELL UNIV	215	27,243,031	91	18,005,278	24	3,875,948	78	3,587,992	7	446,813	12	1,204,821	3	122,179
CTR FOR GVNMNTL RSRCH INC	1	14,985									1	14,985		
CUNY BARUCH COL	2	40,519	1	5,220			1	35,299						
CUNY BROOKLYN COL	14	524,432	8	262,647					2	56,786			4	204,999
CUNY CENTRAL SYS OFF	1	52,321					1	52,321						
CUNY CITY COL	26	1,359,397	16	782,134	2	124,730	3	145,000					5	307,533
CUNY GRAD SCH & UNIV CTR	5	272,113	2	41,011			1	1,200					2	229,902
CUNY HUNTER COL	7	283,492			2	75,657	4	201,755					1	6,080
CUNY JOHN JAY C CRIM JUST	1	87,476					1	87,476						

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
NEW YORK														
CUNY LEHMAN COLLEGE	3	274,968	1	15,364			1	38,445					1	221,161
CUNY QUEENS COL	9	455,946	4	78,112	1	51,892							4	325,942
CUNY YORK COLLEGE	1	28,750											1	28,750
DUDLEY OBSERVATORY	1	100,000			1	100,000								
FORDHAM UNIV	1	14,255	1	14,255										
GENERAL ELECTRIC COMPANY	2	54,200			1	35,000							1	19,200
GENETICS SOC OF AMERICA	1	27,700					1	27,700						
GRUMMAN CORPORATION	1	19,200											1	19,200
HAMILTON COL	2	102,040											2	102,040
HEALTH RESEARCH INC	10	494,777					8	307,285			1	170,000	1	17,492
HOBART AND WM SMITH COL	2	45,249											2	45,249
HOFSTRA UNIV	2	111,800					1	70,000					1	41,800
INFORM INC	1	46,736											1	46,736
INST OF ELECT ENGRS	5	148,218	3	20,270					1	4,000			1	123,948
INST OF PUBLIC ADMIN	1	103,000							1	103,000				
INST ON MAN & SCIENCE	1	57,853							1	57,853				
INST SOC, ETHICS LIFE SCI	1	92,883											1	92,883
INT BUS MACHINES CORP	1	19,200											1	19,200
ITHACA COL	3	42,687							1	14,837			2	27,850
JOINT OCEAN INSTS INC	3	1,797,862			3	1,797,862								
LONG ISLAND UNIVERSITY	12	602,389			1	52,108	2	46,064			1	81,790	8	422,427
MANHATTAN COLLEGE	1	42,920											1	42,920
MANHATTANVILLE COL	1	10,447											1	10,447
MARIST COL	3	99,322											3	99,322
MED FDN OF BUFFALO INC	2	41,500	2	41,500										
MONTEFIORE HOSP & MED CTR	1	85,620											1	85,620
MT SINAI SCHOOL CITY UNY	8	371,056					8	371,056						

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
NEW YORK														
MT ST MARY COL	1	12,378											1	12,378
MUSEUM OF THE AMER INDIAN	1	4,929					1	4,929						
MUSICAL OBSERVATIONS INC	1	41,650					1	41,650						
N Y ACAD OF SCIENCES	4	22,700					3	17,700			1	5,000		
N Y BOTANICAL GARDEN	12	547,898					11	517,898	1	30,000				
N.Y. CITY BOARD OF EDUC	1	29,720											1	29,720
NATL COMM US-CHINA RELATN	1	23,035											1	23,035
NEW YORK MEDICAL COL	3	128,280					3	128,280						
NEW YORK STATE SENATE	1	30,000									1	30,000		
NEW YORK UNIVERSITY	48	2,717,127	27	1,674,415	2	90,000	18	909,592	1	43,120				
POLYTECHNIC INST OF N Y	17	1,042,945	12	716,410							2	179,121	3	147,414
QUANTRONIX CORPORATION	1	24,960									1	24,960		
RENSSELAER POLYTECH INST	53	3,092,265	34	1,789,804	2	68,900	2	35,200	3	119,425	5	830,940	7	247,996
RES FOUND FOR MENTAL HYG	4	239,019					4	239,019						
ROCHESTER INST OF TECH	2	41,648											2	41,648
ROCKEFELLER UNIV	30	1,351,604	6	248,656			24	1,102,948						
RUSSELL SAGE COL	2	23,861											2	23,861
SIENA COLLEGE	1	15,000					1	15,000						
SKIDMORE COL	2	23,578											2	23,578
SLOAN KETTERING CANCERRES	7	371,266			1	68,100	5	298,310	1	4,856				
SOC SCI RES COUNCIL	2	537,471					2	537,471						
ST BONAVENTURE UNIV	1	11,172											1	11,172
ST JOHNS UNIV	2	66,302					1	35,000					1	31,302
ST LAWRENCE UNIV	1	83,704							1	83,704				
STATE UNIV N Y SYST OFF	5	305,596	1	10,000	3	193,776						80,000	1	21,816
SUNY AGT COL ALFRED	1	249,962											1	249,962
SUNY C ENV SCI & FORESTRY	13	451,194	5	165,700		5,000	4	178,851	1	5,208	1	90,000	1	6,435

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
NEW YORK														
SUNY COL BROCKPORT	3	301,816					1	53,994					2	247,822
SUNY COL BUFFALO	2	68,100					1	58,100					1	10,000
SUNY COL CORTLAND	2	144,827											2	144,827
SUNY COL FREDONIA	3	46,635											3	46,635
SUNY COL GENESEO	1	9,909											1	9,909
SUNY COL NEW PALTZ	1	11,856											1	11,856
SUNY COL OSWEGO	1	10,382											1	10,382
SUNY COL PLATTSBURGH	3	62,095	1	25,800									2	36,295
SUNY COL POTSDAM	2	20,698											2	20,698
SUNY COLLEGE ONEONTA	1	118,077											1	118,077
SUNY DUTCHESS CMTY COL	1	212,308											1	212,308
SUNY JAMESTOWN CMTY COL	1	36,937											1	36,937
SUNY ST U ALBANY	51	1,883,725	13	309,107	17	780,583	11	494,344	1	16,790	2	153,189	7	129,712
SUNY ST U BINGHAMTON	32	1,020,369	9	277,229	6	80,111	12	431,696			2	178,232	3	53,081
SUNY ST U BUFFALO	53	2,802,110	30	1,632,543	7	533,547	13	570,509	1	20,100	1	30,000	1	15,411
SUNY ST UNIV STONY BROOK	103	6,678,110	45	3,623,821	20	1,014,000	27	1,200,660	2	126,560	3	467,102	6	246,167
SUNY UPSTATE MED CTR	5	153,937					5	153,937						
SUNY WESTCHESTER CMTY COL	1	21,676											1	21,676
SYRACUSE RESEARCH CORP	2	184,532			1	34,600			1	149,932				
SYRACUSE UNIV	37	1,860,199	21	1,155,788			14	670,527	2	33,884				
TEACHERS COL	4	243,700					3	193,701					1	49,999
TISSUE CULTURE ASSN INC	1	116,252									1	116,252		
UNION COL	1	59,000					1	59,000						
UNITED ENG TRUSTEES	4	33,100	3	23,100							1	10,000		
UNIV OF ROCHESTER	53	4,746,049	29	2,757,107	4	202,040	12	430,119	1	64,831	3	1,235,777	4	76,175
UTICA COL OF SYRACUSE U	2	50,901					1	24,100	1	26,801				
VASSAR COL	4	74,751	1	10,600			1	22,629					2	41,522

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
NEW YORK														
WAGNER COLLEGE	1	6,523											1	6,523
WEIDLINGER ASSOCIATES	1	417,329									1	417,829		
YESHIVA UNIV	21	1,016,297	5	112,626			14	749,635	1	22,295	1	131,741		
OTHER GRANTS & CONTRACTS	111	587,994	14	34,809	10	17,576			37	42,371	12	29,887	38	463,351
STATE TOTAL		91,993,606		41,351,349		17,494,078		17,160,803		1,879,626		6,435,423		7,672,327
		1,335		464		189		373		74		60		175
NORTH CAROLINA														
APPALACHIAN STATE UNIV	3	66,306											3	66,306
BARBER-SCOTIA COL	1	115,775											1	115,775
BENNETT COL	1	219,213											1	219,213
CHARLOTTE-MECKLENBURG SCH	1	27,962											1	27,962
DUKE UNIV	72	4,429,179	16	696,843	6	945,900	42	2,175,220	3	136,593	1	218,096	4	238,527
EAST CAROLINA UNIV	6	429,681	1	12,938	1	4,268					1	145,578	3	267,099
JOHNSON C SMITH UNIV	2	14,547											2	14,547
MARYLAND TECHNICAL INST	1	1,590											1	1,590
N C AGRIC & TECH ST UNIV	3	137,382	1	75,000									2	62,382
N C STATE MUSEUM	1	11,939					1	11,939						
N C STATE UNIV AT RALEIGH	41	2,060,957	23	1,047,915	4	172,438	6	349,312	1	28,146	3	259,366	4	203,580
NO CAROLINA CENTRAL UNIV	6	86,002					1	3,350					5	82,452
NORTH CAROLINA FDN M H R	3	145,245					3	145,245						
RESEARCH TRIANGLE INST	4	207,496	1	52,797			1	63,858			1	4,563	1	86,300
RICHARD JAPLIN S ASSOCS	1	24,820									1	24,820		
SALEM COL	1	10,808											1	10,808
SOUTHERN GRTH POLICIES BD	1	45,000									1	45,000		
ST ANDREWS PRESBY COL	1	5,766											1	5,766
ST AUGUSTINES COL	1	18,194											1	18,194

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
NORTH CAROLINA														
UNIV OF N C AT CHAP HILL	75	3,371,858	32	1,286,253	6	257,559	32	1,525,685	1	144,175	1	110,511	3	47,705
UNIV OF N C AT CHARLOTTE	5	89,926									1	44,227	4	45,699
UNIV OF N C AT GREENSBORO	4	64,420					2	45,975					2	18,445
UNIV OF N C SYS OFF	2	111,996	1	94,000									1	17,996
UNIV OF NC AT WILMINGTON	2	51,920			1	35,620							1	16,300
WAKE FOREST UNIV	1	33,418					1	33,418						
WESTERN CAROLINA UNIV	4	88,951											4	88,951
OTHER GRANTS & CONTRACTS	23	183,720	2	25,074	2	560			8	7,881	3	18,270	5	128,935
STATE TOTAL		12,029,103		3,290,618		1,414,345		4,354,382		336,793		870,431		1,762,532
		283		77		20		89		13		13		51
NORTH DAKOTA														
N D ST U CENTRAL OFFICE	9	540,975	4	121,200	1	39,400					1	125,000	3	55,375
NORTH DAKOTA LEAG OF CTYS	1	38,185									1	38,185		
UNIV OF NORTH DAKOTA	5	270,728					3	235,000					2	35,728
OTHER GRANTS & CONTRACTS	9	18,548	1	57					5	5,283			3	13,208
STATE TOTAL		868,436		121,257		39,400		235,000		5,283		163,185		104,311
		24		5		1		3		5		2		8
OHIO														
AMERICAN LIQUID XTAL CHEM	1	25,000									1	25,000		
ANTIOCH UNIVERSITY	2	65,694											2	65,694
BATTELLE MEMORIAL INST	8	568,289	3	270,000	2	84,951			1	148,900	1	45,238	1	19,200
BOWLING GREEN STATE UNIV	10	222,653	2	39,492			3	118,381					5	64,780
CAPITAL UNIV	1	23,387											1	23,387
CASE WESTERN RESERVE UNIV	66	4,066,276	39	2,503,006	6	355,396	15	657,144	1	144,754	3	365,976	2	40,000
CENTRAL STATE UNIV	2	28,217											2	28,217

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
OHIO														
CHAS F KETTERING RES FDN	4	335,954					3	160,000			1	175,954		
CLEVELAND MUS OF NAT HIST	2	79,781					2	79,781						
COL OF ST JOSEPH-ON-OHIO	1	21,150											1	21,150
COL OF WOOSTER	2	20,936											2	20,936
COLUMBIA GAS SYS SERVICE	1	4,800											1	4,800
DENISON UNIV	2	25,354											2	25,354
EUCLID PUBLIC SCHOOLS	1	19,202											1	19,202
HEIDELBERG COL	1	14,010											1	14,010
JOHN CARROLL UNIV	1	12,443											1	12,443
KENT STATE UNIV	17	598,058	8	298,383			5	163,829			1	74,591	5	61,255
KENYON COL	1	2,532											1	2,532
MARIETTA COL	1	17,370											1	17,370
MIAMI UNIV	9	293,922	1	23,360	1	27,780	4	173,603					3	66,179
MIDDLETOWN, CITY OF	1	136,609									1	136,609		
MT UNION COL	1	23,863											1	23,863
MUSKINGUM AREA TECH C	1	7,181											1	7,181
MUSKINGUM COL	4	28,720											4	28,720
NE OH CHAPNATL SPIMALCRD	1	47,200											1	47,200
NE OHIO UNIVS COL OF MED	4	287,760					4	287,760						
NOTRE DAME COL OF OHIO	2	26,880											2	26,880
OBERLIN COL	2	104,778					2	104,778						
OCLC INC	1	42,321							1	42,321				
OHIO STATE UNIV	109	4,708,646	52	2,458,406	18	524,985	30	1,105,451	2	111,775	4	419,045	3	88,986
OHIO UNIV	12	327,258	5	172,049	1	26,826	3	59,536					3	68,845
STARK TECHNICAL COL	1	14,932											1	14,932
UNIV OF AKRON MAIN CAMPUS	6	349,731	3	168,750			1	64,858	1	100,000			1	16,123
UNIV OF CINCINNATI	33	987,666	19	458,373	2	57,400	7	351,877	1	47,224			4	92,789

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GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
OHIO														
UNIV OF DAYTON	4	102,633							1	66,873			3	35,760
UNIV OF TOLEDO	7	208,552	1	55,000	2	75,400	1	36,845					3	61,307
WILBERFORCE UNIV	1	92,862											1	92,862
WILMINGTON COL	1	18,910											1	18,910
WITTENBERG UNIV	2	22,613											2	22,613
WRIGHT STATE UNIV	6	76,741	1	21,249	1	3,100	1	1,569	1	15,830			2	36,993
XAVIER UNIV	1	10,840											1	10,840
YOUNGSTOWN STATE UNIV	1	12,694											1	12,694
OTHER GRANTS & CONTRACTS	29	236,739					1	165	15	31,520	2	19,500	11	185,554
STATE TOTAL		14,318,159		6,448,073		1,133,833		3,365,577		709,197		1,261,913		1,399,561
		365		136		33		80		24		14		78
OKLAHOMA														
BACONE COL	1	180,252											1	180,252
NORTHWESTERN OKLA STATE U	1	56,875											1	56,875
OKLA MEDICAL RES FDN	2	110,620			1	75,620	1	35,000						
OKLAHOMA ST LEGIS CNCL	1	121,000									1	121,000		
OKLAHOMA STATE UNIV	19	645,749	7	208,378			5	215,702	1	70,000	1	80,000	5	71,669
OSCAR ROSE JR COLLEGE	1	9,829											1	9,829
SOUTH OKLA CITY JR COLLEGE	1	24,450											1	24,450
SOUTHWESTERN STATE COL	2	27,248											2	27,248
UNIV OF TULSA	3	70,756	1	6,794			1	35,980					1	27,982
UNIV OKLA NORMAN CAMPUS	32	1,116,737	9	284,225	10	405,393	6	207,368			1	126,788	6	92,963
UNIV OKLA-HEALTH SCI CTR	1	6,800					1	6,800						
OTHER GRANTS & CONTRACTS	4	9,316			1	930			1	900			2	7,486
STATE TOTAL		2,579,632		499,397		481,943		500,850		70,900		327,788		498,754
		94		17		12		14		2		3		20

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GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
OREGON														
COLUMBIA EDUCATION CENTER	1	26,633											1	26,633
COOP MUSEUM COMMISSION	1	9,280											1	9,280
GOOD SAMARITAN HOSP&MED C	1	78,541					1	78,541						
LEWIS AND CLARK COL	2	209,812											2	209,812
MATH LEARNING CENTER	1	29,897											1	29,897
OREGON COL OF EDUCATION	3	70,899											3	70,899
OREGON GRADUATE CENTER	6	359,560	2	97,024	2	177,000					1	36,203	1	49,333
OREGON INST OF TECHNOLOGY	1	15,575											1	15,575
OREGON MUS OF SCI & IND	1	18,730											1	18,730
OREGON STATE UNIV	102	7,374,993	22	991,225	51	4,639,261	18	1,266,384	2	24,267	2	158,742	7	297,114
PORTLAND STATE UNIVERSITY	3	189,201							1	119,827			2	69,374
REED COL	4	143,170					2	119,695					2	23,475
SOUTHERN OREGON STATE COL	2	73,247											2	73,247
U OF OREGON HLTH SCS CTR	5	130,211					5	130,211						
UNIV OF OREGON - EUGENE	56	3,009,706	24	1,021,695	5	321,126	24	1,274,488			1	205,295	2	187,102
WRIGHT INSTITUTE	1	21,999					1	21,999						
OTHER GRANTS & CONTRACTS	9	77,582			2	150			1	1,400			6	76,032
STATE TOTAL		11,839,036		2,109,944		5,137,537		2,889,318		145,494		400,240		1,156,503
		199		48		60		51		4		4		32
PENNSYLVANIA														
ACAD OF NAT SCI OF PHILA	14	860,164					13	710,130			1	150,034		
ALLEGHENY COL	2	41,553			1	32,453							1	9,100
ALLEGHENY COUNTY COMM COL	1	10,520											1	10,520
BEAVER COL	1	27,300											1	27,300
BIOCHEM TECHNOLOGY INC	1	105,763	1	105,763										
BRYN MAWR COL	4	237,755					2	65,474					2	172,281

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
PENNSYLVANIA														
BUCKNELL UNIV	5	61,368					1	39,492					2	21,876
CARNEGIE INST	2	72,266					2	72,266						
CARNEGIE LIBRARY	1	50,500					1	50,500						
CARNEGIE MELLON UNIV	81	5,382,629	55	3,672,513	1	31,803	14	684,689	3	289,459	6	644,632	2	59,533
CERAMIC FINISHING COMPANY	1	143,134									1	143,134		
CHATHAM COL	1	98,663											1	98,663
CHEYNEY STATE COL	1	252,270											1	252,270
CLARION STATE COL	1	37,396											1	37,396
CNCL OF NATL LIB ASSNS	1	20,000							1	20,000				
COL MISERICORDIA	1	190,946											1	190,946
CONRAD RESEARCH CORP	2	31,925									2	31,925		
DICKINSON COL	2	27,702					1	20,302					1	7,400
DREXEL UNIVERSITY	16	767,995	10	322,458	3	151,935					2	287,052	1	6,550
DUQUESNE UNIV	2	81,000					2	81,000						
EASTERN COLLEGE	2	140,389											2	140,389
EDINBORO STATE COL	1	15,562											1	15,562
FRANKLIN AND MARSHALL COL	5	49,700			1	15,218	1	24,500					1	9,982
FRANKLIN INST	10	698,595	3	32,545	4	442,390			1	40,355	1	84,305	1	119,000
GANNON COL	3	44,213											3	44,213
GETTYSBURG COL	1	11,999											1	11,999
HAVERFORD COL	4	153,786	1	40,000	2	51,750	1	62,036						
IMMACULATA COL	1	4,521											1	4,521
INST FOR CANCER RESEARCH	6	375,500					6	375,500						
INST FOR SCIENTIFIC INFO	4	91,108							4	91,108				
INST FOR STUDY HUM ISSUES	2	8,744					2	8,744						
INST STUDY CIVIC VALUES	1	39,387											1	39,387
JUVIATA COL	1	23,029											1	23,029

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GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
PENNSYLVANIA														
KEYSTONE JR COL	1	26,750											1	26,750
LA SALLE COLLEGE	3	25,762											3	25,762
LAFAYETTE COL	1	20,000											1	20,000
LANCASTER LABS INC	1	21,210									1	21,210		
LEHIGH UNIV	31	1,640,614	19	1,050,852	2	87,905	2	70,000			4	367,575	4	64,282
LINCOLN UNIV	1	198,798											1	198,798
MEDICAL COLLEGE OF PA	1	12,000											1	12,000
MILLERSVILLE STATE COL	1	12,500			1	12,500								
MONELL CHEM SENSES CENTER	5	227,652					5	227,652						
PENNSYLVANIA INST OF TECH	1	67,895											1	67,895
PENNSYLVANIA STATE UNIV	103	4,685,106	50	2,308,750	23	1,245,139	18	741,659	4	59,818	2	202,084	6	127,656
PHIL REG INTRO MIN ENGRG	1	23,720											1	23,720
PHILA COL OF TEXT & SCI	3	41,088											3	41,088
RES FOR BETTER SCHS INC	1	50,000											1	50,000
ROSEMONT COL	1	500											1	500
SHIPPENSBURG STATE COL	2	57,975											2	57,975
SIAM INST FOR MATH & SOC	1	32,465	1	32,465										
SLIPPERY ROCK STATE COL	2	27,000											2	27,000
ST JOSEPH'S UNIVERSITY	2	40,951											2	40,951
SWARTHMORE COLLEGE	7	202,936	1	5,800	2	100,800	3	73,255				11,100	1	11,981
TEMPLE UNIVERSITY	21	857,235	8	211,167			11	402,341	1	186,662			1	37,065
THOMAS JEFFERSON UNIV	1	37,262					1	37,262						
UNITED ENG & CONST INC	1	34,075	1	34,075										
UNIV OF PENNSYLVANIA	114	9,861,102	49	6,359,754	6	205,119	51	2,577,857	4	387,758	2	272,793	3	57,621
UNIV OF SCRANTON	1	51,031											3	51,031
UNIVERSITY OF PITTSBURGH	75	5,063,903	36	3,110,268	13	463,010	15	586,042	7	601,204		78,000	4	225,379
W PA SCHOOL FOR THE DEAF	1	18,340											1	18,340

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
PENNSYLVANIA														
WESTINGHOUSE ELECT CORP	5	841,114	2	213,518							1	627,596		
WIDENER COLLEGE	2	61,263											2	61,263
WISTAR INST	3	107,600					3	107,600						
OTHER GRANTS & CONTRACTS	78	283,501	3	1,397	2	5,222	2	2,946	33	77,758	15	25,995	23	170,183
STATE TOTAL		54,768,535		17,501,330		2,845,244		7,021,247		1,754,122		2,927,235		2,719,357
		650		239		61		157		58		38		97
RHODE ISLAND														
AMER MATHEMATICAL SOC	8	165,369	8	165,369										
BROWN UNIVERSITY	84	6,147,077	50	4,259,502	12	819,648	18	901,743	1	3,042	1	126,312	2	36,830
GORDON RES CONFERENCES	11	95,393	8	27,643	1	8,000	2	55,650				4,100		
PROVIDENCE COL	1	9,840											1	9,840
RHODE ISLAND COLLEGE	1	8,850											1	8,850
ROGER WILLIAMS COLLEGE	2	29,832											2	28,832
SAVE THE BAY INC	1	39,793											1	39,793
UNIV OF RHODE ISLAND	51	5,610,094	8	433,998	33	4,482,584	2	70,652	2	14,015	4	494,717	6	114,128
OTHER GRANTS & CONTRACTS	6	29,061	1	9,950					3	4,456			2	14,655
STATE TOTAL		12,134,309		4,896,462		5,310,232		1,028,045		21,513		625,129		252,928
		167		73		46		22		6		5		15
SOUTH CAROLINA														
CENTRAL WESLEYAN COL	1	8,351											1	8,351
CLEMSON UNIVERSITY	16	567,477	5	159,926	3	82,539	4	181,824			2	98,791	2	44,397
COL OF CHARLESTON	2	41,800											2	41,800
COLUMBIA COL	1	4,498											1	4,498
CONVERSE COL	1	4,358											1	4,358
ERSKINE COL & SEMINARY	2	15,670											2	15,670

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
SOUTH CAROLINA														
FOLLY BEACH CITY OF	1	21,900											1	21,900
FRANCIS MARION COLLEGE	2	16,480											2	16,480
FURMAN UNIV	3	68,639	1	33,800									2	34,839
LANDER COL	1	20,000											1	20,000
MED UNIV OF S CAROLINA	1	30,000					1	30,000						
S C OFFICE OF LT GOV	1	18,806									1	18,806		
SO ED COMMUNICATIONS ASSN	1	205,903											1	205,903
TRI-COUNTY TECHNICAL COL	1	13,112											1	13,112
UNIV OF S C AT COLUMBIA	41	1,911,956	14	611,422	9	239,951	11	596,014	2	128,903	1	155,000	4	80,668
OTHER GRANTS & CONTRACTS	1	5,153											1	5,153
STATE TOTAL		2,854,105		805,148		322,490		807,838		128,903		272,597		517,129
		76		20		12		16		2		4		22
SOUTH DAKOTA														
AUGUSTANA COL	1	26,710							1	26,710				
MT MARTY COL	3	32,750											3	32,750
SOUTH DAK SCH MINES TECH	3	219,875	1	7,175	2	212,700								
SOUTH DAKOTA STATE UNIV	2	59,580	1	56,252									1	3,328
UNIV OF SOUTH DAKOTA	5	257,723					1	50,000			1	124,985	3	82,738
STATE TOTAL		596,638		63,427		212,700		50,000		26,710		124,985		118,816
		14		2		2		1		1		1		7
TENNESSEE														
AUSTIN PEAY STATE UNIV	1	6,400											1	6,400
BELMONT COL	1	2,556											1	2,556
CARSON-NEWMAN COL	1	18,910											1	18,910
CHRISTIAN BROTHERS COL	4	50,787	1	5,800									3	44,987

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
TENNESSEE														
EAST TENNESSEE STATE UNIV	4	144,013					3	135,013					1	9,000
FISK UNIV	2	15,966											2	15,966
KNOXVILLE COL	1	12,000											1	12,000
LEE COL	1	10,054											1	10,054
MEHARRY MEDICAL COL	3	158,340											3	158,340
MEMPHIS STATE UNIV	3	60,703											3	60,703
MIDDLE TENN STATE UNIV	1	31,127											1	31,127
NASHVILLE STATE TECH INST	1	6,000											1	6,000
OAK RIDGE NATIONAL LAB	6	1,897,553	2	428,440			4	1,469,113						
SOUTHWESTERN AT MEMPHIS	1	9,100			1	9,100								
TENNESSEE A&I STATE UNIV	1	24,141											1	24,141
TENNESSEE TECHNOLOGL UNIV	5	220,731											5	220,731
U OF TENN CTR HEALTH SCS	4	190,219					3	164,212	1	26,007				
UNIV OF TENN AT CHATTNGA	3	79,360	1	32,000					1	41,860			1	5,500
UNIV OF TENN AT KNOXVILLE	31	1,326,603	15	571,920	2	84,994	11	354,133	1	14,650		55,000	2	245,906
UNIV OF TENN AT MARTIN	2	27,268											2	27,268
VANDERBILT UNIVERSITY	29	1,332,256	13	760,495	1	15,863	13	500,851		19,089		20,000	2	15,958
OTHER GRANTS & CONTRACTS	15	113,752			2	500			1	1,127			12	112,125
STATE TOTAL		5,737,839		1,798,655		110,457		2,623,322		102,733		75,000		1,027,672
		120		32		6		34		4				44
TEXAS														
BAYLOR COL OF MEDICINE	7	356,706					7	356,706						
BAYLOR UNIVERSITY	2	74,132					2	74,132						
BISHOP COL	1	32,612											1	32,612
D H CLAYTON & ASSOCIATES	1	25,000									1	25,000		

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
TEXAS														
DALLAS CO CC DIST SYS OFF	1	7,189											1	7,189
DALLAS, CITY OF	1	32,713											1	32,713
DONHAISER MARINE INC	3	324,383			3	324,383								
FOR THE PEOPLE INC	1	41,062											1	41,062
GREENHILLS CTR EXP STATN	1	49,900											1	49,900
HARDIN-SIMMONS UNIV	1	13,480											1	13,480
LAMAR UNIVERSITY	3	52,204									1	52,204		
MIDLAND COLLEGE	1	18,000											1	18,000
NAVARRO COLLEGE	1	385,548											1	385,548
NORTH TEXAS STATE UNIV	6	125,062	2	29,800			3	66,256					1	29,006
OUR LADY LAKE UNIV OF S A	1	261,571											1	261,571
PAN AMERICAN UNIVERSITY	3	45,173											3	45,173
PAUL QUINN COL	1	180,975											1	180,975
PRAIRIE VIEW AGR & MECH U	3	283,597											3	283,597
RESEARCH FOR GRWTH&TRANSF	1	25,000									1	25,000		
RICE UNIVERSITY	49	1,906,033	28	1,092,582	15	518,901	6	239,110				40,000		15,440
SAM HOUSTON STATE UNIV	2	47,639											2	47,639
SOUTHERN METHODIST UNIV	17	838,696	1	23,000	3	119,200	8	376,111					5	320,385
SOUTHWEST RESEARCH INST	1	19,200											1	19,200
SOUTHWEST TEXAS ST UNIV	1	18,636											1	18,636
ST EDWARDS UNIV	1	16,385											1	16,385
ST MARYS UNIV SAN ANTONIO	1	42,617											1	42,617
SUMMER INST LINGUISTICS	1	11,717					1	11,717						
TEX HLTH SC CTR HOUSTON	9	444,751					9	444,751						
TEXAS A & M UNIV SYS OFF	5	134,134	1	56,000			1	30,875					1	47,259
TEXAS A&I UNIVERSITY	1	30,796	1	30,798										
TEXAS A&M UNIVERSITY	70	5,529,599	29	1,607,049	24	2,855,293	8	539,512	2	12,782	4	460,589	3	54,374

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
TEXAS														
TEXAS CHRISTIAN UNIV	5	171,052	2	94,000			1	29,332	1	40,000			1	7,720
TEXAS SOUTHERN UNIV	5	131,360											5	131,360
TEXAS TECH UNIVERSITY	22	992,471	11	420,255	1	11,050	4	138,300			2	131,565	4	271,301
TEXAS WOMANS UNIV	3	46,620											3	46,620
TRINITY UNIV	3	93,217					1	54,700					2	38,517
TX ST TECH INST WACO CAMP	1	24,928											1	24,928
U HOUSTON CENTRAL CAMPUS	25	1,390,525	12	1,007,777	4	105,542	5	190,767	1	7,500	1	40,000	2	38,939
U OF HOUSTON-DOWNTOWN COL	1	15,282											1	15,282
U TEX HLTH SC CTR DALLAS	4	150,500					4	150,500						
U TEX HLTH SC CTR SAN ANT	2	89,600					2	89,600						
U TEX MED BRNCH GALVESTON	7	400,565					6	313,862			1	86,703		
U TEX SAN ANTONIO	5	165,711			1	49,900	2	57,000					2	58,811
UNIV OF DALLAS	2	42,043											2	42,043
UNIV OF TEXAS AT DALLAS	21	1,027,637	4	215,841	13	634,784	1	64,553	2	29,390		80,000	1	23,071
UNIV OF TEXAS SYSTEM OFF	1	49,800			1	49,800								
UNIV OF TEXAS-ARLINGTON	3	122,607											3	122,607
UNIV OF TEXAS-AUSTIN	124	6,030,517	47	2,038,899	22	1,411,188	38	1,757,794	7	270,794	3	245,934	7	305,908
UNIV OF TEXAS-EL PASO	1	8,715											1	8,715
WHARTON COUNTY JR COL	1	9,832											1	9,832
OTHER GRANTS & CONTRACTS	34	211,802							14	44,229	3	6,805	17	160,768
STATE TOTAL		22,549,298		6,616,001		6,080,041		5,005,578		404,695		1,173,800		3,269,183
		463		138		87		109		27		17		85
UTAH														
BRIGHAM YOUNG UNIV	4	125,246			2	65,646	2	59,600						
DRILLING RESEARCH LAB INC	1	24,995									1	24,995		
HANSEN PLANETARIUM	2	52,893											2	52,893

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
UTAH														
INSTITUTE OF ECOLOGY	2	150,975					2	150,975						
LEAGUE WOMEN VOTERS UTAH	1	21,218											1	21,218
SNOW COLLEGE	1	4,394											1	4,394
TERRA TEK, INC	3	519,985									3	519,985		
UNIVERSITY OF UTAH	70	3,548,883	45	2,502,233	7	271,900	11	537,426	3	43,129		30,000	4	164,195
UTAH GEOPHYSICAL INC	2	49,613									2	49,613		
UTAH STATE UNIVERSITY	16	1,308,036	1	21,000	5	367,600	7	747,255	1	12,473	1	141,233	1	18,475
WEBER STATE COL	2	60,104											2	60,104
WICAT INC	2	414,940											2	414,940
OTHER GRANTS & CONTRACTS	1	2,637							1	2,637				
STATE TOTAL		6,283,917		2,523,233		705,146		1,495,254		58,239		765,826		736,219
		109		46		14		22		7		7		13
VERMONT														
CTR FOR NORTHERN STUDIES	1	23,169			1	23,169								
LYNDON STATE COL	1	1,709					1	1,709						
MIDDLEBURY COL	4	286,452			1	41,758							3	244,694
NORWICH UNIV	1	10,300			1	10,300								
ST MICHAEL S COLLEGE	2	27,118											2	27,118
UNIVERSITY OF VERMONT	11	516,722	5	115,735			4	146,100					4	54,887
VERMONT NAT RES CNCL INC	1	40,227											1	40,227
OTHER GRANTS & CONTRACTS	1	11,256											1	11,258
STATE TOTAL		916,955		115,735		75,227		147,809						378,184
		22		5		3		5						11

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
VIRGINIA														
ALEXANDRIA, CITY OF	1	18,967									1	18,967		
AMER GEOLOGICAL INST	1	69,400			1	69,400								
ASSOC ACADEM HEALTH CTRS	1	52,524							1	52,524				
COLLEGE OF WILLIAM & MARY	9	405,671	5	320,516	1	17,500	1	26,757					2	40,898
COLONIAL WILLIAMSBURG FDN	1	96,577											1	96,577
DATA USE & ACCESS LAWS	1	9,620					1	9,620						
E VA MEDSCH E VA MED AUTH	2	67,673					2	67,673						
FORUM INC	2	59,384									2	59,384		
GEORGE MASON UNIVERSITY	3	53,212	1	15,012			2	38,200						
HAMPTON INST	5	178,754			1	100,000							4	78,754
HUMAN RESOURCES RES ORG	1	46,215											1	46,215
INTERTECHNOL/SOLAR CORP	1	23,431									1	23,431		
JAMES MADISON UNIV	1	14,850											1	14,850
LINGUISTIC SOC OF AMERICA	1	5,000							1	5,000				
MARINE SCI CONSORTIUM	1	37,650											1	37,650
MARY BALDWIN COL	1	103,792											1	103,792
NAT COUNCIL TCHRS OF MATH	1	86,800											1	86,800
NORTHERN VIRGINIA COMM CO	1	208,691											1	208,691
OLD DOMINION UNIV	4	128,897	1	31,646			1	69,993					2	27,258
POTOMAC RESEARCH INC	1	4,000							1	4,000				
RADFORD UNIVERSITY	1	17,343											1	17,343
RANDOLPH-MACON WOMANS COL	1	3,595											1	3,595
SHENANDOAH C CONSV MUSIC	1	2,384											1	2,384
SOUTHERN SEMINARY JR COL	1	85,052											1	85,052
SPACE RADIATION EFFECTS L	1	25,000	1	25,000									1	21,217
SWEET BRIAR COL	1	21,217												
UNIVERSITY OF VIRGINIA	70	3,890,674	31	1,537,229	8	577,505	24	1,088,681	1	40,776	4	377,901	2	274,586

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
VIRGINIA														
VIRGINIA COMMONWEALTH U	10	344,746					8	303,460					2	41,286
VIRGINIA GENERAL ASSEMBLY	1	96,100									1	96,100		
VIRGINIA MILITARY INST	3	178,373											3	178,373
VIRGINIA POLYTECHNIC INST	55	3,075,791	30	1,533,358	7	401,184	8	557,675	2	55,213	5	466,152	3	62,209
VIRGINIA STATE UNIVERSITY	2	37,211											2	37,211
VIRGINIA WESLEYAN COL	1	7,700											1	7,700
OTHER GRANTS & CONTRACTS	191	359,603	16	73,463	15	21,359	12	12,113	64	94,920	43	95,144	41	62,604
STATE TOTAL		9,821,901		3,536,224		1,186,948		2,174,172		252,433		1,137,079		1,535,045
		378		85		33		59		70		57		74
WASHINGTON														
BOEING ENGRS & CONSTRUCTN	1	73,696	1	73,696										
CENTRAL WASHINGTON UNIV	1	17,852											1	17,852
EASTERN WASHINGTON UNIV	1	14,465											1	14,465
EVERGREEN STATE COLLEGE	4	79,521					1	40,000					3	39,521
F HUTCHINSON CANC RES CTR	2	78,151					2	78,151						
FDN GLACIER & ENVRNL RES	1	10,710											1	10,710
FLOW INDUSTRIES INC	1	264,494									1	264,494		
GONZAGA UNIVERSITY	2	34,732											2	34,732
INST OF APP PHYSIO & MED	1	108,799									1	108,799		
MATHEMATICAL SCIENCE N W	1	294,000	1	294,000										
MERCER IS SCHOOL DIST	1	19,350											1	19,350
PACIFIC LUTHERAN UNIV	1	38,000	1	38,000										
PACIFIC NW INNOVATN GRP	3	195,541									3	195,541		
PACIFIC SCIENCE CTR FOUND	1	141,542											1	141,542
SEATTLE COMMUNITY COLLEGE	1	179,836											1	179,836
SEATTLE PACIFIC UNIV	2	74,645			1	50,700							1	24,145

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
WASHINGTON														
SEATTLE UNIVERSITY	1	32,615											1	32,615
SMALL TRIBES ORG W WASH	1	26,800											1	26,800
UNIVERSITY OF PUGET SOUND	1	70,000			1	70,000								
UNIVERSITY OF WASHINGTON	206	13,165,080	57	3,296,170	80	6,021,483	52	2,796,913	1	26,769	8	662,070	6	363,675
VA MASON FDN MED EDUC&RES	1	3,541					1	3,541						
WALLA WALLA COL	2	62,000			1	37,000							1	25,000
WASHINGTON STATE UNIV	42	1,718,109	13	446,063	4	165,215	18	716,464	2	36,189		35,000	5	321,198
WESTERN WASHINGTON UNIV	4	140,296			1	15,002	2	76,715				32,380	1	16,199
WEYERHAEUSER COMPANY	1	9,600											1	9,600
OTHER GRANTS & CONTRACTS	19	68,726	1	760					9	9,072	3	6,089	6	52,805
STATE TOTAL		16,922,301		4,148,689		6,359,400		3,707,764		72,030		1,304,373		1,330,045
		302		74		88		76		14		16		34
WEST VIRGINIA														
BETHANY COL	3	34,125											3	34,125
NAT RADIO ASTRON OBSERV	6	22,703,001			6	22,703,001								
W VIRGINIA INST OF TECH	1	36,616											1	36,616
WEST VIRGINIA UNIVERSITY	16	874,252	5	147,047	1	53,165	2	125,000	1	22,700	4	216,443	3	309,899
WEST VIRGINIA WESLEYN COL	1	14,180											1	14,180
OTHER GRANTS & CONTRACTS	2	15,398									1	60	1	15,338
STATE TOTAL		23,677,572		147,047		22,756,164		125,000		22,700		216,503		410,158
		29		5		7		2		1		5		9
WISCONSIN														
BELOIT COL	3	35,469											3	38,469
CARROLL COL	1	42,208											1	42,208
EDGEWOOD COL	1	161,534											1	161,534

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
WISCONSIN														
GLOBE UNION INC	1	19,200											1	19,200
LAKESHORE GROUP LTD	1	90,100									1	90,100		
LAWRENCE UNIVERSITY	2	7,410											2	7,410
MADISON AREA TECH COLLEGE	1	6,000											1	6,000
MARQUETTE UNIVERSITY	10	270,388	6	154,744			1	56,945			1	29,755	2	28,944
MEDICAL COLLEGE OF WISC	7	164,448					7	164,448						
MILWAUKEE AREA TECH COL	1	24,791											1	24,791
MILWAUKEE PUBLIC MUSEUM	2	54,300					2	36,300						
NELSON INDUSTRIES INC	1	9,600											1	9,600
SOC FOR DEV WISC	1	13,000					1	13,000						
UNIV OF WIS EXTENSION DIV	1	7,805	1	7,805										
UNIV OF WIS-GREEN BAY	2	210,326											2	210,326
UNIV OF WIS-LA CROSSE	1	24,239											1	24,239
UNIV OF WIS-MILWAUKEE	31	1,158,130	16	590,065	3	98,500	11	425,347	1	44,218				
UNIV OF WIS-OSHKOSH	2	28,234											2	28,234
UNIV OF WIS-PARKSIDE	3	94,845					2	82,899					1	11,946
UNIV OF WIS-RIVER FALLS	2	48,152		10,000	1	26,052							1	12,100
UNIV OF WIS-STEVENS POINT	3	50,090											3	50,090
UNIV OF WIS-SUPERIOR	3	55,953											3	55,953
UNIV OF WIS-WHITEWATER	1	4,474											1	4,474
UNIV OF WISCONSIN CTR	1	26,910					1	26,910						
UNIV OF WISCONSIN SYS OFF	6	339,890	3	92,212			2	135,000			1	112,678		
UNIV OF WISCONSIN-MADISON	213	14,995,746	84	5,638,732	39	2,352,286	78	5,720,276	2	13,186	6	1,008,394	4	262,872
VITERBO COL	1	15,750											1	15,750
WISC ACAD OF SCI ARTS	1	30,000											1	30,000
OTHER GRANTS & CONTRACTS	15	99,856							7	6,792			8	93,076
STATE TOTAL		18,073,850		6,493,558		2,476,838		6,661,125		64,186		1,240,927		1,137,216
		318		110		43		105		10		9		41

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
WYOMING														
UNIVERSITY OF WYOMING	25	1,434,036			16	999,588	5	262,477			1	116,286	3	55,685
OTHER GRANTS & CONTRACTS	2	20,528							1	180			1	20,348
STATE TOTAL		1,454,564				999,588		262,477		180		116,286		76,033
	27				16		5		1		1		4	
UNITED STATES TOTAL		808,779,238		270,112,686		231,442,684		155,087,241		23,988,842		60,662,874		67,484,911
		13,089		4,093		2,114		3,171		876		776		2,059

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
FEDERAL GOVERNMENT														
DEPARTMENT OF AGRICULTURE														
AGR RESEARCH SERVICE	1	11,116							1	11,116				
AGENCY TOTAL		11,116								11,116				
		1								1				
DEPARTMENT OF COMMERCE														
BUREAU OF THE CENSUS	4	425,000							4	425,000				
DEPARTMENT OF COMMERCE	3	70,000					2	50,000			1	20,000		
NAT BUREAU OF STANDARDS	5	296,425	2	130,000					1	12,300	2	154,125		
NATIONAL TECH INFO SERV	1	156,172							1	116,172		40,000		
NATL OCEANIC ATMOS ADMIN	14	1,676,372			14	1,676,372								
AGENCY TOTAL		2,623,969		130,000		1,676,372		50,000		553,472		214,125		
		27		2		14		2		6		3		
DEPARTMENT OF DEFENSE														
DEPARTMENT OF ARMY	3	253,406			3	243,656		9,750						
DEPARTMENT OF DEFENSE	4	33,706,932			3	33,681,932					1	25,000		
DEPARTMENT OF NAVY	9	390,700	1	13,520	6	332,180	1	30,000			1	15,000		
NAVAL WEAPONS CENTER	2	208,700									2	208,700		
AGENCY TOTAL		34,559,738		13,520		34,257,768		39,750				248,700		
		22		1		16		1				4		

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GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
DEPARTMENT OF H.E.W.														
DEPARTMENT OF HEW	1	20,000					1	20,000						
NATL INSTITUTES OF HEALTH	2	20,001							2	20,001				
AGENCY TOTAL		40,001						20,000		20,001				
		3						1		2				
DEPARTMENT OF INTERIOR														
DEPARTMENT OF INTERIOR	2	33,025									2	33,025		
GEOLOGICAL SURVEY	13	1,454,091			11	392,211			1	68,000	1	993,880		
AGENCY TOTAL		1,487,116				392,211				68,000		1,026,905		
		15				11				1		3		
DEPARTMENT OF LABOR														
BUREAU OF LABOR STAT	1	148,000							1	148,000				
AGENCY TOTAL		148,000								148,000				
		1								1				
DEPARTMENT OF STATE														
DEPARTMENT OF STATE	4	321,000							4	321,000				
AGENCY TOTAL		321,000								321,000				
		4								4				
DEPT. OF TRANSPORTATION														
DEPT OF TRANSPORTATION	1	686,700			1	686,700								
AGENCY TOTAL		686,700				686,700								
		1				1								

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GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
ENERGY RES & DEVELP ADMIN														
DEPARTMENT OF ENERGY	9	339,307	3	77,725					5	112,682	1	148,900		
AGENCY TOTAL		339,307		77,725						112,682		148,900		
		9		3						5		1		
INTL COMMUNICATION AGENCY														
INTL COMMUNICATION AGENCY	1	170,000							1	170,000				
AGENCY TOTAL		170,000								170,000				
		1								1				
LIBRARY OF CONGRESS														
LIBRARY OF CONGRESS	2	168,275			1	131,033			1	37,240				
AGENCY TOTAL		168,275				131,033				37,240				
		2				1				1				
NATIONAL COM LIB INF SCI														
NATIONAL COM LIB INF SCI	1	40,335							1	40,335				
AGENCY TOTAL		40,335								40,335				
		1								1				
NATL AERO & SPACE ADMIN														
NASA	3	719,220	1	425,350	2	293,870								
AGENCY TOTAL		719,220		425,350		293,870								
		3		1		2								

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
SMITHSONIAN INSTITUTION														
SMITHSONIAN INSTITUTION	3	251,870			2	212,087	1	39,789						
AGENCY TOTAL		251,870				212,087		39,789						
		3				2		1						
FEDERAL GOVERNMENT TOTAL		41,566,651		646,595		37,650,041		349,539		1,481,846		1,638,630		
		93		7		47		5		23		11		

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GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
U.S. POSSESSIONS														
GUAM														
UNIVERSITY OF GUAM	1	18,469											1	18,469
POSSESSION TOTAL		18,469												18,469
		1												1
PUERTO RICO														
BAYAMON CENTRAL UNIV	1	15,180											1	15,180
CARIBBEAN UNIV COLLEGE	1	19,822											1	19,822
COMM WORKERS PROTECT CONS	2	119,526											2	119,526
HUMACAO UNIVERSITY COL	1	18,096											1	18,096
INT AMER U OF PR CENT OFF	1	115,252											1	115,252
INT AMER U PR SAN GERMAN	4	72,183											4	72,183
INTER AMER U PR HATO REY	1	12,000											1	12,000
NATIONAL ASTRON,IONOSPHER	3	4,761,450			3	4,761,450								
PUERTO RICO JUNIOR COL	1	237,553											1	237,553
TURABO UNIVERSITY COLLEGE	1	12,971											1	12,971
U OF PR MED SCIS CAMPUS	1	7,720											1	7,720
UNIV OF P R MAYAGUEZ	7	228,171	1	21,000	1	39,944							5	167,227
UNIV OF P R RIO PIEDRAS	11	395,978	4	189,400									7	206,578
WORLD UNIVERSITY	1	139,474											1	139,474
POSSESSION TOTAL		6,155,176		210,400		4,801,394								1,143,382
		36		5		4								27

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
VIRGIN ISLANDS														
COL OF VIRGIN ISLANDS	1	5,177											1	5,177
ISLAND RESOURCES FDTN	1	36,000											1	36,000
OTHER GRANTS & CONTRACTS	1	244											1	244
POSSESSION TOTAL		41,421												41,421
		3												3
U.S. POSSESSIONS TOTAL		6,215,066		210,400		4,801,394								1,203,272
		40		5		4								31

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
FOREIGN COUNTRIES														
ARGENTINA														
GOVT OF THE ARG REPUBLIC	1	100,000			1	100,000								
COUNTRY TOTAL		100,000				100,000								
		1				1								
AUSTRALIA														
AUST DEPT SCI & CONS AFFS	1	131,100			1	131,100								
OTHER GRANTS & CONTRACTS	2	6,240			2	6,240								
COUNTRY TOTAL		137,340				137,340								
		3				3								
BERMUDA														
BERMUDA BIOL STA FOR RES	2	63,507				26,667	2	36,840						
COUNTRY TOTAL		63,507				26,667		36,840						
		2						2						
CANADA														
UNIVERSITY OF REGINA	1	13,046			1	13,046								
OTHER GRANTS & CONTRACTS	1	75			1	75								
COUNTRY TOTAL		13,121				13,121								
		2				2								

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
EGYPT														
OTHER GRANTS & CONTRACTS	1	4,000											1	4,000
COUNTRY TOTAL		4,000												4,000
		1												1
FRANCE														
INTRGOVRNM OCEANOGRP COMM	1	50,000			1	50,000								
COUNTRY TOTAL		50,000				50,000								
		1				1								
GERMAN DEMOCRATIC REPUBLIC														
OTHER GRANTS & CONTRACTS	2	2,584			1	1,715			1	869				
COUNTRY TOTAL		2,584				1,715				869				
		2				1				1				
NETHERLANDS														
OTHER GRANTS & CONTRACTS	1	120							1	120				
COUNTRY TOTAL		120								120				
		1								1				
SWITZERLAND														
SWISS FED INST OF TECH	1	68,031			1	68,031								
COUNTRY TOTAL		68,031				68,031								
		1				1								

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
UNITED KINGDOM														
BRITISH ANTARCTIC SURVEY	2	136,544			2	136,544								
UNIV OF EAST ANGLIA	1	15,850			1	15,850								
UNIV OF READING	1	61,200			1	61,200								
COUNTRY TOTAL		213,594				213,594								
		4				4								
FOREIGN COUNTRIES TOTAL		652,297				610,468		36,840		989				4,000
		18				13		2		2				1
GRAND TOTAL		857,213,232		270,969,681		274,504,587		155,273,620		25,471,677		62,501,504		68,692,183
		13,240		4,105		2,178		3,178		901		787		2,091

FISCAL YEAR 1979

PROGRAM GRANTS AND CONTRACTS AWARDED

FROM

NSF SPECIAL FOREIGN CURRENCY APPROPRIATIONS

SUMMARY (Amount in Thousands of Dollars)	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
ARIZONA	1	1							1	1				
CALIFORNIA	8	71							8	71				
COLORADO	2	1,404							2	1,404				
CONNECTICUT	4	46							4	46				
DELAWARE	1	2							1	2				
DISTRICT OF COLUMBIA	12	85							12	85				
GEORGIA	2	3							2	3				
HAWAII	2	9							2	9				
IDAHO	2	5							2	5				
ILLINOIS	5	9							5	9				
MARYLAND	2	3							2	3				
MASSACHUSETTS	3	3							3	3				
MICHIGAN	6	98							6	98				
MINNESOTA	1	18							1	18				
NEW HAMPSHIRE		2								2				
NEW JERSEY	2	3							2	3				
NEW YORK	14	219							14	219				
NORTH CAROLINA	4	16							4	16				
OHIO	4	84							4	84				
OREGON	1	1							1	1				
PENNSYLVANIA	7	11							7	11				
SOUTH CAROLINA	1	1,080							1	1,080				
TENNESSEE	2	4							2	4				
TEXAS	5	7							5	7				
UTAH	3	6							3	6				
WASHINGTON	2	4							2	4				

SUMMARY (Amount in Thousands of Dollars)	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
WISCONSIN	1	40							1	40				
UNITED STATES TOTAL	97	3,238							97	3,238				
FOREIGN COUNTRIES TOTAL	20	761							20	761				
GRAND TOTAL	117	3,998							117	3,998				

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Aeronautical, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
ARIZONA														
OTHER GRANTS & CONTRACTS	1	584							1	584				
STATE TOTAL		584								584				
	1								1					
CALIFORNIA														
CALIFORNIA INST OF TECH	1	22,400							1	22,400				
UNIV OF CALIF-BERKELEY		24,500								24,500				
UNIVERSITY OF SANTA CLARA		10,304								10,304				
OTHER GRANTS & CONTRACTS	7	13,928							7	13,928				
STATE TOTAL		71,132								71,132				
	8								8					
COLORADO														
NAT CTR FOR ATMOS RES		1,400,000								1,400,000				
OTHER GRANTS & CONTRACTS	2	3,716							2	3,716				
STATE TOTAL		1,403,716								1,403,716				
	2								2					
CONNECTICUT														
YALE UNIVERSITY	1	40,533							1	40,533				
OTHER GRANTS & CONTRACTS	3	5,850							3	5,850				
STATE TOTAL		46,383								46,383				
	4								4					

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
DELAWARE														
OTHER GRANTS & CONTRACTS	1	1,817							1	1,817				
STATE TOTAL		1,817								1,817				
	1								1					
DISTRICT OF COLUMBIA														
AMER ASSOC FOR ADVT SCI	1	13,500							1	13,500				
AMERICAN CHEMICAL SOC	1	23,750							1	23,750				
GEORGE WASHINGTON UNIV	1	30,303							1	30,303				
OTHER GRANTS & CONTRACTS	9	17,726							9	17,726				
STATE TOTAL		85,279								85,279				
	12								12					
GEORGIA														
OTHER GRANTS & CONTRACTS	2	3,305							2	3,305				
STATE TOTAL		3,305								3,305				
	2								2					
HAWAII														
CTR CULT&TECH INTERCHANGE	1	7,500							1	7,500				
OTHER GRANTS & CONTRACTS	1	1,591							1	1,591				
STATE TOTAL		9,091								9,091				
	2								2					

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
IDAHO														
OTHER GRANTS & CONTRACTS	2	5,289							2	5,289				
STATE TOTAL		5,289								5,289				
	2								2					
ILLINOIS														
OTHER GRANTS & CONTRACTS	5	9,444							5	9,444				
STATE TOTAL		9,444								9,444				
	5								5					
MARYLAND														
OTHER GRANTS & CONTRACTS	2	2,779							2	2,779				
STATE TOTAL		2,779								2,779				
	2								2					
MASSACHUSETTS														
OTHER GRANTS & CONTRACTS	3	3,477							3	3,477				
STATE TOTAL		3,477								3,477				
	3								3					
MICHIGAN														
MICHIGAN STATE UNIVERSITY	1	32,010							1	32,010				
WAYNE STATE UNIV	1	57,750							1	57,750				
OTHER GRANTS & CONTRACTS	4	8,111							4	8,111				
STATE TOTAL		97,871								97,871				
	6								6					

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
MINNESOTA														
ST OLAF COL	1	18,390							1	18,390				
STATE TOTAL		18,390								18,390				
	1								1					
NEW HAMPSHIRE														
DARTMOUTH COL		2,200								2,200				
STATE TOTAL		2,200								2,200				
NEW JERSEY														
OTHER GRANTS & CONTRACTS	2	2,908							2	2,908				
STATE TOTAL		2,908								2,908				
	2								2					
NEW YORK														
ASIA SOCIETY	1	193,014							1	193,014				
UN OFF FOR SCI & TECH	1	5,750							1	5,750				
OTHER GRANTS & CONTRACTS	12	20,719							12	20,719				
STATE TOTAL		219,483								219,483				
	14								14					
NORTH CAROLINA														
N C STATE UNIV AT RALEIGH	1	9,964							1	9,964				
OTHER GRANTS & CONTRACTS	3	6,033							3	6,033				
STATE TOTAL		15,997								15,997				
	4								4					

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
OHIO														
BATTELLE MEMORIAL INST	1	9,779							1	9,779				
UNIV OF CINCINNATI	1	71,943							1	71,943				
OTHER GRANTS & CONTRACTS	2	2,691							2	2,691				
STATE TOTAL		84,413								84,413				
	4								4					
OREGON														
OTHER GRANTS & CONTRACTS	1	1,155							1	1,155				
STATE TOTAL		1,155								1,155				
	1								1					
PENNSYLVANIA														
OTHER GRANTS & CONTRACTS	7	10,623							7	10,623				
STATE TOTAL		10,623								10,623				
	7								7					
SOUTH CAROLINA														
UNIV OF S C AT COLUMBIA	1	1,080,000							1	1,080,000				
STATE TOTAL		1,080,000								1,080,000				
	1								1					
TENNESSEE														
OTHER GRANTS & CONTRACTS	2	4,137							2	4,137				
STATE TOTAL		4,137								4,137				
	2								2					

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GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
TEXAS														
OTHER GRANTS & CONTRACTS	5	7,268							5	7,268				
STATE TOTAL		7,268								7,268				
	5								5					
UTAH														
OTHER GRANTS & CONTRACTS	3	6,434							3	6,434				
STATE TOTAL		6,434								6,434				
	3								3					
WASHINGTON														
OTHER GRANTS & CONTRACTS	2	4,328							2	4,328				
STATE TOTAL		4,328								4,328				
	2								2					
WISCONSIN														
UNIV OF WIS-MILWAUKEE	1	40,050							1	40,050				
STATE TOTAL		40,050								40,050				
	1								1					
UNITED STATES TOTAL		3,237,553								3,237,553				
	97								97					

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS													
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
EGYPT														
CAIRO UNIVERSITY	3	219,726							3	219,726				
EG SOC ISS UNIV CULKHOW	1	100,000							1	100,000				
UNIV OF ALEXANDRIA	1	59,786							1	59,786				
OTHER GRANTS & CONTRACTS	2	36,432							2	36,432				
COUNTRY TOTAL		415,944								415,944				
	7								7					
INDIA														
INDIAN INST TECH, BOMBAY	1	32,217							1	32,217				
INDIAN INST TECH, MADRAS	1	50,000							1	50,000				
OTHER GRANTS & CONTRACTS	3	76,081							3	76,081				
COUNTRY TOTAL		158,298								158,298				
	5								5					
PAKISTAN														
MESSRS SAAD PUBLICATIONS	1	65,000							1	65,000				
PAKISTAN CNCL SCI IND LAB	1	18,251							1	18,251				
PESHAWAR UNIVERSITY	1	85,962							1	85,962				
OTHER GRANTS & CONTRACTS	1	9,179							1	9,179				
COUNTRY TOTAL		178,392								178,392				
	4								4					

GRANTEE OR CONTRACTOR	PROGRAM GRANTS AND CONTRACTS											
	TOTAL		Mathematical and Physical Sciences, and Engineering		Astronomical, Atmospheric, Earth, and Ocean Sciences		Biological, Behavioral, and Social Sciences		Scientific, Technological and International Affairs		Applied Science and Research Applications		Science Education	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
SAUDI ARABIA														
OTHER GRANTS & CONTRACTS	1	1,104							1	1,104				
COUNTRY TOTAL		1,104								1,104				
	1								1					
SRI LANKA														
OTHER GRANTS & CONTRACTS	2	3,669							2	3,669				
COUNTRY TOTAL		3,669								3,669				
	2								2					
TUNISIA														
NATIONAL SCH OF ENGNG	1	3,520							1	3,520				
COUNTRY TOTAL		3,520								3,520				
	1								1					
FOREIGN COUNTRIES TOTAL		760,927								760,927				
	20								20					
GRAND TOTAL		3,998,480								3,998,480				
	117								117					

FISCAL YEAR 1979

GRADUATE FELLOWSHIPS

FELLOWSHIPS

SUMMARY (Amount in Thousands of Dollars)	No.	Amount	
		Institution	Individual
ALABAMA	1	3	4
ALASKA	2	7	9
ARIZONA	14	21	60
ARKANSAS	1	3	4
CALIFORNIA	397	1,350	1,709
COLORADO	12	41	51
CONNECTICUT	43	146	185
DELAWARE	1	3	4
DISTRICT OF COLUMBIA	2	7	9
FLORIDA	18	61	77
GEORGIA	7	24	29
HAWAII	2	7	8
IDAHO	1	3	4
ILLINOIS	101	343	435
INDIANA	19	55	82
IOWA	6	20	26
KANSAS	5	17	21
KENTUCKY	1	3	4

FELLOWSHIPS

SUMMARY (Amount in Thousands of Dollars)	No.	Amount	
		Institution	Individual
MARYLAND	12	55	81
MASSACHUSETTS	285	972	1,230
MICHIGAN	64	211	275
MINNESOTA	17	58	72
MISSISSIPPI	1	3	4
MISSOURI	12	51	51
MONTANA	1	3	4
NEW HAMPSHIRE	2	7	8
NEW JERSEY	68	231	293
NEW MEXICO	6	20	26
NEW YORK	137	354	456
NORTH CAROLINA	44	150	193
OHIO	10	34	43
OKLAHOMA	4	14	18
OREGON	8	27	34
PENNSYLVANIA	53	170	213
RHODE ISLAND	5	17	22

FELLOWSHIPS			
SUMMARY (Amount in Thousands of Dollars)	No.	Amount	
		Institution	Individual
SOUTH CAROLINA	5	10	13
TENNESSEE	7	24	30
TEXAS	27	92	116
UTAH	4	14	17
VIRGINIA	11	34	43
WASHINGTON	33	112	141
WEST VIRGINIA	1	3	4
WISCONSIN	53	180	228
WYOMING	1	3	4
UNITED STATES TOTAL	1,476	4,985	6,338
U.S. POSSESSIONS TOTAL	4	17	22
FOREIGN COUNTRIES TOTAL	13	34	43
GRAND TOTAL	1,493	5,036	6,403

FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
ALABAMA			
TUSKEGEE INSTITUTE	1	5,430	4,320
STATE TOTAL		5,430	4,320
		1	
ALASKA			
UNIV OF ALASKA FAIRBANKS	2	5,830	5,640
STATE TOTAL		5,800	8,640
		2	
ARIZONA			
ARIZONA STATE UNIVERSITY	2	5,800	8,640
UNIVERSITY OF ARIZONA	12	14,630	51,000
STATE TOTAL		21,430	59,640
		14	
ARKANSAS			
U-ARKANSAS FAYETTEVILLE	1	5,430	4,320
STATE TOTAL		5,430	4,320
		1	
CALIFORNIA			
CALIFORNIA INST OF TECH	53	130,230	225,860
OCCIDENTAL COL	1	5,430	4,320
STANFORD UNIV *	161	547,430	695,520
PAGE 1			

FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
CALIFORNIA			
UNIV OF CAL SANTA BARBARA	3	13,200	12,960
UNIV OF CAL-SAN FRANCISCO	11	37,400	47,520
UNIV OF CALIF-BERKELEY	96	325,400	412,200
UNIV OF CALIF-DAVIS	13	34,000	42,360
UNIV OF CALIF-IRVINE	3	13,200	12,960
UNIV OF CALIF-LOS ANGELES	16	54,400	69,120
UNIV OF CALIF-SAN DIEGO	37	125,800	159,420
UNIV OF CALIF-SANTA CRUZ	3	13,200	12,960
UNIV OF SOUTHERN CALIF	3	13,200	12,960
STATE TOTAL		1,349,800	1,739,160
		397	
COLORADO			
COLORADO STATE UNIVERSITY	1	3,400	4,320
UNIV COLORADO AT BOULDER	11	37,400	46,260
STATE TOTAL		40,800	50,580
		12	
CONNECTICUT			
UNIVERSITY OF CONNECTICUT	3	13,200	12,540
YALE UNIVERSITY	40	155,000	172,380
STATE TOTAL		165,200	184,920
		43	

FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
DELAWARE			
UNIVERSITY OF DELAWARE	1	5,400	4,320
STATE TOTAL		5,400	4,320
		1	
DISTRICT OF COLUMBIA			
GEORGETOWN UNIVERSITY	1	5,400	4,320
HOWARD UNIVERSITY	1	5,400	4,320
STATE TOTAL		5,800	8,640
		2	
FLORIDA			
FLORIDA STATE UNIV	5	17,000	21,180
UNIV OF SOUTH FLORIDA	1	5,400	4,320
UNIVERSITY OF FLORIDA	11	37,430	47,520
UNIVERSITY OF MIAMI	1	5,400	4,320
STATE TOTAL		51,230	77,340
		19	
GEORGIA			
ATLANTA UNIV	1	5,400	4,320
GEORGIA INST OF TECH	2	5,830	8,640
UNIVERSITY OF GEORGIA	4	13,630	16,440
STATE TOTAL		25,800	29,400
		7	
PAGE	3		

FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
HAWAII			
UNIV OF HAWAII-MANOA	2	5,800	8,220
STATE TOTAL		5,800	8,220
		2	
IDAHO			
IDAHO STATE UNIVERSITY	1	3,400	4,320
STATE TOTAL		3,400	4,320
		1	
ILLINOIS			
ILLINOIS INST OF TECH			
NORTHERN ILLINOIS UNIV	25	85,000	107,160
NORTHWESTERN UNIVERSITY	11	37,400	47,100
SOUTHERN ILL U-CARBONDALE	2	5,800	5,640
UNIVERSITY OF CHICAGO	63	214,200	272,160
OTHER GRANTS & CONTRACTS			
STATE TOTAL		343,400	435,060
		131	

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FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
INDIANA			
IND U-PURDUE U-INDNPLS			
INDIANA UNIV-BLOOMINGTON	6	23,400	25,920
PURDUE UNIVERSITY	13	41,200	55,740
STATE TOTAL		64,630	81,660
		19	
IOWA			
IOWA ST U OF SCIENCE&TECH	5	17,000	21,600
UNIVERSITY OF IOWA	1	3,400	4,320
STATE TOTAL		20,400	25,920
		5	
KANSAS			
KANSAS STATE UNIVERSITY	2	6,800	8,640
U OF KANSAS MAIN CAMPUS	3	10,200	12,120
STATE TOTAL		17,000	20,760
		5	
KENTUCKY			
UNIV OF KENTUCKY	1	3,400	4,320
STATE TOTAL		3,400	4,320
		1	
PAGE	5		

FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
MARYLAND			
JOHNS HOPKINS UNIVERSITY	14	47,600	59,640
MORGAN STATE UNIVERSITY	1	3,400	4,320
UNIV OF MD COLLEGE PARK	4	13,600	17,280
STATE TOTAL		64,600	81,240
		19	
MASSACHUSETTS			
BOSTON UNIV	1	3,430	4,320
HARVARD UNIVERSITY	150	510,000	642,540
MASS INST OF TECH	125	425,000	540,000
NORTHEASTERN UNIV	1	3,430	4,320
TUFTS UNIV	3	13,200	12,960
UNIV-MASS AMHERST CAMPUS	6	23,430	25,920
STATE TOTAL		972,430	1,230,350
		286	
MICHIGAN			
MICHIGAN STATE UNIVERSITY	8	20,400	34,560
UNIVERSITY OF MICHIGAN	54	183,600	232,020
WAYNE STATE UNIV	2	6,800	8,220
STATE TOTAL		210,800	274,800
		64	
PAGE	6		

FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
MINNESOTA			
UNIV OF MINNESOTA	17	57,800	72,180
OTHER GRANTS & CONTRACTS			
STATE TOTAL		57,800	72,180
		17	
MISSISSIPPI			
MISSISSIPPI STATE UNIV	1	3,400	4,320
STATE TOTAL		3,400	4,320
		1	
MISSOURI			
ST LOUIS UNIVERSITY	1	3,400	4,320
UNIV OF MISSOURI ROLLA	2	5,800	8,220
WASHINGTON UNIVERSITY	9	33,630	38,040
STATE TOTAL		40,800	50,580
		12	
MONTANA			
UNIVERSITY OF MONTANA	1	3,400	4,320
STATE TOTAL		3,400	4,320
		1	
PAGE	7		

FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
NEW HAMPSHIRE			
DARTMOUTH COL	2	5,800	8,220
STATE TOTAL		5,800	8,220
		2	
NEW JERSEY			
PRINCETON UNIV	68	231,200	293,340
STATE TOTAL		231,200	293,340
		58	
NEW MEXICO			
NEW MEXICO STATE UNIV	2	5,800	8,640
UNIVERSITY OF NEW MEXICO	4	13,600	17,280
STATE TOTAL		20,400	25,920
		5	
NEW YORK			
COLUMBIA UNIV	12	43,800	50,580
CORNELL UNIV	69	234,600	293,460
CUNY CITY COL	1	3,400	4,320
NEW YORK UNIVERSITY	2	6,800	8,640
RENSSELAER POLYTECH INST	1	3,400	4,320
ROCKEFELLER UNIV	13	45,200	56,160
SUNY ST U ALBANY	3	13,200	12,960
SUNY ST U BINGHAMTON	1	3,400	4,320
SUNY ST UNIV STONY BROOK	1	3,400	4,320
PAGE	8		

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FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
NEW YORK			
SYRACUSE UNIV	2	6,800	8,640
UNIV OF ROCHESTER	1	3,400	4,320
YESHIVA UNIV	1	3,430	4,320
STATE TOTAL		363,800	456,360
		137	
NORTH CAROLINA			
DUKE UNIV	18	61,200	77,760
N C STATE UNIV AT RALEIGH	5	17,000	21,600
UNIV OF N C AT CHAP HILL	21	71,430	93,720
STATE TOTAL		142,630	190,080
		44	
OHIO			
BOWLING GREEN STATE UNIV	1	3,400	4,320
CASE WESTERN RESERVE UNIV	2	6,800	8,640
OHIO STATE UNIV	7	23,830	30,240
STATE TOTAL		34,000	43,200
		10	
PAGE	9		

FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
OKLAHOMA			
UNIV OKLA NORMAN CAMPUS	4	13,500	15,440
STATE TOTAL		13,630	15,440
		4	
OREGON			
OREGON STATE UNIV	4	13,600	16,860
U OF OREGON HLTH SCS CTR	1	3,430	4,320
UNIV OF OREGON - EUGENE	3	10,200	12,960
STATE TOTAL		27,230	34,140
		8	
PENNSYLVANIA			
CARNEGIE MELLON UNIV	18	61,230	78,920
PENNSYLVANIA STATE UNIV	11	37,430	46,260
TEMPLE UNIVERSITY	1	3,430	4,320
UNIV OF PENNSYLVANIA	19	64,600	81,660
UNIVERSITY OF PITTSBURGH	1	3,430	4,320
STATE TOTAL		170,000	213,480
		53	
RHODE ISLAND			
BROWN UNIVERSITY	4	13,600	17,280
UNIV OF RHODE ISLAND	1	3,400	4,320
STATE TOTAL		17,000	21,600
		5	
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FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
SOUTH CAROLINA			
COL OF CHARLESTON	2	5,830	8,640
MED UNIV OF S CAROLINA	1	5,400	4,320
STATE TOTAL		13,230	12,960
		5	
TENNESSEE			
UNIV OF TENN AT KNOXVILLE			
UNIV OF TENN AT NASHVILLE	3	13,230	12,540
VANDERBILT UNIVERSITY	4	15,630	17,280
STATE TOTAL		23,830	23,820
		7	
TEXAS			
BAYLOR COL OF MEDICINE	2	5,830	8,640
RICE UNIVERSITY	5	17,000	21,600
TEX HLTH SC CTR HOUSTON	1	5,430	4,320
TEXAS A&M UNIVERSITY	3	13,200	12,960
TEXAS CHRISTIAN UNIV	1	5,400	4,320
TEXAS SOUTHERN UNIV	2	5,830	8,640
TEXAS TECH UNIVERSITY	2	5,830	8,640
U TEX HLTH SC CTR DALLAS	2	6,800	8,640
UNIV OF TEXAS-AUSTIN	9	53,630	38,240
STATE TOTAL		91,800	115,800
		27	
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FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
UTAH			
UNIVERSITY OF UTAH	5	13,200	12,540
UTAH STATE UNIVERSITY	1	3,400	4,320
STATE TOTAL		13,600	16,860
		6	
VIRGINIA			
UNIVERSITY OF VIRGINIA	7	23,830	30,760
VIRGINIA COMMONWEALTH U	1	3,400	4,320
VIRGINIA POLYTECHNIC INST	2	5,830	9,640
STATE TOTAL		34,030	43,200
		13	
WASHINGTON			
UNIVERSITY OF WASHINGTON	31	105,430	132,660
WASHINGTON STATE UNIV	2	5,830	8,640
STATE TOTAL		112,200	141,300
		33	
WEST VIRGINIA			
WEST VIRGINIA UNIVERSITY	1	3,400	4,320
STATE TOTAL		3,430	4,320
		1	

FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
WISCONSIN			
MEDICAL COLLEGE OF WISC			
UNIV OF WIS-MILWAUKEE	1	3,400	5,295
UNIV OF WISCONSIN-MADISON	52	176,830	222,540
STATE TOTAL		180,230	227,835
		53	
WYOMING			
UNIVERSITY OF WYOMING	1	3,400	4,320
STATE TOTAL		3,400	4,320
		1	
UNITED STATES TOTAL		4,985,400	6,338,235
		1,475	

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FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
U.S. POSSESSIONS			
PUERTO RICO			
U OF PR MED SCIS CAMPUS	1	1,430	4,320
UNIV OF P R MAYAGUEZ	1	3,400	4,320
UNIV OF P R RIO PIEDRAS	2	13,230	12,960
POSSESSION TOTAL		17,030	21,600
		4	
U.S. POSSESSIONS TOTAL		17,000	21,600
		4	

FELLOWSHIPS			
GRANTEE OR CONTRACTOR	No.	Amount	
		Institution	Individual
FOREIGN COUNTRIES			
SWEDEN			
UNIV OF LUND	1	3,400	4,520
COUNTRY TOTAL		3,430	4,520
		1	
UNITED KINGDOM			
CAMBRIDGE UNIV	6	23,400	25,920
OXFORD UNIV	3	10,230	12,750
COUNTRY TOTAL		33,630	38,670
		9	
FOREIGN COUNTRIES TOTAL		34,000	42,990
		17	
GRAND TOTAL		5,335,430	5,432,825
		1,490	

WITNESSES

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