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NATIONAL SCIENCE FOUNDATION LEGISLATION,

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HEARING

BEFORE THE

SPECIAL SUBCOMMITTEE ON
NATIONAL SCIENCE FOUNDATION

OF THE

COMMITTEE ON
LABOR AND PUBLIC WELFARE
UNITED STATES SENATE

NINETY-THIRD CONGRESS

SECOND SESSION

ON

S. 3299

NATIONAL SCIENCE FOUNDATION AUTHORIZATION
ACT OF 1975

S. 3344

TO AUTHORIZE APPROPRIATIONS FOR ACTIVITIES OF THE
NATIONAL SCIENCE FOUNDATION, AND FOR OTHER PURPOSES

APRIL 5, 1974



Printed for the use of the Committee on Labor and Public Welfare

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INFORMATION



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CONTENTS

Text of:	Page
S. 3299-----	4
S. 3344-----	6

CHRONOLOGICAL LIST OF WITNESSES

FRIDAY, APRIL 5, 1974

Stever, Dr. H. Guyford, Director, National Science Foundation, accompanied by Dr. Raymond L. Bisplinghoff, Deputy Director; Dr. Edward C. Creutz, Assistant Director for Research; Dr. Alfred J. Eggers, Assistant Director for Research Applications; Thomas E. Jenkins, Assistant Director for Administration; Dr. Thomas B. Owen, Assistant Director for National and International Programs; and Dr. Lowell Paige, Assistant Director for Education-----	12
Hornig, Donald, president, Brown University, on behalf of the American Council on Education, the Association of American Universities, and the National Association of State Universities and Landgrant Colleges--	68
Handler, Philip, president, National Academy of Sciences-----	92
Wright, Prof. Richard, Biology Department, Gordon College, Wenham, Mass.; Prof. Jean C. Belcher, professor of ecology, Sweet Briar College, Sweet Briar, Va.; and Miles M. Fisher, executive secretary, National Association for Equal Opportunity in Higher Education, a panel of science educators-----	102
Belcher, Jane C., Dorys McConnell Duberg professor of ecology, Sweet Briar College, Sweet Briar Va., on behalf of the Association of American Colleges and the National Council of Independent Colleges and Universities-----	105
Fisher, Miles Mark, IV, executive secretary for the National Association for Equal Opportunity in Higher Education, Washington, D.C-----	123

STATEMENTS

Belcher, Jane C., Dorys McConnell Duberg professor of ecology. Sweet Briar College, Sweet Briar, Va., on behalf of the Association of American Colleges and the National Council of Independent Colleges and Universities-----	105
Prepared statement-----	107
Fisher, Miles Mark, IV, executive secretary for the National Association for Equal Opportunity in Higher Education, Washington, D.C-----	123
Handler, Philip, president, National Academy of Sciences-----	92
Hornig, Donald, president, Brown University, on behalf of the American Council on Education, the Association of American Universities, and the National Association of State Universities and Land-grant Colleges--	68
Stever, Dr. H. Guyford, Director, National Science Foundation, accompanied by Dr. Raymond L. Bisplinghoff, Deputy Director; Dr. Edward C. Creutz, Assistant Director for Research; Dr. Alfred J. Eggers, Assistant Director for Research Applications; Thomas E. Jenkins, Assistant Director for Administration; Dr. Thomas B. Owen, Assistant Director for National and International Programs; and Dr. Lowell Paige, Assistant Director for Education-----	12
Prepared statement-----	45
Wright, Prof. Richard, Biology Department, Gordon College, Wenham, Mass.; Prof. Jean C. Belcher, professor of ecology, Sweet Briar College, Sweet Briar, Va.; and Miles M. Fisher, executive secretary, National Association for Equal Opportunity in Higher Education, a panel of science educators-----	102

ADDITIONAL INFORMATION

Publications, reports, et cetera:

National Science Foundation Energy Related Research Activities for fiscal year 1975-----	Page 23
"Federal Policy Alternatives Toward Graduate Education," a report with recommendations of the National Board on Graduate Education, Washington, D.C. January 1974-----	70
"Science Indicators, 1972," report of the National Science Board, 1973, National Science Foundation, January 31, 1973-----	145

Communications to:

Kennedy, Hon. Edward M., a U.S. Senator from the State of Massachusetts, from:	
Belcher, Jane C., Dorys McConnell Duberg, professor of ecology, Sweet Briar College, Sweet Briar College, Va., April 11, 1974---	119
Downs, Dr. Theodore, past president, Society of Vertebrate Paleontology, Los Angeles, Calif., April 9, 1974-----	143
Guarrera, John J., president, the Institute of Electrical and Electronics Engineers, Inc., New York, N.Y., April 3, 1974---	127
Handler, Philip, president, National Academy of Sciences, Washington, D.C., April 18, 1974-----	99
Holden, D. A., executive director, Council of Independent Colleges in Virginia, Charlottesville, Va., April 3, 1974-----	137
Howe, Wallace B., State geologist and director, Missouri Geological Survey and Water Resources, Rolla, Mo., April 12, 1974-----	139
Lomon, Earle L., professor of physics at MIT, and director, unified science and mathematics for elementary school project, Education Development Center, April 1, 1974-----	131
Maxwell John C., parish professor of geological sciences, the University of Texas at Austin, Austin, Tex., April 11, 1974---	141
Mineta, Norman Y., mayor, city of San Jose, Calif., March 29, 1974-----	136
Ohle, E. L., Coastal Mining Co., Salt Lake City, Utah, April 24, 1974-----	144

Charts:

Figure 1.—U.S. energy: Where we get it and where it goes-----	26
Figure 2.—Timonium School (before modification)-----	34
Figure 3.—Timonium School-----	34
Figure 4.—Boston School Experiment-----	35
Figure 5.—Solar Energy System-Lexan Plastic Glazing (Boston School)-----	35
Figure 6.—Collector Utilizing a Nonselective Coating (Boston School)-----	36

Tables:

Table—President's fiscal year 1975 budget estimates, amounts included for National Science Foundation, fiscal year 1973-75-----	14
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NATIONAL SCIENCE FOUNDATION LEGISLATION, 1974

FRIDAY, APRIL 5, 1974

U.S. SENATE,
SPECIAL SUBCOMMITTEE ON THE
NATIONAL SCIENCE FOUNDATION
OF THE COMMITTEE ON LABOR AND PUBLIC WELFARE,
Washington, D.C.

The committee met at 10:20 a.m. in room 4232, Dirksen Senate Office Building, Hon. Edward M. Kennedy, chairman of the subcommittee, presiding.

Present: Senators Pell and Stafford.

Senator KENNEDY. The subcommittee will come to order.

We have before us this morning the \$788.2 million budget request for the National Science Foundation for fiscal 1975. It is the largest budget ever submitted to the Congress for the Foundation, and is a reflection of the growing recognition that the research it supports is an essential part of our effort to solve the problems which confront us as a Nation. The scientific community is making its voice heard in virtually every agency and office of Government—and that voice must be strong if the Nation is to reap the benefits of our increasingly complex technology.

The basic research sponsored by the Foundation is an investment in discovery and innovation. It may lead to new sources of energy; to advances which will create new industries and transform old ones; to increased understanding of the principles that govern the physical, life, and social sciences—understanding which is essential if we are to enhance the quality of life.

And through its applied research program, the Foundation is focusing scientific and technical resources on carefully selected problems of national importance—like energy, the environment and productivity. This program provides an essential link between new discoveries in science and their early application and availability to the public at large.

In a recent survey, designed to determine public attitudes towards science and technology, 70 percent of those interviewed responded that they felt science and technology have changed life for the better. When asked to describe their general reaction to science and technology, 49 percent expressed satisfaction or hope, and 23 percent excitement or wonder. Only 6 percent expressed indifference or lack of interest.

It is the responsibility of the National Science Foundation to see that our scientists receive the financial support they need to carry forward promising research. As the only Federal agency with a direct mandate to strengthen science and education in science, it is called on to perform a critically important and unique function.

For the coming fiscal year, the Foundation has been given a major responsibility in carrying out research and development which may lead us to new energy sources, to purer air and cleaner water, and to improved efficiency of present energy systems. One-third of its \$788.2 million budget is directed to this effort—pushing forward our knowledge on the frontiers of basic research and applying the results of that research to the introduction of new energy sources which hold enormous potential in our effort to free this Nation from its dependence on dwindling fossil fuel supplies. The Foundation has extensive capabilities in this area, and its full participation in the formulation of public policy and the national effort to develop new energy sources is essential if that effort is to meet with success.

Just last week, this Subcommittee heard testimony from officials of the Foundation with regard to the potential for the early application of solar heating and cooling systems. Today we will hear about on-going efforts to tap the potential of geothermal energy, to develop coal gasification techniques, and to use wind energy to generate the power we need to run our homes, schools, offices and industries.

At the same time, however, the Foundation must continue to extend support to other essential research efforts—efforts which may provide us with solutions to the problems which lie over the horizon. They, too, merit the full support of the Federal Government—and they must have that support on a continuing basis.

And underlying these efforts must be a continued investment in science education and in support for graduate students and faculty members in the science disciplines at our colleges and universities. The training of men and women in the most advanced techniques and concepts of basic science is essential to the development of new technology—technology we will need to insure our continued progress as a Nation.

Our need for trained scientists is as great now as it has ever been, and covers the whole range of science disciplines. We are looking to our scientists for guidance in finding solutions to air and water pollution control problems; for improved designs for mass transportation systems; for more effective utilization and delivery of health services; and for methods of allocating our scarce resources as fairly and effectively as possible.

Inflation has affected the cost of scientific research and equipment even more than it has affected the cost of food, housing, and fuel. This is as true for applied research aimed at meeting our immediate needs, as it is for basic research from which benefits may only be reaped by future generations. Yet, despite the unprecedented level of support requested by the Foundation—its funding for non-energy-related work remains virtually unchanged from fiscal 1974 levels. There are also proposed reductions in important science information activities, in institutional grants for science which are of critical importance to our small colleges, and in science education improvement efforts.

We have the intellectual and the financial resources to carry forward work in all these areas. We have the responsibility to insure that in our rush to a solution to the energy crisis, we do not overlook work in science disciplines which may be of critical importance to us in the future.

We will also look at questions which go beyond funding levels, to broader issues of management and direction. Can the Foundation

effectively absorb an overall increase of this magnitude, and does it have the personnel it needs to administer these programs effectively? Can the Foundation's applied research effort effectively focus on the broad range of projects which it now encompasses, and coordinate those efforts with research and development efforts being supported by other agencies of Government? What steps have been taken to insure that the academic community, industry, and the individual scientists have an adequate opportunity to compete for funding of worthwhile research efforts?

These are issues which are critical to the success of the ambitious research program the Foundation plans for the coming year.

We are now working on a draft bill for the 1975 authorization which we hope to introduce shortly. When this has been introduced in the Senate, without objection, I order the text of that bill printed following the text of S. 3299.

[The bills referred to follow:]

93^D CONGRESS
2^D SESSION

S. 3299

IN THE SENATE OF THE UNITED STATES

APRIL 3, 1974

Mr. DOMINICK introduced the following bill; which was read twice and referred to the Committee on Labor and Public Welfare

A BILL

National Science Foundation Authorization Act of 1975.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*
3 That there is hereby authorized to be appropriated to the
4 National Science Foundation for the fiscal year ending
5 June 30, 1975, to enable it to carry out its powers and
6 duties under the National Science Foundation Act of 1950,
7 as amended, and under title IX of the National Defense
8 Education Act of 1958, out of any money in the Treasury
9 not otherwise appropriated, \$783,200,000.

10 SEC. 2. Appropriations made pursuant to authority pro-
11 vided in sections 1 and 4 shall remain available for obliga-

1 tion, for expenditure, or for obligation and expenditure, for
2 such period or periods as may be specified in Acts making
3 such appropriations.

4 SEC. 3. Appropriations made pursuant to this Act may
5 be used, but not to exceed \$5,000, for official consultation,
6 representation, or other extraordinary expenses upon the
7 approval or authority of the Director of the National Science
8 Foundation, and his determination shall be final and conclu-
9 sive upon the accounting officers of the Government.

10 SEC. 4. In addition to such sums as are authorized by
11 section 1, not to exceed \$5 million is authorized to be appro-
12 priated for fiscal year ending June 30, 1975, for expenses of
13 the National Science Foundation incurred outside the United
14 States to be paid for in foreign currencies which the Treasury
15 Department determines to be excess to the normal require-
16 ments of the United States.

17 SEC. 5. This Act may be cited as the "National Science
18 Foundation Authorization Act, 1975".

93D CONGRESS
2D SESSION

S. 3344

IN THE SENATE OF THE UNITED STATES

APRIL 10, 1974

Mr. KENNEDY introduced the following bill; which was read twice and referred to the Committee on Labor and Public Welfare

A BILL

To authorize appropriations for activities of the National Science Foundation, and for other purposes.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*
3 That there is hereby authorized to be appropriated to the
4 National Science Foundation for the fiscal year ending
5 June 30, 1975, for the following categories:

6 (1) Scientific Research Project Support, \$363,-
7 700,000.

8 (2) National and Special Research Programs,
9 \$94,700,000.

10 (3) National Research Centers, \$52,500,000.

11 (4) Science Information Activities, \$8,300,000.

1 (5) International Cooperative Scientific Activities,
2 \$8,000,000.

3 (6) Research Applied to National Needs, \$148,-
4 900,000.

5 (7) Intergovernmental Science Program, \$5,000,-
6 000.

7 (8) Institutional Improvement for Science, \$23,-
8 000,000.

9 (9) Graduate Student Support, \$21,000,000.

10 (10) Science Education Improvement \$83,-
11 000,000.

12 (11) Planning and Policy Studies, \$2,700,000.

13 (12) Program Development and Management,
14 \$39,500,000.

15 SEC. 2. Notwithstanding any other provision of this
16 or any other Act—

17 (a) of the total amount authorized under section
18 1 of this Act not less than \$23,000,000 shall be avail-
19 able for the purpose of "Institutional Improvement for
20 Science";

21 (b) of the total amount authorized under section 1
22 of this Act not less than \$21,000,000 shall be available
23 for the purpose of "Graduate Student Support";

24 (c) of the total amount authorized under section
25 1 of this Act not less than \$83,000,000 shall be avail-

1 able for the purpose of "Science Education Improve-
2 ment";

3 (d) of the total amount authorized under section 1
4 category (2) not less than \$8,000,000 shall be avail-
5 able for "Ship Construction/Conversion";

6 (e) of the total amount authorized under section 1
7 category (10) not less than \$9,600,000 shall be avail-
8 able for "Ethnic Minorities and Women in Science
9 Program";

10 (f) of the total amount authorized under section 1
11 category (10) not less than \$4,000,000 shall be avail-
12 able for "Science Faculty Fellowships for College
13 Teachers";

14 (g) of the total amount authorized under section 1
15 category (10) not less than \$7,900,000 shall be avail-
16 able for "Student Programs" including "Undergrad-
17 uate Student Projects", and "Student Originated
18 Studies";

19 (h) of the total amount authorized under section 1
20 category (10) not less than \$21,900,000 shall be avail-
21 able for elementary and secondary school programs;

22 (i) the Director of the National Science Founda-
23 tion shall be responsible for planning, coordinating, and
24 directing the solar energy research programs of the
25 Federal Government.

1 SEC. 3. In addition to such sums as are authorized by
2 section 1, not to exceed \$5,000,000 is authorized to be ap-
3 propriated for fiscal year ending June 30, 1975, for expenses
4 of the National Science Foundation incurred outside the
5 United States to be paid for in foreign currencies which the
6 Treasury Department determines to be excess to the normal
7 requirements of the United States.

8 SEC. 4. Appropriations made pursuant to authority pro-
9 vided in sections 1 and 4 shall remain available for obliga-
10 tion, for expenditure, or for obligation and expenditure, for
11 such period or periods as may be specified in Acts making
12 such appropriations.

13 SEC. 5. No funds may be transferred from any partic-
14 ular category listed in section 1 to any other category or
15 categories listed in such section if the total of the funds so
16 transferred from that particular category would exceed 10
17 per centum thereof, and no funds may be transferred to any
18 particular category listed in section 1 from any other cate-
19 gory or categories listed in such section if the total of the
20 funds so transferred to that particular category would exceed
21 10 per centum thereof, unless—

22 (A) a period of thirty legislative days has passed
23 after the Director or his designee has transmitted to the
24 Speaker of the House of Representatives and to the
25 President of the Senate and to the Committee on Science

1 and Astronautics of the House of Representatives and
2 to the Committee on Labor and Public Welfare of the
3 Senate a written report containing a full and complete
4 statement concerning the nature of the transfer and the
5 reason therefor, or

6 (B) each such committee before the expiration of
7 such period has transmitted to the Director written
8 notice to the effect that such committee has no objection
9 to the proposed action.

10 SEC. 6. Notwithstanding any other provision of this or
11 any other Act, the Director of the National Science Founda-
12 tion shall keep the Committee on Science and Astronautics
13 of the House of Representatives and the Committee on
14 Labor and Public Welfare of the Senate fully and currently
15 informed with respect to all of the activities of the National
16 Science Foundation.

17 SEC. 7. This Act may be cited as the "National Science
18 Foundation Authorization Act, 1975".

Senator KENNEDY. This morning we will hear from Dr. H. Guyford Stever, Director of the National Science Foundation; from Dr. Philip Handler, president of the National Academy of Sciences; from Dr. Donald Hornig, president of Brown University and former Science Adviser to President Johnson, and from a panel of science educators.

As chairman of this special subcommittee I want to welcome the witnesses who will testify this morning. The members of this subcommittee are strong supporters of the programs of the National Science Foundation. We are very much aware of the new responsibilities which are being assumed by the Foundation in the energy area, and of the ongoing RANN projects, which involve industry as well as academic and nonprofit groups in a coordinated effort to develop alternative energy sources.

But I, as well as some other members of this subcommittee, am concerned about the level of support which is proposed in the fiscal 1975 budget for the Foundation's education programs. The National Science Foundation appears to be ready to cutback on some of these programs as it increases support for energy-related research. This is a matter of very considerable concern for the future of this country and our scientific and technical capabilities.

We are strengthening the mandate of the National Science Foundation in important areas of energy research. The Foundation is carrying out ambitious oceanographic research programs, in which Senator Pell is particularly interested. It is working on various aspects of solar energy, which Senator Stafford and I had the opportunity to learn a great deal about at hearings last week. But we question the wisdom of cutting back in the education area, and we will devote special attention to this during the course of the hearing this morning.

I will ask whether any of the other subcommittee members present have an opening comment to make.

Senator PELL. I have no opening comment, Mr. Chairman, but I must leave early because I am managing a bill on the floor, and hope I may have an opportunity to ask a few questions before I leave.

Senator STAFFORD. I have no opening statement, Mr. Chairman. I am looking forward to these hearings very much.

Senator KENNEDY. Dr. Stever, we want to welcome you back to the subcommittee, together with your colleagues. We are extremely interested in listening to your testimony outlining achievements of the Foundation and challenges which lie ahead. We look forward to your testimony this morning.

I think we have identified all those who are accompanying you before the subcommittee. I believe most have testified before us in the past, but perhaps for the record you would be kind enough to introduce them.

STATEMENT OF DR. H. GUYFORD STEVER, DIRECTOR, NATIONAL SCIENCE FOUNDATION; ACCOMPANIED BY DR. RAYMOND L. BISPLINGHOFF, DEPUTY DIRECTOR; DR. EDWARD C. CREUTZ, ASSISTANT DIRECTOR FOR RESEARCH; DR. ALFRED J. EGGERS, ASSISTANT DIRECTOR FOR RESEARCH APPLICATIONS; THOMAS E. JENKINS, ASSISTANT DIRECTOR FOR ADMINISTRATION; DR. THOMAS B. OWEN, ASSISTANT DIRECTOR FOR NATIONAL AND INTERNATIONAL PROGRAMS; AND DR. LOWELL PAIGE, ASSISTANT DIRECTOR FOR EDUCATION

Dr. STEVER. Mr. Chairman and members of the subcommittee, I will be happy to introduce those accompanying me.

On my left is Dr. Bisplinghoff, the Deputy Director; next to him is Dr. Edward Creutz, Assistant Director for Research; and on his left Dr. Alfred Eggers, Assistant Director for Research Applications. On my immediate right is Mr. Thomas Jenkins, Assistant Director for Administration, and to his right Dr. Thomas Owen, Assistant Director for National and International programs, and the only new member of the team, Dr. Lowell Paige, Assistant Director for Education.

We are very pleased that most of this team has been coming back here for a number of years. It is a pleasure for me to appear here once again to present the National Science Foundation's program for fiscal year 1975.

This subcommittee has given strong support to the Foundation's program of basic and applied research, science education, and related science support activities. The subcommittee recognized early the significance and vital importance to the Nation of increasing our basic scientific knowledge while at the same time focusing the Nation's science and technology capabilities directly on domestic problems.

Let me stress that we deeply appreciate the positive actions taken by this subcommittee which have been so instrumental in furthering efforts to strengthen the Nation's science and technology capabilities. For example, your efforts to strengthen the Foundation's energy programs last year were most timely.

Mr. Chairman, in my brief overview today, I thought it would be of most interest to the subcommittee if I described the fiscal year 1975 program in terms of how it addresses five key issues. These issues span the breadth of NSF activities and they spotlight the major thrusts of our program for fiscal year 1975. These issues are:

First—Will the proposed program strengthen U.S. science?

Second—Will it help the Nation focus science and technology on domestic problems, such as energy and the environment and other areas of social concern?

Third—Are the necessary management capabilities incorporated in the program to permit the National Science Foundation to carry it out effectively?

Fourth—Are the research capabilities of the institutions participating in National Science Foundations programs adequate to undertake the energy and expanded basic research programs being proposed?

Fifth—What are the prospects for the nonenergy and nonscience-discipline oriented programs of the Foundation in fiscal year 1975?

STRENGTHENING OF BASIC RESEARCH

Taking these issues in order I will address first the National Science Foundation program aimed at strengthening U.S. science. You are well aware of the Foundation's role in supporting basic science across the scientific disciplines as well as through national and special research programs such as the International Decade of Ocean Exploration, and the Antarctic research program. Prior to the time the energy problem became a crisis, an increase in basic research had been given high priority by the administration, together with the National Science Board and the National Science Foundation staff. Thus, even without the substantial increases for energy research, a higher level of support for basic science was planned for fiscal year 1975.

Mr. Chairman, may I please go over to page 4 of my testimony.

Senator KENNEDY. Of course, and I appreciate your moving right along through because I know we have many questions to ask you.

Let me say at this point that we take notice of the fact that the National Science Foundation made more sizable requests in the areas of science information and institutional support for science than were actually granted by OMB. I realize that in the decisionmaking process there have to be adjustments and accommodations in attempting to reach priorities. But, I am going to make these figures a part of the record, for I gather that you felt when you made those requests of OMB that they were justifiable requests, and that they were necessary.

Would I be safe in assuming that?

[The material referred to follows:]

PRESIDENT'S FY 1975 BUDGET ESTIMATES
AMOUNTS INCLUDED FOR NATIONAL SCIENCE FOUNDATION
FY 1973 - FY 1975

	FY 1973 Actual	FY 1974 Estimate	FY 1975 Estimates to Congress	FY 1975 Estimates to Congress
Scientific Research Project Support	\$277,252,364	\$291,294,617	\$333,000,000	\$363,700,000
National and Special Research Programs	103,252,969	91,600,000	95,100,000	84,800,000
National Research Centers	39,750,000	42,500,000	50,000,000	52,500,000
Science Information Activities	8,464,408	8,000,000	8,300,000	5,000,000
International Cooperative Scientific Activities	4,664,183	6,400,000	8,000,000	8,000,000
Research Applied to National Needs	69,867,314	75,100,000	82,000,000	148,900,000
Intergovernmental Science and Research Utilization	997,733	1,000,000	1,000,000	1,000,000
Institutional Improvement for Science	9,101,767	10,000,000	9,000,000	3,000,000
Graduate Student Support	15,308,895	13,000,000	12,000,000	12,700,000
Science Education Improvement	46,924,510	67,500,000	60,000,000	61,400,000
Planning and Policy Studies	1,689,870	2,600,000	2,900,000	2,700,000
Program Development and Management	28,619,198	31,660,000	37,150,000	39,500,000
Subtotal	605,929,111	640,654,617	698,450,000	783,200,000
Special Foreign Currency Program	4,342,121	5,657,879	5,000,000	5,000,000
TOTAL, NSF	610,271,232	646,312,496	703,450,000 ^{1/}	788,200,000 ^{2/}

^{1/} Does not include \$1,100,000 estimated as the cost in FY 1975 of the Federal Salary Increase effective October 1, 1973.

^{2/} Includes \$116,100,000 for energy related budget amendment.

2/21/74

PRESIDENT'S FY 1975 BUDGET ESTIMATES
AMOUNTS INCLUDED FOR NATIONAL SCIENCE FOUNDATION
FY 1973 - FY 1975

	FY 1973 Actual	FY 1974 Estimate	FY 1975 Estimates to CMB	Estimates to Congress
Scientific Research Project Support				
Atmospheric Sciences	\$ 11,927,869	\$ 12,600,000	\$13,800,000	\$ 14,500,000
Earth Sciences	9,763,409	10,700,000	12,700,000	13,700,000
Oceanography	12,662,053	13,800,000	15,100,000	15,900,000
Biological Sciences	65,415,703	68,594,617	78,700,000	85,400,000
Physics	34,883,571	36,400,000	43,400,000	44,800,000
Chemistry	25,081,400	26,400,000	31,400,000	37,100,000
Astronomy	8,794,164	9,600,000	12,000,000	11,500,000
Mathematical Sciences	14,063,659	14,700,000	17,600,000	17,100,000
Social Sciences	23,633,285	24,800,000	27,200,000	29,000,000
Engineering	26,158,678	28,500,000	31,300,000	37,900,000
Materials Research	34,973,251	35,700,000	39,200,000	45,400,000
Computing Activities	9,895,322	9,500,000	10,600,000	11,300,000
Subtotal	277,252,354	291,254,617	333,000,000	363,700,000
National and Special Research Programs				
Global Atmospheric Research Program	3,445,122	3,500,000	4,000,000	4,000,000
Experimental R&D Incentives Program	11,459,566	12,325,000	11,000,000	1,000,000
National R&D Assessment Program	2,291,268	2,000,000	3,000,000	3,000,000
International Decade of Ocean Exploration ..	16,934,313	14,000,000	15,000,000	15,500,000
Ocean Sediment Coring Program	9,594,106	10,500,000	11,000,000	11,000,000
Arctic Research Program	3,434,681	3,500,000	3,500,000	3,500,000
U.S. Antarctic Research Program	44,004,243 ^{1/}	24,275,000	25,500,000	25,800,000
Oceanographic Facilities and Support	10,993,719	17,900,000	16,000,000	15,000,000
Solar Eclipse Support	681,821	100,000	-0-	-0-
Science and Technology Policy Research	-0-	1,000,000	1,500,000	1,500,000
Energy R&D Policy Research	-0-	2,500,000	4,600,000	4,500,000
Subtotal	103,268,869	91,600,000	95,100,000	84,800,000

^{1/} Includes \$19,740,000 for LC-130R Aircraft Procurement.

PRESIDENT'S FY 1975 BUDGET ESTIMATES
AMOUNTS INCLUDED FOR NATIONAL SCIENCE FOUNDATION
FY 1973 - FY 1975
(Continued)

	FY 1973 Actual	FY 1974 Estimate	FY 1975 Estimates to Congress	Estimates to Congress
<u>National Research Centers</u>				
National Astronomy and Ionosphere Center .	\$ 3,250,000	\$ 3,100,000	\$ 3,300,000	\$ 3,300,000
Kitt Peak National Observatory	7,850,000	7,800,000	7,800,000	7,800,000
Cerro Tololo Inter-American Observatory ..	2,700,000	2,600,000	3,200,000	3,200,000
National Radio Astronomy Observatory	9,950,000	12,100,000	17,600,000	20,500,000
National Center for Atmospheric Research .	16,000,000	16,900,000	18,100,000	17,500,000
Subtotal	39,750,000	42,500,000	50,000,000	52,500,000
<u>Science Information Activities</u>	8,464,408	8,000,000	8,300,000	5,700,000
<u>International Cooperative Scientific Activities</u>	4,664,183	6,400,000	8,000,000	8,000,000
<u>Research Applied to National Needs</u>				
Energy Research and Technology	14,229,027	28,100,000	35,000,000	94,900,000
Environmental Systems and Resources	22,562,434	17,200,000	17,200,000	22,700,000
Advanced Technology Applications	14,708,796	15,500,000	15,500,000	14,300,000
Social Systems and Human Resources	13,352,323	10,500,000	10,500,000	13,000,000
Exploratory Research and Problem Assessment	5,094,734	3,800,000	3,800,000	4,000,000
Subtotal	69,887,314	75,100,000	82,000,000	148,900,000
<u>Intergovernmental Science and Research Utilization</u>	997,733	1,000,000	1,000,000	1,000,000
<u>Institutional Improvement for Science</u>	9,101,767	10,000,000	9,000,000	3,000,000

PRESIDENT'S FY 1975 BUDGET ESTIMATES
AMOUNTS INCLUDED FOR NATIONAL SCIENCE FOUNDATION
FY 1973 - FY 1975
(Continued)

	FY 1973 Actual	FY 1974 Estimate	FY 1975 Estimates to Congress	FY 1975 Estimates to Congress
Graduate Student Support	\$ 15,308,895	\$ 13,000,000	\$12,000,000	\$ 12,700,000
Science Education Improvement	46,924,510	67,500,000	60,000,000	61,400,000
Planning and Policy Studies	1,689,870	2,600,000	2,900,000	2,700,000
Program Development and Management	28,619,198	31,660,000	37,150,000	39,500,000
Subtotal	605,929,111 ^{2/}	640,654,617	698,450,000	783,200,000
Special Foreign Currency Program	4,342,121	5,657,879	5,000,000	5,000,000
TOTAL, NSF	610,271,232	646,312,496	703,450,000 ^{3/}	788,200,000 ^{4/}

- 2/ Excludes \$1,178,409 in obligations from funds appropriated to the Office of Science and Technology.
^{3/} Does not include \$1,100,000 estimated as the cost in FY 1975 of the Federal Salary Increase effective October 1, 1973.
^{4/} Includes \$116,100,000 for energy related budget amendment.

Dr. STEVER. Yes, Senator, you are safe in assuming that. The National Science Board and the Foundation staff are strong supporters of science education.

Senator KENNEDY. So, as I understand, for science information activities you have requested \$8,300,000, and you actually received \$5 million?

Dr. STEVER. That is correct for the science information activity.

Senator KENNEDY. For institutional support you requested \$9 million, and you received \$3 million; for science education you received, as a matter of fact, an increase to \$61.4 million from your request of \$60 million—but this is for a program that the Congress funded at \$67.5 million last year.

Dr. STEVER. Yes sir.

Senator KENNEDY. Now, before we move out of this area, would you tell us how many qualified requests for funding under science information activities and institutional improvement for science came in last year.

Dr. STEVER. Yes, sir. We can give you our estimates of the number of research proposals anticipated in these areas and the approximate percentage of those which we will be able to support with the funds requested.

Senator KENNEDY. Yes; the number of requests that came in to NSF that your people reviewed and said, "These are quality proposals. If we had the amount of money we would like we would approve them. We do not have that amount of money, so we have to pick and choose."

Dr. STEVER. I would be glad to, and let me call on some of the assistant directors for the specifics. By and large it varies considerably from field to field.

In a few fields we are able to fund more than 50 percent of the proposal requests, but in most of them the ratio of support is considerably lower than that, and in terms of amount of money requested, even lower still.

Dr. OWEN. Of the number submitted over a 2-year period in that area I believe it would be about 200, and in that time we would fund just over 100.

Senator KENNEDY. Of the 200, how many are really quality proposals?

Dr. OWEN. Mr. Chairman, we feel the 100 or so we select are the quality ones.

Senator KENNEDY. I am sure you are picking them because they are deserving in quality, but of the others, if you had the resources, how many would you approve?

Dr. OWEN. I would assume of the 50 percent roughly remaining, an additional 20 percent or more would be of quality sufficient for funding under the Foundation's quality standards.

Senator KENNEDY. Could you furnish precise figures?

Dr. STEVER. Yes.

Senator KENNEDY. What I am interested in primarily are the institutions and general education. How many requests came in last year? What do you anticipate for this year—requests that, if you had the resources, you might go ahead with.

Dr. STEVER. We will submit that for the record.

[The information subsequently supplied follows:]

Question:

What you have had requested in the period of the last year, what you anticipate for this year, and what your people would feel would be under normal circumstances quality applications.

Answer: Science Information Activities

<u>SIS</u>	<u>FY 1973</u>	<u>FY 1974 (estimate)</u>
proposals received	95	111
total amount requested	\$ 14,525,567	\$ 14,000,000
proposals awarded	69	62
total amount awarded	\$ 8,464,408	\$ 8,000,000
high quality proposals unsupported	13	22
total amount requested	\$ 4,673,200	\$ 3,000,000

Answer: Research Management Improvement Program

In Fiscal Year 1974, the Research Management Improvement (RMI) Program received 157 proposals requesting a total of \$16,049,800. Of these, 11 projects were supported with a total of \$992,385. The unsupported projects were judged to be of less than high quality.

Thus far in Fiscal Year 1974, the RMI Program has received 57 proposals requesting a total of \$7,511,100. Of these, four have been supported with a total amount of \$473,900, 36 have been denied support, and action is pending on the remaining 17. These data are summarized in the table below.

<u>RMI</u>	<u>FY 1973</u>	<u>FY 1974</u>
proposals received	157	57
total amount requested	\$ 16,049,800	\$ 7,511,000
proposals awarded	11	4
total amount awarded	\$ 992,385	\$ 473,900

In process are awards to be made that will essentially commit all funds in the RMI program.

- 2 -

Answer: Education Directorate 1/

<u>AD/E</u>	<u>FY 1973</u>	<u>FY 1974 (estimate)</u>
proposals received	5,363	4,500
total amount requested	\$ 185,612,000	\$ 170,000,000
proposals awarded	1,305	2,000
total amount awarded	\$ 46,924,510	67,500,000
high quality proposals unsupported	2,248	1,433
total amount requested	\$ 43,020,000	\$ 23,705,000

1/ Figures exclude the NSF Fellowship Programs

Dr. STEVER. Mr. Chairman, I would say that in most fields the percentage of the fraction that we can fund of qualified research proposals is considerably lower so that we are only attempting to strike a reasonable balance.

Mr. Chairman, there are a number of reasons this year for making fiscal year 1975 a year to strengthen the fundamental research, and speaking of the priorities that you mentioned earlier, we recognize that budget constraints do not permit us to grow in all the areas we would like to and do as well as we could.

The National Science Board and the Foundation staff this year placed special priority on basic research. The energy priority came second to the basic research one, and came along in the latter half of the year.

There are a number of urgent reasons for making fiscal year 1975 a year for strengthening fundamental research. Let me mention only three:

First, recent scientific advances in the various disciplines have presented many unique and highly promising research opportunities that have a high potential for helping to solve some of the Nation's long-term problems. For example, research in such areas as catalysis, enzymes, wind effects engineering, economic theory, materials, and others have great potential for practical applications.

They are also of vital importance in strengthening the base of scientific understanding. It is important that we seize these opportunities without further delay in order that our Nation may realize early practical benefits, as well as maintaining its competitive edge in R. & D. over the long term.

Second, it is of great importance to the future health and strength of this Nation that we provide opportunities for our best young science and engineering students to participate in productive research on some of the unanswered questions concerning natural phenomena, the processes taking place in man's environment, and social and economic problems.

Third, in recent years, the limited growth in the level of basic research has been largely eroded by inflation. Rising costs of carrying out advanced research leave much high quality research unfunded. The tendency of the mission agencies to direct more of their research dollars to mission specific efforts has also affected the dynamics of the Foundation's basic research program.

To protect the health of basic science across all disciplines—a primary goal—the Foundation in many instances has been forced to fund projects at a level considerably below the most effective level—with new instrumentation being a highly vulnerable item in this resource allocation.

However, we feel that our proposed fiscal year 1975 program will provide a significant step toward improving this situation and alleviating some of the recognized concerns within the scientific community. At this point let me skip to page 6.

To summarize: A key element of the fiscal year 1975 program is to strengthen basic science. We have given top priority to increases in scientific research project support in the various disciplines and we are proposing the largest program for basic research in the National Science Foundation's history. I want to dwell on this point for just a moment.

In fiscal year 1969, the Foundation obligated \$183 million for basic research in the science disciplines under our principal basic research activity scientific research project support. We also obligated funds for basic research in national and special research programs and some of our other activities that brought the total basic research support of the Foundation in fiscal year 1969 to \$248 million.

By comparison, in fiscal year 1975 we are requesting nearly \$364 million for basic research in the science disciplines under scientific research project support. That is an increase of \$181 million or nearly 100 percent above the fiscal year 1969 level.

This \$364 million plus \$206 million for basic research funding in other National Science Foundation activities brings our total for basic research in fiscal year 1975 to \$570 million, which can be compared to \$248 million 5 years ago.

The point that I want to stress is that there has been no diminution in the importance assigned to basic research. Rather our support of basic research will more than double from fiscal year 1969 to fiscal year 1975 increasing from 62 percent to 72 percent of the total National Science Foundation program.

Senator KENNEDY. Just before we move on, could you give us a basic idea of how much of this is energy related and how much is related to other fields?

Dr. STEVER. Yes, sir. The National Science Foundation energy research activities for fiscal year 1975 total \$252.6 million composed of \$101.8 million direct energy research and \$150.8 million for energy supporting research; \$113 million of the energy supporting research total of \$150.8 million is for basic research. Almost 20 percent of our total basic research of \$570 million in fiscal year 1975 is energy related.

Senator KENNEDY. Can you give us a breakdown in the other areas?

Dr. STEVER. Would you like it now?

Senator KENNEDY. You can submit it.

Dr. STEVER. We have I think a very good breakdown of that.

Senator KENNEDY. Do you have it with you today?

Dr. STEVER. We have it here.

[The information referred to follows:]

Supporting Energy R&D Programs

Supporting Programs

Basic Research

Environmental Effects

Manpower Resources

NSF Energy Related Research Activities for FY 1975—Tie-in to President's Budget Amendment.

The following tables show the distribution of the NSF energy related research program for fiscal years 1973, 1974, and 1975 among the above activities and subactivities. The first table shows the distribution of the total energy related research activities for FY 1975 in the amount of \$252.6 million; the second table shows the distribution of the special energy thrust for NSF of \$116.1 million which is included in the President's FY 1975 budget amendments and the third table shows a comparison of the NSF energy related activities, summarized under the President's program categories, for fiscal years 1973, 1974, and 1975.

**NATIONAL SCIENCE FOUNDATION
TOTAL ENERGY RELATED RESEARCH - FY 1975**

(In millions of dollars)

PRESIDENT'S ENERGY PROGRAM CATEGORIES																		4	
NSF PROGRAM ACTIVITY	CONSERVATION		OIL & GAS		COAL			RENEWABLE RESOURCES			OTHER DIRECT			SUPPORTING PROGRAMS				PROGRAM DEVELOPMENT & MANAGEMENT	TOTAL
	Improved Efficiency	Advanced Automotive	Subtotal	Resource Assessment	Direct Combustion	Liquefaction	Gasification	Subtotal	Solar Energy	Geothermal Energy	Subtotal	Systems Studies	Inter Coop Sciences	Subtotal	Basic Research	Environmental Effects	Management Resources		
Scientific research															111.1	19.0	130.1	130.1	
Project Support												4.5			0.2	3.5	3.7	8.9	
National & Social Research Programs				0.7											0.7		0.7	0.7	
National Research Centers																		0	
Science Information Activities																		0	
International Coop Science Activities													1.0	1.0				1.0	
Research Applied to National Needs	11.7	0.9	12.6		1.0	1.4	1.4	3.8	50.0	22.3	72.3	4.7		4.7	1.5	8.0	9.5	102.9	
Intergovernmental Science & Research Utilization																		0	
Institutional Improvement for Science																		0	
Graduate Student Support																			
Science Education Improvement																	3.2	3.2	
Planning & Policy Studies																	1.4	1.4	
Program Development & Management																	0.4	0.4	
TOTAL	11.7	0.9	12.6	0.7	1.0	1.4	1.4	3.8	50.0	22.3	72.3	9.2	1.0	10.2	113.5	30.5	5.0	149.0	252.6
																		4.0*	4.0

* PD&M amount (\$4.0 million) includes only the "Special Energy Research Initiatives" portion of PD&M. This does not reflect any of the PD&M funding that was included in the base budget for energy related research.

Senator KENNEDY. As I understand it, you don't have any money in the pipeline. I always find that when we go to the floor and start talking about increases, we are always asked: What is being carried over from the year before? I understand under the minimums we established you spent everything.

Dr. STEVER. By the end of this year, we will have obligated everything; yes, Senator.

Senator KENNEDY. This is the first year you have not had a carryover?

Dr. STEVER. Yes, sir.

Senator KENNEDY. I am sure that has been because of the need in these areas.

Dr. STEVER. Yes, sir. Mr. Chairman, in view of brevity, I have some examples I was going to call on Dr. Creutz to show on some slides.

Senator KENNEDY. What are the slides on?

Dr. STEVER. The slides are on several examples of basic research to show you the breadth of the program. One of the difficult things in science is we support really between 10,000 and 20,000 reserved projects in the National Science Foundation each year. To pick good illustrations is always difficult. Would you like to see those?

Senator KENNEDY. I think perhaps we could hold those and come back to them depending on the time. I would like to say to your slide man that I think the ones we may be most interested in are in the energy area; but why don't we hold that and see how the questions go.

FOCUS ON PROBLEMS OF NATIONAL CONCERN

Dr. STEVER. I have spoken about basic research, which is our highest priority this year, but let me speak on problems of national concern. While basic science not focused on problems of national concern often contributes to their amelioration in an unforeseen fashion, as in the laser example, the Foundation proposes to support substantial amounts of basic and applied research in areas where possible contributions to the solution of societal problems can be foreseen.

The RANN program is designed to focus U.S. scientific and technical resources on selected problems of national importance with the objective of contributing to their practical solution. An important purpose of RANN in this process is to shorten the leadtime between the discoveries of science and their application in meeting the Nation's needs. Thus, RANN provides a key bridge between the Foundation's basic research and education programs and the development and operating programs of the Federal mission agencies, State and local governments, industry, and other users.

For example, in the environmental area, basic research under the atmospheric sciences discipline includes fundamental meteorological research on the dynamics, physics, and chemistry of the lower atmosphere and the stratosphere. A RANN counterpart aims at reducing, through weather modification, damaging effects of hail on the Nation's production of food. Both the basic studies and the more applied RANN hail experiments, incidentally, use the facilities and aircraft of the National Center for Atmospheric Research, the National Science Foundation supported national center near Boulder, Colo.

Mr. Chairman, I would like to mention that in the tragic tornadoes of yesterday and the day before in the Middle West some of the instrumentation that we had put up in the Middle West, particularly I believe in Illinois—is that correct—

Dr. OWEN. Yes.

Dr. STEVER [continuing]. Was installed as part of our hail experiment. This instrumentation recorded a number of those tornadoes going through, and, as a result, we hope to have some very good scientific information about the tornadoes.

Senator KENNEDY. You could not get much in advance?

Dr. STEVER. We wish we could, and some day we hope to.

Senator PELL. May I interrupt? Can you make tornadoes?

Dr. STEVER. The Foundation has no research projects in that area.

Senator PELL. Is that not possible in the present state of the art?

Dr. STEVER. We are certainly trying to ameliorate the undesirable effects of the weather, and we hope some day to lessen the formation of hail and the damage from that.

The energy that gets into tornadoes is an unbelievable amount, and it is going to be very difficult for us to do it, but we will keep at it.

The Foundation's program for fiscal year 1975 includes a major direct and supporting energy research effort. These energy research activities cut across most major program areas of the agency. More than 85 percent of the effort is concentrated in the closely interlinked programs of scientific research project support and research applied to national needs. This vugraph (fig. 1) shows the different energy sources and their major categories of use.

[The material referred to follows:]

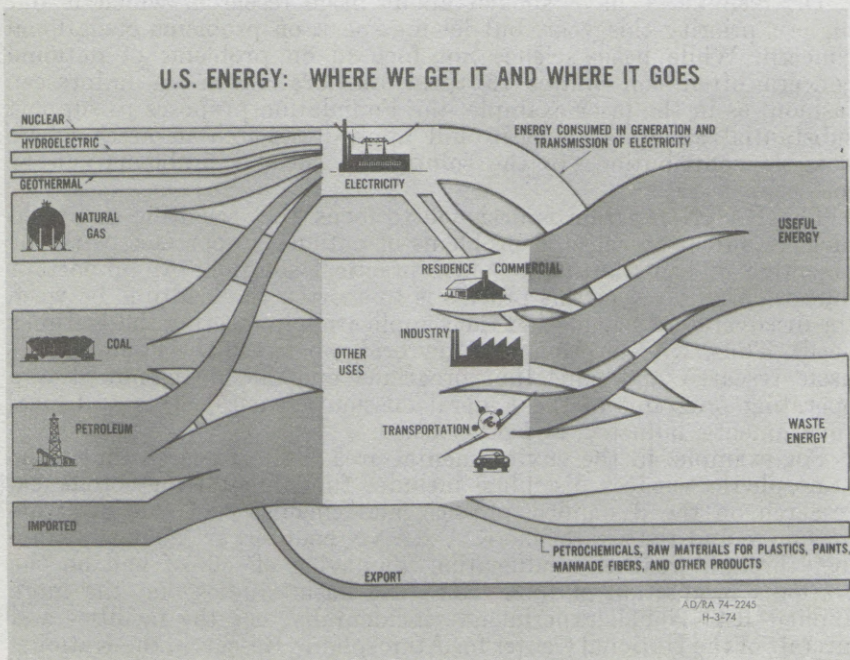


FIGURE 1

Dr. STEVER. Of the total you can see that nuclear is 16 percent; hydroelectric, 4 percent; geothermal less than 1 percent; natural gas, 35.6 percent; coal, 20.1 percent; petroleum, 27.8 percent and 11.8 percent is imported.

As you can see it goes through the various processes and comes out the other end as useful energy in the top black bar, and waste energy in the lower white bar, and you can see the field for doing research and development in energy.

If we can reduce the transmission costs of the mechanical inefficiencies, the loss of energy caused by incomplete combustion and so on in that right bar, will automatically have lowered substantially our waste.

Senator KENNEDY. Is that about half?

Dr. STEVER. Yes; it is of the order of half. It varies in various people's calculations, but that is the way that it works out.

National Science Foundation energy research deals with conservation which would affect the upper bar there, conservation in which we use more effectively the useful energy we produce through better insulation, use of smaller cars, and so on.

Our energy work is on conservation and transmission, and production, which would affect the lower white bar.

Also our research points to an environmental quality and the impact of energy production on the ecology and economy of a given area.

As you know, Mr. Chairman and members of the committee, solar and geothermal energy systems are major thrusts of this broad gauge program.

Senator KENNEDY. Doctor, could we interrupt you at this point. Senator Pell would like to ask some questions.

Senator PELL. I ask the forgiveness of both our committee members and our distinguished witnesses, but I do have to be on the floor in a very few moments, and I thank you, Mr. Chairman, for letting me take this up out of order.

First, I would like to congratulate you on your responses to inquiries from the Congress. In general, I think the Foundation is very responsive to our requests for information, but I do have one question. When a Member of Congress asks for the reasons why there is a turnaround of an application for a grant your policy is to let the applicant know but not to let the Congressman know.

I am wondering what the reason is for that?

Dr. STEVER. Senator Pell, the major reason is that we would rather confine that information to a very small number of people because we are a little afraid that might be used against the investigators.

We really try to respect the investigator's name, as you know. This is the very simple reason.

Senator PELL. It is, but I think you are one of the very few agencies in the Government that does this, and I think that we are usually pretty discrete ourselves.

Dr. STEVER. I know that is true, Senator.

Senator PELL. This information gives us a way of assessing the merits of that particular applicant and of seeing whether a constituent has been fairly treated. I wonder if you could perhaps at least review that policy?

Dr. STEVER. I will be glad to, and it may be that we can construct some useful way of communicating with people on this, because we really do try to protect them, and we just do not want it said that the person was weak or an organization was weak in certain research capabilities and have us be the source of that rumor or fact.

Senator PELL. You are unique in this policy, so, as I said, I wish you would take a look at it.

Dr. STEVER. We will, Senator.

Senator PELL. In the specific area of oceanography for fiscal 1974, \$3.5 million was provided by Congress for the construction of oceanographic research vessels to replace obsolete vessels, although NSF requested no funds.

Again this year, however, you have requested no funds for ship construction. Why have no funds been requested?

Dr. STEVER. This is one of the hard priority problems that we face, Senator Pell. We know that we must continue to construct some ships, partly to replace some very old ones. The new ones we construct are more efficient than the old ones. They are able to carry more experiments, and so on. We have two ships being built at the present time.

The difficulty is getting the operational support for these ships. As you know, that is a pretty scarce item, and so it gets down to a rough priority decision.

Senator PELL. How many vessels in our academic research fleet are more than 20 years old?

Dr. STEVER. I would refer that to Dr. Owen.

Dr. OWEN. At the completion of the recent building program, Senator Pell, we will have 8 that will be more than 20 years old.

Senator PELL. How many are more than 15 years old?

Dr. OWEN. I haven't the figures—

Senator PELL. Would it be more than eight?

Dr. OWEN. Yes sir.

Senator PELL. I wish you would submit that for the record.

[The information referred to follows:]

Question: How many vessels in the academic research fleet are more than twenty years old? More than fifteen?

Answer: Presently there are ten ships more than twenty years old. None of the ships currently in the fleet were built between 1954-1959; hence, there are no additional ships in the fifteen to twenty year old category.

<u>Institution</u> <u>Ship</u>	<u>Length Overall</u> <u>Feet</u>	<u>Age</u>
University of California - Scripps		
<u>Agassiz</u>	180	30
<u>Oconostota</u>	101	30
Columbia University-Lamont		
<u>Vema</u>	202	51
University of Georgia-Skidaway		
<u>Kit Jones</u>	65	36
Johns Hopkins		
<u>Maury</u>	65	24
Oregon State University		
<u>Yaquina</u>	180	30
University of Rhode Island		
<u>Trident</u>	180	30
University of Southern California		
<u>Velero IV</u>	110	26
University of Washington		
<u>Hoh</u>	65	31
Woods Hole Oceanographic Institution		
<u>Chain</u>	213	30

Senator PELL. Addressing myself to the chairman, should not there be planning for replacement of these aging vessels?

Dr. STEVER. Yes, sir.

Dr. OWEN. Senator, certainly we would like this. At the same time that we are engaged in a building program the other Federal agencies are putting ships out of commission because of problems in connection with the support for their programs, so we would be in a paradoxical situation here, and we have to resolve it in order to insure that the best interests of the oceanographic community are satisfied.

Senator PELL. Which agency is putting vessels out of commission?

Dr. OWEN. For example, the Navy is putting the ships *Lee* and *Sands* out of commission. In one case, the *Lee* is being transferred to the Geological Survey, and the *Sands'* disposition has not yet been determined.

The National Marine Fisheries Service, I believe, has one or two ships that are temporarily out of service, and it is the role of the Federal agencies to try to satisfy the needs of the oceanographic community and take these situations to account as well.

Senator PELL. What about the Coast and Geodetic Survey? What about the Coast Guard?

Dr. OWEN. I cannot comment on the former. The Coast Guard put their ocean station ships out of commission last year, as I recall.

Senator PELL. Does that mean some of the 380-foot cutters will be available for this kind of purpose or not?

Dr. OWEN. They will not be available for ocean station vessels.

Senator PELL. Some of them are ocean stations. I am curious whether they would be used or whether some of the old frigates would be used.

Dr. OWEN. I am sorry, sir, I do not know.

Dr. STEVER. I think, Senator Pell, if you look at the areas of science that have substantial facilities, this would include oceanography, astronomy, the atmospheric sciences. Where computers are needed, we always find difficulty in getting large funding needed through the system. We are only able to support the high-priority items. We do not come to you every year for a new facility in each field. We find also that when we commit ourselves to a facility, there are increased operational costs which also must be supported in later years. We are always caught in having to make priority choices because we always have to be highly selective because of limited funds.

Senator PELL. Then I will just leave this subject with the notation that you are asking for no ship construction, yet you have eight that are more than 20 years old and a larger number that are more than 15 years old. I would hope the next time you come up, you will ask for money for new vessels.

Your request for operating expenses for oceanographic facilities and support for fiscal year 1975 is \$14 million compared to \$13.6 million for last year. Included in this amount is \$1,206,000 for fuel and lubricants, compared to \$992,000 for fiscal year 1974.

As you know, fuel prices have skyrocketed since October. Estimates are that these may be from three to five times the prices they were. Why was this increase not taken into account? What was the reason for this?

Dr. OWEN. Senator, we do recognize that fuel costs have increased. At the time this budget was prepared and submitted, we felt that there were adequate funds in it to take care of fuel costs. We do recognize that the cost of fuel in the academic fleet will approximately double, and we are examining that situation very carefully and considering how we might best handle it.

Senator PELL. Will it not be more than double? Will it not be triple?

Dr. OWEN. We figure the fuel costs for the academic fleet in fiscal year 1973 were \$1 million. We figure that in 1975 it will be about \$2.5 million—this is for the total fleet—and our share of that support of \$2.5 million for fuel would be about \$1.8 million.

Senator PELL. Will that not mean fewer steaming days?

Dr. OWEN. Yes, sir.

Senator PELL. So if you steamed as many days as you did in 1973, you would need about three times—minimum—the amount of money for fuel; is that correct?

Dr. OWEN. Yes, sir. One cannot anticipate what direction fuel costs may take, Senator.

There is another problem, Senator, and that is we are only partial funders of the academic fleet, and the share that we have been bearing continues to increase year by year.

We do feel, however, that the share that we do bear will more than satisfy the oceanographic research that the National Science Foundation itself is sponsoring.

Senator PELL. Then even under your estimate, which I do not think is correct, and also as you suggest may well involve fewer steaming days—which is a pity, because we should have more, not less—you should at least double your budget.

It would seem to me to be incumbent upon either you or this committee to raise your budget for fuel so you can do as much steaming as you did 2 years ago with the vessels you have.

Dr. OWEN. Fuel costs represent only one part of the operation, Senator. As I say, we have looked at it very carefully.

Senator PELL. The other costs of operation have been taken into account, the increase of wages, you knew about that, but the thing you did not know about when you prepared this was fuel, so it would seem it is incumbent on us to make sure that the authorization would take that into account.

Dr. OWEN. We do have a fuel problem, and its magnitude is still yet to be determined, but less than a million dollars.

Senator PELL. Let me point out that you have come to us with a budget that you say is adequate, yet when pressed, as you are in this case, you say the budget is adequate for about half your estimate of the fuel requirement.

Dr. STEVER. Senator Pell, yes, we know we have a fuel problem in this area, and in a couple other areas such as the Antarctic area. We have gone to OMB; they are studying this across the entire Government because it affects some agencies more than us, and we hope we will soon have some resolution.

We agree with you that we should make every effort to maintain steaming days.

Senator PELL. Right. Under the budget submitted to us by the administration, your steaming days would be reduced about 50 to 60 percent.

Dr. STEVER. No, sir. By judicious reprogramming from other areas, we hope to maintain fleet viability.

Senator PELL. Perhaps the ball bounces back to this committee, and I would ask the chairman if he might be willing to increase the fuel to an adequate amount.

Senator KENNEDY. It is accepted.

Senator PELL. Mr. Chairman, leaving that subject, I have one final question. You say NSF is the lead Federal agency for solar and geo-thermal energy. What about energy from the oceans, the tides, and using differences in water temperature?

Dr. STEVER. Yes, Senator, these areas fall under our solar energy program.

Senator PELL. You put tides under solar?

Dr. STEVER. Yes, sir. You see, the heat in the ocean and the temperature comes from the sun.

Senator PELL. And also the tides come from the pull of the earth's gravity.

Dr. STEVER. Yes sir; that is they come from the pull of the Sun and Moon's gravity upon the Earth.

Senator PELL. I thank you very much. I only regret that I will not be able to be here to introduce Dr. Donald Hornig, who is president of Brown University. I know his testimony will be extremely helpful, and he has done a wonderful job in this field.

Senator KENNEDY. Would you like a breakdown, Senator Pell, on the tides and temperatures, what has been done this year and what is projected in terms of next year?

Senator PELL. Yes.

Senator KENNEDY. Could you give that to us? You might submit that and send it to Senator Pell.

Dr. STEVER. I can give Senator Pell a quick rundown now and then submit a fuller answer to him. In the ocean thermal area we will use \$743,000, and we have \$3 million in for next year on the ocean thermal energy program.

Senator KENNEDY. Will you tell us where that is going to take place?

Dr. STEVER. We will.

Senator PELL. And how much of it is devoted to the tides and how much to the question of getting energy from the other sources.

Dr. STEVER. The latter is the bigger user of it.

Senator PELL. From the tides?

Dr. EGGERS. Very little for tides.

Senator PELL. Any?

Dr. EGGERS. Yes, there is some, but it would measure in the few thousands of dollars. We continue to study it from a theoretical point of view, but so far as in terms of having a major contribution to meeting energy needs, it is a poor contender as far as we can tell. The ocean thermal as far as order of magnitude is more attractive.

Senator PELL. Thank you very much.

Senator KENNEDY. We have an indication of the congressional interest in this in terms of the Passamaquoddy tidal power project. We have had authorizations of several hundred thousand dollars for it. There is every indication that there will be a serious push in this area in regard to harnessing the tides. So I think, particularly in our part of the country, we would be interested in what applications you have had for tide research.

Perhaps you could give us a note on who has applied for research grants for tidal studies, where these studies would have been done, and your disposition of them. Could you do that?

[The information referred to follows:]

Although NSF does receive some inquiries about technological research on tidal energy conversion, none of those inquiries has reached a proposal stage. NSF has performed the examination mentioned above, and concluded that the questions in the tidal possibility are more economic than technological. If we are interested in obtaining significant energy from the oceans, we believe that our research dollars are most needed and best invested in the high-payoff potential of ocean thermal energy conversion.

Dr. STEVER. Our energy research, as I mentioned, deals with conservation, conversion, production, and transmission, as well as with issues of environmental quality and the impact of energy production on the ecology and economy of a given area. Solar and geothermal energy systems are major thrusts of this broad-gage program.

Also, Mr. Chairman, another important feature of the Foundations' integrated energy program includes combined efforts to deal with the very difficult problems involved in transferring needed new technology into practical use on a broad scale.

NSF is the lead Federal agency for solar and geothermal energy. These efforts are concentrated in our program of Research Applied to National Needs (RANN). The objective is to bring solar and geothermal energy sources into wide-scale application as quickly as possible with NSF supporting the basic and applied research in these efforts through proof-of-concept.

For example, under the RANN solar energy program, four schools have been outfitted with experimental solar heating systems, which were in operation in March of this year. These heat augmentation experiments which involve schools located at Timonium, Md.; Boston, Mass.; Warrenton, Va.; and Minneapolis, Minn., will provide important initial information on the system's performance and on their acceptability to the public. They will also provide the basis for obtaining valuable information on the retrofit application of solar heating systems to a variety of schools and other buildings at various locations in the Nation. They will be operated through June 1975.

Mr. Chairman, I have a number of vugraphs on this. Would you like to see them? I think they are interesting and fairly short.

Senator KENNEDY. Yes.

Dr. STEVER. This vugraph (figure 2) shows the Timonium elementary school before it was modified. The next vugraph (figure 3) shows the school after the solar collectors were installed. The experiment at this school is testing collectors that involve a glass-covered honeycomb design which is intended to make them suitable substitutes for conventional roof structures.

The Boston school (figure 4) experiment is testing a solar energy system (figure 5) which employs Lexan plastic glazing. This collector (figure 6) utilizes a nonselective coating that is somewhat less efficient than one with a selective coating, but it has the advantages of being lightweight and relatively vandal proof. This experiment and the one at the Baltimore school have been in operation the longest, and the experimental solar heating and augmentation systems have performed well thus far.

[The figures referred to follow:]

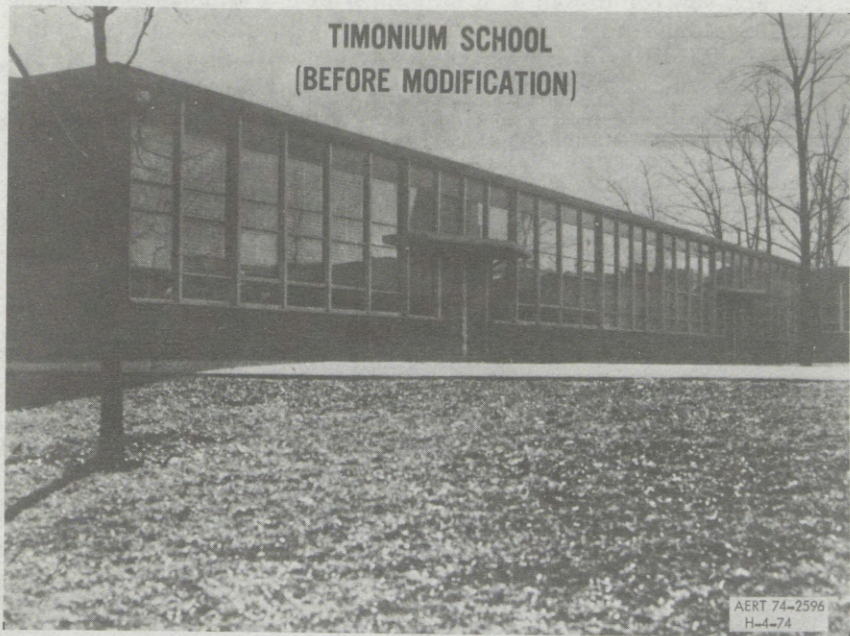


FIGURE 2

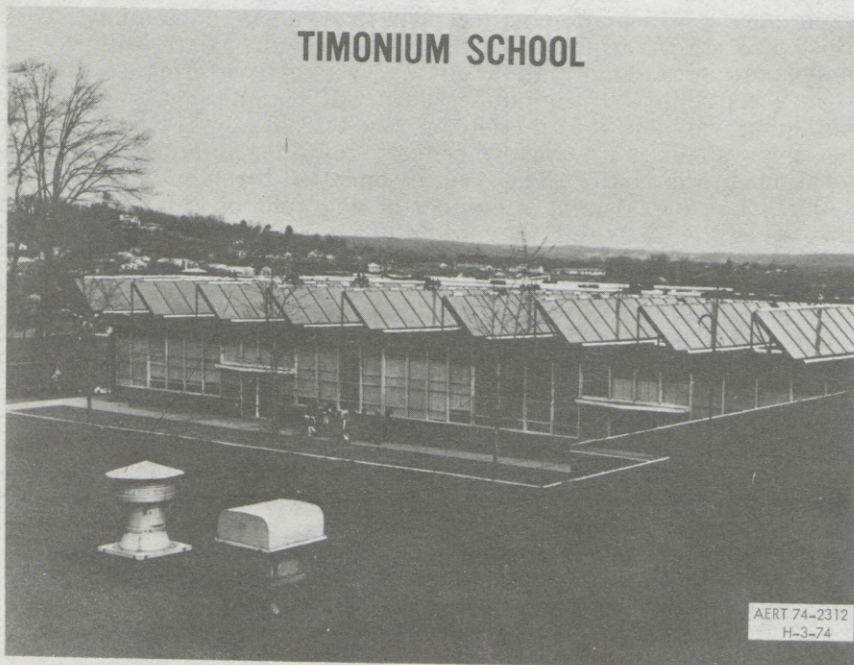


FIGURE 3

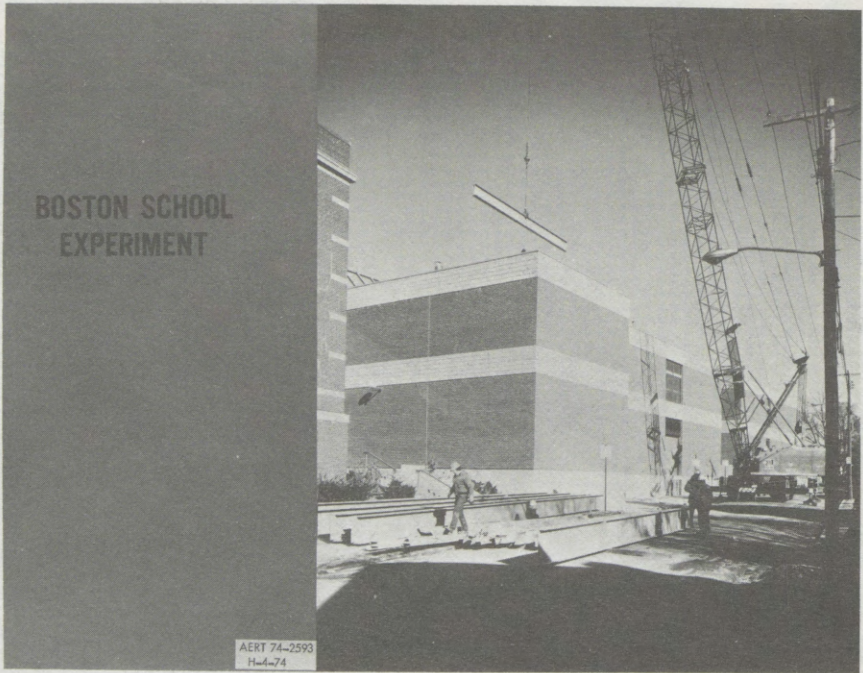


FIGURE 4



FIGURE 5

COLLECTOR UTILIZING A NONSELECTIVE COATING
(BOSTON SCHOOL)

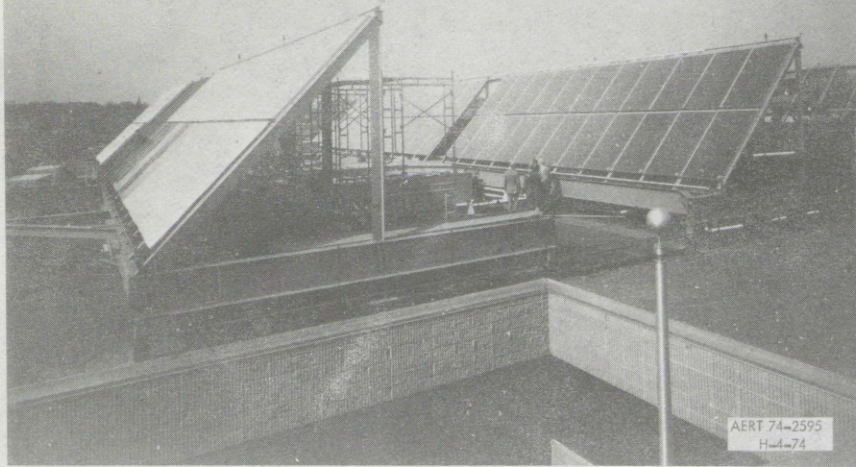


FIGURE 6

Dr. STEVER. I should note, Mr. Chairman, that the Foundation has fully implemented the NSF energy program approved by the Congress for fiscal year 1974 and it is this expanded program which made it possible for the National Science Foundation to undertake the accelerated fiscal year 1975 effort. I believe that the energy goals of the administration and the Congress are in agreement; that is, to achieve energy self-sufficiency for the United States in the shortest time possible and in a manner that will balance social, economic, and environmental considerations.

As Dr. Eggers indicated in his testimony on H.R. 11864 before this subcommittee on March 27, the National Science Foundation is utilizing the best experts from Government, industry, and universities in this broad-scale energy research undertaking. Industry-university teams have been established and they are working effectively.

You will recall, Mr. Chairman, that this committee and others insisted that we have a certain portion of our RANN program in the energy field. I would like to make an aside, Mr. Chairman. I think there was a decade or more of science research in this country in which Government support tended to pull universities away from industry teams, and in talking in the late 1960s one got the feeling that the universities were not close enough to the industry teams in science and technology. We think many of our joint programs have an additional payoff in addition to the results we are getting. They tend to bring those segments closer together.

Key users of the results of the research involving the mission agencies and manufacturers are being brought into the projects at an early stage so that we are able to pass along research results to the major users at every step along the way toward broad scale demonstration.

Mr. Chairman, as you know the Research Applied to National Needs (RANN) program also provides the Federal Government with an important tool for examining emerging problems. We are at the present time doing exploratory research and problem assessment in several potential problem areas. These include critical materials and minerals, food, and fibers. Our objective is to provide a basis for future research on emerging national needs, and I will have to tell you Mr. Chairman, of the battering that the science community has gotten, sometimes not justified, because they did not foresee the energy problem. We are trying to make sure we are ahead on the next emerging problems and crises, and that is one of our major objects, not only of the RANN program but our programs that support the science advisors.

The fiscal year 1975 RANN program will also emphasize research contributing to productivity, including enzyme technology and industrial processing, research on the environment, and research designed to reduce the damaging effects of natural hazards such as earthquakes.

MANAGEMENT CAPABILITIES

Mr. Chairman, there have been questions raised about our management capabilities, and under this committee's encouragement and others we have greatly strengthened our management capabilities for both basic and applied research.

This effort began in earnest shortly after the passage of the 1968 amendments to the NSF act which provided for additional top level personnel to better equip NSF to handle its increased responsibilities. Since that time, research managers from industry and mission agencies have been added to a growing number of science and engineering experts drawn from the ranks of universities to form what I believe to be one of the strongest research management teams anywhere in the Nation, and I would add anywhere in the world.

We have made organizational changes to better equip us to deal with our energy research responsibilities. The first of these was the establishment of an Energy R. & D. Policy Office to assist me in my Science Adviser role. Second, a Division of Advanced Energy Research and Technology was established in RANN in direct response to your suggestion last year to manage that portion of the energy program.

Most recently, an Office of Energy Related General Research was set up to assist Dr. Creutz in the management of the Research Directorate's energy-related program activities.

To staff these offices we have drawn heavily on NSF personnel previously involved in work related to energy.

CAPABILITIES OF NSF PROGRAM PARTICIPANTS FOR EXPANDED BASIC RESEARCH AND ENERGY RESEARCH

We are often asked if we ask for more funds in this basic research, is our constituency, which is to a considerable extent the university world but also the industrial world, able to absorb this work?

Over half the energy-related research proposed for fiscal year 1975 will consist of scientific research project support in appropriate disciplines. Based on the number of high quality research proposals which we have received and the active interest shown to date, we are convinced that adequate capacity exists in the universities of this country to carry on effectively the fiscal year 1975 programs which we have proposed.

I would like to ask Dr. Creutz to just give us some numbers in the basic research field to show you the percentages of the programs we are now able to fund and something we will be able to.

Dr. CREUTZ. Mr. Chairman, I would like to tell you the fraction of the proposals we can support in certain areas. Of course we get very few really poor proposals. We have been turning down many proposals. Last year the percentage supported was 44. We believe at least another half of those that were turned down could be well supported.

ON THE BASIS OF VALUABLE SCIENTIFIC CONTRIBUTION

This percentage varies from field to field, and in the biological sciences we support about 43 percent. In mathematics, about 50 percent; one of the lowest categories was in the social sciences.

As you know, we have a strong program in social sciences, but we do find we cannot support as large a fraction in some areas as in others.

In engineering the NSF support is only about 10 percent of the academic research funded in this field by the Government. So our support, although small, is of critical nature because it is for basic work. We support about 30 percent of our engineering proposals.

Overall, in all fields of science the number of dollars we can support is about 36 percent, whereas we support 44 percent of the number of proposals received.

Senator KENNEDY. How do you get that figure?

Dr. CREUTZ. We very frequently want to support a proposal which requests a certain amount of money. We feel we cannot afford as much money as the principal investigator said he required.

Senator KENNEDY. So you cut him back?

Dr. CREUTZ. Yes, sir.

Dr. STEVER. Unfortunately when we have to cut back, it is either against personnel or equipment that is needed. It is not a good thing.

The RANN energy support makes up most of the balance of the energy research program and will involve industry and nonprofit organizations as well as universities. The RANN role of coupling basic research with more applied efforts is proving to be of significant value in the energy area. While the task will not be easy, we are convinced that the institutional capabilities are there to do the job.

Let me address some of the other areas, and, Mr. Chairman, you pointed out in your opening remarks that we were going up in basic research and we were going up in our energy research, but there are other areas where the priorities have not been increased. These I would like to discuss now.

NATIONAL AND SPECIAL RESEARCH PROGRAMS, NATIONAL RESEARCH
CENTERS, SCIENCE INFORMATION, SCIENCE EDUCATION

I have discussed thus far something of the NSF support for basic science, RANN, and energy related activities. Let me go on to several other Foundation efforts which are expected to contribute in a significant manner to the Nation's scientific strength.

The oceanographic activities in the National and International Program Directorate continue with support of over \$40 million. There are three programs—International Decade of Ocean Exploration (IDOE), Ocean Sediment Coring Program (OSCP), and Oceanographic Facilities and Support (OFS)—which relate directly to oceanographic research and complement our scientific research project support in this area.

The IDOE is a major effort to improve our understanding of the total ocean environment, its influences on man, and man's impact on the oceans.

We have underway a number of large-scale, coordinated projects through which we are trying to accelerate understanding of the oceans' effects on weather and climate, establish the scientific basis for preservation of the ocean environment, develop the basic comprehension needed for man to utilize intelligently the oceans' living resources, and provide fundamental data on the structure and dynamics of the processes of the seabed that produce mineral and petroleum resources.

A modest increase only is being requested, principally to allow planning for fiscal year 1976 field work in environmental forecasting and studies of pollutants which may develop as a result of accelerated development and use of fossil fuels.

The Ocean Sediment Coring Program will continue its work in achieving a thorough understanding of the ocean basins of the world. The drilling ship, *Glomar Challenger*, has probed every major ocean basin except the Arctic and has recovered sediment and rock cores from 322 locations. The U.S.S.R. has formally agreed to participate in the program and will contribute \$1 million a year.

Mr. Chairman, there was a little story on that \$1 million a year contribution. At first we thought we would get it in useful barter, that is, \$1 million of petroleum given to the United States for which they would pay us. That did not work out, and the Soviet Union decided they would fund this \$1 million through the Soviet Academy of Sciences.

That academy sent \$250,000, the first installment, to Dr. H. E. Stever, the Director of the National Science Foundation in Washington, D.C. [Laughter.]

The international banking system ended up with \$250,000 in my personal checking account, which I discovered by accident. [Laughter.]

Needless to say, how I disposed of that has been well documented. I think we have the system straightened out.

The Foundation is continuing our efforts to improve the effectiveness of the academic fleet of oceanographic research ships. As a result of the fiscal year 1974 appropriations, we were able to provide for the construction of another medium-size replacement ship for this

fleet. This ship is being constructed jointly with one provided for in fiscal year 1972. When available, these ships plus two Navy-built ships commissioned in fiscal year 1974 will reduce the number of overage ships in the academic fleet to eight.

Polar programs—the Arctic and the Antarctic research programs—are being continued at about the fiscal year 1974 level. In the Antarctic, the fact that we were able to carry out a program of research this past austral summer was due to the timely delivery of the three LC-130R aircraft provided in our fiscal year 1973 supplemental appropriation. By the way, these planes were delivered on schedule and within the original cost estimate. We are very pleased.

Senator KENNEDY. Who made them, do you remember?

Dr. STEVER. Yes. These are Hercules aircraft constructed in Georgia at the Lockheed plant, an outstanding aircraft, and the Navy gave us absolutely unbelievable logistic support in this research program. We cannot thank them enough, and we cannot thank Lockheed enough for getting those out on time and at cost.

These three planes were delivered on schedule and within the original cost estimate. You will recall that U.S.N.S. *Eltanin*, the research ship that surveyed much of the southern circumpolar ocean was withdrawn from service in December 1972.

I am pleased to report that we have arranged with Argentina for shared use of the ship and the circumpolar survey is being resumed.

Activities of the National and International Programs Directorate also include support for five national research centers. These provide facilities and support needed in astronomy and atmospheric science not available at individual institutions.

I am going to try to shorten my testimony here this morning because I know you need time, Mr. Chairman, but there is one area we are trying to accelerate, the Very Large Array radio telescope being constructed in New Mexico.

We have already talked about the Science Information Service, and I say we believe this to be a very valuable program. I would enter my comments on this Science Information Service into the record.

I would like to discuss science education activities. These activities are planned to continue at a level which allows an overall increase in those program areas specified in the fiscal year 1974 authorization. In addition to providing fellowships for outstanding graduate students, the proposed program continues to support efforts aimed at making improved science education available to more students at the elementary and high school as well as college levels.

Senator KENNEDY. As I understand it funding for Improvement for Careers in Science is down 3 percent. Education for Scientific Literacy is down 14 percent. The funds to increase the Effectiveness in Educational Processes are down 10 percent; Problem Assessment, and Experimental Projects, down 33 percent, and the Ethnic Minority and Women in Science Program is down by \$1 million.

Dr. STEVER. Dr. Paige, can you check those?

Dr. PAIGE. This is approximately correct. This is from the decrease of the \$75 million of Congress last year.

Senator KENNEDY. It would certainly appear as far as the OMB's recommendations that science education was not a very high priority in their budget.

Dr. STEVER. I think that is correct, what you have said. When I first came to the Foundation and discovered that its Education in the Sciences budget was tending to go down, I really tried to ascertain whether this was a move by the administration to cut it out, and I learned that was not the case at all. There are in fact units of the administration that want to keep this going. We have been changing the direction of it in recent years.

We think we have it into a very good shape with Dr. Lowell Paige guiding the program. We think we are tooled up to do a fine job, and we are very anxious to move forward.

SCIENCE ADVISER ROLE

Let me go quickly to the Science Adviser role. I would like to point out I now have 9 months experience in that. In addition to the Energy R. & D. Policy Office which I mentioned earlier, I have been aided considerably by the Science and Technology Policy Office which I established to provide staff support for my Science Adviser responsibilities.

I have been giving emphasis to developing communication channels to the scientific and technological community and to the assessment of potential future national problems, such as in materials and food, which may lead to the establishment of new directions and new priorities for Federal R. & D. efforts, and I can say I think these studies are coming not too soon.

Let me just summarize by saying we are trying to maintain the strength of science, yet we hope to make this program move forward across the board.

Senator KENNEDY. Under the post-doctoral program as I understand it, you will fund only applicants doing energy-related work—no others.

Dr. STEVER. Yes sir. That was added in the Energy Amendment.

Senator KENNEDY. You don't plan to fund institutional grants either.

Dr. STEVER. In this request there is an institutional research management program, but none for the institutional formula grants.

Senator KENNEDY. We expect to hear some later testimony with regard to that particular decision. Is there anything you would like to say to justify your position?

Dr. STEVER. I respect the people who will testify as to their opinions on this. This is all I can say.

Senator KENNEDY. With regard to your role as a science adviser to the President, can you give us any idea as to how frequently you were consulted with regard to energy development and research?

Dr. STEVER. Yes. I will tell you, first of all, we participated fairly heavily in that. As you know the administration would like to see a bill come through to focus on energy R. & D. However in the absence of such, we have had several exercises which I think have proposed a pretty good across-the-board R. & D. program for energy.

The National Science Foundation role has been in several areas. First of all, there was a major energy study last fall. The National Science Foundation contributed several of the leaders: Dr. Creutz in basic research, Dr. Eggers in solar energy, and Dr. Donovan aided the

Office of Management and Budget in putting together the budget for the increase of about close to a billion dollars—almost doubling the energy R. & D. program of the administration program for all agencies.

Also, I was appointed by the President as chairman of an advisory panel on energy. All members except myself are outside the Government. There are about 14 members, half from industry, half from academic institutions.

This advisory commission met to criticize constructively as much as we could on the energy program that was submitted to the Office of Management and Budget. There were three major areas in which we criticized this.

We felt that the Government program was too heavy in nuclear energy and not heavy enough in fossils fuel research and as a result the Office of Management and Budget raised the budget there.

The second one was we felt that their basic science was not emphasized in the program enough, and the Office of Management and Budget raised that.

In the third area, in energy and environment issues, we felt the budget was not large enough, and we got the Office of Management and Budget to raise that. So we have been involved quite heavily.

Senator KENNEDY. Finally, as a scientist what is your prediction or projection on the amount of time necessary for the United States to achieve energy self-sufficiency?

Dr. STEVER. It is a little hard to describe energy self-sufficiency. I described it as the time in which we can feel confident that the programs we have put in as possible substitutes for outside importation of energy. I do not think we will, even when our programs get going, if the cost of oil overseas is lower, give up on buying that. When we have the potential to supply ourselves completely, I think will be some time in the 1980's.

The President picked the earliest goal. Most of his advisers would have settled for 1985 or something like that, but I guess he felt great confidence in this, so he picked 1980.

Senator KENNEDY. Can you give us a figure on what it would cost, roughly?

Dr. STEVER. No. This is of course one of the great uncertainties. It will cost a lot.

Senator KENNEDY. I hear the range is from \$500 billion to \$600 billion.

Dr. STEVER. Yes, it is way up there, because the problem is not so much the R. & D. but the establishment of new plants, and that will be very costly to put in the new kinds of plants to do this.

Senator KENNEDY. I am not sure we have any real appreciation of that in terms of our total economy and the resources of this country. It is just mind boggling.

Dr. STEVER. Yes, it is.

We had a very interesting program along that line supported by Dr. Donovan's office which I believe is at Bechtel Corp. They are studying the implications through the entire economy of these shifts in energy.

Senator KENNEDY. Who is working on it?

Dr. STEVER. The Bechtel Corp., under a grant from the National Science Foundation. It is under a grant made by Dr. Donovan's office.

A typical question which this study seeks to answer is if you are ordering new steel for these plants, what effect is that going to have on our steel industry?

Senator KENNEDY. When is that going to be in?

Dr. DONOVAN. We expect preliminary results before September, and these will cover a broad range of manpower and materials requirements; the transportation system; needs for technical people and trades people such as welders, steamfitters, and so forth; needs for raw and fabricated materials will also be included. The whole picture is being looked at.

Senator KENNEDY. Is it continuing and ongoing?

Dr. DONOVAN. This will have to be an ongoing program because much of the data that are needed to come up with accurate resource requirements and estimates of their impact on our economy are not available yet.

Senator KENNEDY. We would appreciate being kept abreast of that.

Dr. STEVER. We will see that you are.

Senator Kennedy, the whole object of having this special office to help me in the science adviser role on energy R. & D. policy is to explore the broader issues and not specifically our mission with respect to solar energy, which is RANN, and we would like to keep you fully informed as these results come in.

Senator KENNEDY. Senator Stafford.

NSF AS LEAD AGENCY

Senator STAFFORD. Thank you, Mr. Chairman. There are a few questions that I would like to ask. I will limit them in view of time constraints this morning.

Doctor, is it appropriate for an agency such as the National Science Foundation, which is heavily committed to basic research, to be the lead agency for solar and geothermal energy research?

Dr. STEVER. Senator Stafford, I think it is. Let me say that we believe that we have pushed forward quite hard in basic science. This, I guess, is one of our first opportunities as a lead agency in applied scientific research, and we believe that we are moving forward quite vigorously in that area.

We do believe that our RANN program is proving to be successful in moving ideas out of basic into the applied science area. We know that we are going to have to turn it over to others.

We are trying to set up the appropriate transfer mechanism for doing that. We do not operate in such a way that we rob Peter to pay Paul in this. We are not taking money away from the basic scientific research programs. In fact, we always try to submit these programs to Congress as separate programs even though they are related. As the information is transferred, we do not try to get them in a position where we can determine to take away from one to aid the other.

I honestly believe that this is an important role. This committee, Senator Kennedy and members of the committee, has been strongly of the belief that the power of science in this country was not used well enough in application of research results. I think this a useful role. We are not trying to become a great powerful mission agency, and take that role from others, but we would like to move it along through a certain part of the transition.

NEED FOR FURTHER RESEARCH

Senator STAFFORD. Doctor, in your opinion, is further research really needed on the solar heating and cooling abilities?

Dr. STEVER. Yes, it is. We do not want to stop the movement to get solar heating of buildings out very quickly. We think that some of the results that we will get from these experimental schools and on our mobile van utilizing solar energy for heating will move us much quicker to utilization of this energy source by the general public.

Dr. EGGERS. The mobile van leaves tomorrow morning from the National Bureau of Standards and goes to Warrenton, Va.

Dr. STEVER. It will join there with the building we have there, and they will work together.

We think results from these experiments will help quite a bit. There are some missing links. We are not sure about some of the facts, but we are close enough to be confident that in a few years this is going to be quite practical.

INDUSTRY CONTRIBUTION TO JOINT PROJECTS

Senator STAFFORD. Is industry contributing anything to the projects in which it participates with National Science Foundation support?

Dr. STEVER. Indeed, yes, they are. Our major programs all have industry involvement in the solar energy research. They have industry and university teams.

I am sorry, was your question were they contributing of their own money?

Senator STAFFORD. That is what I really meant.

Dr. STEVER. Yes, they are.

Senator STAFFORD. Can you give us any idea of the extent?

Dr. STEVER. Fifty percent of the cost of this mobile laboratory is contributed by industry, for example.

Senator STAFFORD. Is the NSF doing any exploration for resources in the Antarctic; for example, in investigation of possible oil resources in Antarctic waters?

Dr. STEVER. Our investigations in the Antarctic are not particularly aimed at discovering new resources, but our science investigations cannot help but give us a lot of knowledge about them. So I would say that indirectly we are, but our research is not primarily aimed at resources.

Senator STAFFORD. Thank you, Doctor.

Senator KENNEDY. We will submit some additional questions for you. Doctor, I want to thank you very much. We are going to try if we can to send a little more money your way. I am hopeful we will be successful, but we may need some additional information.

Dr. STEVER. We will be willing at any time to bring it.

[The prepared statement of Dr. Stever and the answers to additional questions submitted to him follow:]

STATEMENT OF DR. H. GUYFORD STEVER
DIRECTOR
NATIONAL SCIENCE FOUNDATION
BEFORE THE SPECIAL SUBCOMMITTEE ON THE NSF
COMMITTEE ON LABOR AND PUBLIC WELFARE
UNITED STATES SENATE
APRIL 5, 1974

Mr. Chairman and members of the Subcommittee, it's a pleasure for me to appear here once again to present the National Science Foundation's program for FY 1975.

This subcommittee has given strong support to the Foundation's program of basic and applied research, science education, and related science support activities. The Subcommittee recognized early the significance and vital importance to the Nation of increasing our basic scientific knowledge while at the same time focusing the Nation's science and technology capabilities directly on domestic problems.

Let me stress that we deeply appreciate the positive actions taken by this Subcommittee which have been so instrumental in furthering efforts to strengthen the Nation's science and technology capabilities. For example, your efforts to strengthen the Foundation's energy programs last year were most timely.

Mr. Chairman, in my brief overview today, I thought it would be of most interest to the Subcommittee if I described the FY 1975 program in terms of how it addresses five key issues. These issues span the breadth of NSF activities and they spotlight the major thrusts of our program

-2-

for FY 1975. These issues are:

- First - Will the proposed program strengthen U. S. science?
- Second - Will it help the Nation focus science and technology on domestic problems, such as energy and the environment and other areas of social concern?
- Third - Are the necessary management capabilities incorporated in the program to permit NSF to carry it out effectively?
- Fourth - Are the research capabilities of the institutions participating in NSF programs adequate to undertake the energy and expanded basic research programs being proposed?
- Fifth - What are the prospects for the non-energy and non-science-discipline oriented programs of the Foundation in FY 1975?

STRENGTHENING OF BASIC SCIENCE

Taking these issues in order I will address first the NSF program aimed at strengthening U. S. science. You are well aware of the Foundation's role in supporting basic science across the scientific disciplines as well as through national and special research programs such as the International Decade of Ocean Exploration, and the Antarctic research program. Prior to the time the energy problem became a crisis,

-3-

an increase in basic research had been given high priority by the Administration, together with the National Science Board and the NSF staff. Thus even without the substantial increases for energy research, a higher level of support for basic science was planned for FY 1975.

As the members of this subcommittee know, advances in science and technology are made possible and spurred on by increased understanding of natural laws and fundamental processes and phenomena. History seems to show that, sooner or later, the "best" basic research generally turns out to be the most useful--often in totally unforeseeable applied contexts. A good example is provided by the laser.

Lasers, as you know, are a family of optical devices which have so many remarkable properties and applications that we must guard against thinking of them as a kind of universal technological cure-all. Historically, the laser is an out-growth of the maser, and the experiment in which maser action was first demonstrated represented the confluence of three very basic lines of physical research. One was the theoretical concept of "stimulated emission" proposed by Albert Einstein for very general reasons having to do with the symmetry of thermodynamic equilibrium in systems which include radiation. The second was the refinement, and exploitation for molecular spectroscopy of microwave techniques developed during the Second World War. And the third was the very specialized technique of molecular beams which

-4-

had been devised and was being used to verify and demonstrate some fundamental quantum mechanical properties of atoms and molecules.

Once the maser had been demonstrated, the Defense Department provided encouragement and support for a broad range of efforts which resulted in the first several generations of lasers. Lasers by now are available in great variety and with an absolutely astonishing number of applications. Just a few of these applications include: optical communications, photo-chemistry, eye surgery, isotope separation, precision surveying and measurement, specialized machining and welding--and, possibly, the ignition of controlled nuclear fusion reactions for nuclear energy.

We have barely scratched the surface of the laser story here; it has fascinating ramifications no matter in what direction we choose to follow it. But I wanted simply to raise the example; none of these very promising applications would have been accepted as self-evident motivation or justification for those very fundamental lines of scientific investigation which led to the technology.

There are a number of urgent reasons for making FY 1975 a year for strengthening fundamental research. Let me mention only three:

o First, recent scientific advances in the various disciplines have presented many unique and highly promising research opportunities that have a high potential for helping to solve some of the Nation's long-term problems. For example, research in such areas as catalysis, enzymes, wind effects engineering, economic theory, materials, and others have great potential for practical applications. They are also of

-5-

vital importance in strengthening the base of scientific understanding. It is important that we seize these opportunities without further delay in order that our Nation may realize early practical benefits, as well as maintaining its competitive edge in R&D over the long term.

o Second, it is of great importance to the future health and strength of this nation that we provide opportunities for our best young science and engineering students to participate in productive research on some of the unanswered questions concerning natural phenomena, the processes taking place in man's environment, and social and economic problems.

o Third, in recent years, the limited growth in the level of basic research has been largely eroded by inflation. Rising costs of carrying out advanced research leave much high quality research unfunded. The tendency of the mission agencies to direct more of their research dollars to mission specific efforts has also affected the dynamics of the Foundation's basic research program. To protect the health of basic science across all disciplines--a primary goal--the Foundation in many instances has been forced to fund projects at a level considerably below the most effective level--with new instrumentation being a highly vulnerable item in this resource allocation. However, we feel that our proposed FY 1975 program will provide a significant step toward improving this situation and alleviating some of the recognized concerns within the scientific community. Mr. Chairman, I have some other examples illustrated by these vignettes which we will describe informally.

-6-

To summarize: A key element of the FY 1975 program is to strengthen basic science. We have given top priority to increases in scientific research project support in the various disciplines and we are proposing the largest program for basic research in the National Science Foundation's history. I want to dwell on this point for just a moment.

In FY 1969, the Foundation obligated \$183 million for basic research in the science disciplines under our principal basic research activity Scientific Research Project Support. We also obligated funds for basic research in National and Special Research Programs and some of our other activities that brought the total basic research support of the Foundation in FY 1969 to \$248 million. By comparison, in FY 1975 we are requesting nearly \$364 million for basic research in the science disciplines under Scientific Research Project Support. That is an increase of \$181 million or nearly 100 percent above the FY 1969 level. This \$364 million plus \$206 million for basic research funding in other NSF activities brings our total for basic research in FY 1975 to \$570 million. The point that I want to stress is that there has been no diminution in the importance assigned to basic research. Rather our support of basic research will more than double from FY 1969 to FY 1975 increasing from 62% to 72% of the total NSF program.

FOCUS ON PROBLEMS OF NATIONAL CONCERN

While basic science not focused on problems of national concern often contributes to their amelioration in an unforeseen fashion, as in the laser example, the Foundation proposes to support substantial amounts

-7-

of basic and applied research in areas where possible contributions to the solution of societal problems can be foreseen.

The RANN program is designed to focus U. S. scientific and technical resources on selected problems of national importance with the objective of contributing to their practical solution. An important purpose of RANN in this process is to shorten the lead time between the discoveries of science and their application in meeting the Nation's needs. Thus RANN provides a key bridge between the Foundation's basic research and education programs and the development and operating programs of the Federal mission agencies, State and local governments, industry, and other users.

For example, in the environmental area, basic research under the atmospheric sciences discipline includes fundamental meteorological research on the dynamics, physics and chemistry of the lower atmosphere and the stratosphere. A RANN counterpart aims at reducing, through weather modification, damaging effects of hail on the Nation's production of food. Both the basic studies and the more applied RANN hail experiments, incidentally, use the facilities and aircraft of the National Center for Atmospheric Research, the NSF supported national center near Boulder, Colorado.

The Foundation's program for FY 1975 includes a major direct and supporting energy research effort. These energy research activities cut across most major program areas of the agency. More than 85 percent of the effort is concentrated in the closely interlinked programs of Scientific Research Project Support and Research Applied to National

-8-

Needs. This vugraph (Figure 1) shows the different energy sources and their major categories of use. As you can see, only about half of all the energy we consume lights and heats our homes, powers our industries, and drives our cars. The remaining half is accounted for by transmission losses, mechanical inefficiencies, and incomplete combustion.

Overall, our energy research deals with conservation, conversion, production, and transmission, as well as with issues of environmental quality and the impact of energy production on the ecology and economy of a given area. Solar and geothermal energy systems are major thrusts of this broad gauge program. Also, Mr. Chairman, another important feature of the Foundation's integrated energy program includes combined efforts to deal with the very difficult problems involved in transferring needed new technology into practical use on a broad scale. NSF is the lead Federal agency for solar and geothermal energy. These efforts are concentrated in our program of Research Applied to National Needs. The objective is to bring solar and geothermal energy sources into wide-scale application as quickly as possible with NSF supporting the basic and applied research in these efforts through proof-of-concept. For example, under the RANN solar energy program, four schools have been outfitted with experimental solar heating systems, which were in operation in March of this year. These heat augmentation experiments which involve schools located at Timonium, Maryland; Boston, Massachusetts; Warrenton, Virginia; and Minneapolis,

Minnesota, will provide important initial information on the systems performance and on their acceptability to the public. They will also provide the basis for obtaining valuable information on the retrofit application of solar heating systems to a variety of schools and other buildings at various locations in the Nation. They will be operated through June 1975.

- This vugraph (Figure 2) shows the Timonium Elementary School before it was modified. The next vugraph (Figure 3) shows the school after the solar collectors were installed. The experiment at this school is testing collectors that involve a glass-covered honeycomb design which is intended to make them suitable substitutes for conventional roof structures.

- The Boston School (Figure 4) experiment is testing a solar energy system (Figure 5) which employs Lexan Plastic glazing. This collector (Figure 6) utilizes a nonselective coating that is somewhat less efficient than one with a selective coating, but it has the advantages of being lightweight and relatively vandal-proof. This experiment and the one at the Baltimore School have been in operation the longest, and the experimental solar heating and augmentation systems have performed well thus far. I should note, Mr. Chairman, that the Foundation has fully implemented the NSF energy program approved by the Congress for FY 1974 and it is this expanded program which made it possible for NSF to undertake the accelerated FY 1975 effort. I believe

that the energy goals of the Administration and the Congress are in agreement; that is, to achieve energy self-sufficiency for the U. S. in the shortest time possible and in a manner that will balance social, economic, and environmental considerations.

As Dr. Eggers indicated in his testimony on H. R. 11804 before this Subcommittee on March 27, the NSF is utilizing the best experts from government, industry, and universities in this broad scale energy research undertaking. Industry-university teams have been established and they are working effectively. Key users of the results of the research involving the mission agencies and manufacturers are being brought into the projects at an early stage so that we are able to pass along research results to the major users at every step along the way towards broad scale demonstration.

Mr. Chairman, as you know the RANN program also provides the Federal government with an important tool for examining emerging problems. We are at the present time doing exploratory research and problem assessment in several potential problem areas. These include critical materials and minerals, food, and fibers. Our objective is to provide a basis for future research on emerging national needs.

The FY 1975 RANN program will also emphasize research contributing to productivity, including enzyme technology and industrial processing, research on the environment, and research designed to reduce the damaging effects of natural hazards such as earthquakes.

MANAGEMENT CAPABILITIES

Mr. Chairman, the Foundation has greatly strengthened its management capabilities for both basic and applied research. This effort began in earnest shortly after the passage of the 1968 amendments to the NSF Act which provided for additional top level personnel to better equip NSF to handle its increased responsibilities. Since that time, research managers from industry and mission agencies have been added to a growing number of science and engineering experts drawn from the ranks of universities to form what I believe to be one of the strongest research management teams anywhere in the Nation.

We have made organizational changes to better equip us to deal with our energy research responsibilities. The first of these was the establishment of an Energy R&D Policy Office to assist me in my Science Adviser role. Second, a Division of Advanced Energy Research and Technology was established in RANN in direct response to your suggestion last year to manage that portion of the energy program. Most recently, an Office of Energy Related General Research was set up to assist Dr. Creutz in the management of the Research Directorate's energy-related program activities. To staff these offices we have drawn heavily on NSF personnel previously involved in work related to energy.

CAPABILITIES OF NSF PROGRAM PARTICIPANTS FOR
EXPANDED BASIC RESEARCH AND ENERGY RESEARCH

Over half the energy-related research proposed for FY 1975 will consist of scientific research project support in appropriate disciplines. Based on the number of high quality research proposals which we have received and the active interest shown to date, we are convinced that adequate capacity exists in the universities of this country to carry on effectively the FY 1975 programs which we have proposed. The RANN energy support makes up most of the balance of the energy research program and will involve industry and non-profit organizations as well as universities. The RANN role of coupling basic research with more applied efforts is proving to be of significant value in the energy area. While the task will not be easy, we are convinced that the institutional capabilities are there to do the job.

NATIONAL AND SPECIAL RESEARCH PROGRAMS, NATIONAL RESEARCH
CENTERS, SCIENCE INFORMATION, SCIENCE EDUCATION

I have discussed thus far something of the NSF support for basic science, RANN, and energy related activities. Let me go on to several other Foundation efforts which are expected to contribute in a significant manner to the Nation's scientific strength.

The oceanographic activities in the National and International Programs Directorate continue with support of over \$40 million. There

-13-

are three programs--International Decade of Ocean Exploration (IDOE) Ocean Sediment Coring (OSCP), and Oceanographic Facilities and Support (OFS)--which relate directly to oceanographic research and complement our scientific research project support in this area. The IDOE is a major effort to improve our understanding of the total ocean environment, its influences on man, and man's impact on the oceans. We have underway a number of large-scale, coordinated projects through which we are trying to accelerate understanding of the oceans' effects on weather and climate, establish the scientific basis for preservation of the ocean environment, develop the basic comprehension needed for man to utilize intelligently the oceans' living resources, and provide fundamental data on the structure and dynamics of the processes of the seabed that produce mineral and petroleum resources. A modest increase is being requested, principally to allow planning for FY 1976 field work in environmental forecasting and studies of pollutants which may develop as a result of accelerated development and use of fossil fuels.

The Ocean Sediment Coring Program will continue its work in achieving a thorough understanding of the ocean basins of the world. The drilling ship, Glomar Challenger, has probed every major ocean basin except the Arctic and has recovered sediment and rock cores from 322 locations. The USSR has formally agreed to participate in the program and will contribute \$1 million a year.

The Foundation is continuing our efforts to improve the effectiveness of the academic fleet of oceanographic research ships. As a result of the FY 1974 appropriations, we were able to provide for the construction of another medium-size replacement ship for this fleet. This ship is being constructed jointly with one provided for in FY 1972. When available, these ships plus two Navy-built ships commissioned in FY 1974 will reduce the number of overage ships in the academic fleet to eight.

Polar Programs--the Arctic and the Antarctic Research Programs--are being continued at about the FY 1974 level. In the Antarctic, the fact that we were able to carry out a program of research this past austral summer was due to the timely delivery of the three LC-130R aircraft provided in our FY 1973 supplemental appropriation. These three planes were delivered on schedule and within the original cost estimate. You will recall that USNS Eltanin, the research ship that surveyed much of the southern circumpolar ocean was withdrawn from service in December 1972. I am pleased to report that we have arranged with Argentina for shared use of the ship and the circumpolar survey is being resumed.

Activities of the National and International Programs Directorate also include support for five national research centers. These provide facilities and support needed in astronomy and atmospheric science

-15-

not available at individual institutions. The major increase in FY 1975 in the funding support for these centers is for the Very Large Array (VLA) radio telescope being constructed in New Mexico.

I turn now to the Science Information Service (SIS) activities. This program plays an important role in fostering and coordinating efforts to improve science communications in an environment of a rapidly growing body of scientific and technical information and increasing demand for timely access. In the past, much of the SIS budget has supported automation of seven major discipline based information systems--chemistry, physics, geology, engineering, psychology, mathematics, and biology. These systems are now reasonably well automated and should be able to operate effectively without continued Federal support. About two-thirds of the reduction is accounted for by completion of support for these systems. The balance of the reduction is attributable to termination of support through this program of selected dissemination activities such as journals, monographs and other publications which are properly supported by other Federal R&D programs.

SIS is now concentrating on how to improve the capabilities of the users of scientific information by research on information programs, development of national information programs, and design of user support services. In addition, there is an increasing interest in the international exchange of information.

Next, I would like to discuss the Foundation's Science Education Activities. These activities are planned to continue at a level which allows an overall increase in those program areas specified in the FY 1974 authorization. In addition to providing fellowships for outstanding graduate students, the proposed program continues to support efforts aimed at making improved science education available to more students at the elementary and high school as well as college levels.

The Science Education Improvement Program is aimed at the educational needs of those who will pursue careers in science and those who will not. Both types of needs are addressed through programs designed to reach a broader segment of the population. Emphasis is placed on elementary and secondary school programs adopting a "hands on" problem solving approach, designed to appeal to students whose orientation is more toward the practical than the theoretical. College level efforts include the continuation of the program to improve the quality of science education available at institutions attended mainly by ethnic minority students. The Foundation plans to continue to support projects at the forefront of science education, projects attempting new and innovative approaches to improving effectiveness.

An energy manpower thrust is included in the FY 1975 education program to meet the Foundation's lead agency responsibility with

-17-

respect to manpower for energy R&D. At the graduate level it provides for energy-related traineeships and postdoctorals. Technician training and foreign energy scholar programs have also been included.

SCIENCE ADVISER ROLE

Prior to closing this review of the proposed FY 1975 program I would like to discuss briefly my role as Science Adviser. I have now had about nine months of experience at this. In addition to the Energy R&D Policy Office which I mentioned earlier, I have been aided considerably by the Science and Technology Policy Office which I established to provide staff support for my science adviser responsibilities.

I have been giving emphasis to developing communication channels to the scientific and technological community and to the assessment of potential future national problems, such as in materials and food, which may lead to the establishment of new directions and new priorities for Federal R&D efforts. My relationships within the Federal establishment in my new role have been good and should become even better as we build additional staff capability.

OVERALL PROGRAM THRUSTS

Mr. Chairman, it is clear that our Nation's science enterprise must be responsive to the needs of the people if we are to maintain our strength as a Nation. The basic and applied research programs of NSF

are providing opportunities for the U. S. scientific community to meet this challenge.

We anticipate that the programs which have been tightly constrained by our emphasis on basic and energy research efforts in FY 1975 will merit special consideration in FY 1976 in order that progress in those areas will not be interrupted.

In summary, the Foundation's highest program priorities for FY 1975 are for strengthening research in the science disciplines and for energy-related research cutting across the entire spectrum of NSF activities.

This table (Figure 7) shows the Foundation's Authorization Request for FY 1975 which totals \$788,200,000. The Foundation strongly endorses H. R. 12816, which provides for the authorization of the NSF program in accordance with the request included in the President's program for FY 1975.

This concludes my formal statement. I will be glad to answer any questions you may have regarding our FY 1975 program.

NATIONAL SCIENCE FOUNDATION FY 1975 AUTHORIZATION REQUEST

(IN MILLIONS OF DOLLARS)

	<i>FY 1974 Program</i>	<i>FY 1975 Authorization Request</i>
Scientific Research Project Support	\$ 291.3	\$ 363.7
National & Special Research Programs	91.6	84.8
National Research Centers	42.5	52.5
Science Information Activities	8.0	5.0
International Cooperative Scientific Activities	6.4	8.0
Research Applied to National Needs	75.1	148.9
Intergvt. Science and Research Utilization	1.0	1.0
Institutional Improvement for Science	10.0	3.0
Graduate Student Support	13.0	12.7
Science Education Improvement	67.5	61.4
Planning & Policy Studies	2.6	2.7
Program Development & Management	31.7	39.5
Subtotal S&E Appropriation	640.7	783.2
Special Foreign Currency Program	5.7	5.0
TOTAL	646.4	788.2

ADDITIONAL MATERIAL SUBMITTED FOR THE RECORD BY DR. STEVER

Question: Can you describe for us the process followed in RANN in determining whether a particular project should be funded by NSF or by a mission agency. What steps are taken to avoid duplication of effort? Perhaps you could take a particular case, and describe how the NSF handles these questions.

Answer: RANN support of problem-focused research on a problem of national significance is undertaken with extensive coordination with Federal mission agencies. The principal mechanism for program coordination is the RANN Interagency Coordinating Committee and its panels. In many instances, RANN formulates a comprehensive research plan setting milestones to be achieved in meeting program objectives and reviews this plan with all the agencies having an interest in the area. This procedure has been followed, for example, in solar and geothermal energy. Research proposals appropriate to the research plan are forwarded to peer groups and the using community for assessment and evaluation. Interested Federal mission agencies participate as both a peer reviewer and as a member of the ultimate using community. Individual projects in all instances are reviewed before funding by the principal agencies which have related programs before a final funding decision is made. Many projects have advisory boards or oversight committees and federal mission agency representatives often serve on these groups to ensure that the project results will be useful. It is through such arrangements as well as frequent meetings of interagency coordination panels that unnecessary and unwarranted duplication of effort is avoided.

Question: What programs initiated by RANN, have now been transferred to other agencies? Are there some programs presently in RANN which are about to be moved to other agencies?

Answer: The focus of RANN research is to provide solutions to selected problems of national importance and to expeditiously transfer research results to the using community. In most instances the ultimate user is most often a State or local government agency, a private sector industry or an industrial market which needs to be augmented. In some a Federal mission agency is also the ultimate user of RANN supported research. For this reason, a few research projects and programs have been transferred to Federal agencies including the Heat Subterrene and the Lithium Sulfide Battery projects which AEC will continue. In FY 1975 the RANN Fire Research program will be transferred to the Department of Commerce.

Question: Has the growth of the RANN program over the past few years detracted from the Foundation's basic research programs?

Answer: Quite the contrary. Basic research support is stronger in the Foundation today after more than four years of experience with major applied research programs. In that time the foundation has greatly increased its support of basic research in the science disciplines with the amount for this purpose doubling during the period in which we launched and nurtured our problem-focused research efforts. The number of proposals we are receiving in basic research is increasing each year and research discoveries resulting from projects sponsored by NSF are increasing. We also have found that cross-fertilization is taking place and the basic and applied research programs of the Foundation, which are running in parallel, are proving to be a compatible and complementary set of research support activities which together are helping to achieve national goals for science and society.

Question: RANN is involved in a great many areas now -- all grouped in the three major areas of energy, environment and productivity. Can you devote sufficient attention to all of them?

Answer: RANN has been selective in initiating new research activities in order to be assured that management attention will not be widely diverted and diffuse. With the exception of the Energy program, RANN activities in environment and productivity research are essentially a continuation of planned efforts initiated in FY 1973 and FY 1974. These programs are moving aggressively but will not require the degree of management attention planned for Energy. As shown in the FY 1975 Budget the growth in the RANN program is confined to the thrust in Energy Research and Technology. Concurrent with this program growth, RANN is to be authorized an additional 83 personnel to give proper attention to this enlarged effort. With an adequate sized staff of skilled program managers together with an experienced management team, there are foreseen no obstacles to providing sufficient attention to the primary thrusts of the RANN program.

Question: The RANN program is scheduled to double in the coming fiscal year. Will this result in management problems? Do you expect to receive a sufficient number of high quality requests for funding?

Answer: As noted earlier, the increase in the RANN budget is associated with energy related matters for which adequate increases in staff size are anticipated. While management problems may be encountered, we are currently engaged in planning the expanded program and believe that RANN has acquired the necessary experience in handling management matters. As a result of actions taken over the past three years, a number of highly effective management techniques are in operation and will enable program growth to be accommodated with minimal disruption to on-going efforts.

In FY 1974 RANN is experiencing a continuous flow of high quality unsolicited proposals and there is no expectation that this rate will decline. However, in order to ensure a steady flow of high quality proposals specifically oriented to the problems which constitute the focus of RANN research, greater use will be made of Program Announcements, Request for Proposals and other solicitation mechanisms.

Question: With regard to RANN's wind energy program. In FY 1974, I believe the Foundation plans to spend about one million dollars on that program; for fiscal year 1975 you have requested \$7 million.

Of the one million dollars available in FY 1974, \$850,000 was given to NASA to test a 100 Kilowatt Windmill Generator.

Were there so few worthwhile projects coming in from the academic and industrial communities? What priority, if any, do you plan to give non-government research in this area in allocating the \$7 million you have requested for fiscal 1975.

Answer: In March 1974, approximately two months after the FY 1975 budget was printed, it was decided to increase the FY 1974 Wind Energy Budget from \$1,000,000 to \$2,345,000. The revised program consists of the following major increments.

- a. \$865,000 awarded to the Lewis Research Center to construct and test an experimental wind energy system so as to identify operational problems.
- b. \$1,000,000 for aero generator design studies solicited from the academic and industrial communities.
- c. \$480,000 for Advanced Research and Technology unsolicited proposals from academic and industrial researchers.

In FY 1975 RANN will continue to award Wind Energy grants and contracts to academic and industrial researchers who (1) submit high quality proposals that focus research on wind energy problems and (2) submit responsive proposals in reply to NSF and Lewis Research Center initiated Program Solicitations and Requests for Proposal.

Question: In your role as Science Adviser to the President, have you been consulted on a regular basis, particularly with regard to the Administration's energy proposals? Has the F.E.O. called on you for assistance?

Answer: Yes, we have participated and have been consulted extensively in the development of the Administration's energy proposals. This has involved extensive interaction with the former White House Energy Policy Office; major participation in the Federal Power Commission's National Power Survey; and leadership in developing the final summary of the FCST R&D Goals Report and its follow-on activity. I chaired the President's Energy R&D Advisory Council which reviewed the Dixy Lee Ray study and made recommendations to OMB. These recommendations affected the President's energy proposals. Even prior to that point we had a major role in the structuring and analysis of this five-year \$10 billion energy R&D budget as well as the add-on program the President proposed for FY 1974. Similarly we have been involved in the task force to develop the structure of ERDA.

We have been called on by F.E.O. for assistance in their Project Independence efforts and have detailed a staff professional to them three days a week. We have also provided support to them for studies, reviews and analyses in such areas as: critical path analysis; constraints to self-sufficiency; foreign investment strategies; assessment of international energy R&D cooperation; regulatory effects of energy R&D; and energy manpower needs.

Question: With regard to coordinating efforts of the various federal agencies involved in solar heating and cooling technology and in your capacity as Chairman of the Federal Council on Science and Technology, do you feel that the Council is the appropriate body to coordinate these efforts. If not, would you recommend the establishment of a new organization for this purpose such as the National Solar Energy Coordinating Council proposed in S. 2650; or do you feel these coordinating activities can be best carried out by the Executive Branch under existing authority.

Answer: Existing Executive Branch authority and mechanisms are quite adequate to coordinate the various federal agencies involved in solar heating and cooling technology. An interagency panel has been established under OMB auspices for each of the energy R&D program areas and the Solar Energy Panel is headed by the National Science Foundation. The assisting agencies are the Atomic Energy Commission, the Department of Commerce, The Federal Energy Office, the General Services Administration, the Department of Housing and Urban Development, and the National Aeronautics and Space Administration. Other agencies will be invited to participate as appropriate. At this time I do not believe the Federal Council on Science and Technology will be needed for coordination purposes in this area.

Senator KENNEDY. Our next witness is Donald Hornig, who is president of Brown University. He has appeared before this subcommittee on a number of different occasions.

We want to extend a warm welcome to you on behalf of Senator Pell who is on the floor managing the campaign financing legislation. We look forward to your comments.

STATEMENT OF DONALD HORNIG, PRESIDENT, BROWN UNIVERSITY, ON BEHALF OF THE AMERICAN COUNCIL ON EDUCATION, THE ASSOCIATION OF AMERICAN UNIVERSITIES, AND THE NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES

Mr. HORNIG. Mr. Chairman, and members of the committee, thank you for the opportunity to appear before the subcommittee on the authorization for the National Science Foundation for fiscal year 1975.

My name is Donald Hornig, and I am president of Brown University. I am testifying on behalf of the American Council on Education, the Association of American Universities, and the National Association of State Universities and Land-Grant Colleges. The concern of these institutions with the programs of the National Science Foundation can be gaged by the fact that the members of these associations conduct virtually all federally financed research in colleges and universities and these same colleges and universities award almost all Ph. D.'s in the physical, biological, and social sciences.

On behalf of these institutions of higher learning, I wish to express our gratitude to the committee for its willingness to hear our views in years past and for its continuing interest in the issues which are of great concern to us.

These institutions are naturally interested in the entire NSF budget since virtually every aspect of the budget affects colleges and universities.

The institutions that I represent are dedicated to learning in the broadest sense, not only learning by our students but learning about the natural laws which are going to make it possible to meet some of the problems in energy, ecology, and so on, that we have talked about earlier this morning.

We all rely on NSF to maintain the quality of our efforts in generating the knowledge that will be needed. We are pleased to see the proposed expansion of the NSF overall budget, and particularly the increase in research project support from \$277 million in fiscal year 1972 to \$364 million in fiscal year 1975.

In our view, the central role of NSF continues to be the original role—the furtherance of basic research and related education at all levels. This is the one activity of the Foundation that cannot be adequately financed by other agencies, and it is the activity which in our judgment is most vital over the long run to the scientific and technological strength of this country.

Moreover, it is a task that the NSF has carried out and is carrying out competently. We support Research Applied to National Needs (RANN), research on energy and other targeted goals.

NSF has taken care to see that basic research support continues while these tasks are assumed. However, we hope that the committee will

be vigilant in probing this question and in making sure that a reasonable balance is sustained.

Despite the significance of many elements in the NSF budget, on this occasion our comments will concentrate on two matters, the level of graduate fellowship support and institutional support by NSF.

We are convinced that the administration is following a short-sighted course in holding the number of NSF fellowships to 500 new starts per year. In the words of the January 1974, report of the National Board on Graduate Education, Federal Policy Alternatives Toward Graduate Education: "The rapidity and severity of Federal cutbacks in the last 5 years will, if continued, undermine the Nation's capability for high quality graduate education and research * * *."

The national board has pointed out that unemployment of Ph. D.'s is in fact very low—about 2 percent. This corresponds with my own observations, and it contradicts the notion of a Ph. D. glut in the areas of interest to the National Science Foundation. In addition, I must emphasize that the long range outlook and not the current job situation should influence policy toward Federal support for training scientists and engineers.

I commend this report to the attention of the committee and ask that the summary of the report be entered in the record of these hearings.

[The report referred to and subsequently supplied for the record follows:]

Federal Policy Alternatives toward Graduate Education

A Report with Recommendations of the

**NATIONAL BOARD ON
GRADUATE EDUCATION**

Washington, D.C.

Number 3 • January 1974

1 Conclusions, Recommendations, and a Positive Program

CONCLUSIONS AND RECOMMENDATIONS

1

Graduate education, scholarship, and research occurring within the nation's universities are of immense significance for the scientific, economic, and cultural development of the nation. The flow of new knowledge developed through basic research, coupled with the advanced education of individuals that enables them to contribute new knowledge and apply the research findings, are essential to such basic social concerns as eliminating disease, feeding the world's population and controlling its growth, developing new sources of energy, controlling environmental pollution, maintaining the competitiveness of our industries, understanding and alleviating problems of urban life—including housing, mass transportation, and racial tension—and expanding our knowledge and understanding of history, government, economics, art, music, and religion. There is hardly a sphere of life that is untouched or unaffected by graduate education and research, although the universities that perform these activities are only a small percentage of the approximately 10,000 institutions of postsecondary education. The continuing contributions to society that can be expected from graduate education and research indicate a clear national interest in ensuring their continued strength, vitality, and flexibility.

In addition to their value to society, graduate education, scholarship, and research are of central importance within the university. The most basic

task of the university is *learning*, in the sense of transmitting the known and discovering the new. The unity of the university derives from its commitment to learning, which is the foundation of all its activities, whether in undergraduate education, graduate education, research, or public service. Graduate education and research are not mere appendages to the university, but are instead its defining element, infusing a spirit of inquiry and a concern for scholarship throughout the institution.

2

The nature of graduate education and research requires the federal government to assume a central role in financing these activities.¹ The labor market for highly trained scientists and scholars is national as well as local and regional. Knowledge is part of the public domain and the advancement of knowledge is of national or international consequence. *Neither the private market nor local areas or states can be expected to bear the whole burden of financing graduate education and research when the benefits are diffused so widely.*

The federal government also bears a special responsibility for graduate study and research because of its broad obligation toward the economic and cultural development of the nation, which is heavily dependent on highly trained and broadly educated people and on the cultivation of knowledge and the arts. The federal government, moreover, employs the services of a large number of scientists and scholars, both directly and indirectly, and therefore has a special interest in their education. The federal government is the only agency that can redress inequalities and imbalances among geographic regions in the availability of facilities for graduate education and research, which are of great importance in regional development. Finally, the federal government is the agency best equipped to deal with economic inequalities among persons that affect opportunity for advanced study. The graduate schools with their educational and research programs are a *national resource* of the first order, and the role of the federal government in their maintenance and advancement is critical.

3

The stress placed on the importance of federal support for graduate education and research in this report does not mean that federal aid should replace either private giving or state support. The \$1.6 billion in private gifts to colleges and universities in 1971–1972 is a central and indispensable source of revenue for many institutions, and provides the margin for excellence in

¹ National Science Board, *Toward a Public Policy for Graduate Education in the Sciences* (Washington, D.C.: U.S. Government Printing Office, 1969), p. 37.

many others. It is not only the amounts of private gifts but the fact that they provide a countervailing force for state and federal funds that is important. With regard to state support, the federal government cannot be expected to assume responsibility for the basic institutional support of state universities. Accordingly, the health of the important publicly supported segment of graduate education depends decisively on the basic state appropriations for the public universities. No foreseeable change in the purposes or amount of federal support will change this basic dependency. Indeed, the trend toward specific state support of private graduate education, developed most notably in New York state, points toward an expanded financial role for the states.

4

Federal support for basic research in universities and for graduate students grew rapidly from post-World War II until 1968. In the last five years, however, funds for research have declined slightly in constant dollar terms while federal fellowship and traineeship support has fallen dramatically from over 50,000 students supported in 1968 to a projected 6,600 in FY 1974.² In addition, several federal programs that provided semicategorical institutional support linked to graduate education and research have been eliminated or are being phased out. (For details, see Chapter 2 and the Appendix Tables.)

In retrospect, it is clear that the rapid growth of federal support, particularly in the early and middle 1960's, could not have been expected to continue. However, the rapidity and severity of federal cutbacks in the last five years will, if continued, undermine the nation's capability for high quality graduate education and research. A reassessment of current federal practice for the purpose of developing a sound federal policy oriented toward the requirements of the 1970's is clearly called for.

5

As the graduate schools adjust to the changed circumstances of the 1970's, national efforts should be directed toward achieving the following goals:

- *Enhancing the effectiveness and efficiency of graduate education, scholarship, and research.*

Strengthening the national structure for graduate education, scholarship, and research by supporting strong programs currently in existence in all regions and ensuring that the most talented students are not denied access to these programs.

² Federal Interagency Committee on Education. The 1974 estimate is based on the FY 1974 budget, not final appropriations.

Discouraging the proliferation of graduate programs, while ensuring that universities have the necessary resources to develop programs in new fields of study and to meet new social needs. In a period of limited resources for higher education, careful review and elimination of weak graduate programs is one potential source of the resources required for such new programs.

Ensuring that the supply of persons with master's, professional, and doctoral level education is in reasonable balance with the long term demands of a complex, technological society.

Sustaining a flow of new research findings, basic and applied, required for both the cultural and material well-being of the nation.

Protecting the freedom and the adaptive capacity of the nation's universities.

- *Ensuring the responsiveness of graduate education to the needs of society.*

Ensuring that graduate education contributes to the national commitment to eliminate discrimination based on race, sex, age and socioeconomic status.

Stimulating changes that will encourage the most effective contribution of graduate education and research to the solution of urgent national problems.

Encouraging responsiveness to the needs of students, including the development of graduate programs that serve part-time and older students, as well as the needs of urban residents.

Realization of these goals is complicated by several problems and unresolved issues currently facing graduate education, including:

Labor market prospects for doctorates Although we reject forecasts of an impending "Ph.D. glut," graduate schools do face major adjustment problems to a changing labor market (pp. 27-29).

Financial pressures Marked reductions in federal government support for basic research, graduate students, and graduate institutions in the last five years threaten, if continued, to erode the quality of graduate education and to undermine the nation's research capability (pp. 29-36).

Access to graduate education Although it has not become national policy to guarantee access to graduate education, certain invidious barriers that have operated to restrict access for minority group members, for women, and for older students must be eliminated (pp. 36-40).

Planning, management and cost analysis Improved management of resources is imperative for all higher education, including graduate education and research, but the current interest in developing unit cost measurements poses a particular problem for graduate education because of the interrelated nature of "inputs" and "outputs" (pp. 40-41).

Adjustment problems to the steady state of the 1970's After more than

a decade of rapid growth, graduate education faces a prolonged period of slow (or no) growth, which poses such problems as determining the "proper" national distribution of resources (geographic dispersion versus concentration), maintaining the vitality of the disciplines in an era of limited faculty expansion and turnover, and ensuring that the adjustment process to reduced federal support is directed toward the goals outlined at the beginning of this section (pp. 41-44).

The lack of coordination among federal policies toward graduate education The absence of coordination and stability complicates the planning process for universities, and has become particularly severe in the recent period of abrupt change in many federal policies affecting graduate education (pp. 44-45).

6

Recent shifts in federal policies toward graduate student support have significantly reduced the number of students supported by federal fellowships and traineeships and increased the number for whom self-support and loans are the major source of financing. The basic policy question is whether, and to what extent, these trends should be continued.

In our judgment, the benefits of graduate education are both private and social, accruing to the individual student and to the state, region, and nation. This argues for pluralistic sources of student finance, with fellowships, traineeships, teaching and research assistantships, loans and family resources, and subsidized tuition all playing a part.

For the 1970's we endorse the following principles for graduate student support:

- Graduate tuition should be maintained at levels below the "full cost" of graduate education in recognition of the broad social benefits that result from graduate education (pp. 47-48).

- Assuming no major increase in graduate tuition, federal fellowships and traineeships should *not* be increased to their 1968 highs. Neither should they be totally phased out, however, which is the direction of current administration policy. Three specific rationales for specialized federal fellowship and traineeship programs appropriate to the foreseeable needs of the 1970's lead to distinct federal programs for support of graduate students (pp. 49-54):

Merit fellowships A limited number of portable fellowships, awarded in national competition on the basis of academic merit, to be used for doctoral study in any academic discipline. These fellowships would be designed to

recognize individuals with outstanding intellectual potential and to ensure that no financial obstacles prevent them from attending graduate school. The number of awards should not fluctuate in response to labor market conditions.

Specialized manpower and research programs National programs which provide traineeships to support students (or postdoctoral researchers) in new programs oriented toward such urgent social problems as energy supply, conservation, and distribution; health care delivery; and the manifold problems of urban life, including housing, mass transportation, and racial tension. In the absence of traineeship support, the trained manpower and research efforts necessary to work toward solution of these national concerns will not be forthcoming in adequate number, quality, and time. The traineeships would be awarded by the institution (laboratory, institute or department) responsible for the program, and the students would use the award only at that institution. The number of awards should be adjusted to the best possible estimate of future manpower and research requirements in the special areas, and would have strict time limits, subject to review.

*We strongly endorse recent United States congressional action in appropriating funds for FY 1974 to continue the National Institutes of Health/ National Institute of Mental Health (NIH/NIMH) training grant programs.*³ These programs incorporate many of the objectives in the areas of biomedical research and health care of our proposed program.

Minority group program A program to promote participation in graduate education for historically disadvantaged minority groups will be specified in a forthcoming report. Provision of financial support for minority group students will be a major part of the program.

A specific proposal for funding levels of two of these three programs is contained in the final section of this chapter.

- At this time, federal fellowships specifically for the purpose of stimulating additional students to prepare for academic careers are not required. For this reason, and in light of the more essential fellowship and traineeship programs recommended above, we do not recommend funding for the fellowships authorized under Title IX, Part B, of the Education Amend-

³ Due to the recent passage of the FY 1974 appropriations bill for the Department of Health, Education and Welfare and the Labor Department (complicated by changes in budget categories, impoundment uncertainties, and administrative provisions), the precise allocation of funds to the NIH/NIMH training grants program and the NIH general research support program remain unclear at this time. Reference to current support levels of these programs throughout this report should be regarded as tentative until final verification.

ments of 1972. The authorization for these fellowships should not be allowed to expire, however, since funding of these programs may be necessary if other sources of student support prove to be inadequate (pp. 54-55).

- A national program of grants for graduate students based on financial need and modeled on the undergraduate Basic Opportunity Grant is *not* endorsed, for both philosophical and practical reasons (pp. 48-49).

- Research and teaching assistantships are assumed to be important continuing sources of graduate student support.

- Loans should continue to be a significant component of a total plan for graduate student support, but there are limits to the utility of loans. In individual cases, loans should not be so large that highly capable students are discouraged from undertaking graduate work. Several technical problems, moreover, in the terms, conditions, and administration of existing loan programs prevent their expansion much beyond current levels. These problems are sufficiently difficult that substantial analysis, debate, and negotiation will be required to resolve them. Consequently, policymakers should not expect existing loan programs to continue to take up the slack caused by reduction of other support programs (pp. 55-60).

- The Education Amendments of 1972 should be amended to increase the individual loan limit from \$10,000 to \$15,000, and to extend the repayment period from 10 to 20 years. Experimentation by individual universities with variable annual loan repayment schedules and with methods for taking financial need into account should be encouraged (pp. 58-59).

7

The national research effort is conducted in universities and colleges, private industry, government agencies, and in various specialized research institutions. The emphasis in universities is primarily on *basic* research (as contrasted with applied research and development), and most of the nation's basic research is conducted in universities. The federal government provides over 60 percent of the funds for all basic research in the United States, and over 50 percent of federally funded basic research is conducted in universities and colleges.

The process of graduate education is inextricably linked with research, since most doctoral programs (and many master's degree programs) culminate in independent research, i.e., the dissertation. In many fields, graduate students serving as research assistants make important contributions to the production of research. Moreover, to be effective teachers, faculties must themselves engage in active scholarship and research, particularly at the level of graduate education.

The essential place of research in graduate education, and the central

importance of the federal government in supporting basic research in universities, make federal research policies of utmost significance to graduate education. Unfortunately, there are no clear-cut guidelines for determining the "optimal" scale for the national effort in basic research. Growth at the rate experienced in the early 1960's (average annual increases in excess of 15 percent) could not be maintained forever; on the other hand, restricting basic research to what was essentially no growth in real terms, as in the last five years, seems unwise as a long-term policy. Our nation—and the world—face many serious problems relating to economic productivity, the environment, energy, resource depletion, the cities, health services, education, poverty, unemployment, inflation, international affairs, crime, and social morale. To solve most of these problems, research in the physical sciences, social sciences, and humanities is needed, and highly trained professional people are needed who depend on a research environment for their education. It is unlikely that the present level of support for basic research is too high; on the contrary, there are indications that it may be too low.

The report advances two recommendations:

- Federal funds for support of basic research should grow, *at a minimum*, at the same rate as the growth of the gross national product (GNP) (pp. 67-68).
- To implement the first recommendation, whenever the federal mission-oriented agencies shift priorities and reduce their support of basic research, the research budgets of the National Science Foundation and the National Foundation for the Arts and Humanities should be increased by offsetting amounts in order to maintain stable and moderate growth of total federal support for basic research (pp. 67-68).

8

Federal support of graduate education and research has been concentrated on financial aid to students and categorical grants for research and training programs. Broader institutional support has been provided largely by states, by private giving, and by student tuition. Although this federal policy of specifically targeting support for graduate education and research has sometimes worked against the development of the universities as coherent and balanced institutions, *we believe that the division of responsibility for higher education which has been evolving over the past 25 years is fundamentally sound, namely, that the states and the private sector assume responsibility for basic operation of the institutions and that the federal government assumes increasing responsibility for the financing of students,*

research, and selected institutional programs in the national interest. The federal government has provided semicategorical institutional aid in the form of cost-of-education allowances accompanying fellowships and traineeships, supplemental aid accompanying research grants, development grants, and grants and loans for buildings and equipment—but most of these programs have been substantially reduced or phased out.

We recommend the following program:⁴

- Cost-of-education allowances accompanying existing and recommended federal fellowships should be continued and increased in amount to reflect the rapid cost increases that have occurred in the past decade (p. 77).
- National Science Foundation (NSF) and NIH research supplement grants complementing federal project grants should be continued (p. 77).
- The recommended specialized manpower and research programs would include funds for associated institutional costs in addition to traineeship support. These grants, awarded through the federal mission-oriented agencies, would be similar to the NIH training grant programs, with the institutional support component used for such expenses as special equipment, renovation of facilities, and salaries for faculty and support staff (pp. 77–78).
- Funding of the general institutional support provisions of the Education Amendments of 1972 (Title X, Sec. 1001) should be based on a separate assessment of the needs of all sectors of postsecondary education (p. 78).

9

The complexities inherent in university–federal government relationships create a need for improved forms of analytical and policy coordination at the federal level:

- We strongly emphasize the need for improved information and analysis as a critically important first step in the long run process of developing sound, flexible, and responsive policies to guide university–federal government relationships. The American Council on Education should convene conferences to discuss and develop a framework for analysis and to allocate responsibilities among specific private and public groups for securing con-

⁴ Recommended funding levels for these programs are contained in the final section of this chapter.

sistent and timely data. The operation of an improved information and analytical structure would require additional funds, and Congress would, in our judgment, be wise to supply the necessary resources for an improved system (pp. 81-83).

- We urge the Science Adviser to call together the heads of the major federal agencies involved in support of graduate education to discuss methods for anticipating and minimizing the harmful effects upon universities, graduate education, and research caused by sudden changes in federal policy and in levels of funding (pp. 83-84).

- We support the current efforts in Congress to introduce a greater degree of systemization into the appropriations process and to redistribute committee assignments in both House and Senate to bring educational matters together more coherently in the House Committee on Education and Labor and in the Senate Committee on Labor and Public Welfare (p. 84).

- We recommend the creation of a Joint Education Committee, similar to the Joint Economic Committee, which would have a role in education and dissemination, without considering substantive legislation (p. 84).

10

State and federal officials have expressed a desire for procedures to develop standard and comparable cost figures for programs of higher education. A number of unresolved and very complex analytical problems confront this effort at the level of graduate education and research, and existing techniques for generating such cost figures are not adequate. This topic is considered in detail in a supplement to this report by Frederick E. Balderston of the University of California at Berkeley (pp. 87-109).

A POSITIVE PROGRAM

The main elements of our positive program for federal policy toward graduate education are summarized below, together with an estimate of costs. This program has been developed in light of the currently existing federal programs and levels of support for graduate education and research. We believe that our program and recommendations will strengthen the national interest in graduate education and research by improving those federal programs which are presently inadequate, by pointing out some of the existing programs which have proven to be particularly effective and productive, and by promoting the federal responsibility in other areas which are in the national interest.

It must be stressed that these recommendations are not based on a "scien-

tific formula" which produces a uniquely desirable level of support; rather, they are based on levels of support that are reasonably related to the goals and principles spelled out in this report.

Graduate Student Support

1. *Merit fellowships*, to be awarded in national competition on the basis of academic excellence, providing fully portable, three year support and available for study in all academic disciplines. Each fellowship would be accompanied by a cost-of-education allowance, accepted in lieu of tuition and applied toward the institution's cost of providing the graduate training.

We propose 2,000 new awards per year. This means that the number of awards would be equal to about $\frac{1}{4}$ of 1 percent of the seniors graduating from college each year. Since the National Science Foundation currently awards 500 such fellowships per year in the physical, biological, and social sciences, our recommendation calls for an additional 1,500 awards annually. A counterpart program covering the humanities should be established in the National Endowment for the Humanities, with the total number of awards apportioned between the two agencies in relation to the size and number of eligible disciplines under their purview. Assuming an average stipend of \$3,500 per student and a cost-of-education allowance of \$4,500,⁵ when fully funded, the program would support 6,000 students at an annual cost of \$48 million (Table 1).

TABLE 1 Merit Fellowships

Terms per Student		Total Program (New and Continuing Awards)	
Value/Year	Duration, yrs	No. Students/Year	Total Annual Costs
\$3,500 stipend	3	6,000	\$48 million
\$4,500 allowance to institution ^a			

^a Cost-of-education allowance in lieu of tuition to be applied toward the institution's costs of providing graduate training.

2. *Specialized manpower and research programs*, providing 5-year grants to universities, and enabling them to develop high priority programs for research and graduate training directed toward solution of urgent national problems. The grants would include graduate student (or postdoctoral) support in the form of traineeships, and funds provided to the institutions for associated program costs such as faculty salaries, equipment, and sup-

⁵ For discussion of this figure, see p. 13.

port personnel. The grants would be awarded to universities on the basis of national competition.

Approximately 70 new grants per year should be awarded over a 3-year period, reaching a steady-state level of roughly 200 projects. Based on prior experience with this form of support, \$300,000/year per project would be a reasonable estimate of average project costs. The total annual investment would therefore approximate \$20 million the first year, \$40 million the second, and \$60 million/year when the full program level is reached (Table 2).

TABLE 2 Specialized Manpower and Research Programs

Award to Institution		Total Program (New and Continuing Awards)		
Value/Year ^a	Duration, yrs	Institutional Awards	No. Students/Year	Total Annual Costs
\$300,000	5	200	5,000 ^b	\$60 million

^a Approximately 50 percent of the funds would be used for support of predoctoral students (or postdoctoral researchers), including tuition, and 50 percent would be applied toward the institution's cost of providing the program.

^b Institutions would be permitted to support postdoctoral researchers as well as graduate students according to their program needs.

Approximately half the funds would be used to support both graduate students and postdoctoral researchers. Up to 5,000 predoctoral students could be supported on these programs at full funding levels.

3. *A minority group program*, designed to promote successful participation by historically disadvantaged minority groups in graduate education. Provisions will be specified in a forthcoming report of NBGE.⁶

Comparative Note on Student Support

In 1968 over 51,000 graduate students were supported on federal fellowships and traineeships; under the program recommended above, up to 11,000 students per year would be supported, a level roughly 80 percent below the 1968 high. If the NIH/NIMH training grant programs are added in, more than 60,000 students received financial support from federal fellowships, traineeships, and training grants in 1968. This compares with

⁶ Title IX, Part D of the Education Amendments of 1972 authorizes graduate fellowships for persons of ability from disadvantaged backgrounds, with a maximum of 500 fellowships and \$1,000,000/year allowed. Our recommendation regarding this legislation will be included in the forthcoming report.

approximately 20,000 students who would be supported under our recommended program plus the recent appropriation for the NIH/NIMH programs.⁷

Research Support

We propose that federal support for basic research should grow, *at a minimum*, at the same rate as the growth of GNP. Table 3 shows the difference between actual expenditures and recommended expenditures that would have occurred had this recommendation been in effect since 1968.

TABLE 3 Federal Expenditures for Basic Research

Year	Actual Expenditures		Expenditures under NBGE Recommendation		Difference, \$ million
	Amount, \$ million	% of GNP	Amount, \$ million ^a	% of GNP	
1968	2,354	0.27	2,354	0.27	
1969	2,398	0.26	2,542	0.27	+144
1970	2,474	0.25	2,730	0.28	+256
1971	2,416	0.23	2,921	0.28	+505
1972 (est.)	2,525	0.21	3,149	0.27	+624

^a For method of calculation, see p. 68.

This recommendation should not be applied retroactively; the above table is for illustration purposes only. We do propose, however, that our recommendation be applied from this time forward.

Institutional Support

1. *Cost-of-education allowances* accompanying each federally supported fellowship should be increased to \$4,500/year to reflect in part the rapid cost increases that have occurred in the past decade.⁸ The allowances should be reviewed periodically and increased when necessary to maintain their value in real terms. These allowances would be applicable to the 6,000 merit fellowships.

2. NSF and NIH research supplement grants should be maintained, with

⁷ On the basis of past experience, we estimate that approximately 9,000 predoctoral students would be supported by the level of funding in the FY 1974 appropriation. (See footnote 3 in this chapter for qualification.)

⁸ To offset inflation since 1963 when the figure of \$2,500 was established, the allowances would have to be raised to \$3,750. At current rates of inflation, the difference between \$3,750 and \$4,500 will be reached in less than three years.

funding levels set as a modest percentage of federal research project grants. We endorse the FY 1974 Congressional appropriation of approximately \$50 million⁹ for the NIH General Research Support Grant Program and recommend that this funding level grow modestly as federal support for research increases. The current level of support for the NSF Institutional Grants for Science (\$6.9 million) should be increased to roughly \$20 million for FY 1975 to restore the proportion of institutional-to-project support that prevailed in the late 1960's before the phase out began.

3. *Specialized manpower and research programs* contain an institutional support component for costs associated with the programs. Roughly 50 percent of the recommended annual funding level of \$60 million (Table 2) would be applied toward institutional expenses.

This chapter is, necessarily, only a brief outline of our principal conclusions and positive program. Subsequent chapters contain additional conclusions and recommendations which we believe are important to an effective federal role in graduate education and research. A number of other issues are also identified as being of national concern, although a direct federal role is not proposed.

⁹ See footnote 3, p. 6, for qualification.

Mr. HORNIG. The report recommends that the number of new fellowships awarded each year by the National Science Foundation be increased from 500 to 1,000. These awards, which would be decided in national competition, are to insure that the most able young students have an opportunity to continue through graduate school, and to symbolize the interest of the Nation in the development of intellectual excellence. The awards are not based on the assumption that there will be continuing shortages of highly trained manpower, but rather on our conviction regardless of the prospective state of the labor market the Nation will be served best if its most brilliant younger students have the opportunity to develop their capacities to their highest potential.

The report recommends that the students be able to study what they wish, where they wish. From past experiences, about half of them will choose to study in the physical, biological, and social sciences. Each fellowship should be accompanied, as is now the case, by a cost of education allowance to the institution in order to cover part of the cost incurred by the university when it accepts students with fellowships. The report proposes annual stipends of \$3,500 per year plus a cost of education allowance of \$4,500 per year—an increase over the current level to adjust for rising institutional costs.

Senator KENNEDY. Do you think that figure is sufficient?

Mr. HORNIG. That is very hard to say. It does not meet the total cost of graduate education if one includes proportionate allocations of research costs, but since there are other channels for meeting research needs, I think this will be a reasonable foundation.

The total annual cost of such a program would approximate \$24 million in full operation—for example, \$8,000 per year per graduate fellow; 3,000 holding fellowships at any one time. The increment to the President's budget proposal of \$12.7 million for graduate student support by NSF required to add the recommended 500 additional fellowships would be \$4 million.

I might say at this point that we fully support the philosophy that education in science is a continuum. The graduate schools depend on sound undergraduate training in science, and this requires, among other things, alert, competent teachers and adequate teaching equipment. Accordingly, we fully support an expanded budget for science education improvement as recommended by other witnesses.

Senator KENNEDY. Why is that important, Doctor? We have seen funding for science education reduced over the years, or at least stabilized. On the other hand, requests in other areas have been increasing. I value your reaction as to whether we are really meeting our responsibilities in the undergraduate and graduate education programs.

Mr. HORNIG. No; I think that neither government nor the university as an institution is doing well enough at teaching sciences, both to the prospective scientists and to the broad mass of our students who will go out and be citizens in a world in which they have to understand energy problems, ecology problems and what have you.

Therefore, I think that it is critically important that we continue to work on improving the quality of undergraduate education and sciences.

I think it is important also that we emphasize the experimental side, that we provide the kind of instructional equipment which will make

it possible for students to learn about science firsthand and not just by the descriptions they get in books.

Senator KENNEDY. But does this impetus really have to come at the Federal level?

Mr. HORNIG. For an institution such as mine which is strained to the absolute limit of its capability, I suppose we would be glad to look to anyone who might help, but I do not know what other sources there are.

Senator KENNEDY. You are perhaps aware of the requests that were actually made by the NSF of the OMB, and of the programs where they were cut back.

As an educator and also as someone who has been very much concerned with this area, do you think that cutback by OMB is harmful?

Mr. HORNIG. I personally do not think that cutback was wise. As I have already indicated, there are things to be done, and this is going in the opposite direction.

In addition, we strongly support the principle of supplying funds as a package for training persons in carefully selected areas of high social or economic significance. The package should include not only student stipends but also other types of costs that must be incurred to initiate and sustain productive training activities at the graduate level. The administration had phased out NSF traineeships. We believe that they should be reinstituted, along lines that other witnesses will develop. The 150 awards for study of energy problems, recently announced by NSF, is the approach which we endorse.

Mr. Chairman, we now turn to the second aspect of the NSF program which we regard as extremely important to the welfare of both the universities and the Nation. We refer to the proposal of the administration to eliminate general institutional support from the NSF budget.

A brief statement on the precise NSF budget item to which we refer may be useful to the committee. It is "Institutional Improvement for Science," and is referred to in the Director's budget briefing document of February 4, 1974. "Statement of Fiscal Year 1975 Budget," on page 12, and on various tables included in that report.

NSF provides two kinds of support under that item: First, grants to improve research management capability and; second, discretionary flexible funds for use by institutional administrators for science needs.

The first kind of support is proposed at a level of \$3 million. These management funds are needed, and the NSF authorization should provide for this type of support. However, the second kind of support—the discretionary flexible fund—that would be phased out under the President's budget is fundamentally more significant. We consider the proposal to eliminate this grant to be a serious error in public policy.

Our position is that this small amount of money is extraordinarily productive because it can be used flexibly. It is essential to the effective operation of the prevailing system of Federal support of academic science through financing research projects.

The administration has consistently expressed its opposition to this type of support, and the appropriation for it has dropped from \$44.7 million in fiscal year 1970 to a proposed level of zero in fiscal year 1975. The successive reductions reflect a determination on the

part of the administration to remove all support of this type from the Federal budget. Unfortunately, the Congress has ultimately gone along with the President's proposals for cutbacks in this area.

We urge the committee to reverse this trend by authorizing \$25 million for institutional support in fiscal year 1975, as a first step toward rebuilding institutional support to a substantial level. The proposed \$25 million is only 1 percent of the \$2.5 billion which the Federal Government will provide for academic science in fiscal year 1975. It is less than one-half the amount provided in fiscal year 1970, after increases in prices are taken into account.

In this connection, it is not generally recognized that most funds received by universities are earmarked in one way or another for specific purposes. This is true of virtually all Federal funds, and the Federal funds are becoming relatively more significant. When funds are earmarked for specific programs, a degree of rigidity is established. Project funds must be spent for defined, limited purposes.

The funds are made available to individual investigators, or groups of investigators for a program which they have carefully developed. These restrictions are not objectionable under a project system, and they are indeed necessary.

But the project system, by earmarking funds for scientific tasks that are defined in advance, fails to provide funds that can be used flexibly. Because of the lack of funds that can be used flexibly, university scientists and administrators are unable to pursue new ideas in the early stages, to meet unexpected needs, to renovate space, to help younger investigators who are not yet ready to submit formal grant applications, and to provide interim assistance to ongoing research budgets.

By failing to provide funds for these purposes the project system tends to create inflexibility, forestall innovation, impose penalties on younger investigators, and frustrate departmental and institutional planning. These tendencies have to be counteracted if an optimum system is to be designed, and the institutional grant is the counter-vailing force. These funds are valuable out of all proportion to their amount as a means of introducing both flexibility and innovation into a system which the project system tends to make rigid.

We find it paradoxical that the administration stresses the importance of academic science to deal with social and economic problems of high priority, and at the same time rejects the form of support which is most productive in bringing about the very kind of redirection that is desired.

A mature and forward looking Government should see to it that the major institutions on which the knowledge for a modern society depends are kept in good repair. Universities capable of interpreting new information and extending knowledge are national resources of the highest value. Without the sustained capacity of universities to carry on research of the highest quality in all major fields of learning, the posture of the Nation would be diminished and, over the long run, threatened. Institutional support of the kind we advocate maintains the flexibility of a system which the Federal Government has called upon and will continue to call upon in the future for research in fields which can not now be predicted.

The administration argues that if the Federal Government covers the cost of research projects, then the universities should be responsible for providing the funds necessary to avert the undesirable side effects of the project system. There is a direct answer to this contention. The funds are either not available at all or only available at the expense of squeezing some other equally worthy segment of the university budget.

Senator KENNEDY. Could you elaborate on the direct costs and the indirect costs?

Mr. HORNIG. The direct costs and indirect costs, if correctly computed, do cover the costs associated with the performance of the specified research. The problem is one that has lots of pieces which, altogether, make up the research program of an institution, and various things all between the cracks.

So that the direct and indirect costs do not cover these things. I am thinking of startup money for young investigators who for the first year when they begin their research have not had time to make a proposal to the National Science Foundation or to any other Government agency, for example.

Also there is the initial expense of small bits of equipment for the same young investigator who wants to get started and has not had time to put in a proposal. It is this sort of thing.

Senator KENNEDY. I suppose the argument is made: Why shouldn't these priorities be directed by the National Science Foundation or the Congress rather than leaving it up to the institution as to how they will spend institutional grant funds. Could you respond to that point?

Then maybe you can elaborate on how Brown has spent the money it has received in institutional grants.

Mr. HORNIG. I think it is quite proper that all of the major directions be defined by the Federal Government in its National Science Foundation programs. The National Science Foundation has set the priorities on which it will spend its moneys, but unless one were to have a level of bureaucracy that none of us would be willing to contemplate, there is no one in the Federal Government or in the National Science Foundation to respond to all of the little things that usually are not dignified by the word project even, the request for \$500 or \$1,000 which may not have been foreseen in advance.

It is not practicable for the National Science Foundation to be prepared to pick up on short notice the startup costs of young investigators just beginning their work. It is not practicable, even if the priorities are determined here, to be sure there are always funds to cover the gap between the time of application, and the time when actual approval is granted.

Sometimes there is a gap, or there may be a gap between determination of one good project and the initiation of the next phase.

For example, at Brown University, a young physicist has gotten together with others and they have been exploring new approaches to models of the brain function. Now, we have spent some \$2,500 from the institutional grant to provide them computer time while they worked this through and tried to think it out, explore the possibilities so they can present a proposal to one or the other of the agencies.

We have spent out of the last year about the same amount exploring new approaches to urban studies. Our urban studies group include engineers, economists, sociologists. Again they are in the early stages of working out a project, and they need small amounts of support from university funds.

When this project is submitted it will be evaluated in great detail by the National Science Foundation, but the problem is to get it started at all.

We have used institutional grant funds quite consistently as seed money. I have already mentioned the use to help young people to establish their laboratory and to buy special equipment. We have also used it to make it possible for a young investigator to work on through the summer months, for which customarily no salary is provided at our university.

It can be argued that if a university does not provide part of the funds to help finance research financed for the most part by the Federal Government, it will feel no responsibility for the research and will become overly dependent upon the Federal Government. There is an equally direct answer to this contention. That is, institutional support tends to give the university a reasonable degree of freedom to counteract the tendency of Federal research support to influence unduly the total research program of universities. So, all things considered, we remain convinced that the case for restoring institutional support at a reasonable level by the National Science Foundation remains strong and unshaken by the counter arguments.

To conclude, we believe that the time has come to reverse the trend of the past few years, that is, the decline of institutional support, by recognizing that the Nation has an important stake in sustaining the flexibility of universities and that the NSF institutional grant is an important instrumentality for achieving this goal.

Our specific proposal is that the committee authorize \$25 million for institutional grants by NSF in fiscal year 1975. This amounts to only 1 percent of the total Federal funds allocated for academic science.

Senator KENNEDY. Thank you very much. I have two brief questions.

Are you aware that the House took action earlier this week which indicated that in the future the Congress may place fixed ceilings on the percentage of funds spent by the Foundation on applied research efforts. Do you feel such a percentage should be written in a law now, or at some time in the future?

Mr. HORNIG. I think it would be very dangerous if applied research efforts were to divert from the fundamental or basic research efforts. Whether or not there should be fixed ceilings, or whether there should be careful congressional scrutiny of the applied research programs, I am really not prepared to say.

Senator KENNEDY. Finally, of all the things you have said about the burden placed on an institution such as Brown, if institutional grants are cut off, I suppose the effect would be exaggerated in the case of a smaller college, which doesn't have the resources that a university such as Brown has?

Mr. HORNIG. I think that is so, especially since the program for institutional grants placed an extra weight on the small colleges which have even less flexibility; but I have to emphasize that in some ways the problems also grow as the institution gets bigger.

Senator STAFFORD. Thank you, Mr. Chairman. I am happy to join in the welcome of the chairman to you, Dr. Hornig. I know that Brown University believes in excellence, not only in academic affairs but in athletics because I noted 2 years ago you made off with my alma mater's football coach. I hope he is doing well at Brown.

I do not really have any question except I do note that you approve of the fact that the budget proposal for fiscal 1975 of \$364 million for research project support in the NSF budget is up substantially from fiscal year 1974.

I presume though that even that increase is eroded somewhat by the rate of inflation we have had in just the past year. Is that true?

Mr. HORNIG. That is certainly true, and of course also the accumulative effects for several years prior to last year, but the last year was the worst.

Senator KENNEDY. Thank you very much. We have some other questions which I will submit to you in writing and make them a part of the record.

Mr. HORNIG. I will be delighted to respond.

[The information referred to and subsequently supplied follows:]

Questions Asked in Connectionwith the Hornig Testimony

1. If the Federal government pays the full direct costs, and in addition the full indirect costs, of research, why should it also pay in addition an institutional grant?

Answer: When the government pays indirect costs, it is simply reimbursing the university for money that it has already spent. Indirect cost payments are not a profit, or a source of extra money. They simply permit the university to break even on federally financed research. These indirect costs are set in accordance with a federal formula, and they are audited. The GAO has confirmed the view expressed here in a report to Congress on indirect costs.

2. N.I.H. as well as N.S.F. has had an institutional grant based on a percentage of research project grants. Why should two agencies have the same kind of institutional grant?

Answer: In theory, the two grants might be combined. In practice, it is so difficult to secure any institutional support to make the project system work well that two sources are highly desirable. If the administration has its way, there will not be two or one source, but no source at all.

3. The Education Amendments of 1972 provide for a cost of education allowance computed in relation to federal aid to undergraduates and in relation to the number of graduate students. This is a form of institutional support. Why is the N.S.F. institutional grant needed when more general authority for institutional support exists?

Answer: The cost of education allowance in the Education Amendments of 1972 have never been funded, and the prospects for funding in the future are dim. Even if this allowance is funded, it will in all probability not provide adequate money for the important function now served by the N.S.F. grant.

4. As a general goal, what proportion of federal support for academic science should be supplied as an institutional grant?

Answer: As a goal, ten percent would not be unreasonable. The immediate problem is to avoid reduction of the level to zero.

Senator KENNEDY. Our next witness is Philip Handler who is president of the National Academy of Sciences.

STATEMENT OF PHILIP HANDLER, PRESIDENT, NATIONAL ACADEMY OF SCIENCES

Mr. HANDLER. Mr. Chairman, members of the committee, I am most pleased to have the opportunity to appear before you this morning to discuss some aspects of the President's proposed budget for the National Science Foundation for fiscal year 1975.

This will be my last such appearance while still a member of the National Science Board since my term expires in a few weeks. However, it must be understood that I do not purport to speak for that Board; only its excellent chairman, Dr. Herbert E. Carter, is empowered to do so. Nor do I suggest that I speak on behalf of the collective membership of the National Academy of Sciences, since, as such they have never had opportunity to express their views.

Accordingly, my remarks must be taken as an entirely personal statement although I believe that a great many of my colleagues in science do in fact share these views.

First, let me lend my support to the overall proposed budget. This proposal has been constructed with greater care, with more extensive consultation with the scientific community, and with the National Science Board than any previous budget request for the National Science Foundation in my memory. Within the constraints which have been placed upon them, the Director of the Foundation and his colleagues have done a superlative job of preparation of this proposal.

The principal features of that appropriations request, it seems to me, are an earnest attempt to strengthen the general program of research project support which is the backbone of the Foundation's programs, expansion of the RANN program, an adequate budget for national and international centers and programs, and the special request for funds for support of research related to future national energy needs as part of the total Federal energy research and development program.

It is known that I hold certain reservations with respect to the RANN program, but these need not be repeated here.

The planning for the energy research program, although done on relatively short notice has been conducted with considerable care and imagination and I can warmly support it. At some future date, it may prove wise to reconsider the Federal organization for research and development addressed to meeting future national needs for energy.

Meanwhile, I deem it entirely appropriate that the Foundation be strongly engaged in the proposed manner. I say that while recognizing that the underlying philosophy of the overall Federal program seems unresolved, in the sense that it is not clear what the relative roles of government and the private sector will be in the future development of energy technologies, nor have we yet arranged a genuine confrontation with those decisions concerning energy utilization and production which, inexorably, loom in the future.

I am delighted to see the substantial increase in the standard research project support budget that Dr. Stever has presented, but that seemingly substantial increase must be viewed within the

totality of the President's budget request for R. & D. for the coming fiscal year and in the light of the history of the last six or seven years. Taken in their entirety, Federal funds for R. & D. obligations remain at 15-20 percent below fiscal year 1967 in constant dollars.

Considering only civilian R. & D., there is a small overall increase since fiscal year 1967, in the real terms, and that for academic research has now also caught up with and slightly surpassed fiscal year 1967. On the other hand, both non-military R. & D. and academic research have declined considerably when stated as percentages of the GNP. None of us has a formula for the optimal level of Federal investment in R. & D. in which we have genuine confidence. But if the frequently offered proposal, that non-military R. & D. and academic research be held at some fixed fraction of the GNP, has genuine merit, then it is most disturbing that, in these terms, we have slipped back seriously since 1967.

Meanwhile, the intrinsic cost of doing science—again in constant dollars—has continued to increase certainly by at least three to five percent per year. And at the same time, thanks to earlier Federal policy, there has been an annual increment to the pool of scientific manpower which since 1967, has resulted in a net increase of the order of perhaps 40 percent.

Even with the budget before you, many productive scientists will be significantly underfunded, many will not be funded at all, and there will be significant areas of research which will be known to be insufficiently funded or deferred in their entirety.

Simply to name a few areas of science which come within the purview of NSF which are known to be underfunded within this budget I might cite research in cloud physics, fundamental research related to earthquakes or to the geology of ore deposits, various aspects of geodynamics, nuclear structure physics, research in chemical catalysis, social scientific research relating to various disappearing cultures, and to the process of innovation, that is, how various technologies came to be introduced into society as well as the resulting social and economic consequences. I have little doubt but that the staff of the National Science Foundation has greater awareness of such needs than have I. I make these points not so much to suggest a yet larger increase in the appropriation for the support of basic research projects by the Foundation as to make it clear that the increment for research support proposed in the President's budget request is still very far from providing all of the funds which can be wisely utilized by the scientific community.

Senator KENNEDY. Are you concerned in reviewing this budget that it may indicate an expansion of research in the energy related areas at the expense of some other research programs?

Mr. HANDLER. I do not think so, sir. Quite apart from these general considerations, there remain several specific problems which, in my view, are not adequately addressed in the appropriations request.

The first of these is the matter of providing adequate instrumentation for the Nation's research laboratories. The difference between what can be done in science today, as compared with yesterday, derives from a combination of the increasing sophistication of our understanding and the increasing power of our research tools. In the main, we have already accomplished that which is obvious and rela-

tively simple to do. As science progresses, the phenomena which challenge us are increasingly remote from personal experience, from that which can be detected with our own senses. As the scientific frontiers move further from what can be personally experienced, the tools required to address the next set of questions necessarily must be more powerful and, regrettably, also necessarily more expensive. Many such progressions are familiar to all: from magnifying lenses, to light microscopes, to electron microscopes, to flying spot high resolution electron microscopes, to X-ray diffraction analysis; from a small boat to ocean going laboratories, to deep sea drilling; from Galileo's telescope, to the 150-inch telescopes at Kitt Peak and Cerro Tololo, to Greenbank, the VLA, and the orbiting astronomical observatory.

Some forms of new instrumentation are of such character as to permit a great savings of individual labor although what they accomplish might, at least in principle, have been possible by a sufficient number of human hands over a sufficient time. Even these, however, should not be so regarded. What they really do is to permit an investigator to undertake a study which otherwise he would not attempt. This is certainly the case, for example, for the instrumentation which now permits the analysis of amino acid sequences in proteins or the combination of X-ray instrumentation plus computers which permits the visualization of three-dimensional structures of large molecules. But in many cases, there is need and opportunity for the construction of new instruments which permit detection or measurement of phenomena which are otherwise entirely inaccessible, as in astronomy or solid state physics.

Over the past decade, the funds available for acquisition of instrumentation simply have failed to keep pace with the other aspects of the funding of the national research enterprise. Particularly in the period since 1967, available funds have been utilized largely to retain the scientific labor force while making do with older available instruments. Two years ago, at the request of the Foundation, the Academy conducted a survey of instrumentation needs in all scientific disciplines in a sample of large and medium size universities. The accumulated backlog of instrumentation requirements, if American science is to be maximally productive, can now be reckoned in hundreds of millions of dollars. Failure to make provision for this need places an all-too-real ceiling on the potential quality and quantity of the national scientific research endeavor. I would not, however, recommend an appropriation which would attempt to catch up with that backlog in a single fiscal year or two. But I do very strongly urge that there be placed in the Foundation's budget an additional special allocation for the provision of new instrumentation in all scientific disciplines. In my view a sum of the order of \$25 million per year for this purpose would be conservative and highly appropriate; there can be no doubt whatever that it would be extraordinarily well used.

Second, I must note that the institutions in which research is conducted have been markedly affected by their participation in this endeavor. Whereas I deeply believe that the university is enabled far better to function in its educational and service roles than it would be in the absence of the extensive research programs, it is also true that these programs place a significant financial burden upon the university and, potentially, create a situation of great fiscal instability

while frustrating effects at long-term planning. It seems to me that, in consequence, there is a Federal responsibility to provide some measure of fiscal stability for these institutions and also to assure that they can maintain a research capability in being without undue fluctuations occasioned by annual Federal variations in funding, programs, and policies. There is perhaps, a simplistic analogy between this relationship and that between two companies, one of which is the sole supplier of some product to the other, while the latter has no other major customer. In negotiating price, each must recognize the necessity for a mutually acceptable arrangement lest both be destroyed.

Such a responsibility was indeed recognized within the programs of the National Science Foundation for many years, but has been seriously eroded; some components have essentially disappeared from the National Science Foundation budget. It is for these reasons that I am pleased to endorse the testimony concerning institutional support provided here by Dr. Hornig. The relationships involved and the supporting arguments were marshaled in the first report of the National Science Board which has never received the attention it merited. I commend reconsideration of that report to the subcommittee.

Mr. Chairman, there is a third specific aspect of the Foundation's programs which warrants your serious consideration. Throughout most of the history of the Foundation, consecutive administrations in the White House, the National Science Board, and the Congress have all considered that it is incumbent upon the Foundation to assure the Nation of an adequate continuing supply of trained scientific manpower.

When, a few years ago, due largely to the decline in Federal expenditures for aerospace activities, there arose the specter of a continuing oversupply of technically trained manpower with consequent unemployment, that circumstance was utilized to justify the deletion of all postdoctoral fellowship programs, the termination of the traineeship program, and a reduction in scale of the predoctoral fellowship program at the National Science Foundation. It would be less than candid not to note that, underlying these actions, was the conviction on the part of some—a conviction which I do not share—that it is not a Federal responsibility to provide financial assistance to individuals which would make possible their advanced education when, conceivably, they might subsequently benefit financially from such education. And I am aware of the continuing discussion which asked why, almost uniquely, young scientists rather than other professionals should be provided such personal support by the Federal Government during their advanced education. There are efforts underway which will attempt to ascertain whether or not the falloff in Federal assistance for graduate students has affected the numbers, the distribution, or the quality of graduate students who have entered graduate schools in the period since the withdrawal of such support by the National Science Foundation.

Meanwhile, I and, I am sure, most of my knowledgeable colleagues feel rather strongly that provision of support for potential young scientists—whether by fellowship or traineeship mechanisms—is very decidedly in the national interest. I will not argue that entire case today but would like, instead to make a few simple points.

1. There is no significant unemployment of Ph. D. scientists in the United States today, in any discipline. As we regard the future, as we recognize that it is impossible much less desirable to turn back the clock to some simpler, nontechnological age, as we recognize that the fuel shortage of 1973 is a punctuation mark in history after which, forever more, the industrialized nations must ever understand the limitations imposed upon our civilization by the resources available in the thin skin of this seemingly ever-smaller planet, we have no choice but to maintain as vital, vigorous, and capable a research enterprise as our resources of trained scientists, facilities, institutions, and finances will permit. If one accepts that credo, if one recognizes that the total potentially available scientific manpower will begin to decline after 1980 simply in consequence of our shifting population age-distribution, then one must recognize that the possibility of technical unemployment is highly unlikely. To the contrary, a considerable series of congressional actions has steadily created an increasing demand for scientists and engineers. I would be pleased to cite some examples of that process if that be of interest.

Senator KENNEDY. Why is the shifting population distribution of consequence?

Mr. HANDLER. By about 1980 the college-entering population is going to decline, and the number of people available to go on to advanced education will decline by all available projections. That can be easily projected because those bodies are all here; the children can be counted now.

2. As I have noted, I cannot this morning bring to bear statistical evidence that the withdrawal of graduate student support by the NSF has seriously injured our potential pool of competent, trained scientific manpower. It is true that, for several years, there has been a significant decline in the population of graduate students directed toward scientific careers and, also, that there has been a moderate shift of enrollment from the primary research institutions of the Nation to institutions of lesser research capability. This year, for the first time, there appears to have been a tiny reversal of at least one trend, namely, there is a small increase in first-year graduate student enrollments in the natural sciences as compared with the previous year although I am unaware of the distribution of those students by institution or by discipline.

I strongly believe that it would be in the national interest to increase the number of graduate fellowships available through the National Science Foundation, and hope that the committee will give consideration to this possibility, largely on the grounds that it would not be in the national interest for highly qualified young scientists to be deprived of advanced educations for personal financial reasons. Specific recommendations in this regard have been offered by the National Board of Graduate Education in the report already cited by Dr. Hornig. This board is an instrument of four bodies: The American Council on Education, the American Council of Learned Societies, the Social Sciences Research Council and the National Research Council of the National Academy of Sciences, and is quartered within the academy. Again, I am pleased to associate myself with Dr. Hornig in supporting the recommendations of that board.

3. I can also, in totally good conscience, urge that the committee authorize and insist upon the funding of a significant number of

postdoctoral fellowships. At this time, the only such fellowships available through the foundation are those, recently made available, for a very small number of the teaching faculty of 2- and 4-year colleges, provided that each such faculty member is willing to devote his postdoctoral year to an applied problem of the general category supported by the RANN program.

I have no intrinsic objection to such a program; indeed I could support it. But I consider it a travesty that this should be the only postdoctoral program at the National Science Foundation. There is ample evidence that, for almost two decades, those responsible for selection of NSF postdoctoral fellows were remarkably successful at identifying the most productive young scientists in the Nation and assisting them in their careers at a crucial period. It is a mockery, then, that this program, which contributed so highly to the disciplinary scientific strength of the Nation, should have been abandoned by the only agency charged with maintaining the general scientific strength of the Nation and replaced in small part with a program which, by comparison, stands relatively little chance of making an equal contribution to the national welfare.

At this time, it seems likely that a significant fraction of those who, otherwise, would have successfully competed for NSF postdoctoral fellowships have been placed in approximately equivalent situations around the country by support as junior research associates whose stipends are defrayed from research grants and contracts. But, mark you, only at the expense of other uses of those funds so that the increment in research support is reduced in proportion. There are no data to indicate the magnitude of this trend but that it is indeed occurring is evident from much anecdotal information.

However, one acute aspect of the postdoctoral situation is readily documented. Unfortunately, there is one valuable type of postdoctoral experience for which that research grant and contract mechanism cannot substitute—experience in a laboratory outside our own national boundaries. Throughout the history of the NSF postdoctoral fellowship program, a significant fraction of all such fellows elected to take their most advanced experience in a major research laboratory overseas. In consequence, there was a steady, small stream of some of the brightest young American scientists bringing back to our own laboratories the philosophy and the techniques of the most prominent foreign laboratories. At this time, when the research capability of other nations significantly rival our own and, frequently, can boast unique research instruments unavailable in our own country, it seems foolish in the extreme to have cut off that stream of bright young Americans. That circumstance is equally regretted abroad. Indeed the absence of young Americans in foreign laboratories was first directed to my attention at a meeting in London last June by the officers of the Royal Society.

Accordingly, Mr. Chairman, may I urge that there be reinstated at the National Science Foundation a program of postdoctoral fellowships which would, *inter alia*, permit a significant number of young American scientists a year or two of experience in foreign laboratories engaged in fundamental research.

Let me suggest that the subcommittee consider, for this purpose, an addition of at least \$2.5 million to the President's budget request for fiscal year 1975 for the National Science Foundation. In my view, the return on this investment will be highly disproportionate to the

sum involved, and I hope that the committee will give this matter the most serious consideration.

Once again let me express my appreciation, Mr. Chairman, to you and to the committee for the privilege of being with you this morning.

Senator KENNEDY. Thank you very much. Your commentary has been very helpful, very direct. You have underscored your points of concern which will be instructive to this committee in considering your suggestions.

With regard to the planning for our energy research development programs, what would be the impact on NSF of the establishment of ERDA for example? Do you anticipate a number of problems?

Mr. HANDLER. I would expect so; yes.

Senator KENNEDY. With what impact on NSF?

Mr. HANDLER. So long as the Foundation retains the vigorous programs and the underlying fundamental research which one must have in any case in our energy crisis to go forward, I would not be concerned. I think that would be a perfectly reasonable arrangement.

There comes a point in the history of any such R. & D. effort where, as Dr. Stever said this morning, it will be incumbent upon the Foundation to transfer program responsibility to another arm of the executive branch which can properly manage the developing phase of the program.

Senator KENNEDY. You have had quite a reorganization, I understand, in your shop. Could you briefly indicate what you think its impact will be on the ability of the Academy to carry forward its mission.

Mr. HANDLER. If we have done it wisely, and if it is successful, sir, then we are, I believe, in far better position to be of assistance to the Congress and to the executive branch as required by our congressional charter. Specifically, in the future we will be better able to manage those advisory activities that are related to those great societal problems which necessarily cross the jurisdictional boundaries of various Federal agencies and also across the boundaries of individual scientific disciplines. That is the general objective. I hope we can make it possible and as you know the Congress has already begun to challenge us in that respect.

Senator KENNEDY. Senator Stafford.

Senator STAFFORD. Doctor, in your prepared statement you say: "Even with the budget before us, most scientists will be significantly underfunded. Many will not be funded at all."

In the light of that statement and your subsequent statements, might I ask you if you are in a position to recommend any figure for a budget at this time.

Mr. HANDLER. I am not, sir. I would not pretend that I have sufficiently precise numbers in front of me so as to give you a rational judgment.

No, sir, I would not try to do it.

Senator STAFFORD. Would it be possible for you in the near future to make any judgment as to sufficiently adequate funding?

Mr. HANDLER. I can make an attempt to. If you ask, sir, I would try.

[The following information was subsequently supplied for the record:]

NATIONAL ACADEMY OF SCIENCES

OFFICE OF THE PRESIDENT
2101 CONSTITUTION AVENUE
WASHINGTON, D. C. 20418

April 18, 1974

The Honorable Edward M. Kennedy
Chairman
Special Subcommittee on the National
Science Foundation
Committee on Labor and Public Welfare
United States Senate
Washington, D. C. 20510

Dear Mr. Kennedy:

The following statement is submitted, for the record, in response to the question by Senator Stafford with respect to a specific recommendation concerning the proposed budget for the basic research program of the Foundation -- Scientific Research Project Support.

In my prepared testimony I recommended an increment of \$25 million to this element of the Foundation's budget to be utilized for the upgrading of instrumentation in the nation's fundamental research laboratories, largely in universities. Among the types of instrumentation that I had in mind one might include the following: seismic profilers are required for research on the continental shelves. High voltage scanning electron microscopes, which can be used in engineering, materials research, the biological sciences, and in chemistry are particularly essential for the study of surfaces which act as heterogeneous catalysts, a field of ever-increasing importance. Sophisticated mechanical test systems are needed for testing the mechanical properties of new materials. University equipment in this area is now badly out of date. Medium power lasers are acquiring a great multitude of uses, but are unavailable in most laboratories. Remote sensing devices, particularly for use in astronomy, would markedly upgrade the capability of existing optical equipment. Signal-averaging equipment for on-line data acquisition would enhance the capability of numerous laboratories in many disciplines. There is a considerable backlog of requests for equipment for doing chromatography, amino acid analysis, sophisticated spectrophotometry, etc. Commercial manufacturers have developed new instrumentation

The Honorable Edward M. Kennedy
April 18, 1974
Page Two

for measurement of radioactivity which would multiply the efficiency of numerous chemical and biological laboratories but cannot be purchased from current project research budgets. And it has been impossible for the Foundation to be adequately responsive to fully legitimate, well-documented requirements for nuclear magnetic resonance spectrometers and high resolution mass spectrometers.

As I indicated in my testimony, the suggested sum of \$25 million can only begin to meet legitimate needs for such instrumentation.

In addition, I would propose that another \$50 million be added to the sum suggested in the Foundation's request for support of Scientific Research Projects, viz., a total increment of \$75 million for this budget category.

The Foundation has indicated that, if their budget proposal were funded in the amount requested, the fraction of all research proposals received by the Foundation which could find support would decrease from 42% in FY 1974 to 39% in FY 1975. Moreover, those proposals which do lead to awards will be funded, on the average, at a level about 30% less than that which the Foundation considers to have been adequately justified. Hence, even those proposals which are funded will be less productive than they otherwise might be. Increasing the SRPS budget by about \$25 million to prevent further dilution of the Foundation's capability to fund basic research in the coming fiscal year seems, to me, to be eminently sound if the nation is to benefit adequately from our previous investment in these resources.

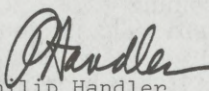
It should be noted that, after making allowance for that fraction of the increment in the SRPS program which is specifically directed toward the new energy program, the increment in SRPS proposed in the Foundation's budget represents an increase of only 11% above the previous year, which can scarcely compensate for the compounded inroads of inflation since 1967.

The Honorable Edward M. Kennedy
April 18, 1974
Page Three

In addition to this general fiscal problem, there are several research fields in which there are significant research opportunities which offer considerable promise for application in the years ahead but which, in my view, are inadequately represented in the Foundation's research budget proposal. These include work in the field of plate tectonics with its implication for the understanding of earthquakes and the identification of mineral resources; oceanography research generally, since oceanography has been very seriously constrained in recent years by rising costs; climatology, a field in which the current state of the art simply is inadequate to support long-range predictions when we stand in dire need of such capability. For these several fields, an increment in the appropriation of about \$25 million would make it possible for the Foundation's programs to be decidedly more responsive to national needs and the opportunities which the fields offer. There can be no doubt that both the investigators and the laboratories capable of wisely utilizing these funds are already in existence.

Thus, in response to Senator Stafford's query, I would suggest that there be authorized to the National Science Foundation for FY 1975, for Scientific Research Project Support, a total sum of \$439 million.

Sincerely yours,


Philip Handler
President

Senator STAFFORD. Could you draw any comparison between the degree of research in this country in the areas you have testified to as compared to, say, the effort and the same are in the U.S.S.R.?

Mr. HANDLER. Most of the areas with which I have some familiarity, sir, indicate the sophistication and productivity of our science remains ahead of theirs.

Senator KENNEDY. Just to carry that forward, what about the research effort? You responded in terms of productivity. What about the amount they are spending for research? Do you have any idea about that?

Mr. HANDLER. I hope to be able to give you a real answer to that perhaps in 5 or 6 months. We are engaged in a set of activities with the Soviet Academy which for the first time indicates they will actually provide us with information, hard numbers, and they are going to try to reconcile those with ours and with our understanding of what so many rubles will really do in a Soviet laboratory. If indeed they are forthcoming, perhaps then we should know a great deal more at the end of the summer than we do today. At this time it would be extremely difficult to make such estimates.

We do know there are numbers of very impressive exercises just beginning in the Soviet Union. Many Americans, given the privilege of seeing their latest installation, are very much impressed at their new starts. Also if you travel about and visit some of the older installations, you find that there are diamonds imbedded in islands of mediocrity.

Senator KENNEDY. When you come back in the late summer or fall we would be very interested to know what you have learned.

Mr. HANDLER. Our committee will have met with theirs twice by that time. We may have learned something we can rely on by then if they are forthcoming.

Senator KENNEDY. Thank you very much. Your testimony has been very helpful.

Mr. HANDLER. It has been a pleasure to be here, sir.

Senator KENNEDY. Our final witnesses are a panel of science educators, Prof. Richard Wright, Biology Department, Gordon College, Wenham, Mass.; Prof. Jean C. Belcher, professor of ecology, Sweetbriar College, Sweetbriar, Va. and Miles M. Fisher, executive secretary, National Association for Equal Opportunity in Higher Education.

STATEMENT OF PROF. RICHARD WRIGHT, BIOLOGY DEPARTMENT, GORDON COLLEGE, WENHAM, MASS.; PROF. JEAN C. BELCHER, PROFESSOR OF ECOLOGY, SWEETBRIAR COLLEGE, SWEETBRIAR, VA.; AND MILES M. FISHER, EXECUTIVE SECRETARY, NATIONAL ASSOCIATION FOR EQUAL OPPORTUNITY IN HIGHER EDUCATION, A PANEL OF SCIENCE EDUCATORS

Mr. WRIGHT. I have been teaching biology for 9 years at Gordon College, a small liberal arts college north of Boston. After finishing my doctoral work at Harvard and a NSF postdoctoral fellowship in Sweden, I went to Gordon for two reasons: Its location on an 800-acre campus, with several lakes close to the ocean, and its commitment to a Christian world and life view, which I share.

The location has proven to be ideal for my research area, aquatic microbiology. My involvement with the college over these years has given me the opportunity to build up a modest department of biology and do my part in the goal of establishing Gordon as a quality liberal arts college.

Our enrollment has been growing each year, in the face of a trend in the other direction for some small colleges.

I will come directly to the point. Our situation in science at Gordon College would be much worse than it is today except for the National Science Foundation's institutional grants for science program. This program has received less funding each year for a number of years, and now has been entirely eliminated from next year's proposal budget.

This is the program that awards funds on a matching basis to institutions that have received a variety of types of research grants from NSF during the previous fiscal year.

The tapered formula used by NSF for the program insures that small institutions will receive significant amounts. For example, I received an NSF research grant in 1966 for \$21,000 to do work in aquatic ecology.

The following year, Gordon College was awarded an institutional grant of \$12,600 because of my research grant. In the past 7 years, we have received institutional grant funds of over \$25,000. I would like to give you some idea of what that kind of money can do for a small college.

With the first grant of \$12,500 awarded in 1967 we completely furnished a small laboratory for eight students, and a faculty laboratory for research and teaching; we purchased equipment for a new course in cell biology, microscopes, physiology equipment and analytical balances. The labs and equipment are in constant use today.

A second major award in 1970 made it possible to double the laboratory space for biology by furnishing a laboratory for 24 students and providing two well-equipped faculty office laboratories. As a result, we have been able to keep up with a rising number of biology majors—presently 5 percent of the student body—during a phase of growth that has seen the college move from 500 to 950 students in 8 years.

The college has not been lax in committing funds to us; we have consistently had the highest budget of any department. We recently obtained a greenhouse and an electron microscope, through the persuasive efforts of the other two members of the biology department.

We certainly do not wait until we get NSF funds before undertaking improvements. Yet the institutional grant funds have played a key role in our biology program at the college. I think it is safe to say that our experience is not unique—small and large institutions have made good use of institutional grant funds since its inception in 1961.

The program is a very strong incentive to stimulate interest in research on the part of scientists and administrators. It rewards those schools where research is going on, and has an especially strong impact at smaller institutions where research is not necessarily encouraged.

The program has been a great source of encouragement to me. I have the feeling that we have been receiving institutional grant funds because we have been doing what scientists should be doing—maintaining an active research program.

There is in small colleges especially the tendency for teachers to relax and do pretty much the same things from year to year.

This is so widely recognized that in the past whenever I have given a paper at a scientific meeting, my colleagues from the larger universities expressed surprise that I was doing research. In recent years, however, the academic job market has tightened up to the extent that new Ph. D.'s coming from research experiences at the large universities have been very happy to get an appointment at a small college.

I have no data to support this idea, but I feel that these next few years represent a time when many smaller institutions can get back into the mainstream of science through the efforts of these younger teachers who are still able to do research.

In many ways, a smaller institution can be a better place for a student, if his teachers are active in research. He has frequent, close contact with active scientists in the classroom, his labs are conducted by people much better qualified than the graduate students who run the labs in the universities, and he often has an opportunity to become involved in research as an undergraduate.

This is a time, when NSF should be in every way possible encouraging scientists in teaching institutions to do research and to upgrade the level of teaching by helping to provide equipment and facilities.

The institutional grant program is a good one, I think. It accomplishes this twofold emphasis in a unique way. I am asking the members of the committee to do what they can to restore it and at least at the level of funding of a few years ago.

I might add a note concerning another NSF program that was also of great benefit to me—the science faculty fellowship program. I was a science faculty fellow at Oregon State University several years ago, and I can testify to the importance of this program for my own career development.

I was able to prepare myself to teach in a new area; I learned some new research techniques and published two papers based on work done there. I understand that this program has been reinstated after 2 years in limbo. I hope it will be continued, for many of the same reasons I cited for the institutional grant program.

I have one more remark to make, and it relates to the relationship between big science and small science, because I think part of the problem we are talking about here involves this relationship.

Big science has its roots in small science. Every scientist must come up through an undergraduate educational process, and this is a level to which we are trying to draw more attention.

The quality of science at this level will have a direct influence, I feel, on the big science in the future. It is less dramatic, it is much more diffuse, hence it is much more vulnerable to neglect; and I think it is right now suffering from a severe case of neglect by the present administration.

Senator KENNEDY. Your statement has been most helpful.

Dr. Belcher.

STATEMENT OF JANE C. BELCHER, DORYS McCONNELL DUBERG
PROFESSOR OF ECOLOGY, SWEET BRIAR COLLEGE, SWEET BRIAR,
VA., ON BEHALF OF THE ASSOCIATION OF AMERICAN COLLEGES
AND THE NATIONAL COUNCIL OF INDEPENDENT COLLEGES AND
UNIVERSITIES

Ms. BELCHER. I am Jane C. Belcher, Dorys McConnell Duberg professor of ecology at Sweet Briar College, an undergraduate college for women with an enrollment of 730 students at Sweet Briar, Va.

I thank you for the privilege of appearing before this subcommittee to discuss the fiscal year 1975 authorizations for the National Science Foundation.

I do so on behalf of the Association of American Colleges, and the National Council of Independent Colleges and Universities, whose memberships comprise almost 1,200 institutions, five-sixth of which are independent.

Mr. Chairman, I have some basis for a feeling of confidence in speaking on this subject, and I want to back up some of the things my colleague on my right has just spoken about. I think he said he had been at this for 9 years, and I have been at it for 34 years at the institution where I teach, and I have that basis of confidence.

Furthermore, I had a very interesting experience just 2 weeks ago when the National Science Foundation organized a workshop for the 187th project directors of their so-called COSIP—college science improvement program. This program had a life of 6 years. It has been phased out, and the project directors are the ones who, of course, have known it best and are the most enthusiastic supporters.

I think that my remarks concerning the National Science Foundation projects will be limited to the ones that I am confident would be endorsed by 100 percent of those project directors who represented most of the 50 States of the Union.

Many of them were from independent colleges, all of them undergraduate institutions, many of them small institutions like the ones Dr. Wright has mentioned.

It has been observed that our colleges are feeling the crunch. Many of the small liberal arts colleges make up 80 percent of their annual budget on the tuitions that they receive.

A falling off in enrollments is a rather drastic event, and all of us have been watching the nervous situation of the small college—well, of all colleges but perhaps particularly the small independent liberal arts college. Inflation has hit them. The competition with the public institutions where tuitions are less has been very difficult for them.

I think that these undergraduate institutions, the independent ones, are worth saving.

I might suggest to you that we have evidence of it in this room. The members of the committee, for instance are from such independent colleges as Harvard, Yale, Middlebury, Amherst, Princeton and Pomona.

With the array I have suggested, and perhaps taking some institutional names represented in the audience behind me, we would find a fine illustration of the kind of pluralism that exists in independent colleges, matching the kind of pluralism we have in the society of the United States of America.

Pluralism creates problems. However, the pluralism in our country has given us the most extraordinary civilization that has ever existed on Earth. The pluralism which we have in our independent colleges is a very rigorous promise of wealth, diversity, imagination, innovation, at all levels of education.

I think this is one of the real and great reasons for protecting and nourishing the independent colleges.

Interest in oceanography has been evidenced here today, so perhaps I can use a part of the ocean as a metaphor. We are all accustomed to certain parts of the ocean that hit the television screen and the Sunday supplement, things like dolphins and whales, for instance.

The independent colleges are not the dolphins and whales of the educational system: The independent colleges are the lagoons; they are the estuaries; they are the coral reefs; they are the source of wealth of this ocean, this community, the community of independent colleges.

Senator KENNEDY. Could you tell us briefly about some of the programs that Sweet Briar is involved in? Then we will have to move along.

Ms. BELCHER. Yes, I will be glad to. We have just completed or are just completing one of the COSIP programs; a fund of \$203,000 was granted to the college in 1970, and it helped raise the levels and abilities of all of the natural and social sciences to the point where there was an equivalency between them which itself was to be put to considerable use, that is, we thought that that equivalency would put us into a position for another major leap forward in the area of environmental studies.

With the behavioral sciences being brought more up to date in the application of quantitative methods in their fields, use of computers, and so forth, requiring sophisticated equipment, and the other sciences proceeding or improving their abilities in appropriate ways, we have made a very good start on the next step in our plans.

Senator KENNEDY. What have you received in terms of institutional grant support?

Ms. BELCHER. I cannot give you the exact figure. I can supply it; we have had some, but not to the extent that Dr. Wright has had.

Senator KENNEDY. Could you supply that for us, as well as information on how you have used those moneys?

Ms. BELCHER. Yes, I would be glad to.

Senator KENNEDY. All right.

Ms. BELCHER. We have also had one of the URP grants, the undergraduate research participation, and it was used in a summer program last summer. We have applied for another one this summer. We found it very important.

We regret however that the faculty fellowships have strings attached now; namely, studies supported by funds from these sources are to be directed toward certain societal problems, energy problems, technological problems. We feel that particularly at the undergraduate level, science should be as pure as we can keep it, especially when it is supported by NSF funds.

[The prepared statement of Ms. Belcher and the information referred to above and subsequently supplied follows:]

Statement of

Professor Jane C. Belcher

Dorys McConnell Duberg Professor of Ecology

Sweet Briar College, Sweet Briar, Virginia

for the

ASSOCIATION OF AMERICAN COLLEGES

and the

NATIONAL COUNCIL OF INDEPENDENT COLLEGES AND UNIVERSITIES

before the

SENATE SPECIAL SUBCOMMITTEE ON NATIONAL SCIENCE FOUNDATION

April 5, 1974

10:00 a.m.

Mr. Chairman and Members of the Subcommittee:

Thank you for the privilege of appearing before this Subcommittee to discuss the FY1975 authorizations for the National Science Foundation. I do so on behalf of the Association of American Colleges and the National Council of Independent Colleges and Universities whose memberships comprise almost 1200 institutions, five-sixths of which are independent.

I am Jane C. Belcher, Dorys McConnell Duberg Professor of Ecology at Sweet Briar College, an undergraduate college for women with an enrollment of 730 students at Sweet Briar, Virginia.

I am here to represent independent colleges and their needs in science education. I have two major bases for confidence in speaking on this subject: (1) I have taught biology at an independent liberal arts college for 34 years and (2) Two weeks ago I attended a stimulating workshop organized by the National Science Foundation for all 187 project directors of the College Science Improvement Program (COSIP) representing most of the 50 states. The views I express today would, I believe, receive vigorous endorsement from our member institutions as well as the COSIP project directors.

I will comment first on the present plight of colleges, particularly in the area of the sciences, and its implications for the future. All colleges are nervous about future financing. Competition from public institutions, plus inflation, have resulted in reduced applications for admission and enrollments. This could spell trouble, since on the average, almost 80% of the annual budget at many independent colleges is received from tuition.

A few colleges, unable to meet the payroll, have closed their doors. In some instances this was perhaps no great loss, but one must remember that the vigor inherent in a pluralistic society has an exact counterpart in the pluralistic community of colleges. Pluralism virtually insures variety in imaginative approaches to the multitude of problems in education. The past few years have seen not only the mushrooming of public institutions but also changing patterns of financial support for private institutions.

During the latest five-year period, including that covered by the proposed budget for FY1975, support for the National Science Foundation has almost doubled. We recognize that much of this increase results from the transfer of mission oriented projects from other departments and agencies to the National Science Foundation. Even with this recognition it is not easily understood why the support for science education and institutional support for science has been cut in half during the same period. Included in this reduction is the proposal in the Administration's FY1975 budget for a cut of \$7.5 million from last year's level of \$67.5 million to \$60 million in science education, plus a cut of \$7 million in institutional support for science from last year's \$10 million to \$3 million. (See Appendix A)

It would appear there has been a trend within the National Science Foundation in recent years that has the effect of separating the relationship of research and education. We should, in fact, recognize their interdependence. We believe the earlier interdependence should be restored and would suggest that a long term goal be established that would fund Science Education Improvement expenditures at approximately one-third the level of Basic Research dollars expended. We feel this relationship is necessary if, in the long run, an adequate number of scientifically educated persons is to be available to carry out basic research essential to meet national needs. (See also Appendix A)

The nation should view with concern any threats to the variety and quality of independent colleges since these colleges are a rich seedbed for culturing scientists

-3-

and other leaders for the future. These colleges represent the grassroots of higher education; they provide the climate where the individual faculty member can work with the individual student, the climate which encourages the freedom to question, to explore and to let the imagination play. It is probably true also that today's science may exist in its purest form on such campuses, for it is here that no question of power, prestige, or financial reward diverts or prostitutes the mind of the budding scientist.

I will now briefly describe the kinds of support needed by colleges, and ways in which the National Science Foundation should supply this support:

1. COLLEGE SCIENCE IMPROVEMENT PROGRAM

We need a reincarnation of the National Science Foundation's College Science Improvement Program and we believe the new program, Restructuring the Undergraduate Learning Environment (RULE), should be curtailed or even abolished. RULE is a program providing for a very few large grants (\$1 million range) for major overhauling of institutional goals and structure, with the idea that the modes of radical change will be transferable. We think there is questionable logic in the idea that a revolutionary project which succeeds brilliantly at one institution will automatically have a chance to succeed at another.

COSIP, during its six years of life, provided many smaller grants (up to the \$200,000 level) for an enormous variety of projects or packages of projects for institutions and consortia, which were designed to effect improvements in science education. It should be noted that in the eyes of a small institution \$200,000 is a very large grant, and the small institution, traditionally accustomed to stretching the dollar, probably completes the grant with a minimum of waste and a maximum of "bang for the buck." The flexibility incorporated in COSIP guidelines permitted evolution of supportive projects during the grant period leading often to unexpected rewards or spin-off benefits. The COSIP guidelines, by placing no restrictions on the kinds of scientific studies to be supported, encouraged science in the purest and truest sense. An extensively indexed catalog of abstracts of the 187 COSIP programs is now being prepared by NSF,

will be widely disseminated, and will provide a storehouse of transferable projects which can be adopted, built on, or modified throughout the community of colleges. COSIP projects are transferable because they serve evolutionary change without unnecessarily disrupting institutional frameworks.

We think the impact of COSIP will be widespread, that the program should be reestablished, and that the National Science Foundation should give serious consideration to establishing a second generation of COSIP programs designed for those institutions which, with the help of "COSIP I," reached a position of readiness for a quantum jump and are failing to make the jump because of COSIP's projected demise.

2. STUDENT - ORIENTED PROGRAMS

The Undergraduate Research Participation (URP) program, particularly in the support it has provided for significant summer projects, has been extremely valuable to colleges and should be retained. We regret, however, a growing tendency to saddle such programs with restrictions, e.g. providing grants for studies with societal significance. Scientists don't oppose the solving of social problems, but dictation of goals moves studies along the spectrum, away from science and toward technology. Science, to be science, must be free. We recommend for the traditional URP, \$5 million; for the Student-Originated Studies, \$3 million; and for Student Science Training, \$4 million.

3. SCIENCE FACULTY FELLOWSHIPS

The traditional Science Faculty Fellowship program has become increasingly helpful in a period when college budgets can't be stretched to support faculty research and study except in a limited way. A new problem has also arisen - the increasing percent of older, tenured faculty as a result of reductions in staff. If these faculty are to serve their institutions well they need retooling in their specialty, or training in newly developing branches of their disciplines. We recommend \$4 million.

4. INSTITUTIONAL SUPPORT

The National Science Foundation's institutional support in the form of unrestricted grants based upon the percent of research funds provided in a given year has become a welcome infusion in the college budget. With such support the college is encouraged to sustain an atmosphere in which research can proceed. We recommend \$14 million.

5. INSTRUCTIONAL SCIENTIFIC EQUIPMENT PROGRAM

Another program of great value to small colleges is the Instructional Scientific Equipment Program (ISEP) and we believe it should be continued. Even in periods when departmental budgets were not being reduced it took careful planning and accumulation of funds over a period of years before a piece of expensive equipment could be purchased. Such delays can dampen enthusiasm for the sciences and ISEP is virtually the only source of funds to meet such needs. We recommend \$8.9 million.

6. EXCESS PROPERTY

Access to government excess property is cut off when an NSF grant is terminated. We suggest a liberalization of this program under which grantee and other institutions can more readily secure equipment from this source. A COSIP grantee values highly excess property as a prized fringe benefit of the grant. My own institution has benefited under this program through obtaining electronic gear, photographic equipment, microscope accessories, audio-visual aids, etc. which we otherwise could not have acquired.

7. NATIONAL SCIENCE BOARD

The project directors attending the recent COSIP workshop strongly recommended additional undergraduate college representation on the National Science Board. The undergraduate colleges are currently under-represented. (See Appendix B):*

*The accompanying appendices are provided through the courtesy of our member colleges who comprise the Associated Colleges of the Midwest and the Great Lakes Colleges Association, who are identified in Washington through their Midwestern Colleges Office.

NATIONAL SCIENCE FOUNDATION

Expenditures By Fiscal Year

	FY 1969	FY 1970	FY 1971	FY 1972	FY 1973	Est. FY 1974	Requested With Energy Budget Program 1975
TOTAL (Millions of dollars)	400.0	440.0	496.1	600.7	610.3	646.4	672.1 788.2
INSTITUTIONAL IMPROVEMENT FOR SCIENCE	37.7	44.7	34.4	21.0	9.1	10.0	3.0
(Millions of dollars)							
BASIC RESEARCH (Scientific Project Research Support)	176.0	161.7	180.4	248.6	277.3	291.3	325.0 363.7
(Millions of dollars)							
EDUCATION (Science Education Improvement)*	79.2	82.5	71.3	65.0	39.9	58.7	52.2 53.6
(Millions of dollars)							
EDUCATION (Including Computer and Public Under- standing Programs)						67.5	60.0 61.4
PERCENTAGE RELATIONSHIP of Education to Basic Research	45.0	51.0	39.5	26.1	14.4	20.2	16.1 14.7

* Excludes Computer in Education programs and Public Understanding of Science programs

Midwestern Colleges Office
March 15, 1974

NATIONAL SCIENCE BOARD MEMBERS, 1950 - 1974

National Science Board Members, Past and Present

	<u>Number</u>	<u>Percentage</u>
B.A. and M.A. Degree-Granting Institutions (C)*	6	6.4
Ph.D. Degree-Granting Institutions (U)	61	64.9
Non-Degree Granting Organizations (ND)	27	29.0
Total	94	

National Science Board Members, Present

	<u>Number</u>	<u>Percentage</u>
B.A. and M.A. Degree-Granting Institutions (C)	1	4.0
Ph.D. Degree-Granting Institutions (U)	17	68.0
Non-Degree Granting Organizations (ND)	7	28.0
Total	25	

* These institutions were Carleton, Defiance, Spring Hill, Texas Southern, West Virginia State, and Mount Holyoke.

Prepared by:
Midwestern Colleges Office

NATIONAL SCIENCE BOARD MEMBERS, 1950-1974

This National Science Board roster lists every member since its inception in 1950, together with his last affiliation while on the NSB.

Present NSB members' names are underlined.

Aberle, Dr. Sophie D.	University of New Mexico
Adams, Dr. Roger	University of Illinois
Barnes, Dr. Robert P.	Howard University
<u>Bing, Dr. R.H.</u> (term expires 5/10/74)	University of Texas at Austin
Bronk, Dr. Detlev W.	Rockefeller University
<u>Brooks, Dr. Harvey</u> (term expires 5/10/74)	Harvard University
Bunting, Dr. Mary I.	Radcliffe College
Baker, Dr. W.O.	Bell Telephone Laboratories
Barnard, Dr. Chester	Rockefeller Foundation
<u>Campbell, Dr. Wesley G.</u>	Hoover Institution
<u>Carter, Dr. H.E.</u> (term expires 5/10/74)	University of Arizona
<u>Charpie, Dr. Robert A.</u>	Cabot Corporation
Clement, Dr. Rufus E.	Atlanta University
Conant, Dr. James B.	Harvard University
<u>Cooke, Dr. Lloyd M.</u>	Union Carbide
Cori, Dr. Gerty T.	Washington University
Davis, Dr. John W.	West Virginia State
<u>Dicke, Dr. Robert H.</u>	Princeton University
Dollard, Mr. Charles	Carnegie Corporation
DuBridge, Dr. Lee A.	California Institute of Technology
Elvehjem, Dr. Conrad A.	University of Wisconsin

Erying, Dr. Henry	University of Utah
<u>Fowler, Dr. William</u> (Term expires 5/10/74)	California Institute of Technology
Fred, Dr. Edwin B.	University of Wisconsin
<u>Gates, Dr. David M.</u>	University of Michigan
Glennan, Dr. T. Keith	Case University
Goldsmith, Dr. Julian R.	University of Chicago
Gould, Dr. Laurence M.	Carleton College
Gross, Dr. Paul M.	Duke University
<u>Hackerman, Dr. Norman</u> (Term expires 5/10/74)	William Marsh Rice University
Hagerty, Dr. William W.	Drexel Institute of Technology
<u>Hahn, Dr. T. Marshall</u>	Virginia Polytechnic Institute
<u>Handler, Dr. Philip</u> (Term expires 5/10/74)	National Academy of Sciences
Hardin, Dr. Clifford M.	University of Nebraska
Haworth, Dr. Leland J. +	National Science Foundation
<u>Harrison, Dr. Anna Jane</u>	Mount Holyoke College
Hesburgh, The Very Reverend Theodore M., C.S.C.	University of Notre Dame
<u>Heffner, Dr. Hubert</u>	Stanford University
Houston, Dr. William W.	Rice University
Humphrey, Dr. George D.	University of Wyoming
Hyman, Dr. O.W.	University of Tennessee
<u>Heyns, Dr. Roger W.</u>	American Council on Education
Jones, Dr. Charles F.	Humble Oil and Refining Company
Jones, Dr. Thomas F., Jr.	University of South Carolina
Loeb, Dr. Robert F.	Columbia University
Macelwane, The Reverend James B., S.J.	St. Louis University
<u>March, Dr. James G.</u> (Term expires 5/10/74)	Stanford University

McBride, Dr. Katherine E.	Bryn Mawr
McCann, Dr. Kevin	Defiance College
McElroy, Dr. W.D. +	National Science Foundation
McLaughlin, Dr. Donald H.	Homestake Mining Company
McShane, Dr. Edward J.	University of Virginia
<u>Meckling, Dr. William H.</u>	University of Rochester
Merck, Mr. George W.	Merck and Company, Inc.
Middlebush, Dr. Frederick	University of Missouri
Moreland, Mr. Edward L.	Massachusetts Institute of Technology
Morison, Dr. Robert S.	Cornell University
Morris, Dr. Joseph C.	Tulane University
Morse, Dr. Marston	Institute for Advanced Study
<u>Murray, Dr. Grover E.</u> (Term expires 5/10/74)	Texas Technological College
Nabrit, Dr. Samuel M.	Texas Southern University
<u>Nierenberg, Dr. William A.</u>	Scripps Institution of Oceanography
O'Brien, Dean Morrough P.	University of California at Berkeley
<u>O'Neal, Dr. Russell D.</u>	Bendix Corporation
Picker, Mr. Harvey	Picker Corporation
<u>Piore, Dr. E.R.</u>	International Business Machines Corporation
Potter, Dr. Andrew A.	Purdue University
<u>Press, Dr. Frank</u>	Massachusetts Institute of Technology
Rees, Dr. Mina S.	City University of New York
Reyniers, Prof. James A.	Notre Dame University
<u>Reynolds, Dr. Joseph M.</u>	Louisiana State University
Rubey, Dr. William W.	University of California at Los Angeles
Russell, Dr. Jane A	Emory University
Seaborg, Dr. Glenn T. 0	University of California at Berkeley

Sears, Dr. Paul B.	Yale University
<u>Smith, Dr. Frederick E.</u> (Term expires 5/10/74)	Harvard University
Snyder, Mr. John I., Jr.	U.S. Industries, Inc.
Spilhaus, Dr. Athelstan F.	Smithsonian Institution
Stakman, Dr. E.C.	University of Minnesota
Stevenson, Dr. Earl P.	Arthur D. Little, Inc.
<u>Stever, Dr. H. Guyford</u> +	National Science Foundation
Stratton, Julius A.	Massachusetts Institute of Technology
Sullivan, Mr. Richard H.	Carnegie Corporation
Tatum, Dr. Edward L.	Rockefeller University
<u>Thieme, Dr. F.P.</u>	University of Colorado
Tyler, Dr. Ralph W.	Center for Advanced Study in the Behavioral Sciences
Volwiler, Dr. Ernest H.	Abbott Laboratories
Walker, Dr. Eric A.	Pennsylvania State University
Waterman, Dr. Allan T. +	National Science Foundation
Weaver, Dr. Warren	Alfred Sloan Foundation
Whitaker, Dr. Douglas M.	Rockefeller University
Willey, Dr. Malcolm M.	University of Minnesota
Wilson, Dr. Charles	General Electric Company
Yancey, The Reverend Patrick, S.J.	Spring Hill College

+ Ex officio

0 Dr. Seaborg resigned from NSB when he became Chairman, Atomic Energy Board

Sources: National Science Foundation
Who's Who in America
American Men of Science
American Universities and Colleges

SWEET BRIAR COLLEGE
SWEET BRIAR, VIRGINIA 24595

DEPARTMENT OF BIOLOGY

April 11, 1974

The Honorable Edward M. Kennedy
Chairman
Senate Special Subcommittee on
National Science Foundation
431 Old Senate Office Building
Washington, D.C. 20015

Dear Mr. Kennedy:

In reply to your April 5th request for certain specifics regarding National Science Foundation Institutional Grants to Sweet Briar College I can now report that such a grant was received in 1973 as a result of a 1972 research grant made to a member of our Psychology Department. Small as this \$1,090 grant might seem, it had a significant impact on the college's evolving program of faculty-student research. Attached documents provide more details of our total program. A brief review of highlights of this program shows how important even a small unrestricted grant can be in capitalizing on momentum achieved with a CoSIP grant.

In 1970 Sweet Briar College received a College Science Improvement Program (CoSIP) grant to develop seven departments to higher and mutually supportive levels of competence which would enable them to participate in a program of environmental studies. A key part of the plan involved use of the relatively unexplored 3,400 acres of Sweet Briar property and the surrounding rural county as natural laboratories for faculty and student field work and research. CoSIP funds supported the following summer research activities, each involving students working under the supervision of one or more faculty members:

- 1) in 1970, '71, '72, demographic and related sociological studies of Amherst County;
- 2) in 1971, '72, '73, studies in biological rhythmicity and related topics;
- 3) in 1970 and 1973, inventory of flora and fauna of Sweet Briar property;
- 4) in 1973, preparation of laboratory procedures for a new course, Biology of Pollution;
- 5) in 1972, an interdisciplinary project focused on the political, economic and psychological impact of the projected annexation of a portion of Amherst County to the City of Lynchburg;
- 6) in 1973, an interdisciplinary course offering college credit, entitled Aftermath of Camille, a study of recovery from disaster in the biological, psychological, sociological, economic and political spheres.

Items 5 and 6 were made possible, again with CoSIP funds, through appointment of a Coordinator of Environmental Studies. Number 6, however, could not

The Honorable Edward M. Kennedy
April 11, 1974

2

have been achieved without an NSF-URP grant and the additional investment of the college's institutional grant in the project. The entire saga of these summer activities is one of innovation, steady growth, dollar-stretching institutional commitment and the interlocking of funds from several sources to insure progress toward a major goal.

We had good reason to believe that 1973's course would be the first of many, each focused on some significant environmental dilemma in Amherst County. The focus for 1974 was to have been the energy flow associated with the James River, Lynchburg and Amherst County. We have reluctantly canceled plans for this project, since we did not receive an URP grant. It is with alarm that we view the proposed elimination of institutional grants for FY 1975, particularly in view of NSF's proposed \$7+ million cut in its education budget. Sweet Briar's base for an FY 1975 institutional grant is \$12,800 from which we would expect \$6,000 to \$7,000 if institutional grants were funded at a minimum \$7 million level.

As a result of first-hand experience with NSF grants it is with considerable feeling that we recommend reestablishment of CoSIP, increase in the URP budget and reestablishment of Institutional Grants. The aid provided by NSF to small colleges through these programs has been of inestimable value in maintaining high quality in the instruction of young scientists.

Thank you for the opportunity to express our views to the Committee on behalf of the Association of American Colleges and to respond specifically to your question with regard to my own personal experience with NSF grants at Sweet Briar College.

Sincerely yours,

Jane C. Belcher
Dorys McConnell Duberg
Professor of Ecology
Sweet Briar College

JCB:ed
Enclosures

MARCH 2, 1973

NATIONAL SCIENCE FOUNDATION SUPPORT TO LYNCHBURG, RANDOLPH-MACON WOMAN'S,
AND SWEET BRIAR COLLEGESAnalysis of National Science Foundation support showing source of support, activity supported,
and impact of support for FY 70, 71, 72, 73.

-1- NSF PROGRAM PROVIDING SUPPORT	-2- INSTITUTIONS SUPPORTED	-3- ACTIVITY OR PROJECT SUPPORTED BY NSF	-4- CHANGE OR IMPACT AFFECTED AND INTERACTION WITH OTHER NSF SUPPORTED ACTIVITIES	-5- DEPARTMENTS INVOLVED IF APPLICABLE	-6- NUMBER OF PEOPLE	-7- AMOUNT OF GRANT
PES-SUMMER & IN-SERVICE IN- STITUTES FOR H.S. TEACHERS	RANDOLPH- MACON WOMAN'S	MULTIPLE FIELD SUMMER INSTITUTES FOR HIGH SCHOOL TEACHERS/ IN-SERVICE INSTITUTES	. 1st major support provided by NSF . Accomplished educational objectives for H.S. teachers seeking masters . Increased cooperation among faculty of 3 colleges teaching in institute	Chemistry Physics Biology	8-9 faculty 60-70 partic- ipants per year (15 on phase out 75)	\$74,022 \$5,828 \$68,194 \$31,722 \$18,400
UES-INSTRUCT- IONAL SCIENTIFIC EQUIPMENT	SWEET BRIAR	EQUIPMENT FOR FIELD ECOLOGY WORK	. Increased interest in ecology and environmental studies . Prepared students for participation in later projects under COSIP & SOS	BIOLOGY	1 professor all ecology students	\$ 2,400 (\$ 2,400) (matching)
UES-INSTRUCT- IONAL SCIENTIFIC EQUIPMENT	RANDOLPH-MACON WOMAN'S	CALCULATORS FOR MATHEMATICS & COMPUTER RELATED WORK	. Extended capability of academic computing program	Mathematics & compo- ting activities	4 professors- all Jr./sr. majors math	3,400 (3,400) matching
COMPUTING ACTIVITIES	LYNCHBURG RANDOLPH- MACON WOMAN'S SWEET BRIAR	TIME-SHARE COMPUTER WITH TERMINALS ON CAMPUS & ON SITE FACULTY TRAINING	. Extensive introduction of academic computer usage . Faculty participation in NSF & non NSF Institutes and training programs . Increased student and faculty original studies and research activities . Encouraged inter-college cooperation . Stimulus to interdisciplinary work & interdepartmental cooperation.	30 Depts in Science and Social Sciences	over 100 faculty est 1500 students	\$150,000
UES-COLLEGE SCIENCE IMPROVE- MENT PROGRAM (COSIP)	SWEET BRIAR	IMPROVEMENT OF 7 DEPARTMENTS DR- ECTED TOWARD PART- ICIPATION IN CENTER OF ENVIRONMENTAL STUDIES	. High impact due to extensive retrain- ing, retelling, introduction of new methods, courses and curriculum changes in a short period. . Encouraged faculty to participate in summer institutes and continue COSIP initiated activities and research. . Focus on environmental studies ad- vanced and consortium plan for Environmental Center resulted. . Attracted outside support and ex- panded scope of program. . Introduced student research and field projects utilizing 3400 acre campus and adjacent counties.	BIOLOGY CHEMISTRY PHYSICS PSYCHOLOGY ECONOMICS GOVERNMENT SOCIOLOGY	22 faculty 110 Jr.-Sr. majors 300 non majors	\$203,900
UES-SUMMER INSTITUTES FOR COLLEGE TEACHERS (ATTENDANCE)	LYNCHBURG RANDOLPH- MACON WOMAN'S SWEET BRIAR	ATTENDANCE OF VARIOUS INSTITUTES IN: COMPUTER SCIENCE, MATHEMATICS, PSYCHOLOGY, PHYSICS, BIOLOGY, ETC.	. Encouraged by computer program and COSIP grant activities, faculty contin- ue to attend summer institutes in oth- er colleges and universities.	N. A.	per year 10 to 15	\$ N. A.
UES-ACADEMIC YEAR RESEARCH CONTINUATION	SWEET BRIAR	PROFESSOR OF PSYCHOLOGY FOR CONTINUATION OF WORK IN SUMMER INSTITUTE	. Encouraged other faculty to pursue similar activities . Encouraged student research partic- ipation. . Provides base for FY73 Institution- al Grant	N. A.	1 Professor	\$ 2,000
UES-STUDENT ORIGINATED STUDIES (SOS)	RANDOLPH- MACON WOMAN'S	INTERDISCIPLINARY STUDY PROJECT DEVELOP- ED BY STUDENTS IN BIOLOGY, CHEMISTRY & SOCIOLOGY FOCUSED ON ENVIRONMENT	. Developed new interest in student research and independent work . Encouraged by and supportive of 3 college environmental program . Provided new avenue for inter-college cooperation for faculty and students . Offered a model for college directed projects on each campus	BIOLOGY CHEMISTRY SOCIOLOGY	15 students	\$ 16,700
INSTITUTIONAL PROGRAMS	LYNCHBURG RANDOLPH- MACON WOMAN'S SWEET BRIAR	INSTITUTIONAL GRANTS BASED ON RESEARCH GRANTS FROM OFFICE OF EDUCATION AND INTERIOR AND NSF.	. Enabled colleges to meet share of additional research . Increased work in environmental research . Attracted additional support from private sources including Mobil and Kellogg Foundations	N. A.	N. A.	\$10,000 \$10,023 \$5,768 \$1,090
TOTAL SUPPORT FY 70-71-72-73						\$534,684

SWEET BRIAR COLLEGE, Sweet Briar, Va. 24595. Dr. Jane C. Belcher, Dorys McConnell
Duberg Professor of Ecology. (804) 381-5604.

Seven departments in natural and social sciences were strengthened through equipment, faculty training, curricular study and innovations, faculty-student research projects and development of environmental studies to achieve more intellectual interplay among the seven, between sciences and humanities, between Sweet Briar and neighboring colleges, and between college and community. New equipment includes calculators, laser, and modular instrumentations. The behavioral scientists, through summer courses and workshops, computer training, employment of a visiting professor and participation in a faculty seminar, familiarized themselves with applications of quantitative methods to their own disciplines. Released time permitted two biologists and members of the chemistry department to study new ways of presenting elementary biology as well as biology curricula at comparable colleges, prepare a new chemistry course entitled Science, Society, and Technology, and plan ways of curricular collaboration between the three local colleges. Visiting scholars in psychology presented lectures and seminars for general audiences and majors, and described interdisciplinary experiments on their campuses. Two biologists and a sociologist, employing student assistants, supervised summer research projects on biological rhythmicity, inventory of local flora and fauna, and demographic characteristics of Amherst County. A new course, Conservation: Agenda for Tomorrow, initiated efforts to establish interdisciplinary environmental studies focused on the natural and cultural features of the college's neighboring area. The course, open to the public, brought some 20 speakers of national distinction representing numerous disciplines. A Coordinator of Environmental Studies was hired and has directed two interdisciplinary summer research projects, focusing the intellectual interests of staff and students representing natural and social sciences on an environmental problem of local concern. He is also directing the newly established Coordinate Major in Environmental Studies, involving, to date, a faculty seminar and an introductory course taught by representatives of the sciences, literature, art and religion.

Senator KENNEDY. Mr. FISHER.

**STATEMENT OF MILES MARK FISHER IV, EXECUTIVE SECRETARY
FOR THE NATIONAL ASSOCIATION FOR EQUAL OPPORTUNITY IN
HIGHER EDUCATION, WASHINGTON, D.C.**

Mr. FISHER. Mr. Chairman and members of the committee. I am Miles Mark Fisher IV, executive secretary for the National Association for Equal Opportunity in Higher Education, Washington, D.C.

I convey the gratitude of this association for the opportunity to present testimony before the Special Subcommittee on the National Science Foundation of the Committee on Labor and Public Welfare, of the U.S. Senate.

The National Association for Equal Opportunity in Higher Education represents the historically black colleges and universities of our Nation. There are 108 institutions located in 15 Southern States, four Northern States and the District of Columbia enrolling more than 180,000 students.

Of these 108 historically black institutions, 21 are community and junior colleges; 87 are 4-year colleges and universities. These schools graduate more than 30,000 students annually with baccalaureate, graduate, and professional degrees.

The historically black colleges have educated and still educate large numbers of black students. These institutions have been means whereby students from low-income populations have been able to attain mobility into the larger society.

The beginning for black colleges dates back to before the Civil War. Through the years these colleges have provided educational opportunity for thousands of young people who otherwise would not have been able to attain higher education.

They have and will be in the foreseeable future a major vehicle for the mobility of many black people into all levels of American life. These institutions, despite handicaps created by neglect and malicious intent, have enabled hundreds of thousands of students shackled by poverty and racism to break free. These institutions have earned the right to a continuing service to the Nation.

The historically black colleges represent an existing mechanism that can be improved and used to intensify the positive efforts to equalize opportunity. Unless there is a genuine commitment to eliminate anything adversely affecting the performance of the historically black colleges, enrollment and graduates will decline, thus prolonging the inequities of this society.

In the past, Federal funds flowing to institutions of higher learning have moved to black schools in inequitable sums. A comparison of the kinds of funding inadequacies that have been meted to these institutions might be illustrated by citing the land-grant colleges as an example.

The discrepancy in funding in States with black and white land-grant colleges was of the order of \$300 million for fiscal year 1970.

The Federal Interagency Committee on Education in its study of Federal agencies and black colleges indicated the following data on National Science Foundation funds going to these institutions for fiscal year 1969, fiscal year 1970, fiscal year 1971, and fiscal year 1972.

A table is included in the statement which indicates the flow of these funds.

Data is not available on the fiscal year 1973 and the fiscal year 1974 totals from the National Science Foundation to the black colleges. Based on these figures, the amount going to black colleges decreased from fiscal year 1969 to fiscal year 1971.

In fiscal year 1972 there was an increase in the funding to these institutions. This increase coincides with the inception in that year of the National Science Foundation's college science improvement program—section D, now known as the minority institutions science improvement program.

There are presently four programs at the Foundation that are specifically directed toward black colleges and minorities. They are: (1) minority institutions science improvement program, (2) research initiation for minority institution improvement, (3) ethnic minorities and women in science program, and (4) minority institution graduate traineeship.

Two of these programs are presently operative; namely, the minority institutions science improvement program and the research initiation for minority institutions improvement. The other two programs are presently gearing up.

A look at these programs might be helpful at this time.

The minority institutions science improvement program was initiated in fiscal year 1972 to improve the quality of science education in the black colleges. First-year funding for this program was at a level of \$5 million. Proposals submitted for this program were on the order of \$20 million.

Four-year traditionally black colleges made up the universe of eligibles. And 17 awards were made to 14 institutions for a total of \$4,992,300. During that year, black colleges received slightly more than \$9.3 million from the National Science Foundation.

Senator KENNEDY. Mr. Fisher, we will put your whole testimony in the record as though read.

What we would be most interested in hearing about in the time we have here, are the particular programs of the NSF that have been most positive in terms of the colleges you represent. Where you feel they are the most threatened in terms of the present budget? And where you would like to see us see programs expanded?

Mr. FISHER. All right. In addition to the minorities science improvement program, the research initiation for minority institution programs has also been very helpful to these institutions.

The ethnic minorities and women in science programs are programs that really have not gotten off the ground.

Senator KENNEDY. In studying this particular budget, do you think these programs will be getting off the ground soon? Have you received any assurances from the people you have talked to at NSF?

Mr. FISHER. They have funds, and the program announcements have been printed, so I suspect it will be just a matter of time.

Senator KENNEDY. Based on your review of the budget that has been submitted, and on your information and contacts with the NSF, do you think these programs will continue to expand?

Mr. FISHER. From the figures in the minority institution improvement or science improvement program, the budget requests \$5 million. That is down \$1 million from the \$6 million for fiscal year

1974, and I think that is a critical issue in view of the inflation that exists today, and also in view of the fact that there is a tendency to continue to expand a pool of eligibles for this program.

By expanding the pool of eligibles for this program, you are eroding the original intent of the program which was initially designed for the historically black universities and colleges.

Senator KENNEDY. Let me ask you this as somebody who is concerned about opportunities for blacks. Do you feel that it is better to have moneys allocated for black colleges where blacks can take advantage of them?

Would it be better to provide more scholarship programs for blacks to go to other schools and colleges where there are perhaps a greater variety of programs available? I suppose you are confronted with this question often.

Mr. FISHER. Yes.

Senator KENNEDY. Can you tell us a little about what your own thinking is?

Mr. FISHER. I think that it is not an either/or kind of situation. I think it is a both/and situation.

I think you need the thrust into the broader institutional universe, but I think you also need to keep in mind the historical perspective, the role that these institutions have played in taking students and moving them through and out and up into the graduate programs and into positions in which the persons can make contributions to society.

I think that we are faced in America today with a very critical kind of arrangement. There is a cutback in funding in many instances. The student aid programs are not adequate for all of the students going to "postsecondary experiences", which they call it today, and I think that what we have done in that instance, is to broaden the base in terms of the numbers of students to be served, but we have not adequately made allowances in the allocation of financial support to really move these persons through the system.

I think we know what the black colleges have done. In view of the declining enrollment of blacks in the other major institutions, and the failure of these institutions to move these students through the system, before we go onto another tangent, we need to protect what we have so as to guarantee that students are going to graduate from these institutions, move on into graduate programs at other institutions, and ultimately come out to help increase the supply of blacks trained in science, as well as give a pluralistic mix in terms of the needs of our society.

Senator KENNEDY. Do you find that the programs that have been developed in the black colleges have really triggered and stimulated an interest in the sciences?

Mr. FISHER. Yes. I think they have been very helpful, and I think we realize that what has been done is a step in the right direction.

We feel that increased support in that area would be very helpful because many of the institutions are strengthening their various departments, upgrading the faculty, and programmatic aspects in the area of science. I think this needs to be continued and encouraged, and the support level should be increased.

In my statement I have noted the erosion of the pool of eligibles, and I think that is something that is very critical for this program.

In fiscal year 1972, 4-year historically black institutions made up the eligibles. In fiscal year 1973, 4-year historically black institutions along with 2-year historically black institutions made up the eligibles. In fiscal year 1974, 4-year historically black institutions, 2-year historically black institutions, plus native American ethnic minority groups, comprise the eligibles.

They are proposing for this year—and the language is very vague—that additional colleges will be eligible to participate in the program: those institutions which are attended predominantly by native Americans, Spanish-speaking or black students; in brief, institutions which are de facto primarily serving ethnic minority groups students because the majority of the student body comprises students of such backgrounds.

A later reiteration of this notion is as follows:

As noted above, the eligibility to participate in the program will be broadened to include those institutions which are attended primarily by students from ethnic minority groups but which are not founded for the purpose of educating these students.

One of the major efforts of the proposed program planned for fiscal year 1975 consists of a continuation, at a level of about \$5 million, of the program to improve the quality of science education available in institutions attended primarily by ethnic minority students.

With the vagueness of the language, there is a possibility that the floodgates will open, and the intended purpose of helping to strengthen a particular group of institutions which historically have been discriminatorily underfunded will be defeated and the funds taken by institutions which have no record of having been discriminatorily underfunded. I think this is one of the critical issues at this time.

Senator KENNEDY. I want to thank all of you very much for this very helpful testimony. These are areas which we are very interested in. We want to thank you very much for coming here today.

Your perspectives are different from those of the witnesses we heard earlier today. This subcommittee and our sister Subcommittee on Education are both very interested in the impact these programs will have on education and educational opportunities.

We thank all of you very much.

At this point, I order printed in the record all pertinent material submitted for the record by interested persons unable to be present for this hearing.

[The following material was subsequently supplied for the record:]



THE INSTITUTE OF
ELECTRICAL AND
ELECTRONICS
ENGINEERS, INC.

345 East 47th Street, New York, N.Y. 10017, U.S.A. Phone (212) 752-6800

Office of the President
John J. Guarrera

April 3, 1974

Senator Edward M. Kennedy
Chairman, Subcommittee on
National Science Foundation
Committee on Labor and Public
Welfare
United States Senate
Washington, D. C. 20510

Re: H. R. 12816, NSF Authorization, F. Y. 1975 --
Intergovernmental Science & Research Utilization
Program

Dear Senator Kennedy:

The Institute of Electrical and Electronics Engineers (IEEE) is the world's largest engineering society. We have over 170,000 members. There are more than 200 very active Sections and Subsections in cities throughout the United States.

Your Subcommittee on the National Science Foundation will soon be considering the NSF's F. Y. 1975 Authorization (H. R. 12816). This bill would authorize \$1 million for Intergovernmental Science and Research Utilization, which is the same level at which this program has been maintained for the last two years. For the reasons set forth below, we believe this program is of substantial public value, could be of much greater public value, and should be expanded to perhaps \$5 million. I firmly believe its worthiness justifies such an expansion.

I am concerned about the imbalance of Federal funding for the utilization of research results as compared to Federal funding for research programs themselves. More resources should be authorized to facilitate maximum utilization of research results in forms tailored to levels of understanding and particular needs of users. The fullest possible dissemination of research information, in similar fashion to the highly successful Agriculture Extension System, is certainly in order. Agriculture, for example, spends a dollar for utilization activities for every dollar invested in research. This is in sharp contrast to other Federal R&D programs. Far too many excellent research projects never advance beyond the scientific report stage, simply because results are not made known to decision makers in local governments and in private industry in a fashion which they can easily understand and readily act upon.

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

Senator Edward M. Kennedy

- 2 -

April 3, 1974

Specifically, I would recommend that Federal research programs be studied to make sure that adequate resources are provided for the active dissemination of successful research results.

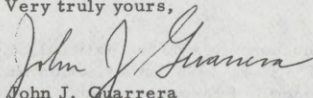
I do not believe that there are many programs in the Federal government which foster the active dissemination and utilization of the results of Federal Research and Development programs. Many of those that do exist seem quite underfunded.

The National Science Foundation's Office of Intergovernmental Science and Research Utilization is one that has taken a leading role in promoting the more effective utilization of Federal research and development. But this office, I feel, has not been funded at a level adequate to sponsor needed active utilization programs nationally.

I believe that the tax-paying public would benefit if that program were expanded. Particularly is this the case since the National Science Foundation's RANN (Research Applied to National Needs) is expanding and the results of RANN-sponsored research programs are now beginning to emerge.

Research Utilization programs for other Federal agencies should be started or expanded as well, as analysis would deem appropriate.

Very truly yours,



John J. Quarrera
President
IEEE

JJG:mc

**NATIONAL
SCIENCE
TEACHERS
ASSOCIATION**



1201 SIXTEENTH STREET, N.W. WASHINGTON, D.C. 20036
Telephone: Area Code 202 833-4283

Robert L. Silber
Executive Director

April 10, 1974

Honorable Edward M. Kennedy
Senate Office Building
Room 431
Washington, D. C.

Dear Senator Kennedy:

We are deeply concerned about the proposed reduction in funding for the National Science Foundation in the area of science education at the elementary school, junior high school, and secondary school level.

In these critical times, the United States faces problems directly related to science and technology.

More than ever, we need well educated citizens to wisely decide on future directions for the country and its people. A background which will allow them to make such decisions must include a reasonable familiarity with science. For the majority of U. S. citizens, their formal training in science ends with graduation from high school and even earlier. Science teachers at these levels need great support in a continuing education program that keeps them in constant touch with the cutting edge of science and the newest innovations of science education. Institutes, seminars, short courses, continuing education materials and other methods allow them this opportunity.

The National Science Foundation was formerly funded to an extent that would allow a substantial number of science teachers to participate in such endeavors. The proposed cut in funding will drastically reduce the possibility for teachers to maintain their vitality and current awareness in the classroom. The result will be the production of large numbers of students who may be "turned off" to science or even develop a negative attitude toward science. Future implications of this portray a crippling of our progress in science and technology due to the limited scope of vision and negative attitude of our voting citizens.

The National Science Teachers Association is a non-profit and educational professional organization concerned with science education, science teachers, and students. For more than thirty years, NSTA has been striving to improve

Page two

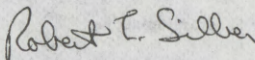
April 10, 1974

science education at all levels and with its more than 40,000 members and subscribers, it has greatly influenced this important area.

As Executive Director of NSTA, I urge you to increase the funding allocated to the National Science Foundation for support of science education at the pre-college level.

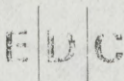
If I can be of further service, please call on me.

Respectfully,



Robert L. Silber
Executive Director

RLS:ms



EDUCATION DEVELOPMENT CENTER
UNIFIED SCIENCE AND MATHEMATICS FOR ELEMENTARY SCHOOLS

MEMORANDUM

TO: Special Subcommittee on the National Science Foundation,
Committee on Labor and Public Welfare, United States Senate

FROM: Earle L. Lomon, Professor of Physics at M.I.T., and Director,
Unified Science and Mathematics for Elementary School Project,
Education Development Center

RE: The national school curriculum improvement program and the
National Science Foundation budget for Fiscal 1975

DATE: April 1, 1974

In commenting on the project support from the National Science Foundation for the improvement of science education, I take the view that Congress intends the Foundation to be mission oriented with regard to education. The Congressional Acts mandating the NSF program in science education imply an intent to cause a positive change in American education; maintenance is left to the localities, states, and to some other federal agencies. Thus, one expects the Foundation budget for science education improvement to reflect the cyclic needs of national programs for change as they phase in and out.

The first major cycle came in reaction to the launching of Sputnik by the U.S.S.R. Although the Foundation had a science education budget which rose from \$1.5M to \$3.5M between FY 1952 and FY 1956, it jumped to \$14.3M in FY 1957 and climbed steadily to a peak of \$134.4M in 1968. It then began to drop and in FY 1973 was \$46.9M.

The rise and decline of the budget between 1957 and 1973 reflected the overlapping stages of planning, development, implementation and evaluation of a national program. The purpose of this program was to improve the quality of training for scientists and engineers in most of the disciplines of natural science, social science and mathematics. New courses were prepared for each subject which not only brought the content up to date, but which was more revealing of the inner structure and important concepts in each area. These courses have been widely utilized and have succeeded in raising the competency of a large number of students and even has produced a temporary oversupply of scientists in some fields.

However, by the mid-1960's it was becoming evident that there were important shortcomings in the thrust of the major post-Sputnik curriculum

Memorandum: Special Subcommittee
 April 1, 1974
 page 2

changes and that more would have to be done to achieve emerging national goals. The beauties of science as seen by scientists was not sufficient motivation nor a useful context for application for the majority of the school population. In some areas of basic skills, this majority was doing less well or at least no better than before.

At the same time the problems of the nation became less amenable to solutions by a few experts, today's problems require the awareness, sound decision-making and intelligent cooperation among large segments of the population. The problems of ethnic tension, overcrowding and crime in large cities, environment, inflation, and resource management are not amenable to control by a few or broad legislation at the top alone. The local aspects of each of these problems must be solved at a community level and wise decisions made by individuals in the local context.

The future of the world is bound up in whether we can close the generation gap, dissolve the disaffection of the new generation and impart to individuals the needed skills and problem-solving process abilities. This requires an education which motivates almost everyone to learn and become involved. Furthermore, training experts in disciplines is not enough. It is even more important to have people learn how facts and skills from many disciplines are put to work in solving practical and everyday problems.

One should not infer from this that the concept and discipline-oriented courses should be abandoned, but rather that the educational program must contain within it a larger variety of learning modes. It is urgent that a mode be incorporated which motivates and involves a large proportion of our population in applying knowledge and skill to improving societies. Given such motivation, there will also be more than enough students who are willing and able to take the direction of specializing in the disciplines and vocations.

Curricular approaches with some of the above attributes began to emerge in the mid-1960's, while the wave of disciplinary-concept type curricula was cresting. With NSF encouragement there are now some curricular materials which emphasize the concrete within the disciplines, and some in which the process of investigation has priority. Curricula now in formation focus on the problems of society and are interdisciplinary in their response to these problems.

This second phase of educational reform began while the first phase was still reaching its peaks. However, it is only in the last two or three years that the great importance of this newer component of learning has become generally recognized as the assessment of the accomplishments and limitations of the first phase has been completed. The conventions of the national educational associations, such as the National Science Teachers Association, the National Council of Social Studies and the National Council

Memorandum: Special Subcommittee
 April 1, 1974
 page 3

of Teachers of Mathematics have been filled with discussions and reports concerning the importance of relating to societal problems and of interdisciplinary learning experiences. Meetings of leaders in education held recently under NSF auspices to consider the present position and needs in science and mathematics education¹ have all recommended the move in that direction. Basic research has defined the learning area clearly and also established its importance.²

During the same period there has been a rapid increase in initiating development of a range of curricula to satisfy the above needs at many grade levels. The early implementation studies of these newer curricula have shown that they can be very effective.

¹Estes Park Conference on Learning Through Investigation and Action on Real Problems in Secondary Schools, January 1973, Supported by a grant from the National Science Foundation, Materials and Instruction Development Section, USMES/EDC, 55 Chapel Street, Newton, Mass.; Conference on the K-12 Mathematics Curriculum, Snowmass, Colorado, June 21-24, 1973, Supported by the National Science Foundation, Mathematics Education Development Center, Indiana University, Bloomington, Indiana; The Cape Ann Conference on Junior High School Mathematics, Sept. 9-12, 1973, Physical Science Group, Dept. of Science and Mathematics Education, Boston University, Boston, Mass.; Orono Conference on the National Middle School Mathematics Curriculum, July 16-20, 1973, University of Maine, Orono, Maine.

²"Let me turn now to still another kind of learning outcome which everyone agrees is of great importance--cognitive strategies. How does the student learn the internal controls which make him an efficient learner, an efficient "rememberer," an ingenious problem-solver?...Several points should be made at the outset. First, such strategies are probably not learned quickly, or in an all-or-none manner, as intellectual skills seem to be. Instead, they probably undergo continued refinement and sharpening as the individual acquires greater experience. One does not 'teach the student to think' by means of a single course in thinking. Instead, if he is properly challenged, he continues to become a better thinker all his life long, or at least until senility takes its toll....If a teacher wants a student to become a good thinker in the field of science, he must provide many opportunities, throughout the course of his instruction, for him to encounter, formulate, and solve problems of many varieties....These are relatively specific intellectual operations by means of which the individual relates to his environment....Some of my previous writings have been concerned with methods of finding out what structures of prerequisite intellectual skills are like and how they may be predicted. These structures are called learning hierarchies." From Gagne, R.M., "Instruction Based on Research in Learning," Engineering Education, vol. 61, no. 6, March 1971; "Domains of Learning," address presented at the Annual Meeting of the American Educational Research Association, Feb. 7, 1971.

Memorandum: Special Subcommittee
 April 1, 1974
 page 4

The import of these deliberations and developmental activities of recent years is that a new program of great importance to the nation has been formulated and is ready to grow to its peak of development and implementation. In support of this, the National Science Foundation should be authorized to increase its funding of those activities consonant with the needs to carry through its mission effectively. Funding should be increasing now.

Although I am not in the position of the Foundation staff who would be able to make accurate estimates, I will venture the opinion that the new educational reform program will be much less costly than the first. The experience in development and implementation previously obtained and the cadre of effective educational leaders now available will help reduce costs. Of importance also is the innate cost effectiveness of the mode of education now at hand. In emphasizing the practical and the interdisciplinary, there are fewer textbooks and apparatus costs involved and less need for extended higher education for teachers (although it is essential to impart to teachers the different teaching style relevant to process-oriented learning).

The part of the Science Education Improvement budget related to development and implementation of curricula is the one of special relevance to the program being discussed. In the years from 1965 to 1973 this could be identified as that of the NSF budget for the Course Content Improvement Program, the program for Summer and Academic Year Institutes and the Cooperative College/School Program. This totalled \$50.3M to \$53.3M in the peak years of FY 1965 to FY 1968. It then dropped to a low of \$20.3M in FY 1973.

Reorganization of NSF education programs has changed the budgetary classifications. In the attached Table I from the budget for Science Education Improvement submitted by the National Science Foundation to the Congress for FY 1975, the analogous activities are marked by a check mark on the left side of the Table. Those items, which total \$20.3M in FY 1973, rose in FY 1974 to \$25.8M but drop again to \$22.6M in the proposed FY 1975 budget. This drop comes largely from the critical category of Improvement of Education for Scientific Literacy (p. K-1 of budget submitted to Congress) and from the key Materials and Instructional Development and Instruction Improvement Implementation Sections of the Foundation.

My understanding is that these cuts were urged by the Office of Management and Budget. I ask that the Congress give strong consideration to restoring the Foundation budget for Science Education Improvement to approximately its FY 1974 level. This action now and some moderate increases in budget in the following few years will enable the nation to take an historic step in the preparation of its youth to be citizens in the world of tomorrow.

Table 1

[illegible]



NORMAN Y. MINETA
MAYOR

CITY OF SAN JOSE
CALIFORNIA

CITY HALL

TELEPHONE 277-4000
EXT. 4287

March 29, 1974

The Honorable Edward M. Kennedy, Chairman
Special Subcommittee on the
National Science Foundation
431 Old Senate Office Building
Washington, D.C. 20510

Dear Senator Kennedy:

Since you will soon be reviewing the budget of the National Science Foundation for 1974-75, I would like to offer some comments which I believe will be useful.

We recognize and appreciate the many steps taken by the Federal Government to ease the problems of the cities. Revenue Sharing, Model Cities, LEAA and other domestic assistance programs have been an enormous help. But much more needs to be done, including expansion of Federal efforts in the little publicized area of increasing technology usage in the city. As you know, the City of San Jose has been fortunate enough to participate in the Four Cities Program developed and sponsored by the Intergovernmental Science and Research Utilization office of the National Science Foundation; this program has enabled each of the four cities to increase its technology utilization through the presence of a senior aerospace engineer placed on its own staff. This work has proven so useful and promising that this year we have budgeted some very hard-to-get City funds to continue operation of the program in San Jose. It has already helped us and the other participants in up-dating computer utilization, selecting optimum helicopter sites, testing and developing the use of a hand-held infrared viewer by Fire and Police Departments.

We would like to expand our local efforts through the Four Cities Program to include development of a model to optimize the use of building facilities and interdepartmental work contacts, simulation of police dispatch strategies and testing of new service delivery methods. Additional funds to strengthen the program in the Four Cities, to expand the experimental nature of the program, and to include additional California cities would be funds well invested in bringing technologically based efficiencies closer to the cities.

If I may be of further assistance by providing more information or making some of our personnel available, please let me know.

Sincerely yours,

Norman Y. Mineta
Norman Y. Mineta
Mayor

NYM/je

COUNCIL OF INDEPENDENT COLLEGES IN VIRGINIA

D. A. HOLDEN
EXECUTIVE DIRECTOR

P. O. BOX 3444
CHARLOTTESVILLE, VIRGINIA 22903

PHON 295-0357
804

April 3, 1974

Senator Edward M. Kennedy, Chairman
Sub-Committee on National Science Foundation
United States Senate
Washington, D. C. 20510

Dear Senator Kennedy:

By way of identifying myself, I was Chairman of the Newport News Shipbuilding and Dry Dock Company when, in the late 60's, we built the Aircraft Carrier John F. Kennedy. You were very helpful at the time of the launching and also on the occasion of the commissioning ceremony in providing guidance to us in making the arrangements and you were most gracious to attend both occasions.

Since retiring from the Shipyard I have found a gratifying activity in assisting the independent colleges in Virginia in some of their endeavors. Thus this letter to you as Chairman of the Sub-Committee on the National Science Foundation. I am concerned as are all of our member colleges, that some funding that is very important to them and to the advancement of science be restored to the National Science Foundation appropriation for educational programs.

The Council of Independent Colleges in Virginia is composed of 26 private four year predominantly undergraduate colleges. These diverse and independent institutions have provided quality liberal arts and science programs with the variety and creativity that flourishes in the small college. Our graduates in the sciences move on into graduate schools and industry.

It is of paramount importance that the National Science Foundation provide support for Teacher Retraining and Professional Development and the very significant and imaginative Student Oriented Research Projects.

We strongly support the positions stated by two of our own teaching scientists, Dr. Jane C. Belcher of Sweet Briar College, and Dr. Ronald L. Webster of Hollins College, and also that of Dr. Martin Reno of Heidelberg College of Tiffin, Ohio. The impact

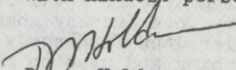
Senator Edward M. Kennedy

-- page 2

of the cut in the proposed NSF budget for education will have a drastic adverse impact on our small institutions. In our colleges ten thousand and fifty thousand dollar grants have a strong positive benefit to faculty and students and two hundred thousand dollar grants for institutional development can have a dramatic influence on the college.

We respectfully urge you to support legislation that will return seven million dollars to the education programs of NSF where these funds will have measurable input to the advancement of science and will be of great benefit to the development of people in the higher education community.

With kindest personal regards,



D. A. Holden

DAH:am



MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES
BUEHLER PARK ROLLA MISSOURI 65401 314-364-1752

WALLACE B. HOWE STATE GEOLOGIST AND DIRECTOR

LARRY D. FELLOWS ASSISTANT STATE GEOLOGIST

April 12, 1974

The Honorable Edward M. Kennedy
Chairman
Senate Special Subcommittee on
National Science Foundation
Senate Office Building
Washington, D.C. 20510

Dear Senator Kennedy:

It is my understanding that a sharp reduction in funding for the National Science Foundation's Office of Science Information Services has been recommended by OMB for Fiscal 1975.

This phase of NSF's program has been directed toward the improvement of information systems and services, and although enormous progress has been made in that area, much remains to be done.

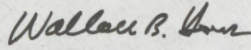
In Missouri, I have been serving as Chairman of a special Committee on technical data sharing within the state's natural resources agencies and institutions. One of our recommendations to Governor Bond will be that an "Interagency Council for Natural Resources Information" be established, so as to meet the rapidly increasing needs for technical data processing within the state and at the same time provide assurance of compatibility with a number of conceptually similar systems being established at Federal level. Among the latter, the Resources and Land Information program (RALI) is of greatest interest because it's projected application nationally corresponds to our needs on the state level. Similar efforts at developing state systems are almost certainly underway in a number of other states and have been completed in some. It is likely that the NSF program under it's office of Science Information would be one of the sources of funding for certain phases of the development of a Natural Resources Data System here in Missouri, and I would assume this would be the case in other states as well.

I have suggested only one example of the potential need for continued funding of information systems and information dissemination systems development as administered thru the Office of Science Information,--an example that I believe and hope will have well-defined meaning. I submit that our problem in handling the enormous amount of technical data being generated have not all been solved, and that this may be particularly true in state government.

The Honorable Edward M. Kennedy
April 12, 1974
page 2

I urge your continued support of this program at a viable level, at least until it is demonstrated that we have the capacity to respond to data systems needs nationwide.

Sincerely yours,

A handwritten signature in dark ink, appearing to read "Wallace B. Howe". The signature is fluid and cursive, with the first name "Wallace" being more prominent.

Wallace B. Howe
State Geologist and Director

WBH:cs



THE UNIVERSITY OF TEXAS AT AUSTIN
AUSTIN, TEXAS 78712

Department of Geological Sciences
P. O. Box 7909
512 471-5172

April 11, 1974

Senator Edward M. Kennedy, Chairman
Senate Special Subcommittee on National Science Foundation
Senate Office Building
Washington, D.C. 20510

Dear Senator Kennedy:

I am writing with regard to the budget of the National Science Foundation's Office of Science and Information Services. It is my understanding that the budget of this office has been cut 40%, from 8 million to 5 million, for the year beginning July 1, 1974, by the Office of Management and Budget. This has such serious implications for the continuing effectiveness of science and engineering in this country that I feel compelled to comment.

Presumably, most people would agree that the continuing health and vitality of our science and engineering professions is of utmost importance to this country's welfare. It is also self-evident that the rate of advance in any discipline is a function of the ease and efficiency of exchange of information and data among the practitioners of the discipline. This latter point is recognized in the National Defense and Education Act of 1968, which directs the National Science Foundation to "provide or arrange for the provision of abstracting and indexing -- leading to more effective dissemination of scientific information, and to undertake the programs to develop new or improved methods including mechanized systems for making scientific information available".

The above directive recognizes not only the desirability of disseminating scientific information, but also implicitly acknowledges the strains imposed on our present scientific information systems by the very rapid growth of publications in all fields. In my own profession of Geology, the rate of growth is about 10% per year. The library of the U.S. Geological Survey adds about 20 feet of shelf space for new publications each week. The rate of addition of publications in the Chemical and Biological sciences is several times greater. Quite obviously, neither the present bibliographic systems nor the physical facilities of libraries can long endure this kind of strain.

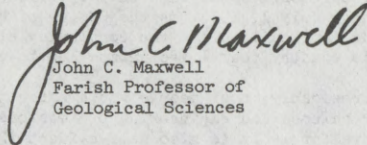
A few years ago the Office of Science and Information Services of the National Science Foundation began a program of encouraging innovation and experimentation on new and more rapid forms of publication and information dissemination. Within my field this has led to the development of a computer-based system called GEOREF, which provides for storage and quick retrieval of information on almost any aspect of the Earth Sciences. This system is on the verge of self-support now and promises to revolutionize the handling of geologic

information. Incidentally, the publication of GEOREF will free the Government of about a half million dollar yearly expenditure entailed in the publication of the Bibliography and Index of North American Geology, formerly compiled and published by the U.S. Geological Survey. I understand that similar innovative systems are under design or trial in the other sciences. It would be most unfortunate if these systems were allowed to lapse before they could become fully effective. Should this happen, it is possible that yearly bibliographies could no longer be published. The resulting chaos and lack of efficiency among scientists and engineers is painful to contemplate. Without free exchange of ideas there would be inevitable multifold duplication of scientific efforts, and correspondingly increased costs for manpower and equipment.

Although I speak only for myself, may I add that within the past four years I have held the responsibilities of the Presidencies of the Geological Society of America and the American Geological Institute, and the Chairmanship of the Earth Sciences Division of the National Research Council. I cite this to indicate the nature of my experience with problems of the type discussed here.

Thank you for the opportunity of presenting my views.

Cordially yours,


John C. Maxwell
Farish Professor of
Geological Sciences

JCM/nre

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SENATOR EDWARD M KENNEDY CHAIRMAN SENATE SPECIAL SUBCOMMITTEE
ON NATIONAL SCIENCE FOUNDATION
SENATE OFFICE BLDG
WASHINGTON DC 20510

I UNDERSTAND CURRENT NATIONAL SCIENCE FOUNDATIONS OFFICE OF
SCIENCE INFORMATIONS SERVICES MAY BE CUT 40 PERCENT, STRONGLY
URGE DO NOT CUT. AT LEAST RETAIN CURRENT 8 MILLION DOLLARS FOR
SAKE OF ALL RESEARCH.

DR THEODORE DOWNS PAST PRESIDENT SOCIETY OF VERTEBRATE PALEONTOLOGY
900 EXPOSITION BLVD LOS ANGELES CALIFORNIA 90007

16:46 EDT

MGMWSHT HSB

Coastal Mining Company

2896 SOUTH MAIN STREET
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P.O. Box 15787

Telephone 801 486-8789

April 24, 1974

The Honorable Senator
Edward M. Kennedy (Dem. Mass.)
United States Senate
Washington, D.C. 20510

Dear Senator Kennedy:

It has come to my attention that there is a proposed cut in the budget of the NSF Office of Science Information Services. Information is power, both for nations and individuals, and it seems incredible to me that our country should be weakening itself in this regard just when we need it most. NSF performs a valuable service to American scientists in accumulating and disseminating valuable scientific data on which our nation can build. Please do what you can to restore the Office of Science Information Services budget to the needed \$8 million.

Thank you.

Yours very truly,

E. L. Ohle

E. L. Ohle

ELO:cjd

Science Indicators 1972

Report of the
National Science Board
1973

National Science Board
National Science Foundation

Letter of Transmittal

January 31, 1973

My Dear Mr. President:

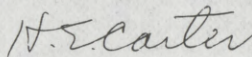
I have the honor of transmitting to you, and through you to the Congress, the Fifth Annual Report of the National Science Board. The Report is submitted in accordance with Section 4(g) of the National Science Foundation Act as amended by Public Law 90-407.

In this Report the National Science Board presents the first results from a newly initiated effort to develop indicators of the state of the science enterprise in the United States. The ultimate goal of this effort is a set of indices which would reveal the strengths and weaknesses of U.S. science and technology, in terms of the capacity and performance of the enterprise in contributing to national objectives. If such indicators can be developed over the coming years, they should assist in improving the allocation and management of resources for science and technology, and in guiding the Nation's research and development along paths most rewarding for our society.

Because of present limitations in data and methodology, the indicators in this Report deal principally with resources—funds, manpower, and equipment—for research and development and the areas to which the resources are directed. The Report presents relatively few measures of the outputs produced from these resources—the scientific advances and technological achievements, and their contributions to the progress and welfare of the Nation. The present paucity of such indices limits the conclusions which can be drawn concerning the quality and effectiveness of our scientific and technological effort.

The Report represents only an initial step toward a system of science indicators. The further development of such indicators is a matter of high priority for future reports in this series.

Respectfully yours,



H. E. Carter
Chairman, National Science Board

The Honorable
The President of the United States

Contents

INTRODUCTION	vii
INTERNATIONAL POSITION OF U.S. SCIENCE AND TECHNOLOGY	1
Level of Research and Development	3
Results of Research and Development	5
Productivity, Technology Transfer, and Balance of Trade	12
RESOURCES FOR RESEARCH AND DEVELOPMENT	19
National Resources for Research and Development	21
Federally Funded R&D and National Objectives	23
Resources for Industrial R&D	26
R&D Funding by Universities and Colleges	29
BASIC RESEARCH	31
Resources for Basic Research	34
Basic Research in Universities and Colleges	36
Basic Research in Federal Laboratories	43
Basic Research in Industry	44
SCIENCE AND ENGINEERING PERSONNEL	47
Current Pool of Scientists and Engineers	49
Enrollments and Degree Production	52
Supply and Utilization	59
INSTITUTIONAL CAPABILITIES	63
Science and Engineering Education	65
Research Equipment and Facilities	71
Federal Intramural Research and Development	74
Industrial Research and Development	77
A DELPHI EXPERIMENT	83
National Problems Warranting Greater R&D	85
Impacts of R&D Funding Changes	86
Changes Needed To Improve Technological Innovation and Diffusion	87
Adequacy of Current Basic Research Efforts	87
Distribution of Basic Research Funds Among Fields of Science ...	90
Changes in Graduate Training of Scientists and Engineers	92
PUBLIC ATTITUDES TOWARD SCIENCE AND TECHNOLOGY ..	95
Total Group Responses	96
Analysis of Results by Demographic Subgroups	99
APPENDIX A—INDICATORS	101
APPENDIX B—DELPHI PANELISTS	141

Introduction

The National Science Board is charged by the Congress with providing an annual report of the state of science in the United States.¹ In its first four reports, the Board dealt with selected aspects of this subject, but with this, the fifth report, the Board begins the development of a system of indicators for describing the state of the entire scientific endeavor. These indicators, expanded and refined in the coming years, are intended to measure and monitor U.S. science—to identify strengths and weaknesses of the enterprise and to chart its changing state.

Such indicators, updated annually, should provide an early warning of events and trends which might reduce the capacity of science—and subsequently technology—to meet the needs of the Nation. The indicators should assist also in setting priorities for the enterprise, in allocating resources for its functions, and in guiding it toward needed change and new opportunities.

A system of science indicators which would fulfill these several purposes must include indices of both intrinsic and extrinsic aspects of the enterprise. Intrinsic measures would include the resources used for science; the condition of institutions involved in training, research, and technical innovation; quantity and quality of associated human resources; and advances in science. Extrinsic indices center around the application of scientific knowledge, and the technology it fosters, to the achievement of national goals—in areas such as health, energy, environment, defense, productivity, and foreign trade—and the consequent impacts on that elusive entity, the “quality of life.” Measures of these extrinsic aspects are particularly difficult to devise; the translation of science into technology, the diverse applications of the two, and their myriad impacts are all intertwined with innumerable economic and social variables.

The realization of such a system of indicators—or even one which is less comprehensive—will be a difficult and long task, requiring

- investigation of many potential indices,
- expansion of the underlying data base,

- improvement of methods for measuring the impacts of science and technology,
- experience in interpreting the indices, and
- demonstration of their utility.

In view of these problems and uncertainties, the effort to develop indicators is regarded as an experiment—a long-term experiment to determine if a useful system of indices can be devised in the years ahead. A central concept of the experiment is an evolving set of indicators, derived from the continuing exploration, refinement, and testing of prospective indices. The set will be expanded, refined, and updated annually, as new data become available and as the enterprise itself changes. Throughout, the criterion of “usefulness” will be used to judge the value of individual indices, and to gauge the success of the experiment as it unfolds.

Quantitative indicators, no matter how useful, are not a substitute for the experience and judgment of the scientific community. Indices, at their best, can only supplement this experience and judgment. Indeed, the interpretation of indicators—what they mean for the present and future health of the enterprise—requires the judgment of this community.

The Report

Indicators in this report deal with facets of the entire scientific endeavor, as well as certain aspects of technology. They range from measures of basic research activity and industrial R&D, through indices of scientific and engineering personnel and institutional capabilities, to indicators of productivity and the U.S. balance of trade in high-technology products. Such a broad range of indices was included in the initial step of the experiment in order (a) to explore the scope of the effort involved in developing a relatively comprehensive system of indicators, (b) to identify gaps in the data base, and (c) to select specific areas for focused efforts in the future.

While many potential indices were conceived for future development and a number of new concepts and even new data collections were

¹ Section 4(g) of the National Science Foundation Act as amended by Public Law 90-407.

initiated, the actual indicators in the report were based largely on readily available data. As a result, the indices deal principally with resources—funds and personnel—for R&D, the disciplinary and functional areas to which the resources are directed, and the institutions which carry out the teaching and research functions. Relatively few output measures of either an intrinsic or extrinsic nature are presented, because of the limited data available and methodological problems of separating the distinct contributions of science and technology from those of other factors. Furthermore, the few such indicators which are presented (e.g., quantity and quality of scientific publications, patent output, and trade in technical knowledge) are subject to considerable uncertainty as to valid interpretation and significance. These deficiencies limit the conclusions which can be drawn regarding the performance and contributions of the enterprise.

The first five chapters of the report present the initial set of indicators. The indices, wherever possible, are time series, usually extending from the early 1960's through 1972. Indicators are presented in graphical form and numbered so as to correspond with the numerical data tables in Appendix A. Preceding

each of these chapters is an "indicator highlights" section which briefly summarizes the major indices presented in the chapter. These sections, it should be noted, often omit important caveats and discussion contained in the full text.

The last two chapters present results from opinion and attitude surveys of topics related to the state of science, which are not amenable to purely quantitative treatment. The first of these is a Delphi survey of the judgments and opinions of a wide cross section of the scientific and technological community; the topics covered include the future role of science and technology in areas of high public concern, impacts of recent R&D funding changes, and basic research and criteria for allocating resources among scientific fields. The second is a survey of attitudes of the public toward science and technology; topics covered in the survey include the public regard for science and technology, their assessment of its impacts, and their desires for its future use in coping with national problems.

The task initiated with this report is ambitious; the present effort clearly represents only a beginning. The reports to follow in this series will aim to improve the concepts, refine the treatment, and expand the scope to include other facets of science and technology.

International Position of U.S. Science and Technology

This chapter compares the position and performance of science and technology in the United States with that of other major R&D-performing nations, through a variety of indicators. These include comparative indices of the level of R&D, in terms of expenditures for such activity and the number of scientists and engineers involved; results of R&D, as measured by the output of scientific reports and patents for new products and processes; and national performance in areas dependent upon science and technology, such as technical knowledge, productivity, and international trade.

International comparisons are confined to general trends and to relative rather than absolute indicators, because of the paucity and limited quality of available information. This applies with particular force to comparisons involving the U.S.S.R. where definitions of R&D and scientific personnel often differ from those of other countries.

Specific indicators must be interpreted with considerable caution. Indices of the level of R&D can be misleading because the costs of such activities, and differences in the productivity and functions of scientists and engineers, cannot yet be equated for the various countries. The output indices of scientific reports and patents reflect only a small part of the total output of science and technology, whereas the last group of indicators—those dealing with technical knowledge, productivity, and international trade—include the effects of many factors, science and technology being only one of them.

INDICATOR HIGHLIGHTS

- The proportion of the gross national product (GNP) spent for research and development (R&D) between 1963-71 declined in the United States, France, and the United Kingdom but increased in the Union of Soviet Socialist Republics (U.S.S.R.), Japan, and West Germany. By 1971, U.S. expenditures for R&D were 2.6 percent of GNP, as compared with an estimated 3.0 percent for the U.S.S.R., approximately 2.0 percent for the United Kingdom and West Germany, and 1.8 percent for both Japan and France.
- The number of scientists and engineers engaged in R&D per 10,000 population declined in the United States after 1969 but continued to increase in the U.S.S.R., Japan, West Germany, and France, with the result that by 1971 the number per 10,000 population for the U.S.S.R. was 37 as compared with 25 for the United States and Japan, 15 for West Germany, and 12 for France.
- All countries included in the comparisons significantly reduced the proportion of their government R&D expenditures for national defense between 1961 and 1969, with such expenditures in the United States dropping from 65 to 49 percent of total government R&D spending. Increases in the United States and most other countries occurred in the areas of space, community services, and economic development.
- In seven of eight scientific areas studied,¹ the United States produces a larger share of the world's scientific and technical literature than any of the other major developed countries; the U.S. share remained essentially unchanged between 1965-71.
- Literature produced by the United States is more frequently cited than that produced by other countries in all the scientific areas studied, with the exception of systematic biology and mathematics where the United Kingdom stands first.

¹ The areas were physics and geophysics; chemistry and metallurgy; molecular biology; systematic biology; mathematics; engineering; psychology; and economics.

- The United States had a favorable but declining "patent balance" (patents of United States versus foreign origin awarded in each country) between 1966 and 1970; the decline was due to a reduced number of patents of U.S. origin in France, West Germany, and the United Kingdom, combined with increased U.S. patents of Japanese origin.
- Starting from a higher base, increases in labor productivity in U.S. manufacturing industries between 1960-71 were the lowest of all countries—39 percent—compared with 210 percent for Japan, 86 percent for West Germany, 81 percent for France, and 50 percent for the United Kingdom. Productivity gains in the United States offset increased labor costs until the mid-1960's, but rose less rapidly than such costs during the 1966-71 period.
- The United States had an increasingly favorable position in the sale of "technical know-how"—patents, techniques, formulas, franchises, and manufacturing rights—during 1960-71; Japan was the major purchaser of U.S. "know-how," surpassing all of Western Europe after 1967.
- The favorable U.S. balance of trade in technology-intensive products grew throughout 1960-71, but was increasingly negative in nontechnology-intensive areas.
- Within the technology-intensive areas, products with the fastest rising trade surplus are aircraft, computers, and plastics. Product areas in which the growth of imports exceeds exports include office machinery, chemical elements and compounds, medicinal products, and telecommunication apparatus.
- The favorable trade balance of the United States in high technology products rested primarily on purchases by developing nations (55 percent in 1971) and countries of Western Europe. A deficit balance with Japan, developed in the mid-1960's and continuing to grow through 1971, exists in electrical machinery, scientific and professional instruments, and nonelectrical machinery.

■ The basis chosen for appraisal of U.S. science and technology in this chapter is an international one, where the position of the United States is compared with that of other developed countries, particularly the major R&D-performing OECD (Organisation for Economic Cooperation and Development) member nations.² For reasons cited previously, comparisons are usually restricted to measures of relative magnitude and to general trends.

LEVEL OF RESEARCH AND DEVELOPMENT

The principal indicators of the level of a nation's R&D effort are the expenditures and manpower devoted to such activities. The general objectives of such efforts, in turn, are suggested by the specific areas (e.g., defense, space, and economic development) to which these resources are directed.

² The U.S.S.R. is included in the comparisons wherever the available data permit. Limited data and differences in definitions restrict the comparisons which can be made.

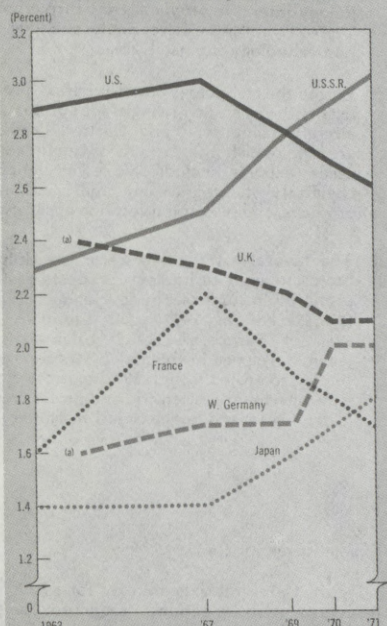
Expenditures for R&D

Figure 1 presents expenditures for R&D as a percentage of gross national product for the six major R&D-performing countries included in the study. The United States, as well as France and the United Kingdom, show a declining ratio, as compared with increases for the U.S.S.R., Japan, and West Germany. Over the 1963-71 period (the only years for which data are available or can be estimated for all countries), the United States exhibits the largest reductions, the U.S.S.R. and Japan the largest increases.

R&D Manpower

Another indicator of the level of a country's R&D effort is the magnitude of the manpower (scientists and engineers) it devotes to these activities. This indicator should be regarded as only an approximation of the true level of R&D in that it fails to account for certain national differences, such as the designation and training of scientists, engineers, and technicians, and the quality of the research equipment available.

Figure 1
R&D Expenditures as a Percent of
Gross National Product, by Country, 1963-71



SOURCE: Organisation for Economic Cooperation and Development; National Science Foundation estimates for 1970 and 1971; U.S.S.R. estimates by Robert W. Campbell, Univ. of Indiana.

These differences also enter into determining the effective R&D level.

The number of scientists and engineers engaged in R&D per 10,000 population in the United States, France, West Germany, Japan, and the U.S.S.R. is shown in figure 2. (Data for the United Kingdom are not available.) Taking the limitations noted above into consideration, these trends indicate that the U.S.S.R. surpassed the United States after 1967 in the proportion of its population employed in R&D,

and that Japan had almost reached the same level as the United States by 1971. Moreover, of the five countries compared, only the United States had a declining ratio of scientists and engineers engaged in R&D.

Government-Funded Research & Development

Governments fund R&D in the pursuit of national objectives in various areas, such as national defense, economic development, and space. The distribution of funding among these objectives reflects national priorities whereas significant changes in the distribution often indicate shifts in national concerns. Government expenditures for R&D, however, represent only a part of the total national investment in R&D; expenditures by the private sector must also be taken into account for international comparisons.

The OECD has attempted to classify government expenditures for R&D into the following six areas:

National Defense, encompassing military-oriented R&D as well as space and nuclear energy activities of a military character;

Space Exploration, restricted to space R&D activities of a civil nature;

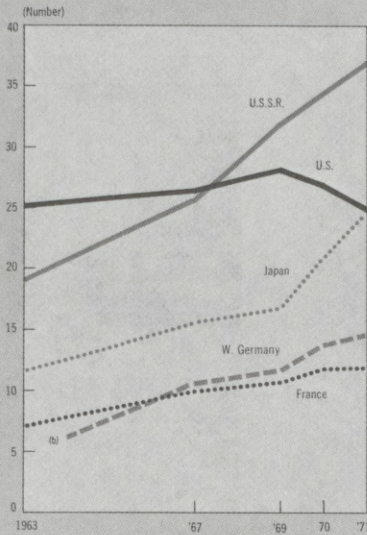
Nuclear Energy, restricted to nuclear energy R&D activities of a civil nature;

Economic Development, including R&D in agriculture, fishing, and forestry, in mining and manufacturing industries, as well as service sectors such as public works, public transportation, communications, and construction;

Community Services, including R&D in health, the environment, public welfare (education, social services, planning, recreation, and culture), disaster prevention, law and order, meteorology, planning, and statistics;

Advancement of Science, including government-funded research in universities, both separately budgeted research as well as research from the general funds of universities provided by the government.

Figure 2
Scientists and Engineers^(a) Engaged in R&D
per 10,000 Population, by Country, 1963-71



(a) Includes all scientists and engineers (full-time-equivalent basis)

(b) 1964

SOURCE: Organisation for Economic Cooperation and Development; National Science Foundation estimates for 1970 and 1971; U.S.S.R. estimates by Robert W. Campbell, Univ. of Indiana.

The distribution of total government expenditures for R&D among these areas is shown in figure 3 for the United States, United Kingdom, France, West Germany, and Japan for the years 1961 and 1969. (Data for the U.S.S.R. are not available.)

The chief changes in the United States between the 1961 and 1969 periods were the proportional reductions in R&D expenditures for national defense (down from 65 percent to 49 percent of total expenditures) and increases in the areas of space, community services, and economic development. Relative reductions in defense R&D also occurred in each of the other

four countries, while the major increases, although differing from country to country, were in space, economic development, and the advancement of science. (Expenditures for the latter area are difficult to compare from country to country because of different government practices in the funding of university research; some governments provide support for such research through general grants to universities, whereas others—such as the United States—provide much of their support through mission-oriented agencies for specific research projects.)

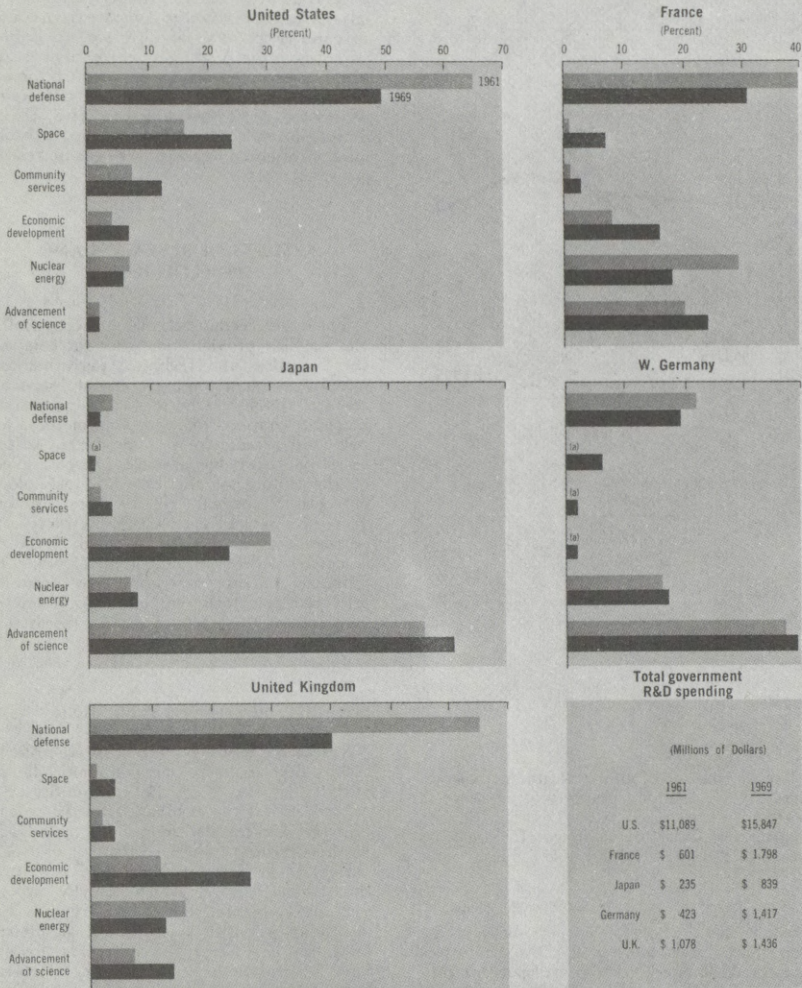
RESULTS OF RESEARCH AND DEVELOPMENT

There are certain relatively direct results of R&D which provide indicators for comparing the scientific and technical performance of nations. Primary among these are reports of research published in scientific and technical journals, citations of reports from these journals, and patents for new products and processes. These provide measures of certain aspects of the output of the scientific-technological enterprise. Journal reports are produced primarily, but not exclusively, by the scientific portion of the enterprise as the result of research, both basic and applied, while new products and processes leading to patents are produced principally by industrial firms and inventors as the result of applied research and development.

Scientific and Technical Publications

Research reports published in scientific and technical journals are one of the more tangible outputs of the scientific community. Such reports reflect the results of specific research efforts. The results themselves may lead to further research, or be used many times over in a variety of practical applications. Furthermore, the critical review which usually precedes publication ensures that the reports have some degree of scientific or technical significance. Indicators based on research reports, however, have several limitations for the purpose of international comparisons: the quantity of such reports may be influenced substantially by the national customs regarding the publishing of research papers, by the availability of funds for

Figure 3
Distribution of Government R&D Expenditures
Among National Objectives, by Country, 1961 and 1969



(a) Less than 1 percent

SOURCE: Organisation for Economic Co-operation and Development.

preparing and printing papers, by journal refereeing and publishing policies, etc. These factors provide good reason for caution in interpreting such indicators.

The data presented here are the results of an initial attempt to:

- (1) Estimate the proportion of the world's significant research and technical literature (in selected scientific areas) which is produced by the United States and other major countries, and
- (2) Assign a figure of merit representing the quality or significance of the literature produced in each area by each country.

The scientific areas and countries encompassed are shown below:

Scientific Areas

Physics and Geophysics
Chemistry and Metallurgy
Molecular Biology
Systematic Biology
Psychology
Economics
Mathematics
Engineering

Countries

France
Japan
United Kingdom
United States
U.S.S.R.
West Germany

National Origins of Literature. Estimates of the distribution of literature among fields and countries were based upon counts of articles, letters, and notes published in some 500 journals covered by the *Science Citation Index* (published by the Institute for Scientific Information, Philadelphia, Pa.), supplemented by data from various abstracting services.³ The results are presented in figure 4.

³ For details of the methodology employed, including validation checks, see *Development of U.S. and International Indicators of the Quantity and Quality of Scientific Literature*, Computer Horizons, Inc., September 1972.

The United States has a larger share of the literature in each of the areas (except for chemistry and metallurgy) than any other country. The U.S. share, as well as those of other countries, shows little change over the short period (1965-71) covered by the data.

In the area of physics and geophysics, the United States produces some 40 percent of the literature, as compared with about 15 percent from the U.S.S.R., and between 5 to 8 percent from each of the other four countries. However, in the other physical science area—chemistry and metallurgy—the U.S.S.R. has the largest share with some 29 percent, versus the 24-percent share of the United States, and the 5- to 9-percent share of each of the other four countries.

In molecular biology the United States produces almost one-half the world's literature, with each of the two next largest producers (United Kingdom and France) having shares of only 9 percent. The U.S. share of the systematic biology literature is considerably less, at some 30 percent, than molecular biology, but still exceeds that of any other individual country by a wide margin.

In psychology and economics, literature of U.S. origin represents the largest share. The available data for both areas, however, were more limited and less reliable than data for other areas. In spite of these limitations, the relative position of the United States in each area is believed to be accurately reflected by the data.

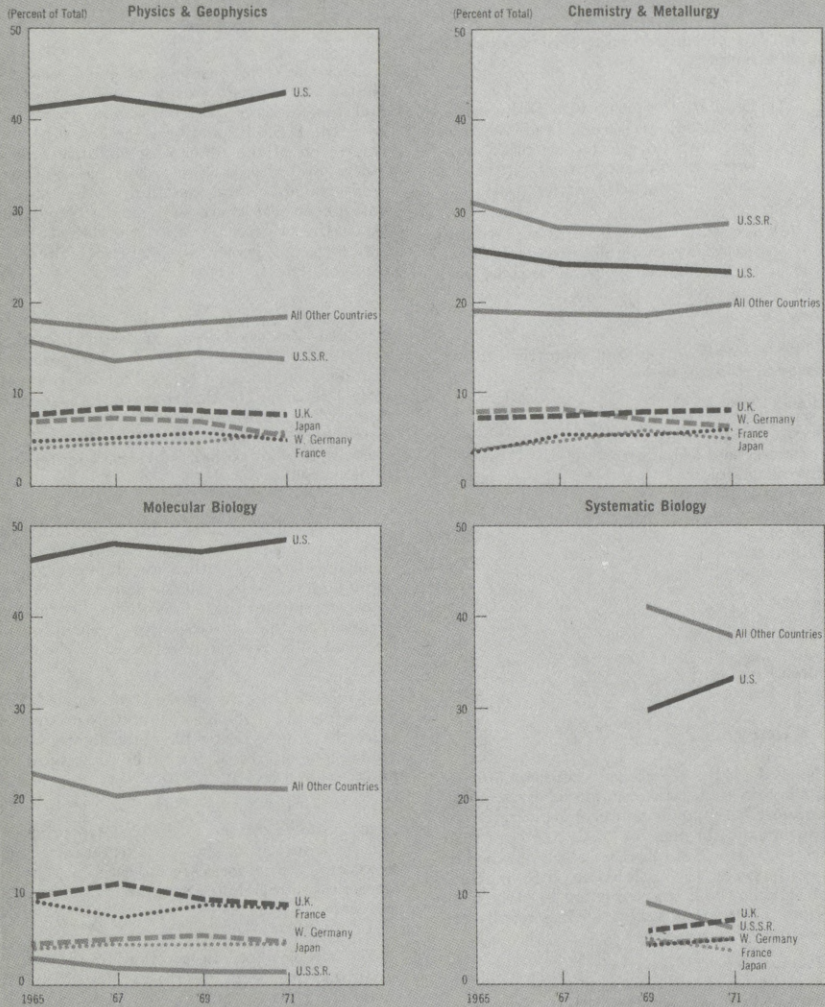
In mathematics the United States and U.S.S.R. share the lead as the major literature producers, with the United States having a slightly larger share. The shares of the other four countries range from 4 to 7 percent.

In engineering the United States produces about 50 percent of the world's literature. The next largest producers are the U.S.S.R. with 12 percent, and the United Kingdom with about 10 percent.

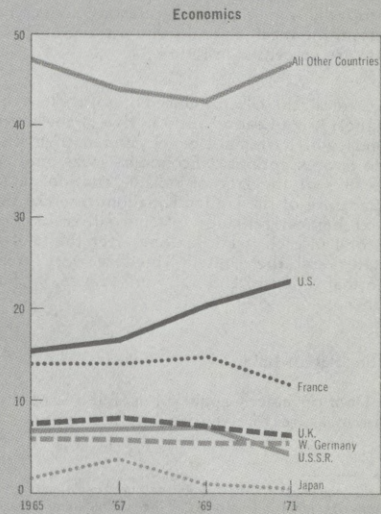
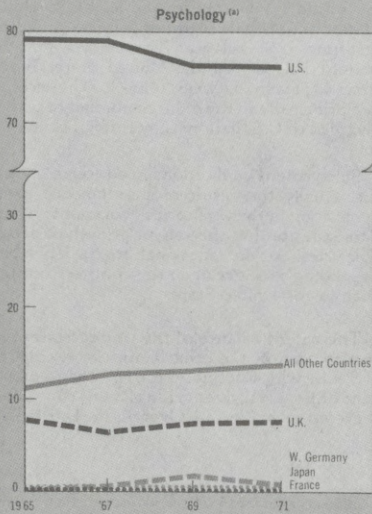
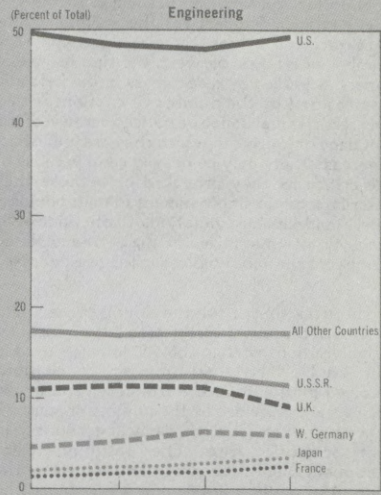
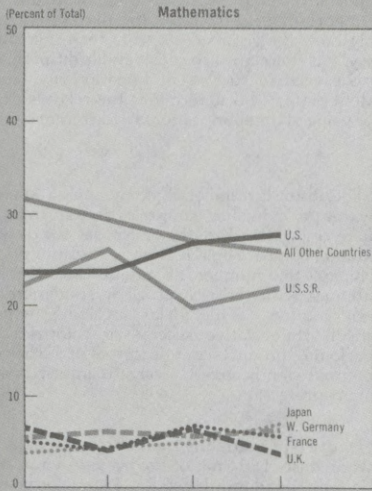
Literature Citations. In addition to the purely quantitative aspects, an effort was made to estimate the relative "quality" or "significance" of the literature. The basis for this indicator was the number of citations to the literature

Figure 4

Scientific Literature in Selected Fields Produced by Major Developed Nations, 1965-71



SOURCE: Computer Horizons, Inc.



(a) Data not available for U.S.S.R. SOURCE: Computer Horizons, Inc.

produced by each country in each scientific area. The general rationale for such an index is the expectation that the most significant literature will be most frequently cited, whereas relatively unimportant research articles will attract few, if any, citations. Support for the validity of this indicator is the high correlation, found in a number of studies, between the significance of papers as judged by researchers in the field and as measured by the number of citations. However, articles may fail to be noticed because of the language or journal in which they are published, whereas others may be heavily cited because of the criticisms they provoked or because they describe a minor improvement in methodology. These and similar limitations of the indicator, however, are minimized by the extremely large number of citations involved in the present case.

The data source for the "significance" indicator was the *Science Citation Index*, which includes all publications cited in the 500 journals used in this study. The total number of citations received by the literature from each country in each area was divided by the number of research articles produced by the particular country in that scientific area. The resulting "citation/publication" ratios were determined for the years 1965, 1967, 1969, and 1971. Since the ratios did not change significantly over the period, the mean annual value was used. These data are presented in figure 5.

Overall, the U.S.-produced literature had the highest "significance" ratio in five of the seven fields, with systematic biology and mathematics the two exceptions. ("Economics" was omitted because of the lack of reliable citation data.) Literature of the United Kingdom received the next highest rankings, placing either first or second in each field. Ranking after the United States and the United Kingdom were West Germany, Japan, U.S.S.R., and France, in that order.⁴

The "Patent Balance"

Data on patent applications and awards are also measures of inventive output. Inventions of

new processes and products, of sufficient originality to be patented, represent potential technological advances. Patents, however, vary greatly in their technical and economic importance and the basis for their award differs in important ways from country to country. Not only does the rigor of the tests for originality vary, but there are also considerable differences in the relative success of litigation involving patent rights; this determines the relative ease and value of obtaining patents in different countries.

The absolute number of patent applications or awards in individual countries is not an adequate indicator for the purposes of international comparisons. It is more meaningful to compare the number of patents awarded to nationals with those awarded to foreigners in each country.⁵ This yields an index which reflects the relative success of countries in developing products and processes of sufficient potential significance to warrant international patent protection.

Figure 6 presents the total number of patents awarded to U.S. nationals by five countries (United Kingdom, U.S.S.R., West Germany, Japan, and France), those awarded by the United States to nationals of these countries, and the resulting U.S. balance. This shows that the "patent balance" of the United States fell by some 40 percent between 1966-70. The decline is due principally to the reduced number of patents awarded to U.S. nationals by foreign countries.

Since patent applications in a foreign country are usually the result of simultaneous patent application in the applicant's own country, these data indicate that the rate of growth of patentable ideas of international merit have been expanding at a greater rate in other countries than in the United States.

The patent balance of the United States relative to each of the other countries (except the U.S.S.R. which accounts for less than one percent of the total patent transactions considered) is presented in figure 7. Overall, the U.S. balance

⁴ The particular sample of journals used in estimating the national origins of literature and the relative significance of the literature may have resulted in some bias favoring English-language publications.

⁵ Patents awarded to U.S. nationals by foreign countries minus patents awarded to foreign nationals by the United States.

Figure 5

Citation/Publication Ratio of Scientific Literature
in Selected Fields [Mean Values for 1965-71]

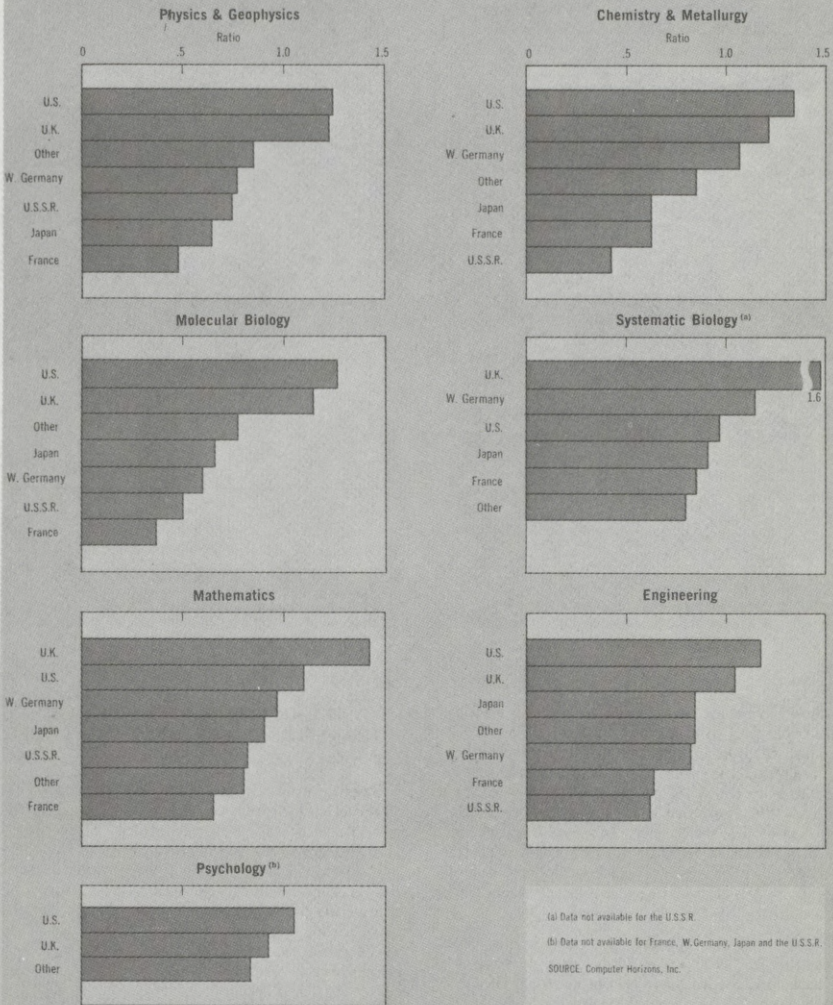
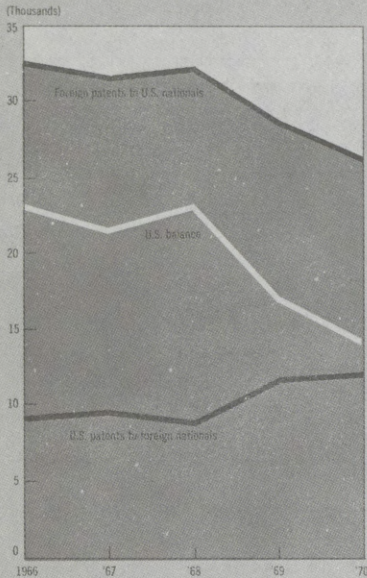


Figure 6

Patents Awarded to U.S. Nationals by Foreign Countries and to Foreign Nationals by the U.S. 1966-70



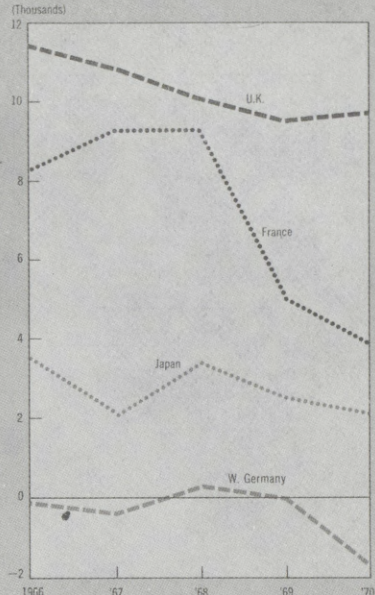
SOURCE: World Intellectual Property Organization, Geneva.

declined in each country, with the major reduction occurring in respect to France, followed by smaller declines in relation to the United Kingdom, Japan, and West Germany in that order. Declines in the U.S. balance vis-a-vis France, United Kingdom, and West Germany were due principally to reductions in the number of patents awarded to U.S. nationals; conversely, the decline with respect to Japan was produced largely by an increasing number of awards to that country by the United States.

Thus, the U.S. patent position, while still favorable in 1970, was eroding for two reasons: (a) a declining number of foreign patents of U.S. origin and (b) an increasing number of U.S. patents of foreign origin.

Figure 7

U.S. Patent Balance with Selected Countries, 1966-70



SOURCE: World Intellectual Property Organization, Geneva.

PRODUCTIVITY, TECHNOLOGY TRANSFER, AND BALANCE OF TRADE

Science and technology play an important role in industrial innovation, productivity, economic growth, and trade among nations. They represent, however, only one component in the complex matrix of factors which determine the technological and economic position of a nation. The numerous other variables involved (legal, financial, social, market, etc.) make it difficult to specify the exact role and contribution of any single factor—such as R&D.

In discussing productivity, technology transfer, and balance of trade, comparisons are limited

to those areas and aspects which depend upon R&D in rather direct and obvious ways.

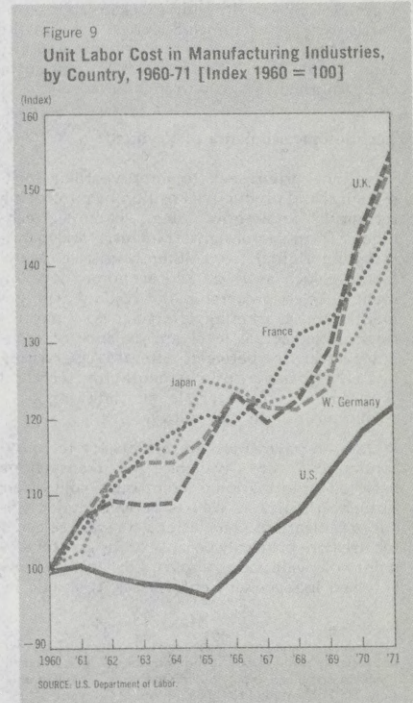
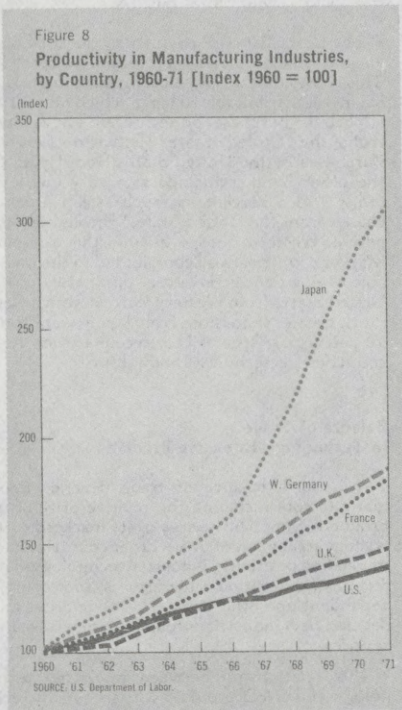
Productivity

Productivity expresses the relationship between the quantity of goods and services produced (the output) and the resources (e.g., labor, capital, land, and energy) used to produce them (the input). One of the most commonly used indices of productivity is "output per man-hour," which relates output to the input of labor time. R&D contributes to productivity by providing advances in technology which increase output per man-hour. All studies of the effects of R&D on productivity growth conclude that

there is a direct relationship which is "positive, significant, and high."⁶

Indices now available do not permit comparison of absolute levels of productivity in different countries, except in the case of certain individual industries. Instead, comparisons are limited to changes in productivity which occur over time in individual countries. Normalized data for changes in relative labor productivity in manufacturing are presented in figure 8 for the United States, United Kingdom, France, West Germany, and Japan.

⁶ *Research and Development and Economic Growth/Productivity*, Papers and Proceedings of a Colloquium, National Science Foundation, NSF 72-303, December 1971.



Japan increased its productivity by 210 percent between 1960-71, compared to about a 39-percent increase in the United States. Productivity gains in manufacturing over the same period were 86 percent for West Germany, 81 percent for France, and 50 percent for the United Kingdom. Of course, the United States, which has already reached a high level of productivity, might not be expected to sustain the same high proportional gains as countries starting from a lower productivity base.

Increases in productivity can translate into lower product cost, providing the productivity gains offset increases in labor costs. Unit labor cost (hourly labor cost divided by output per man-hour) for manufactured products is shown in figure 9 for the same five countries. It can be seen that productivity gains were sufficient to offset increased labor costs in the United States during the 1960-66 period, but not thereafter. Productivity gains in the other four countries were also exceeded by increases in labor costs, particularly after the mid-sixties. Even in the case of Japan, the large increases in productivity after the middle of the decade were not sufficient to offset the growth in labor costs.⁷

Technological Balance of Payments

Nations often seek to improve their technological and productive position by purchasing technical "know-how" (e.g., patents, techniques, formulas, designs, franchises, and manufacturing rights) from other countries. Many factors—such as R&D and economic development policies, ownership and trading arrangements, and marketing effectiveness—may influence the actual level and balance of technology transfer between nations. A persisting favorable balance of payments for technical "know-how," however, is an indicator of a strong position in technology.

Data on payments and receipts for technical "know-how" are available for transactions between multinational companies and their foreign affiliates as well as between independent organizations. The latter data were selected for use here primarily because of the greater element of valuation implicit in transactions between independent enterprises. It should be

noted, however, that the omission of transactions between corporations and their foreign affiliates results in a substantial understatement of the extent of technology transfer. In addition to transactions involving financial exchanges, a considerable amount of technical "know-how" is transferred informally between multinational firms and their foreign affiliates.

The technological balance of payments with respect to the United States is presented in figure 10. Included are U.S. receipts from the sale of technical "know-how" to all countries, payments by the United States to all other countries for such "know-how," and the resulting balance of payments (receipts minus payments). The United States had a strong and increasingly positive balance of payments in this area throughout the decade. U.S. receipts from the sale of "know-how" grew exponentially while its payments—which were some four to five times less than receipts—rose linearly.

The U.S. balance of payments associated with a country or countries is presented in figure 11. This shows that the principal increase in the U.S. balance is attributable to Japan which more than tripled its purchase of technical "know-how" from the United States between 1966-71. Purchases by the United States from Japan, on the other hand, remained at a very low level (only 2 to 4 percent as much as Japan's purchases from the United States) throughout the period. Western Europe (mainly the Common Market countries) also contributed to the favorable U.S. balance; however, purchases by the United States from Western Europe, which were much greater than those from Japan, were some 40 percent as large as U.S. receipts from these countries for technical "know-how."

Balance of Trade in Technology-Intensive Products

A nation's balance of trade depends upon many factors including the relative price of its products, the effectiveness of its marketing, its trading arrangements with other countries, and its relative position in industrial technology. The technology position, in turn, is increasingly dependent upon the use of R&D to improve and develop new industrial products, processes, and services.

This relationship between industrial technology and R&D provides a basis for dividing

⁷ A detailed and comprehensive study of unit labor cost, productivity, and labor compensation is presented in *Competitiveness of U.S. Industries*, United States Tariff Commission, TC Publication 473, Washington, D.C., April 1972.

Figure 10
U.S. Payments and Receipts for Patents,
Manufacturing Rights, Licenses, Etc., 1960-71

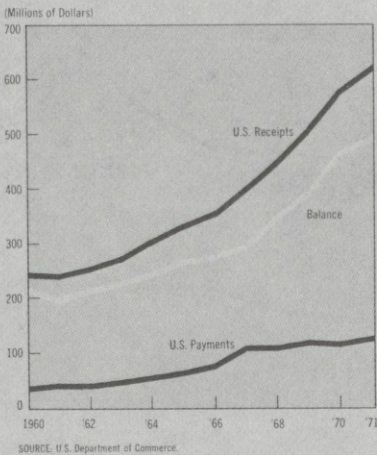
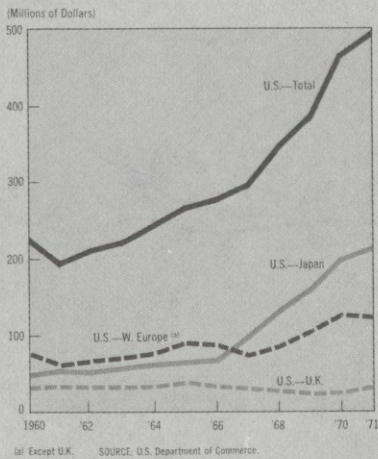


Figure 11
U.S. Balance of Payments for Patents,
Manufacturing Rights, Licenses, Etc.,
by Country, 1960-71



manufactured products into two groups: technology-intensive and nontechnology-intensive products. The grouping is based upon the relative extent of R&D performed by the industries which manufacture the products. Products from industries with (a) 25 or more scientists and engineers engaged in R&D per 1,000 employees and (b) 4 percent or more of their net sales directed to R&D are designated here as "technology-intensive" products while those with a lower level of R&D investment are regarded as "nontechnology-intensive" products. Based on these criteria, the product areas which are technology-intensive are (a) chemicals, (b) non-electrical machinery, (c) electrical machinery, (d) aircraft and parts, and (e) scientific and professional instruments. All other manufactured products are regarded as nontechnology intensive.⁸

The U.S. trade balance (exports minus imports) associated with these two categories of products is shown in figure 12. The favorable balance in technology-intensive industries is clearly indicated; the balance doubled over the 1960-71 period. In contrast, the United States had a large and increasing deficit trade balance in nontechnology-intensive products.⁹

The favorable U.S. export position in high technology products results in large measure from the extensive use of scientists and engineers as well as other skilled manpower.¹⁰ Thus, the U.S. comparative advantage for international trade in manufactured products appears to be in the export of goods that are intensive in the use of highly educated and skilled personnel rather than in low technology mass-produced goods.

The favorable U.S. trade balance in the tech-

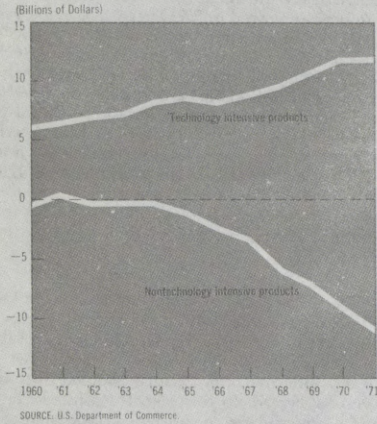
⁸ This grouping, of course, is an approximate one. Products and industries, although highly correlated at the gross level, do not perfectly coincide, with the result that not all products manufactured by a high R&D-performing industry are technology-intensive. Further, the criteria used here result in placing "automobile and parts" products in the nontechnology-intensive group, instead of the other group where they are sometimes assigned.

⁹ The U.S. trade position may also be viewed in terms of capital and consumer goods. The favorable U.S. export performance is largely accounted for by capital goods, almost all of which are produced by technology-intensive industries, while the unfavorable import situation lies largely in consumer goods.

¹⁰ W. H. Brownson and H. B. Junz, "Trends in U.S. Trade and Comparative Advantage," *Brookings Papers on Economic Activity*, 2, 1971.

Figure 12

U.S. Trade Balance in Technology- and Nontechnology-Intensive Manufactured Products, 1960-71

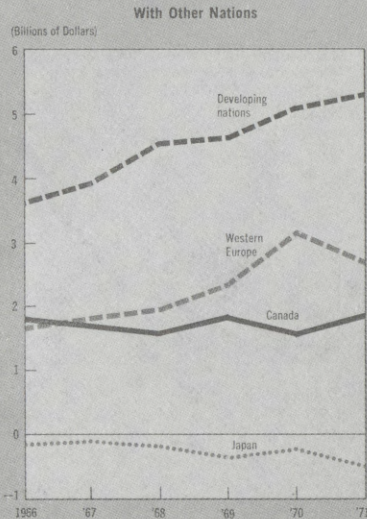
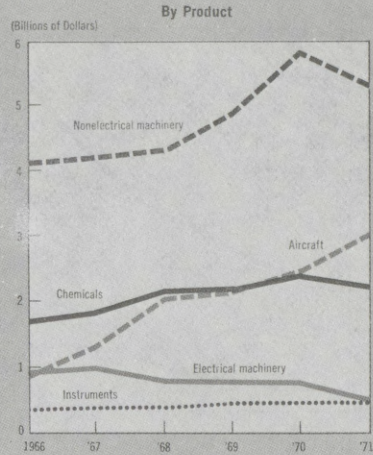


nology-intensive area is shown in figure 13 for each of the five industry groups.

- Nonelectrical machinery declined in net exports during 1971. The decline was primarily due to the continuing rise in imports of office and textile machinery. Computers and construction and mining equipment account principally for the net export position.
- Aircraft and parts had a 9:1 export/import ratio in 1971. Although this has been the fastest growing exporting industry, there are signs that the favorable ratio may decline in the near future.
- Chemical net exports declined in 1971 chiefly due to increased imports of chemical elements and compounds as well as medicinal and pharmaceutical products; major net export products were plastics and resins and radioactive materials.
- Instruments maintained a steady but small growth in net exports.

Figure 13

U.S. Trade Balance in Technology-Intensive Products, 1966-71



SOURCE: U.S. Department of Commerce.

- Electrical machinery continued its rapid decline in net exports, principally as a result of imports of telecommunication apparatus.

This mixture of growing and declining exports illustrates the complexities of the present U.S. trade position. The underlying dynamics of the position, however, are partially explained by the "product cycle" concept.¹¹ Trade in manufactured goods, according to this concept, typically follows a cycle in which the United States initially establishes a net export position with the introduction of a new product, maintains this position until the technologies and skills necessary for manufacturing the product are developed elsewhere, and then becomes an importer as the production is standardized and moves abroad to minimize costs. The concept implies that the product structure of U.S. exports must have a continuous infusion of new products in order for the United States to maintain a favorable trade position.

The favorable position of the United States in high technology areas is based primarily on exports to developing nations and countries of Western Europe (figure 13). In 1971, developing nations accounted for 55 percent of the net exports in these areas, and Western Europe almost 30 percent. In contrast, the deficit balance in the high technology area developed with Japan in the mid-1960's and persisted in the following years, with the largest increase (almost 120 percent) occurring in 1971. This deficit lies primarily in electrical machinery (particularly in consumer electronics), and to a lesser extent in the instrument and nonelectric machinery areas. Only in the aircraft and parts area does the United States have a significant net export position with respect to Japan.

Although the United States still retains a

strong position as a net exporter of technology-intensive products, various indicators suggest that the position may deteriorate in the near future. Not only did the overall trade balance for high technology industries level off between 1970-71, but the two industries most responsible for the favorable balance in previous years (nonelectrical machinery and chemicals) had their first decline in net exports in 1971. Furthermore, net exports of electrical machinery appear to be declining at a faster rate than in recent years; the shift of exports in this area from developed to developing nations is regarded as a further indication that these products are moving from the export to the import stage. In addition to these relatively direct indicators of the U.S. trade position, other indices suggest that R&D trends in these industries may contribute to a deteriorating position in the future: the "R&D intensiveness" of the five industries as a whole declined by some 25 percent in recent years and expenditures for R&D fell by almost 10 percent between 1968-70, as noted elsewhere in this report.

The preceding examination of foreign trade was restricted, for the purposes of this report, to those aspects which provide relatively direct indices of the position and performance of U.S. technology. As a result, the whole area of foreign direct investment and sales of U.S. subsidiaries abroad was neglected.¹² Such sales, mostly in technology-intensive products, exceed exports by some 2.5 times, but are highly correlated with the export position of the individual industries. The large and growing investment income from foreign subsidiaries of the United States helps to finance U.S. imports of nontechnology-intensive products. Furthermore, such investment in developing nations probably generates a considerable market for the export of U.S. technology-intensive products.

¹¹ R. Vernon, "International Investment and International Trade in the Product Cycle," *Quarterly Journal of Economics*, v. 80, May 1966.

¹² A comprehensive discussion of these and related topics is presented in: P. G. Peterson, *The United States in the Changing World Economy*, U.S. Government Printing Office, 1971.

Resources for Research and Development

Indicators in this chapter deal with the financial and human resources employed in research and development. These include measures of the total national R&D effort, in terms of the level and sources of funding; the character of R&D (basic research, applied research, and development); and the scientists and engineers engaged in these activities. The general areas of R&D and the institutions involved are indicated, although these aspects are more fully treated in subsequent sections of the report.

In this chapter resources are viewed both as inputs to the scientific-technological enterprise and as indicators of the level of its R&D. The use of financial resources as a surrogate for level of R&D activity requires that the purchase value of the dollar be adjusted to reflect rising costs. In the absence of an "R&D price index," the implicit price deflator for the gross national product is used to convert R&D expenditures from current to constant dollars; this conversion, it is recognized, may not fully account for the increasing costs associated with R&D.

INDICATOR HIGHLIGHTS

- National expenditures for R&D increased throughout the 1961-72 period when expressed in current dollars; in terms of constant 1958 dollars, however, expenditures declined 6 percent between 1968 and 1971, but increased slightly in 1972 to a level equivalent to that of 1966-67.
- Total R&D expenditures as a proportion of the gross national product declined to 2.5 percent in 1972 from a high of 3.0 in 1964; the decline was due to continued growth of the GNP coupled with the reduced growth of Federal R&D expenditures.
- Federal Government expenditures for R&D in current dollars leveled off after 1968 and declined slightly thereafter—primarily as the result of reduced expenditures for space R&D—before rising in 1971 and 1972; the result in constant 1958 dollars was a reduction which continued through 1971 and amounted to a 12-percent decline.
- The number of scientists and engineers engaged in R&D reached almost 560,000 in 1969 before declining each year thereafter for a total reduction of some 35,000 by 1972; almost all the decline occurred in the industrial sector.
- Most affected by the funding reductions were development activities which leveled off in 1970 before rising again in 1971 and 1972; in constant 1958 dollars, however, expenditures for development declined after 1969 and remained at the lower level through 1972.
- The fraction of total Federal outlays devoted to R&D fell from 12 to 7 percent between 1965-72. The decline was due in large part to the growth of Federal expenditures in areas which have small R&D outlays, such as income security, and to reductions in space R&D.
- Some 73 percent of all Federal R&D expenditures in 1972 went for national defense and space exploration. National defense received 54 percent of total Federal R&D funds in 1972 and space exploration received some 19 percent of the total.
- Federal expenditures for R&D in civilian areas (areas other than national defense and space) increased throughout the 1963-72 period, rising to 27 percent of the total in 1972, up from 14 percent in 1963. Areas receiving the bulk of funds in 1972 were health (8.7 percent), advancement of science and

technology (4.4 percent), transportation (3.8 percent), environment (3.2 percent), and energy conversion and development (2.5 percent).

- Total expenditures for industrial R&D in current dollars increased until 1969, declined in 1970, and then rose in 1971 and 1972; the trend in constant 1958 dollars, however, was one of considerable declines after 1969 and a small increase in 1972, leaving expenditures at their 1965-66 level.
- Industry-funded R&D, which rose in current dollar expenditures throughout the 1961-72 period, is devoted to applied research and development in the electrical equipment, aircraft and missiles, motor vehicles, chemical, and machinery industries. Some 80 percent of Federal expendi-

tures for industrial R&D went to the first two industries in 1970.

- Federal funds for industrial R&D leveled off in the mid-1960's and declined in current dollars after 1969—primarily because of reduced expenditures for space R&D—while industry continued to increase its expenditures, with the result that in 1968 industry replaced the Federal Government as the prime source of support for industrial R&D.
- Universities and colleges, which provided 4 percent of the Nation's R&D funds in 1972, concentrate their expenditures on basic and applied research in the life sciences (almost 50 percent), physical sciences and engineering (20 percent), and the social sciences (16 percent).

■ The Nation devotes a sizable share of its human, institutional, and financial resources to research and development. The largest proportion of these resources is directed toward the achievement of national objectives in areas such as defense, health, space, energy, and the environment. A somewhat smaller share of the resources goes for developing the technological basis for new and improved industrial products and services. And a considerably smaller share is used for improving the fundamental understanding of man and nature.

NATIONAL RESOURCES FOR RESEARCH AND DEVELOPMENT

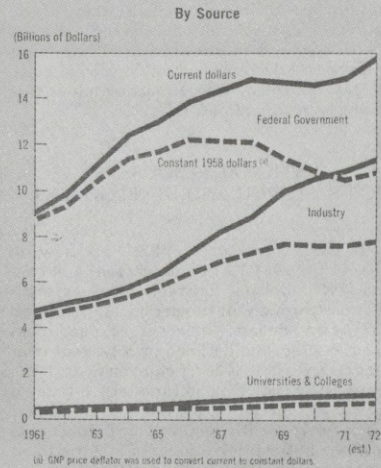
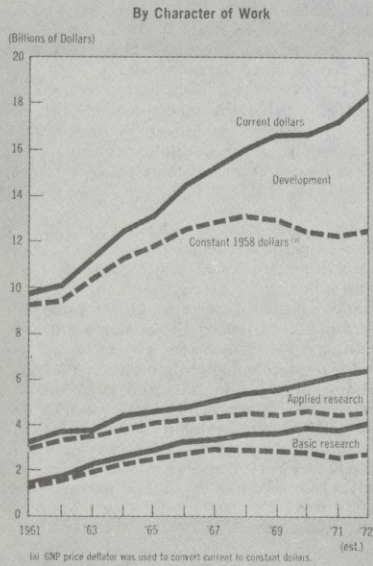
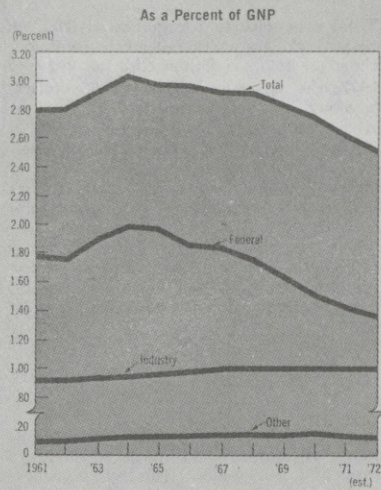
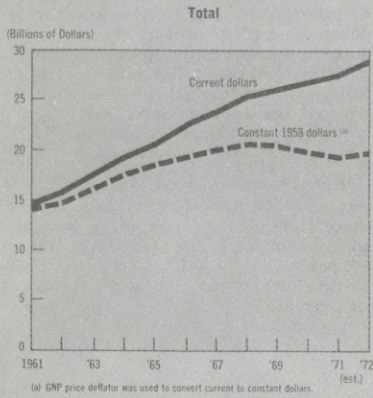
Total U.S. expenditures for R&D are shown in figure 14 for 1961-72 in both current and constant (1958) dollars. Current dollar expenditures rose throughout the period. As measured in constant dollars, however, expenditures peaked in 1968, and declined by 6 percent over the next 3 years to a level equivalent to 1966. Slightly increased expenditures are estimated for 1972. (Coincident with the constant dollar declines were nearly equivalent proportional reductions in the total number of scientists and engineers engaged in R&D, as shown in figure 15.)

As a part of its gross national product, the United States is estimated to have devoted 2.5 percent of GNP to R&D in 1972. This ratio, which reached its highest level of 3.0 percent in 1964, has declined steadily since 1967 (figure 14). The reduction is attributable to the continued growth of the GNP coupled with declines in R&D expenditures by the Federal Government; non-Federal expenditures for R&D remained at approximately 1.2 percent of GNP between 1967-72.

The principal sources of R&D funds are the Federal Government which provided 55 percent of the nation's total R&D expenditures in 1972, private industry 40 percent, and the universities and colleges 4 percent. Other nonprofit institutions contributed the remaining 1 percent (figure 14). Government funding in current dollars declined slightly between 1968 and 1970 and increased in 1971 and 1972; in constant dollars, however, Federal funding declined by 12 percent between 1968-71 before increasing slightly in 1972. Federal expenditures for R&D in FY 1973 are estimated at approximately \$16.5 billion, a 3-percent increase over expenditures for FY 1972, which were in turn 6 percent higher than FY 1971.

Expenditures for R&D in terms of the character of work—basic research, applied research,

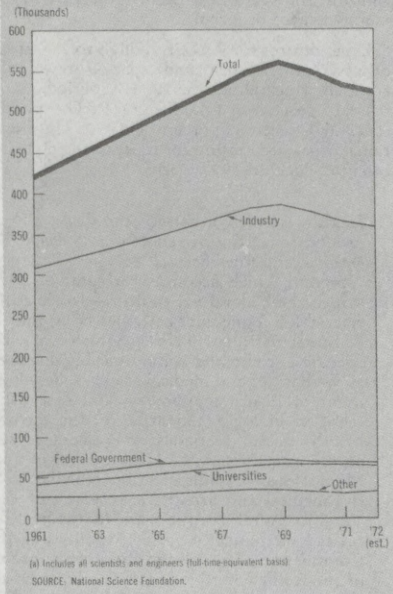
Figure 14
National R&D Expenditures, 1961-72



SOURCE: National Science Foundation.

NOTE: Other nonprofit institutions' R&D expenditures increased from \$110 million in 1961 to \$255 million in 1972.

Figure 15
Scientists and Engineers^(a) Employed
in R&D, by Sector, 1961-72



and development—are shown in figure 14. The most salient change appears in the development area in which constant-dollar expenditures declined during 1969-71. This decline accounts in large part for the overall R&D reduction noted in figure 14. In 1972, development activities accounted for 64 percent of total R&D expenditures, applied research 22 percent, and basic research 14 percent.

A part of the nation's human resources devoted to R&D are the scientists and engineers who are engaged in performing research and development. Their total number reached almost 560,000 in 1969 before declining in each subsequent year for a total reduction of some 35,000 by 1972. Almost all the decline occurred in the industrial sector (figure 15). Industry had

two-thirds of the nation's total scientists and engineers engaged in R&D (on a full-time-equivalent basis) in 1972 as compared with the universities and the Federal Government, each of which had some 13 percent.

FEDERALLY FUNDED R&D AND NATIONAL OBJECTIVES

R&D resources and activities can be related to the national functions they serve, such as defense, space, natural resources, commerce and transportation, and health. Federal expenditures for R&D¹ in these functional areas reflect the extent to which R&D is used by the government in the pursuit of national goals.

Total Federal Outlays and R&D Expenditures

Federal expenditures for R&D, expressed as a percentage of total Federal outlays, declined appreciably after 1965, as shown in figure 16. The reduction resulted from a mixture of (a) rapid growth of Federal outlays in areas which have small R&D expenditures, (b) diminished expenditures for space R&D, and (c) relative decline in expenditures for national defense, as a proportion of total Federal outlays. Federal expenditures for retirement, disability, and unemployed, for example, rose from 20 to 29 percent of total Federal outlays between 1968 and 1972; R&D expenditures, however, were less than 1 percent of the total outlays in this area. In the space area, R&D expenditures declined both in absolute terms and as a percent of total Federal outlays. Total outlays for defense, which has been the major source of R&D funds, fell from 49 percent of all Federal outlays in 1963 to 35 percent in 1972. (For further detail, see *An Analysis of Federal R&D Funding by Function*, National Science Foundation, NSF 72-300.)

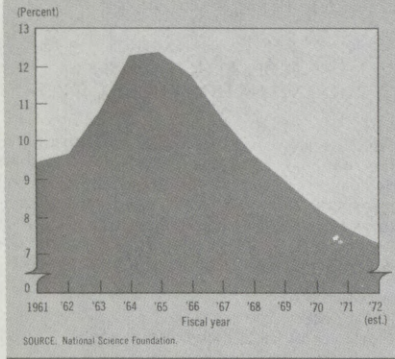
R&D Activities in Functional Areas

Expenditures for the 10 major areas of federally funded R&D are presented for the years 1963-72 in figure 17.² These areas

¹ Expenditure data for other funding sources (e.g., industry) are not available for these functional areas.

² Comparable data are not available for earlier years.

Figure 16
Federal R&D Expenditures as a Percent of
Total Federal Outlays, FY 1961-72



accounted for 99 percent of all Federal expenditures for R&D in 1972. The most salient features represented in the figure are:

- The large role of defense R&D throughout the period
- The rise and fall of space R&D
- The relatively rapid growth in civilian areas.

Defense R&D expenditures between 1963-72 ranged from 48 to 64 percent of total Federal expenditures for R&D. In 1972 they accounted for 54 percent, the highest proportion since 1964. Current dollar expenditures for 1972 were the highest of the 1963-72 period. The 1972 R&D expenditures in this area were directed in the main to development of missiles, aircraft, equipment, and to defense-related atomic energy activities, military sciences, and astronautics.

R&D expenditures for space in 1972 were at their 1963-64 level after declining by more than 40 percent (in current dollars) since the peak year of 1966.³ The area, however, still received 19 percent of all Federal R&D funding in 1972.

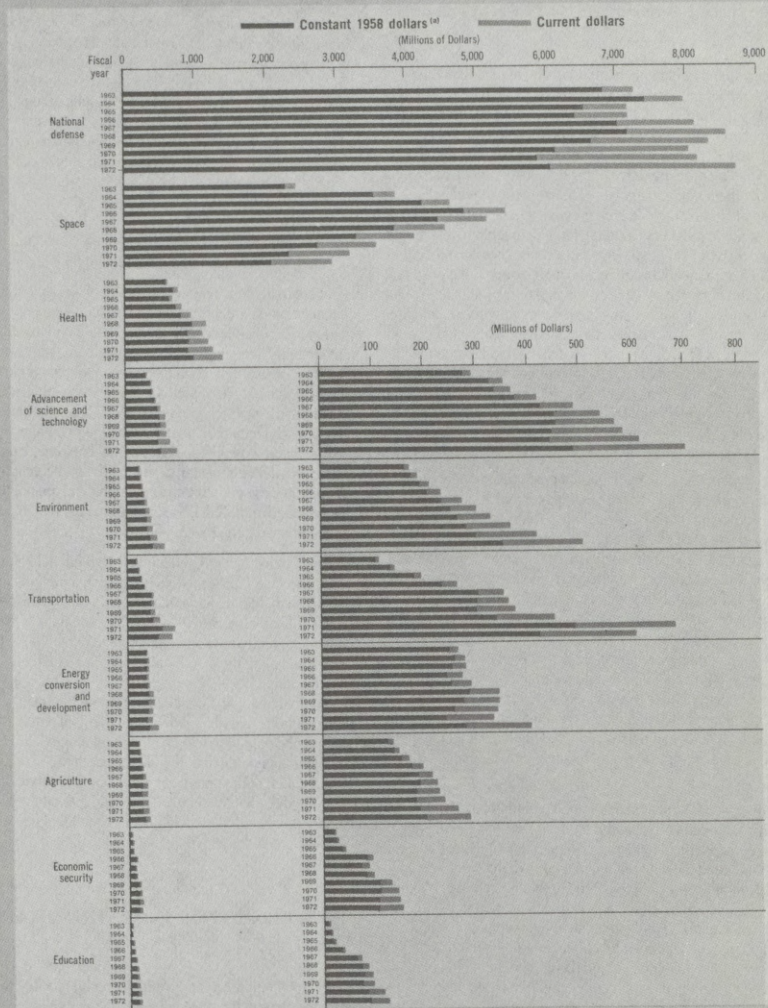
³ The entire activities of NASA are reported as R&D or related support; the R&D component was reported as 98 percent of the agency's total expenditures in 1972.

The principal programs, in terms of magnitude of expenditures in 1972, were manned space flight, space science and applications, supporting activities, and space technology. Recent declines in the space area occurred largely in the manned space program.

Expenditures for R&D in civilian areas—areas other than defense and space—grew substantially throughout the 1963-72 period, rising from 14 percent of total Federal R&D expenditures in 1963 to 27 percent in 1972. The functional areas accounting for most of the civilian-oriented R&D in 1972 were:

- (1) **Health**, which consists of the *development of health resources, the prevention and control of health problems, and the delivery of health care*. The first category, which accounts for some 90 percent of all Federal expenditures for health-related R&D, includes activities of (a) the 10 National Institutes of Health which deal with specific chronic and communicable diseases as well as general medical sciences, development of health manpower, and establishment of biologic standards; (b) the mental health, health statistics, and overseas research activities of the Health Services and Mental Health Administration (HSMHA); (c) the medical and prosthetic research of the Veterans Administration; and (d) the health-related activities of the Atomic Energy Commission. The second category consists of the R&D activities of the Food and Drug Administration, Bureau of Mines, and the preventive health services of HSMHA. The delivery of health care category is comprised of the HSMHA programs in health services planning and development, health services delivery, and Indian health services. Expenditures for R&D in the entire health area, as a fraction of total Federal R&D expenditures, rose from 5.2 percent in 1963 to 8.7 percent in 1972.
- (2) **Advancement of Science and Technology**, which is aimed at strengthening the Nation's scientific base and at application of science and technology to problems of national concern. The largest category is *general science*, comprised principally of basic research projects in the various scientific disciplines supported by the National Science Foundation and most of the physical science research programs (except for controlled thermonuclear research) of the Atomic Energy Commission. A second category is

Figure 17
Federal R&D Expenditures for Selected Functions, FY 1963-72



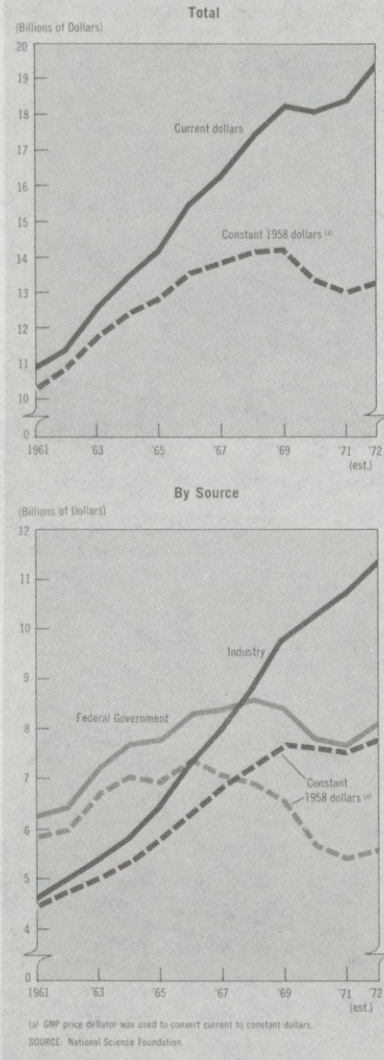
(a) GNP price deflator was used to convert current to constant dollars.
 SOURCE: National Science Foundation.

- the *technology improvement and innovation* programs of the National Bureau of Standards. As a fraction of total R&D expenditures by the Federal Government, this area rose from 2.6 percent in 1963 to 4.4 percent in 1972.
- (3) **Transportation**, which consists of R&D in air, ground, and water transportation. *Air transportation* R&D (which accounted for 70 percent of Federal expenditures for all transportation R&D in 1972) includes NASA's aeronautical technology program, and the activities of this agency and the Department of Transportation in the areas of system safety and future generations of aeronautical vehicles. *Ground transportation* R&D is aimed largely at improved highway and automotive safety and at rapid transit systems. R&D in *water and multimodal transportation* includes programs of the U.S. Coast Guard, Maritime Administration, and others. Expenditures for transportation R&D, as a fraction of all Federal R&D expenditures, increased from 1.0 percent in 1963 to 3.8 percent in 1972.
- (4) **Environment**, which encompasses the *pollution control and abatement* programs of the Environmental Protection Agency and the environmental research programs of the Atomic Energy Commission; *resource development and management* which includes programs of the Forest Service, National Oceanic and Atmospheric Administration (NOAA); Office of Saline Water, and others; and *resource monitoring, measuring, and forecasting* consisting of the R&D activities of the Geological Survey and NOAA. As a fraction of total R&D expenditures by the Federal Government, R&D spending in this area increased from 1.5 percent in 1963 to 3.2 percent in 1972.
- (5) **Energy Conversion and Development**, which consists mainly of *development of nuclear energy capabilities* (85 percent of R&D expenditures) and the *development and utilization of non-nuclear energy resources*. Nuclear energy activities are concentrated on development of the liquid-metal fast breeder reactor; major efforts in the nonnuclear area—which are rising in both absolute and relative terms—center on coal gasification, oxide control technology, and advanced underground electric transmission lines. R&D expenditures in this area, as a proportion of all Federal R&D outlays, rose from 2.3 percent in 1963 to 2.5 percent in 1972.
- (6) **Agriculture**, includes R&D activities aimed at *increasing the quantity and improving the quality of agricultural products* and *expanding the utilization of agriculture resources*. The first category, which comprised more than 90 percent of total R&D expenditures throughout 1963-72, includes the efforts of the Agricultural Research Services and the Cooperative State Research Service of the Department of Agriculture; R&D in the second category includes activities of the Economic Research Service and the Farmer Cooperative Service. As a proportion of all Federal R&D expenditures, those in this area were 1.2 percent in 1963 and 1.8 percent in 1972.
- (7) **Economic Security**, which consists of *manpower resources development, reduction of poverty, and income maintenance*. R&D in this area is aimed primarily at improving the employability of individuals, promoting equality of opportunity, providing systems of income maintenance, and alleviating poverty. Expenditures for such R&D—provided primarily by the Department of Health, Education, and Welfare and the Office of Economic Opportunity—increased from 0.2 percent of total Federal R&D expenditures in 1963 to 1.0 percent in 1972.
- (8) **Education**, which consists of the R&D activities of the Office of Education, the National Institute of Education, and the Office of Child Development, all of the Department of Health, Education, and Welfare. R&D is spread among a wide range of efforts, including the development of improved curriculums and individualized instructional materials, better understanding of the learning process, and the motivation of disadvantaged children. The fraction of total Federal R&D expenditures for this area rose from 0.1 percent in 1963 to 0.8 percent in 1972.

RESOURCES FOR INDUSTRIAL R&D

Total expenditures for industrial R&D, which include expenditures of both government and private industry, are shown in figure 18. The separation of these two funding sources indi-

Figure 18
Industrial R&D Expenditures, 1961-72



cates that the decline in total R&D expenditures in 1970 was due entirely to reductions in the level of Federal support. Federal funding actually leveled off in 1966 while industrial support rose more rapidly than in previous years, with the result that industry replaced the Federal Government in 1968 as the principal source of support for industrial research. By 1972, industry funded 58 percent of all industrial R&D compared with 43 percent in 1961.

Although Federal funding for industrial R&D did not start its decline until after 1968, the effects of a relatively slow rate of growth in funding, compared with the increasing cost of R&D, were apparent as early as 1964 in terms of the source of support for R&D scientists and engineers (figure 19).⁴ The figure shows that the number of scientists and engineers supported by Federal funds started to decline after 1964, although the largest reductions did not occur until after 1969, which coincides with the onset of larger constant dollar funding reductions that are shown in figure 18.

These funding changes did not affect appreciably the relative distribution of funds among basic research, applied research, and development activities. In 1972 as in 1961, industrial R&D was concentrated in development (78 percent), while applied research received some 19 percent and basic research declined from 4 to 3 percent. (The absolute level of basic research, however, declined considerably as shown elsewhere in this report.)

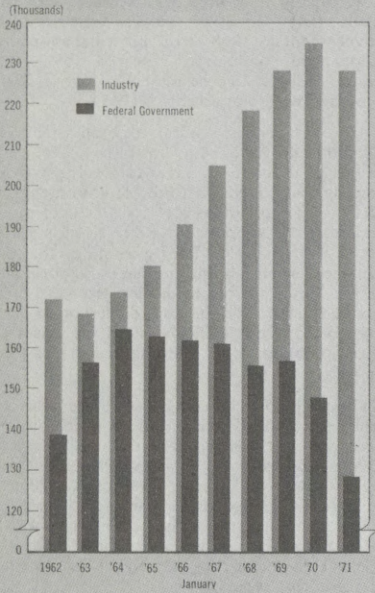
Despite these funding changes, industrial firms still perform the bulk of the Nation's R&D. In 1972, funding of industrial R&D accounted for 68 percent of all R&D conducted in the United States, including 83 percent of the development, 55 percent of the applied research, and 16 percent of the basic research.

Industry-Funded R&D

R&D in this category is performed largely in the seven industries indicated in figure 20. They accounted for about 85 percent of all company R&D expenditures during the period reported. Each of these industries, except for "aircraft and missiles" and "motor vehicles," had increasing R&D expenditures (in current dollars) through

⁴ Comparable data are not available for years prior to 1962.

Figure 19
Scientists and Engineers^(a) Engaged in
Industrial R&D, by Source of Funds, 1962-71

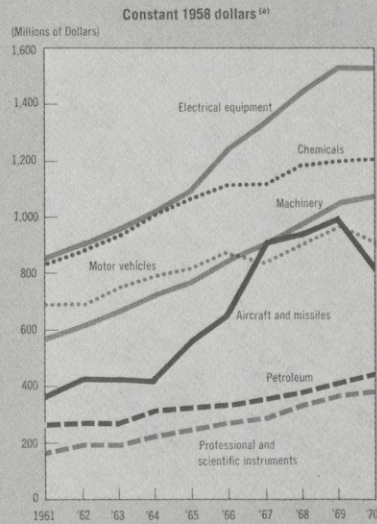
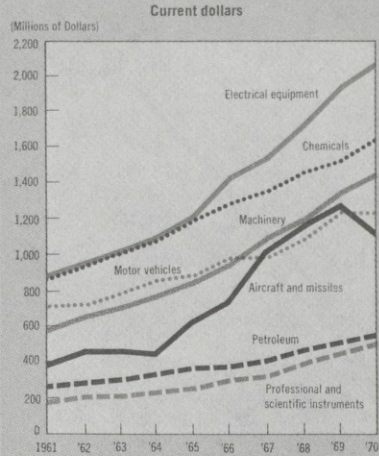


SOURCE: National Science Foundation.

1970 (the latest year for which such data are available). In terms of constant dollars, however, only the petroleum, machinery, and professional and scientific instruments industries indicated increases in 1970.

Industry-funded R&D in 1972 was concentrated in development activities which received 73 percent of the total funds as compared with 22 percent for applied research and 4 percent for basic research. This composition changed continuously over the decade toward more development (from 68 to 73 percent), less applied research (from 25 to 22 percent), and less basic research (from 7 to 4 percent). These long-term shifts do not appear to have been accelerated by recent funding changes.

Figure 20
Industry's Own Funds for R&D,
by Selected Industry, 1961-70



(a) GNP price deflator was used to convert current to constant dollars.

SOURCE: National Science Foundation.

Company-funded R&D is projected to increase by about 25 percent between 1972 and 1975, rising to some \$14 billion, and the number of scientists and engineers employed in such R&D is anticipated to increase to 260,000 in 1975.⁵ Individual industries show some variations from these projected trends. The drug industry (a part of the larger chemical industry) anticipates increases in R&D spending which are larger than the all-industry average; electronic firms expect increases in line with the rest of industry; companies in industrial chemicals and aerospace foresee future R&D growth at a pace somewhat below the rest of industry; and petroleum firms expect only a slight increase in total R&D spending over the next few years.

Federally Funded R&D

The Federal Government funds R&D principally for defense and space purposes. In 1970, for example, all but 14 percent of the Federal funds for industrial R&D came from the Department of Defense and NASA. The funds from Federal agencies are directed to a small number of industries, with more than 90 percent of the funds going to five industries: aircraft and missiles; electrical equipment and communication; machinery; motor vehicles and other transportation equipment; and professional and scientific instruments. Some 80 percent of all Federal expenditures for R&D in industry go to the first two industries.⁶

Federal funds are concentrated in development activities, more so than are the funds supplied by industry. On the average throughout the 1961-72 period, development received about 85 percent of the total funds, applied research 12-14 percent, and basic research 2 percent. The funding reductions noted above had the greatest absolute effects on development activities, expenditures for which peaked in 1966 and subsequently declined 25 percent in constant dollars between then and 1972. (Estimated current dollar expenditures indicate a small increase in 1972.) Similarly, the 1972 funding level for applied research declined by 18 percent after its peak funding year of 1962. But propor-

tionally, basic research was even more adversely affected; the 1972 funding level was down by 40 percent since 1967, the year of its maximum funding.

R&D FUNDING BY UNIVERSITIES AND COLLEGES

These institutions together with other non-profit organizations provide the remaining 5 percent of total national expenditures for R&D, with the universities accounting for 4 percent. University expenditures are concentrated in research, with basic research accounting for 78 percent of expenditures and applied research 20 percent in 1972. This pattern of funding distribution persisted with only minor changes throughout the 1961-72 period.⁷

Research expenditures reported by universities and colleges come from various non-Federal sources, including State governments, industries, and foundations as well as from university funds. In 1970 the separately budgeted research expenditures from non-Federal sources were distributed among major fields of science as follows:

	Percent
Life Sciences	47
Social Sciences	16
Engineering	12
Physical Sciences	9
Mathematics	5
Environmental Sciences	4
Psychology	3

There was little change in this distribution over the 1964-70 period for which data are available. (Academic research is treated more extensively elsewhere in this report.)

⁵ Projections are based on a National Science Foundation survey in 1972 of 50 of the largest corporations in the United States.

⁶ National Science Foundation, *Research and Development in Industry* 1970, NSF 72-309.

⁷ National Science Foundation, *National Patterns of R&D Resources* 1953-72, NSF 72-300.

Basic Research

Indicators of the state of basic research presented in this chapter are confined largely to the resources expended for such activity. These include indicators of the national expenditures for fundamental research; levels of basic research in universities and colleges, Federal laboratories, and industry; and trends in expenditures among scientific disciplines.

Input measures such as these provide only an indication of the level of basic research activity, not its effectiveness or productivity. A research effort, moreover, may be regarded as either basic or applied, depending upon whether the perspective of the sponsor of the research or that of the organization performing it is taken as the point of reference. Additional uncertainties are presented by differing treatments of costs associated with basic research. For example, the construction costs of large government-financed research facilities such as the National Accelerator Laboratory are not included as basic research expenditures, whereas NASA space probes include the costs of spacecraft and launch vehicles. To compound the difficulty of comparability, industrial firms include in their reported expenditures for basic research an annual depreciation cost of the facilities involved, whereas Federal laboratories do not include such costs.

INDICATOR HIGHLIGHTS

- Basic research expenditures, in current dollars, rose continually during the period 1960-72, although the rate of growth slowed after 1968; in constant 1958 dollars, basic research spending in 1972 was approximately equal to the 1967 level, and some 6 percent lower than the peak year of 1968.
- The 1968-72 decline in constant 1958 dollar expenditures for basic research was least in universities and colleges (3 percent) and largest in industry (14 percent).
- The share of total basic research expenditures used by the different sectors changed significantly between 1960-72; the universities' share increased from 43 to 57 percent, while industry's share fell from 28 to 16 percent.
- The Federal Government provided 62 percent of the total 1972 funds for basic research in the United States, as compared with 52 percent in 1960; basic research funds provided by universities and colleges rose from some 16 percent of the total in the early and mid-1960's to approximately 20 percent in 1972.
- Basic research funds (in current dollars) provided by the Federal Government increased rapidly between 1960-68 but slowed to small annual increments thereafter; in constant 1958 dollars, however, a 10-percent decline in funding occurred between 1968-72, which included a 16-percent reduction in basic research funds to industry, a 10-percent reduction to universities and colleges, and a 7-percent decline for nonprofit institutions.
- Total expenditures (Federal and non-Federal) for basic research in universities and colleges increased in current dollars between 1968-72 for 8 of 10 major fields.¹ In constant 1961 dollars, expenditures increased for the biological sciences, clinical medicine, social sciences, and psychology and decreased for astronomy, physics, chemistry, and engineering.
- Federal funds (in current dollars) for basic research in universities and colleges increased between 1968-72 for all fields except astronomy and physics; in constant 1961 dollars, funds declined from the 1968 level in all fields except the environmental sciences and psychology.

¹ The scientific fields included were astronomy, biological sciences, chemistry, clinical medicine, engineering, environmental sciences, mathematical and computer sciences, physics, psychology, and the social sciences.

- Total funds for basic and applied research per scientist and engineer in Ph.D.-granting institutions declined 15 percent between 1968-72 in constant 1961 dollars, as a result of reduced Federal expenditures and continued growth of faculty; research funds per scientist and engineer decreased in all fields except the social sciences, with the largest declines occurring in physics (32 percent), clinical medicine (21 percent), and engineering (17 percent).
- The proportion of Ph.D. scientists in universities and colleges engaged in basic research supported by the Federal Government declined from 69 percent in 1964 and 1966 to 57 percent in 1970.
- Federal support for young investigators (those holding a Ph.D. less than seven years) in universities and colleges declined to a greater extent than support for senior investigators; the proportion of young investigators supported fell from 65 percent in 1964 to 50 percent in 1970, versus 73 percent to 63 percent for senior investigators.
- Government expenditures for basic research in Federal laboratories declined by almost 20 percent in constant 1961 dollars between 1970-72, with the largest reductions occurring in laboratories funded by the National Aeronautics and Space Administration and the Department of Health, Education, and Welfare.
- Current dollar expenditures for industry-funded basic research, which accounts for only a small fraction of all such research, increased until 1966 and remained at nearly that level until 1972 when they again increased; in 1958 constant dollars, however, expenditures declined by some 17 percent between 1966-72.
- Basic research in industry is concentrated in the fields of chemistry and engineering, followed by physics and the life sciences. Recent declines in constant 1958 dollar expenditures for basic research were largest in the areas of physics and chemistry.

■ Basic research is that portion of the total R&D effort whose primary aim is extending the fundamental understanding of man and nature. The strategy of basic research is determined primarily by the structure of science itself which indicates opportunities and possible directions for advancing knowledge. Although potential applications often underlie and ultimately justify support for basic research, such research must emanate from the conceptual structure of science itself.

While the relationships between basic research and eventual applications are often complex and may involve a considerable time interval for realization, there is no doubt that modern technology is increasingly dependent upon the fundamental knowledge base. Basic science, moreover, provides a pool of knowledge and understanding which helps in determining the most efficient strategy for applied research and development, and also serves as a source of ideas for new applications and for attacking social problems as well. The contributions of basic research to the quality and variety of our lives are innumerable, and include:

- **Genetics**, which advanced the development of hybrid grains, stock breeding, vaccines, and medical diagnostic techniques;
- **Chemistry**, which produced polyester fibers, pharmaceuticals, petroleum refining, and pesticides;
- **Physics**, which led to the development of nuclear power generation, transistors, and radioisotope tracers;
- **Electronics**, which developed radar, magnetic tape recording, heart pacemakers, and biomedical recording techniques;
- **Mathematics**, which helped in the development of computers, multivariate analysis techniques, systems analysis, and simulation models; and
- **Social Sciences**, which devised polling and survey methods, national income and product accounting, cost-benefit analysis, aptitude testing, and economic input-output models.

Finally, basic research is an essential part of education. It is not only an integral element of advanced education in the sciences and engineering but its findings constitute the objective knowledge of the physical and social world which is part of the education of the population as a whole.

Whether for educational and cultural purposes, for technological and social reasons, or for the sheer intellectual understanding basic research provides, the health and vitality of such research is a matter of national significance.

RESOURCES FOR BASIC RESEARCH

Expenditures by Performer

Expenditures for the support of basic research are used here as an indicator of the level of this activity. Figure 21 shows total expenditures, by year, for basic research in the United States and the portions of the total performed by the various sectors of the research community. In terms of current dollars, expenditures increased progressively during the 1960-72 period, although the rate of increase slowed after 1968.

Instead of the continuous rise in basic research expenditures depicted by the current dollar curve, expenditures expressed in constant dollars peaked in 1968 and declined almost continuously thereafter (figure 21). The net result is that 1972 expenditures were almost equivalent (in constant dollars) to the 1967 level and some 6 percent smaller than the peak year of 1968.

The small growth in current dollar expenditures after 1968 was not sufficient to offset the effects of inflation, in any of the five sectors. The 1968-72 decline in constant dollar expenditures for basic research was largest in industry (14 percent) and smallest in universities and colleges (3 percent).

The share of the total basic research expenditures used by the different sectors changed significantly between 1960-72. The universities increased their share from 43 to 57 percent, while industry's share fell from 28 to 16 percent and that of the nonprofit institutions declined from 9 to 6 percent. The share of the Federal in-house programs rose from 12 percent in 1960 to 14 percent in 1972, whereas the Federally Funded Research and Development Centers'

(FFRDC) share remained approximately constant at about 7 percent.

Expenditures by Sources

It should be noted that for three of the sectors reported—the Federal Government, universities and colleges, and other nonprofit institutions—the definition of basic research stresses that it is directed toward increases of knowledge in science with "... the primary aim of the investigator being ... a fuller knowledge or understanding of the subject under study, rather than a practical application thereof."² For the industrial sector, in order to take account of an individual industrial company's commercial goals, the definition is modified to indicate that basic research projects represent "original investigations for the advancement of scientific knowledge—which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company."²

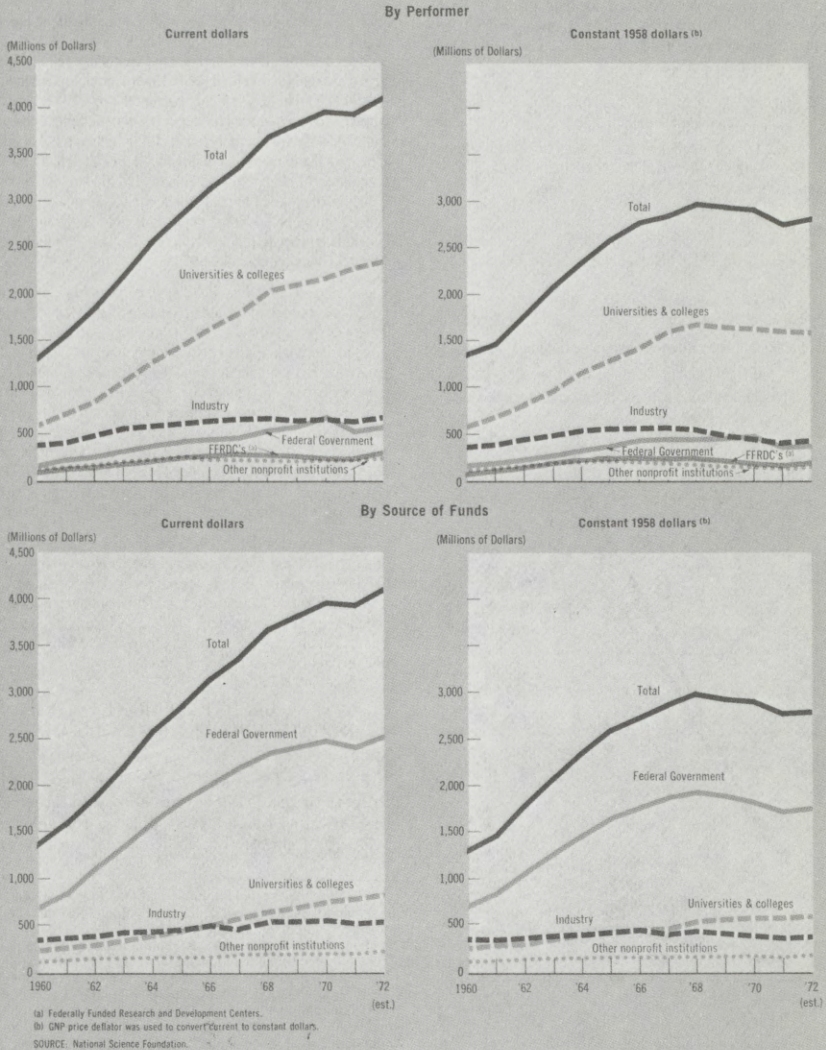
Using these definitions, the total funds for basic research supplied by these sectors are shown for the period 1960-72 in current and in constant dollars in figure 21. It can be seen that the Federal funds increased rapidly during the 1960-68 period, but then slowed to small annual increases, which convert to decreases in constant dollars.

As calculated from these data, the Federal Government provided 62 percent of the total funds for all U.S. basic research conducted in 1972; this proportion has changed little since the mid-60's after rising from a level of 52 percent in 1960. Basic research funds provided by universities and colleges rose from some 16 percent of the total in the early and mid-1960's to approximately 20 percent in 1972 (figure 21). The largest proportional change occurred in industry-funded basic research, the share for which declined steadily from a high of 25 percent in 1960 to only 13 percent in 1972.

Federal Expenditures. Basic research expenditures by the Federal Government are shown in figure 22 for the five performing sectors. Federal support of basic research in universities de-

² National Science Foundation, *National Patterns of R&D Resources 1953-72*, (NSF 72-300).

Figure 21
Basic Research Expenditures, 1960-72



clined by some 10 percent, in constant dollars, for the period 1968-72, while Federal support of its own basic research decreased 6 percent in the same period. Also affected in this period were industry and nonprofit institutions where the reductions in Federal funds were 16 percent and 7 percent, respectively.

Six agencies of the Government supply almost 95 percent of all Federal funds for basic research (figure 23). About 50 percent is provided by two of them—the National Aeronautics and Space Administration (NASA) (31 percent) and the

Department of Health, Education, and Welfare (HEW) (20 percent). The proportion of total Federal funds for basic research provided by each of the several agencies during the 1960-72 period changed significantly. Chief among these were (a) the growth of NASA's share from 16 percent in 1960 to 31 percent in 1972; (b) the decline of the share of the Defense Department (DOD) from 28 to 11 percent—a shift which occurred concurrently with the growth of NASA's share; and (c) the decline in the Atomic Energy Commission's (AEC) share from 17 to 11 percent. The 1967 decline in basic research obligations for DOD and AEC appear to account largely for the reduced rate of growth in overall Federal expenditures for basic research which occurred in 1968.

As noted earlier, NASA provides more funds for basic research than any other Federal agency. The entire activities of that agency, however, are considered as either R&D or support of R&D (outlays for construction of facilities). The latter now comprises less than 2 percent of total outlays, and has never exceeded 14 percent. NASA's obligations for basic research (as well as for applied research and development) include the related costs of spacecraft, launch vehicles, tracking and data acquisition, and the pro rata costs of ground operations and administration.

The estimated FY 1973 Federal obligations (in current dollars) for basic research indicate an increase of almost 9 percent over the obligation level of FY 1972, which in turn represented a 12-percent increase over FY 1971.³ The increase in basic research expenditures in FY 1973 is expected to be less than obligations.

BASIC RESEARCH IN UNIVERSITIES AND COLLEGES

Estimated expenditures for basic research in universities and colleges are shown in figure 24 in both current and 1961 dollars, for selected scientific fields.⁴ (Expenditure data for years

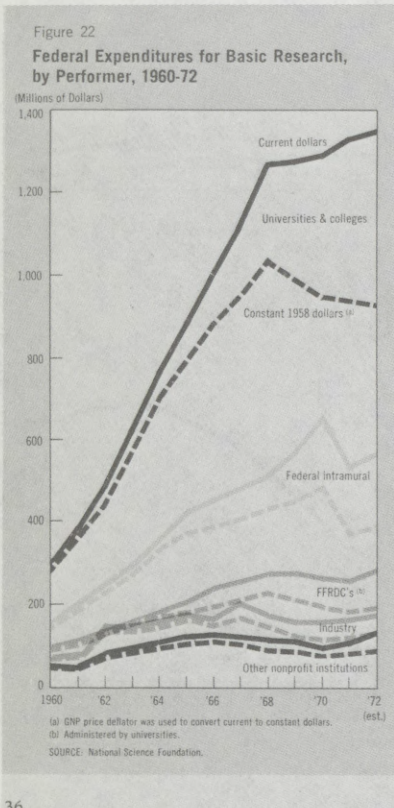
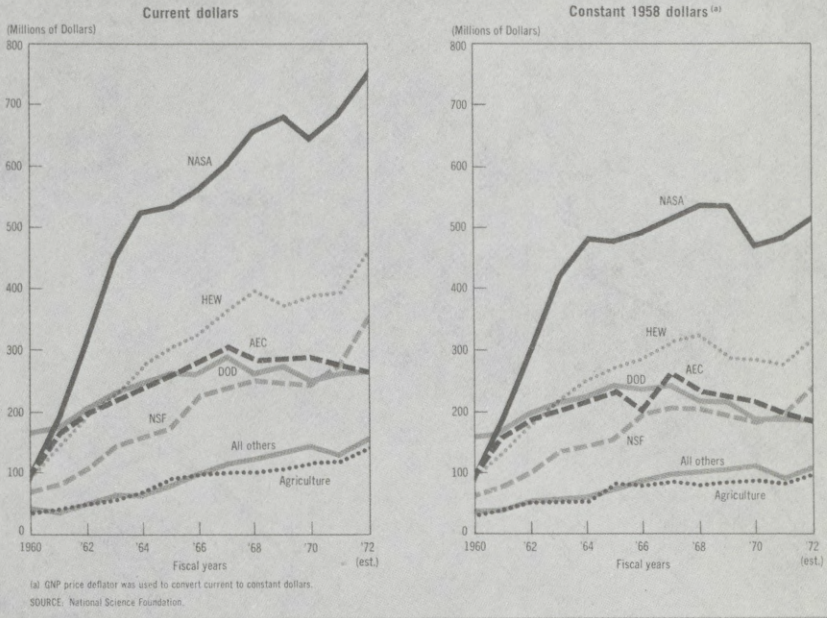


Figure 23

Federal Obligations for Basic Research,
by Supporting Agency, FY 1960-72

prior to 1964 are not available.) The 10 fields represented in figure 24 form three groupings in respect to the relative growth of expenditures between 1964-72: fields recording the largest growth were the social sciences, environmental sciences, and psychology; fields with an intermediate level of growth were biological sciences, mathematical and computer sciences, engineering, and clinical medicine; and those with the smallest growth were chemistry, astronomy, and physics.

Current dollar expenditures for all fields—except mathematical and computer sciences—increased from 1970 to 1972. In constant 1961

dollars, however, expenditures for 1972 declined or remained essentially unchanged from their 1970 level in physics, chemistry, astronomy, and engineering as well as in the mathematical and computer sciences. The declines were due principally to reductions in Federal expenditures for basic research, as shown in figure 25. Current dollar expenditures by the Federal Government increased between 1970-72 for all fields except physics and the mathematical and computer sciences. In terms of constant dollars, however, 1972 Federal expenditures were lower than 1970 expenditures in 6 of the 10 fields, with the largest reduc-

Figure 24
**Estimated Expenditures for Basic Research in
 Universities and Colleges, by Field of Science, 1964-72**

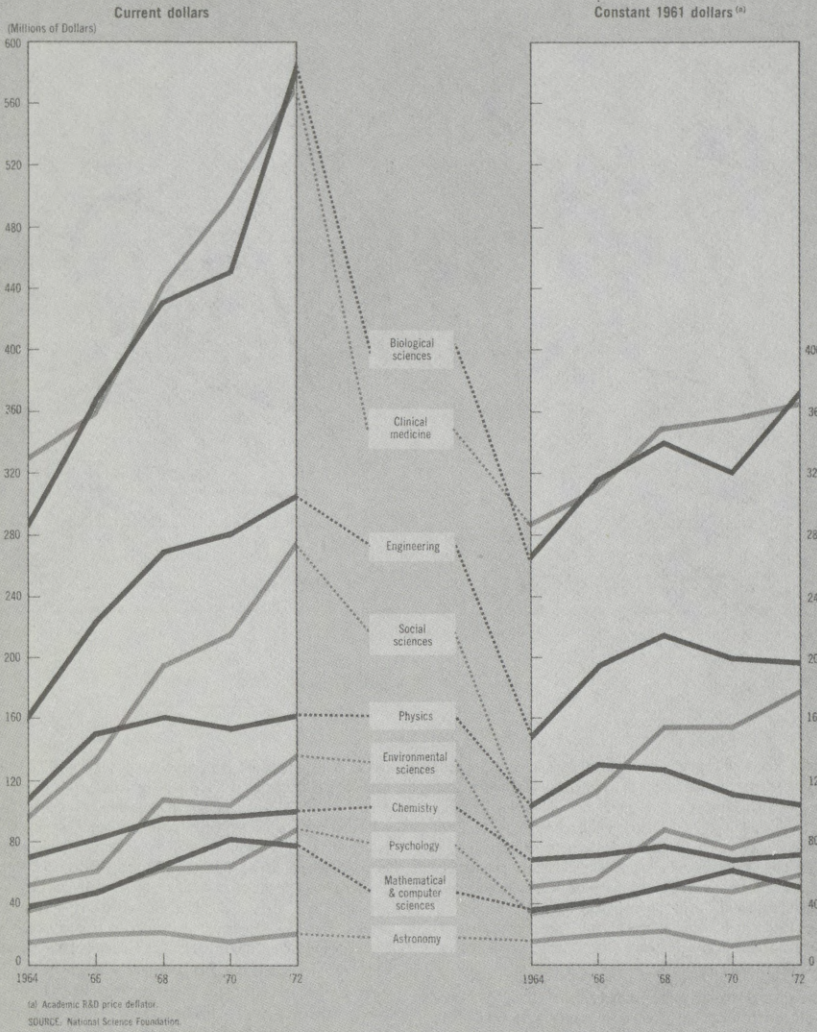
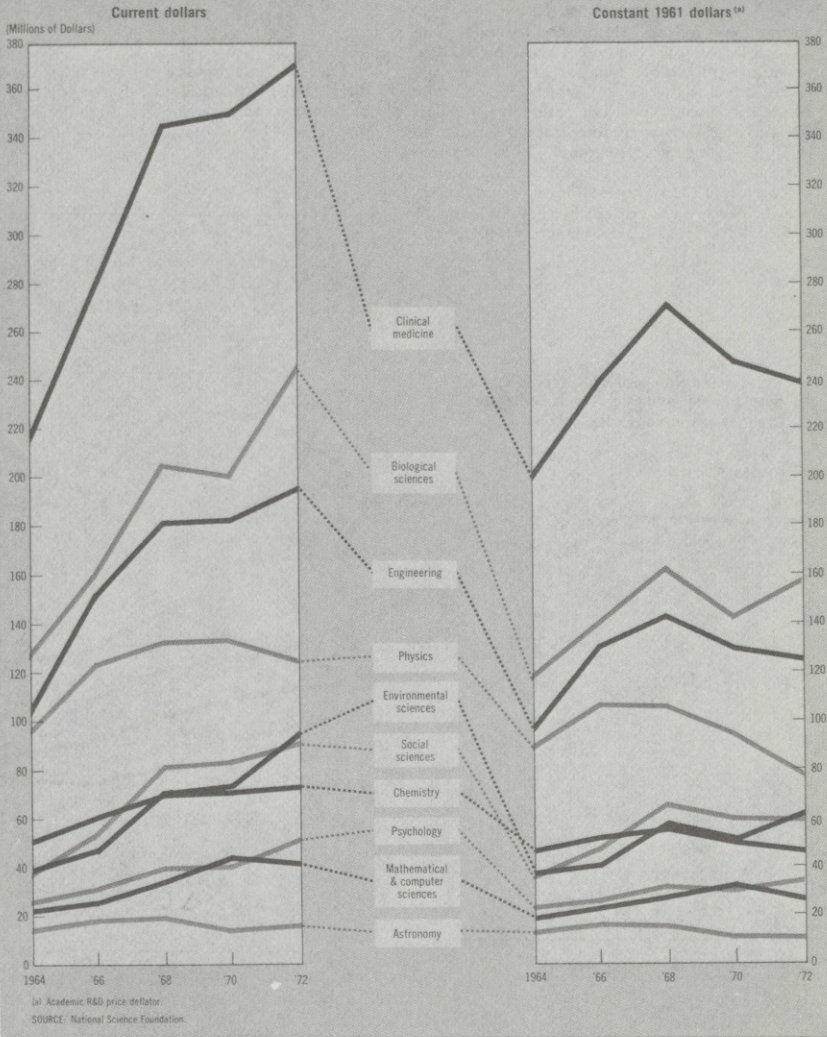


Figure 25

**Estimated Federal Expenditures for Basic Research
in Universities and Colleges, by Field of Science, 1964-72**

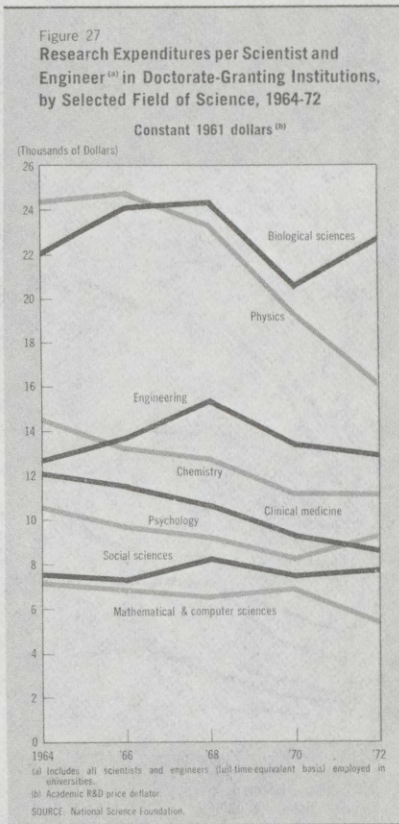
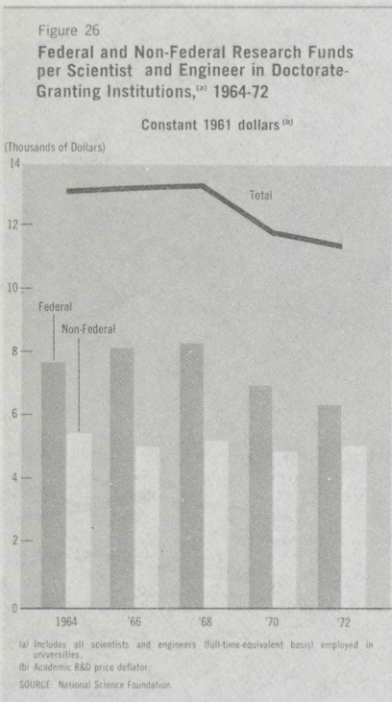


tion (16 percent) occurring in physics. Federal funding for the latter field decreased by some 25 percent between 1968-72.

In view of the declining research expenditures coupled with increased costs of performing research and a larger faculty body, some change in the involvement of academic staff in research is inevitable. One aspect of this change is indicated in figure 26, which presents the funds for applied and basic research per scientist and engineer (excluding graduate students) in Ph.D.-granting institutions. (These institutions accounted for 96 percent of all academic research in 1972.) The 1972 level of such funds was 15 percent lower than in 1968, in terms of 1961 dollars. This reduction is attributable to the

declining level of Federal funding between 1968-72, coupled with the increasing number of scientists and engineers in these institutions; Federal research funds per scientist and engineer declined by 24 percent during the 1968-72 period, in contrast to the relatively unchanged level of support from non-Federal sources.

The individual fields were affected somewhat differently by the combined changes in the levels of funding and scientific and engineering manpower, as shown in figure 27. (The fields of



astronomy and environmental sciences are not included because of the lack of acceptably reliable data.⁵ Although the overall trend is a reduction in the level of research support per scientist and engineer, the funds for some fields declined much more than others. Research funds per physicist, for example, declined by 35 percent between 1966-72, while funds per social scientist changed little even though the number of such scientists increased rapidly.

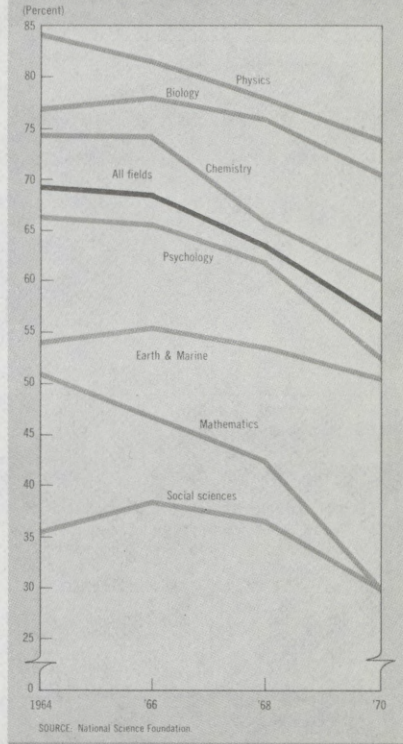
The number of scientists and engineers engaged in research and development (on a full-time-equivalent basis) declined slightly between 1969 and 1971. This may represent a reduction in the average time devoted to R&D by the staff as a whole and/or a reduction in the number of staff engaged in any R&D at all. The available data are not sufficient to resolve this ambiguity. Moreover, it is generally difficult to accurately separate the time devoted to research from other academic activities.

The proportion of the Ph.D. science staff in these institutions receiving Federal support and engaged in basic research is shown in figure 28 for several scientific fields.⁶ The figure indicates that the proportion of Ph.D. academic staff who were wholly or in part supported by the Federal Government and devoted some portion of their time to basic research⁷ was 57 percent in 1970, down from 69 percent in 1964 and 1966. The largest decreases were in mathematics, chemistry, psychology, and physics.

Research support for young investigators⁸ is of particular interest as an indicator, since the progress and quality of future research and innovation depend increasingly on individuals from this group. Federal support for young

Figure 28

Proportion of Ph.D. Academic Staff in Science Receiving Federal Support and Engaged in Basic Research, by Field, 1964-70



⁵ It should be noted that the considerable variation in the level of funding among fields reflects, among other factors, differences in the cost of research associated with each field; some fields, for example, require extensive equipment for research while others require little.

⁶ Included are Ph.D.'s employed by academic institutions who indicated that basic research was their first or second work activity. In 1970, these persons accounted for about 75 percent of all academic Ph.D.'s.

⁷ These data are based on responses to the National Register of Scientific and Technical Personnel for the years 1964, 1966, 1968, and 1970. It is estimated that the responses account for approximately 80 percent of the Ph.D. scientists employed by universities and colleges.

⁸ Defined as those employed by colleges and universities who have held the Ph.D. less than seven years and who reported their primary or secondary work activity as basic research.

investigators engaged in basic research decreased in recent years, falling from 64 percent in 1964 to 50 percent in 1970 (figure 29). While the proportion of senior investigators receiving such support also declined, the reduction was not so large as for the young investigators. Moreover, proportionally fewer young researchers obtained Federal support in certain fields (as indicated in figure 30), especially in mathematics, social sciences, and psychology, where the ratio of young to senior basic re-

Figure 29
Proportion of Young and Senior Ph.D. Academic Staff in Science Receiving Federal Support and Engaged in Basic Research, 1964-70

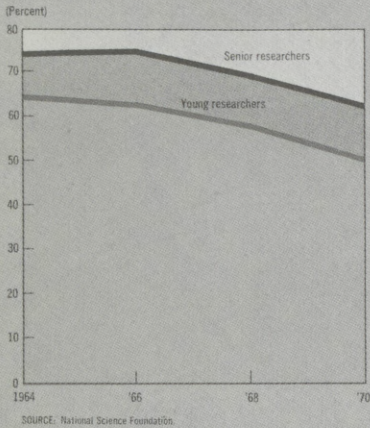
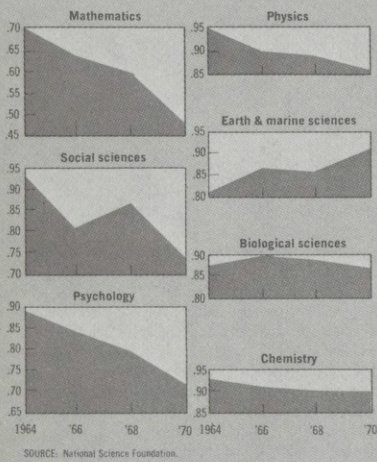


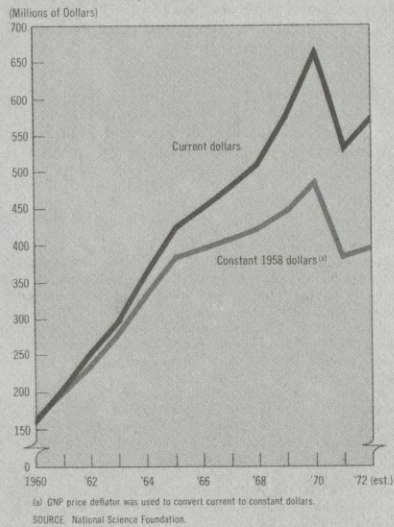
Figure 30
Ratio of Young to Senior Ph.D. Academic Staff Receiving Federal Support and Engaged in Basic Research, by Field, 1964-70



searchers declined between 28 and 18 percent. In other fields, the decline was less than 10 percent.

Research at universities cannot be characterized completely by the parameters discussed so far, namely, manpower and funds. The state of basic research in universities must also be related to the health of the institutions themselves. This is especially significant since the universities have traditionally shared the cost of research in their laboratories. The symbiosis between universities and basic research makes the overall financial situation of the universities a cause for concern in assessing the state of science, especially its future prospects. While research support will not by itself solve the financial problems of universities, its decline has contributed to their difficulties, in that research grants often carry a number of continuing university costs of a long-term nature, such as building maintenance, administration, and a portion of long-term salary commitments to faculty.

Figure 31
Federal Expenditures for Intramural Basic Science, 1960-72

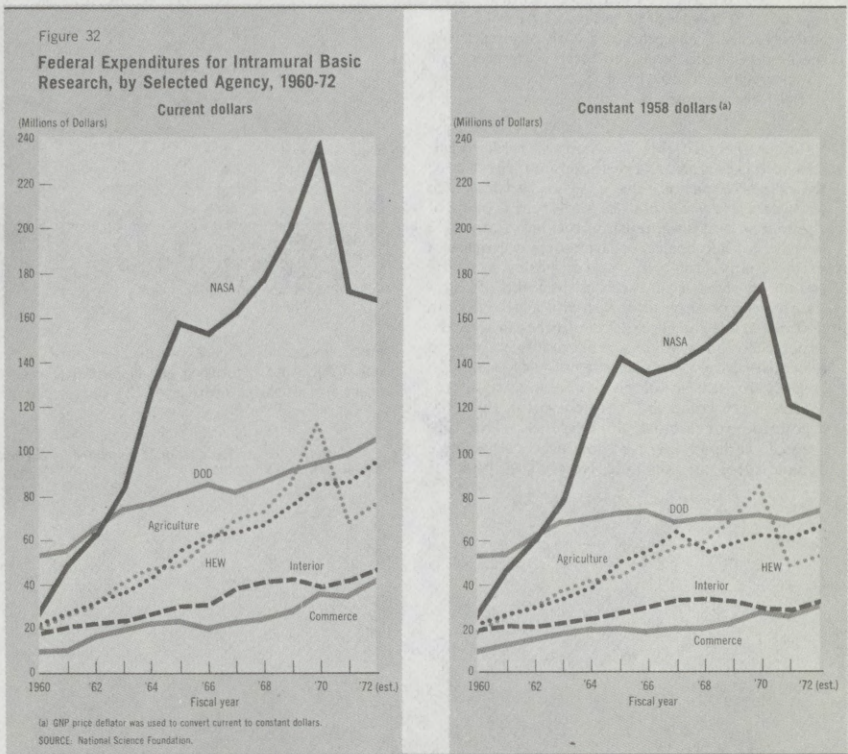


BASIC RESEARCH IN FEDERAL LABORATORIES

Total Federal expenditures for in-house basic research increased over the 1960-72 period in terms of both current (259 percent) and constant (154 percent) dollars (figure 31). However, during the 1970-72 period, expenditures decreased by 13 percent in terms of current dollars and by 19 percent when expressed in constant 1958 dollars. The declines occurred principally in laboratories funded by the National Aeronautics and Space Administration (NASA) and the Department of Health, Education, and Welfare (HEW). In 1972, the in-house basic research effort represented 23 percent of all

Federal expenditures for basic research. Similarly, it accounted for 14 percent of the total expenditures for basic research in 1972, compared with 12 percent in 1960.

Data are not available for segregating the activities by field of science, but obligation data are presented in figure 32 for the Federal agencies which support the bulk of in-house basic research. In 1972, the total Federal obligations for in-house R&D were divided among the agencies as follows: NASA (29 percent), Department of Defense (18 percent), Agriculture (17 percent), HEW (13 percent), Interior (8 percent), and Commerce (7 percent).



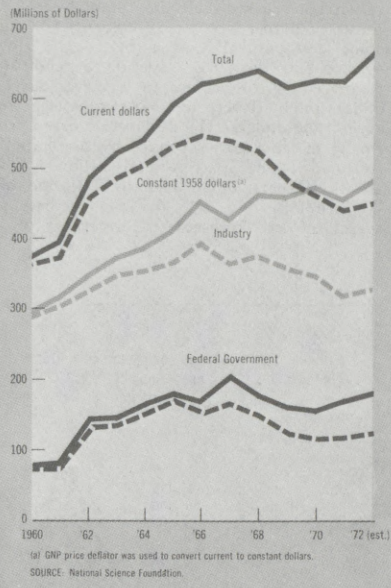
BASIC RESEARCH IN INDUSTRY

Expenditures for basic research in industry are shown in figure 33. In current dollars, total basic research expenditures increased by 3 percent over the period 1968-72; in constant 1958 dollars, the decline in overall funding was 14 percent between 1968-72, which included a 16-percent reduction in Federal funding and a 13-percent decline in industrial support.

Some 75 percent of all industrial basic research was performed by four industries in 1970: chemicals and allied products (36 percent); electrical equipment and communication (24 percent); aircraft and missiles (10 percent); and petroleum refining and extraction (5 percent).⁹ There is considerable difference among these industries in the percentage of total R&D which is devoted to basic research. The chemical industry in 1970 devoted 12 percent of its R&D to basic research, as compared with 3 percent for the electrical equipment industry, 4 percent for the petroleum industry, and 1 percent for the aircraft and missiles industry.

The principal fields of science in which basic research is performed are shown in figure 34 for the 1967-70 period, the only years for which such data are available. As shown, the fields of chemistry and engineering receive almost 65 percent of all basic research expenditures. A major change over the 4-year period was the reduction of basic research in the fields of physics and astronomy; although the available data do not permit the separation of these two fields, expenditures for physics presumably accounted for most of the joint activities of these fields. In respect to the industries involved, basic research performed by the chemical industry accounted for almost 80 percent of the life science and 46 percent of physical science expenditures of all industries. The bulk of

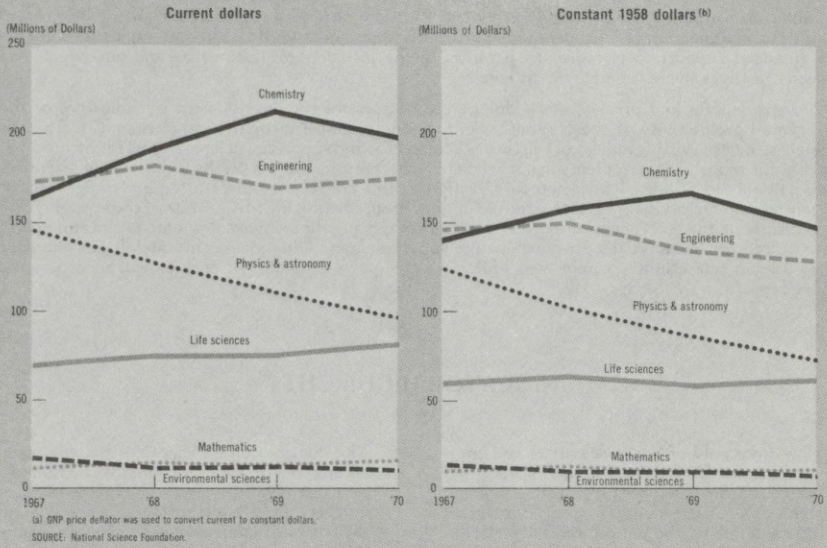
Figure 33
Industrial Basic Research Expenditures,
by Source, 1960-72



engineering research expenditures were by electrical equipment industries (41 percent) and aircraft and missiles industries (21 percent).

⁹ National Science Foundation, *Research and Development in Industry, 1970*, NSF 72-309.

Figure 34
Industrial Basic Research Expenditures,
by Field of Science, 1967-70^(a)



Science and Engineering Personnel

Indicators in this section chart the growth of the national pool of scientists and engineers; present trends in the utilization of such personnel; provide data on undergraduate and graduate enrollments and financial support; depict growth patterns in the production of scientists and engineers; and measure changes in their employment level.

Available data and present methodology did not permit the development of indicators of the quality and productivity of the Nation's scientists and engineers. For the same reasons, it was not possible to devise reliable indices of the future demand for and supply of such personnel for inclusion in the present report. Improvements in both data (e.g., better information on the utilization of scientists and engineers in non-academic, non-R&D activities and the role of immigration and emigration of personnel) and methodology (e.g., better techniques for predicting the future state of the economy and for anticipating the emergence of national problems requiring the services of scientists and engineers) are required for more reliable forecasts of the supply-demand situation. As methodologies and data series used in projections are improved, indicators of supply-demand relationships will be included in future reports of this series.

INDICATOR HIGHLIGHTS

- The total pool of active scientists and engineers in the United States grew by about 50 percent from 1960 to 1971, rising to some 1,750,000. The number with doctorates doubled during the period, reaching 10 percent of the total.
- Scientists and engineers comprised an increasingly larger proportion of total civilian employment over the last two decades, although the extent of the increase in the 1960's (167 to 210 per 10,000 workers) was less than that during the 1950's (93 to 167 per 10,000 workers).
- The proportion of natural scientists and engineers engaged in R&D increased to 37 percent between 1960-64, but declined steadily thereafter. This downward trend was more pronounced among academic than industrial scientists and engineers, and reflects the growth in faculty needed for teaching, as well as the leveling off of R&D funds.
- Between 1968 and 1970 the number of natural scientists and engineers in industrial R&D declined to the 1967 level, the first such decline during the 1960's.
- The distribution of scientists and engineers among major types of employers changed between 1960-70, with the proportion in industry declining from 74 to 66 percent and the fraction in universities and colleges rising from 11 to 18 percent.
- Total enrollments in high school courses of social sciences, natural sciences, and mathematics grew faster than total secondary enrollments between 1960-70, with the largest increases occurring in psychology and economics and the smallest in physics, chemistry, and mathematics. Physics was the only field in which the proportional growth was less than the increase in total enrollments.
- The number of undergraduate students at the junior-year level who declared majors in physics, engineering, and chemistry declined between 1970-71, whereas the number declaring majors in the applied social sciences and professional life sciences increased significantly.
- Graduate enrollments (full-time and part-time combined) in science doctorate departments declined by almost 4 percent between 1969 and 1971, the first such absolute de-

crease in the 1960's. Such enrollments in science and engineering, as a percent of total graduate enrollments, declined steadily from 38 percent in 1963 to 31 percent in 1970.

- The number of full-time graduate students in science and engineering receiving Federal support declined by 15 percent between 1969-71, while those depending on self-support increased by 19 percent from a lower base.
- Annual awards of bachelor's level degrees in science and engineering increased by a factor of 2.2 over the 1959-71 period, with the largest gains in the social sciences (4.1 times) and the smallest in the physical sciences (1.3) and engineering (1.2). First degrees in science and engineering, as a fraction of all bachelor's level degrees, remained essentially constant at 30 percent, due in large part to the rapid growth of social science degrees.
- Annual awards of master's degrees in science and engineering rose by a factor of 2.5 over the 1959-71 period, with the largest gains in mathematical sciences (3.8) and social sciences (3.1) and the smallest in the physical sciences (1.9). Science and engineering master's degrees, as a fraction of all master's degrees, declined from a high of 30 percent to

22 percent in 1970-71, with the largest proportional declines occurring in engineering and the physical sciences.

- Annual awards of Ph.D. degrees in science and engineering rose by a factor of 3.0 over the 1959-71 period, with the largest gains in engineering (4.6) and mathematical sciences (4.4) and the smallest in the physical sciences (2.4). Science and engineering Ph.D. degrees, as a fraction of all Ph.D. degrees, declined from 62 percent in the mid-1960's to 58 percent in 1970-71, with the largest proportional declines in the physical sciences.
- During the last decade, awards of science and engineering doctorates, in terms of location of high school graduation, became more evenly distributed among geographic regions of the United States. The proportion, however, is almost 50 percent lower in the South Atlantic and East South Central regions than in other areas of the country.
- Unemployment rates for scientists and engineers rose after 1969, reaching 2.6 and 2.9 percent, respectively, by early 1971. These rates—which were less than half those reported for all workers—declined to early 1970 levels by late 1972.

■ Substantial changes in the demand for scientists and engineers, which may be produced by factors such as a redirection in Federal funding or the state of the national economy, may occur over periods of from two or three years. But because scientists and engineers require training extending over several years, serious imbalances of supply and demand, inadequacies of training, maldistributions among areas of competence, and similar problems may be corrected only over a longer five- to ten-year span. Therefore, the extended time and high cost involved in producing scientists and engineers require that careful, continuous attention be given to the nature, quality, and applicability of their professional training.

CURRENT POOL OF SCIENTISTS AND ENGINEERS¹

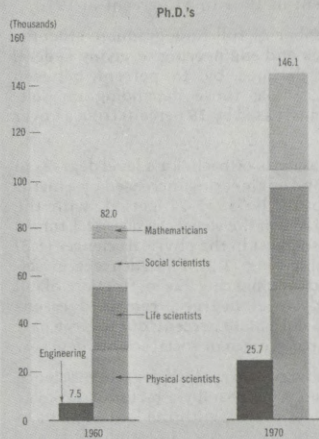
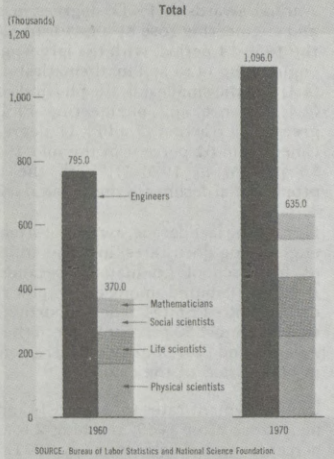
Magnitude

The total pool of active scientists and engineers in the United States grew by some 50 per-

cent between 1960 and 1970, rising from about 1,170,000 to more than 1,700,000 (figure 35). (It is estimated that by 1971 this number had further increased to about 1,750,000.) This rapid growth was due to an increase in science and engineering degree holders and to the "upgrading" of nondegree personnel, principally engineers. From 1960 to 1970 scientists and engineers with doctoral degrees increased from 90,000 to over 170,000. The number of engineering doctorates tripled during this period, while science doctorates increased by about 75 percent. As a result, the percentage of scientists with doctoral degrees remained almost constant during the past decade, while the percent-

¹ Information on the current numbers, types of employer, employment activities, etc., of scientists and engineers must be assembled from numerous data sources. Since not all of these are updated annually, it is possible to develop the latest complete picture only for 1970, even though many pieces of this mosaic are already available for 1971. Unless otherwise specified, scientists and engineers include the natural scientists (including mathematicians), social scientists, and engineers.

Figure 35
Distribution of Scientists and Engineers,
by Broad Field, 1960 and 1970



age of engineers with doctorates doubled—from a low base of less than one percent. In absolute terms more than four times as many science (90,000) as engineering (22,000) doctorates were awarded during this period. Thus, science doctorates as a percentage of all scientists continued to be a much larger ratio than engineering doctorates as a percentage of all engineers. All told, more than 185,000 scientists and engineers with doctorates were working in the United States by 1971.

Another measure of growth is the ratio of the number of natural scientists and engineers to total civilian employment (figure 36). This ratio increased from 93 per 10,000 working adults in 1950 to 167 in 1960 and then to 210 in 1970. Thus, the extent of the growth was greater in the 1950's than in the 1960's.

R&D and Non-R&D Activities

The relative changes during the last decade in the numbers of natural scientists and engineers engaged in R&D—as well as in the percentages of all natural scientists and engineers in R&D—have been substantial (figure 37). In

Figure 36
Natural Scientists and Engineers in Relation
to Total Civilian Employment, 1950-70

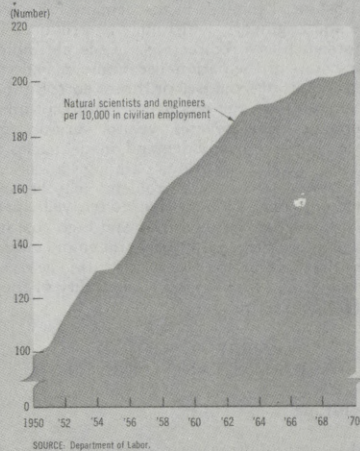
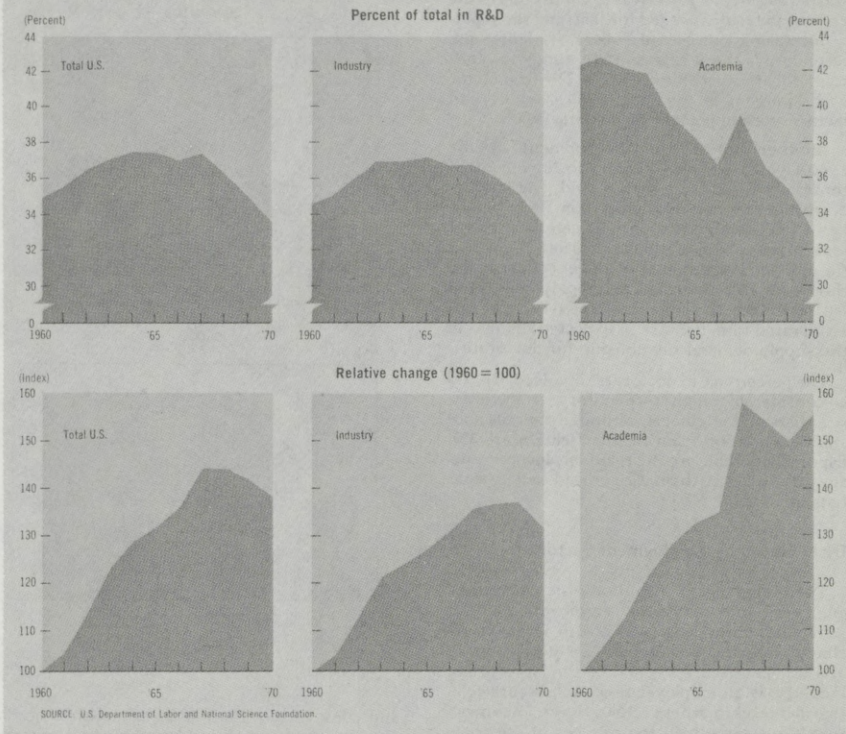


Figure 37
Natural Scientists and Engineers Engaged
in R&D, 1960-70



1970, for the first time since 1960, the total number in R&D decreased. This trend continued in 1971. Most of the decline took place in industrial R&D and was sufficient to reduce the total in this sector to the 1967 level. Not surprisingly, this downward turn followed closely the first reduction in national R&D expenditures (in constant dollars) in the 1960-70 period, a decrease felt most in industrial R&D. (See figure 14.)

Another indicator of the downward trend is the decline in the percentage of all natural scientists and engineers engaged in R&D (figure 37).

This trend began as early as 1964, when it had reached a high of 37 percent. The proportion then steadily declined to 34 percent in 1970. This trend was more pronounced among academic than industrial scientists and engineers.

The relative decline of the proportion in R&D in industry suggests a greater growth of scientists and engineers in technological operations, management, and other non-R&D activities, and possibly a lower priority for R&D in periods of slow economic growth. The first factor was probably a prime cause for the decreases in the mid-1960's, while the second was dominant at

the end of the decade.

The decline in the proportion of academic scientists and engineers engaged in R&D, which started as early as 1961, was primarily due to the growth in faculty needed for teaching the rapidly increasing number of college students and, secondarily, the leveling off of funds (in constant dollars) available for R&D. The first factor was dominant in the early 1960's, while both factors were important in the late 1960's.

Another noteworthy development of the 1960's was the increase (from 5 to 10 percent) of those with natural science and engineering doctorates in non-academic, non-R&D activities.² This change is especially significant as it took place during a "sellers' market," in which the individual scientist or engineer could usually choose his area of work. This employment trend is expected to continue, possibly at an accelerated rate, because of expected changes in the supply/demand relationship for doctorates.

The percentage of doctorates involved in R&D is considerably higher than for nondoctorate scientists and engineers, although there is substantial variation from field to field (figure 38). Especially notable are the relatively low percentages of Ph.D. mathematicians and social scientists involved in R&D.

Distribution by Employment Sector

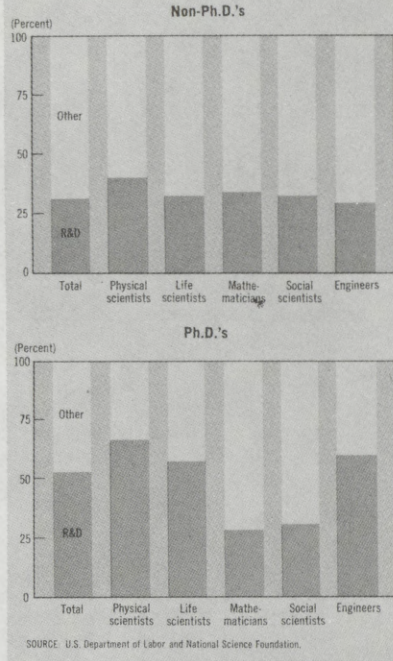
The percentage distribution of scientists and engineers among types of employers changed somewhat during the 1960's, with a relative decline in industry and an increase in universities and colleges (figure 39). While the large size of industry as an employer tends to obscure relative increases in other sectors, figure 39 shows a significant growth in the number of scientists and engineers employed in universities and colleges and other nonprofit institutions.

ENROLLMENTS AND DEGREE PRODUCTION

Enrollments in High School Science Courses

An early indicator of changes in student interest in science is secondary school enrollments in science courses relative to total enrollment. Figure 40 relates enrollments for 1960-61

Figure 38
Distribution of Scientists and Engineers,
by Activity and Broad Field, 1970



and 1969-70 to a 1948-49 based index. Overall, enrollments in science and mathematics courses grew faster than total enrollment, with the largest growth occurring in psychology and economics and the smallest in physics, chemistry, and mathematics. The above average increase in social science course enrollments may be due in part to the limited availability of such courses in earlier years. Only in the field of physics was the growth less than increases in total enrollment.

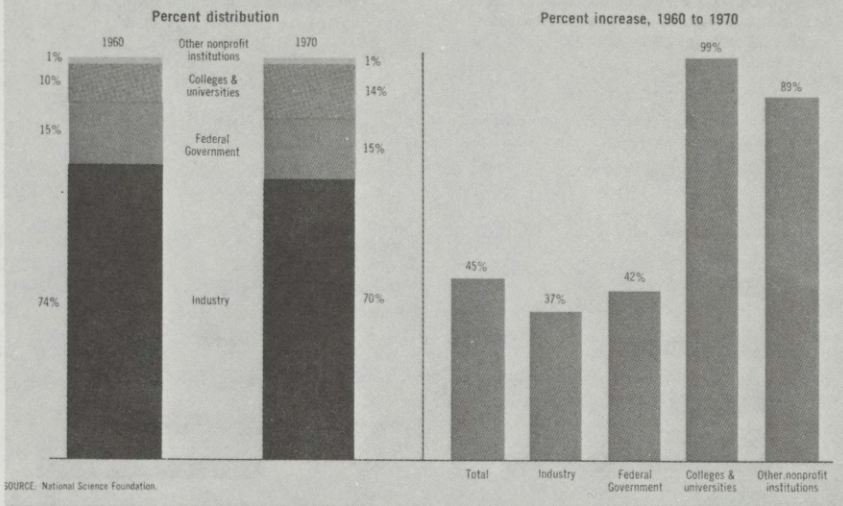
College and University Enrollments and Degree Production

Enrollments. The fraction of first-year college students who intend to work toward careers as

² National Science Foundation, 1969 and 1980 *Science and Engineering Doctorate Supply and Utilization*, NSF 71-20.

Figure 39

Employment of Natural Scientists and Engineers, by Sector, 1960 and 1970



research scientists decreased steadily, from 3.5 percent in 1966 to 2.5 percent in 1971. However, because of larger total enrollments, the absolute number of students intending to pursue this career remained at about the same level. Interest in engineering careers decreased from 9.0 to 5.3 percent over the same period. Although college freshmen frequently change their career interests, such changes have been generally away from science and engineering.³

This early indicator becomes more significant when related to fields selected by junior-year undergraduates for their major area of study. While total junior-year undergraduate enrollments increased by 7.6 percent between the fall of 1970 and the fall of 1971, fewer students chose majors in physics, chemistry, engineering, and mathematics, while basic social science, other physical science, and life science majors increased; applied social science students grew markedly (figure 41).

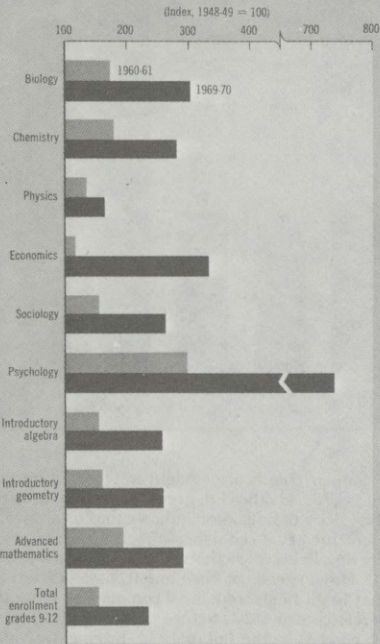
Similar trends are evident in terms of enrollments for advanced degrees. Annual data from the Office of Education indicate that total enrollment for advanced degrees in science and engineering fields more than doubled between 1960-70. However, such enrollment, as a percent of that in all fields, remained constant at about 38 percent until 1963, before declining steadily to 31 percent in the fall of 1970. Engineering and the physical sciences accounted for most of this decline.

Related data, though not strictly comparable with those of the Office of Education, indicate some recent trends in graduate enrollment. Data collected by the National Science Foundation from 2,579 Ph.D.-granting departments showed a decline of 7.1 percent in first-year, full-time science and engineering graduate students from fall 1969 to fall 1971, with most of this change occurring in the last year. In the same period, the number of full- and part-time graduate students in these fields declined by 3.7 percent. The overall change in first-year, full-time students includes greater-than-average declines in mathematics and the physical and social sciences,

³ American Council on Education, *Four Years After College Entry*, ACE Research Reports, Vol. 8, no. 1, March 1973.

Figure 40

Public Secondary School Enrollment in Selected Sciences and Mathematics Courses and Total Enrollment in Grades 9 through 12, 1960-61 and 1969-70



SOURCE: U.S. Office of Education and National Science Foundation.

and smaller decreases in engineering, psychology, and the life sciences, as shown below.

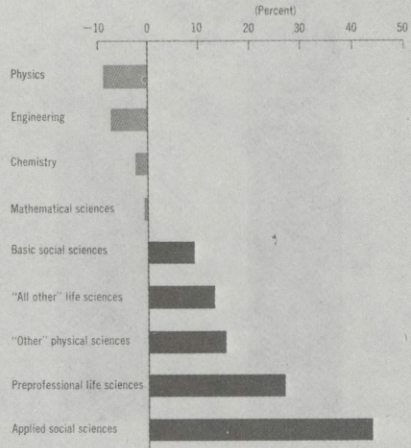
Change in First-year, Full-time Graduate Enrollment in Science and Engineering in Doctorate Institutions, 1969 to 1971

Percent change 1969 to 1971

All areas	7.1
Engineering	0.3
Physical sciences	-15.2
Mathematics	-12.0
Life sciences	-5.3
Social sciences	-9.3
Psychology	-3.3

Figure 41

Percent Change in Majors Declared by Junior-Year Students, 1970 to 1971



SOURCE: Ace Higher Education Panel.

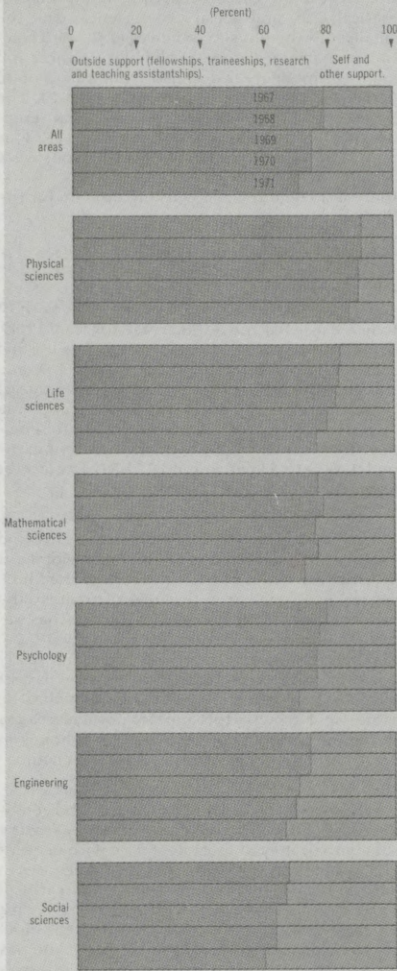
Financial Support. The availability of financial support may influence the number of graduate students entering the sciences and engineering, although the measurement of such direct effects may be confounded by university efforts to provide support for students in all fields of graduate study. Moreover, there are certainly other motivational factors affecting the choice of field for graduate education.

The sources of graduate support for major fields of science and for engineering are shown in figures 42 and 43. The largest percentage of students supported by fellowships, traineeships, and assistantships is in the physical sciences, and the smallest in the social sciences. The number of science and engineering students supported by the Federal Government declined by 15 percent between 1969-71 whereas those depending on self-support increased by 19 percent (from a lower base).

Graduate Production. Annual awards of bachelor's and first professional degrees in the sciences and engineering are shown in figure 44 for the 1959-71 period. The annual recipients of

Figure 42

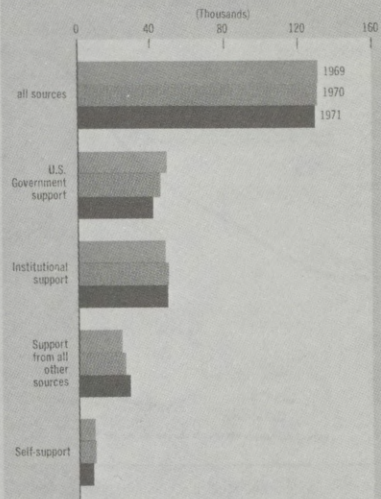
Distribution of Full-time Graduate Students in Doctorate Departments, by Area of Science and Type of Support, 1967-71



SOURCE: National Science Foundation.

Figure 43

Distribution of Full-time Graduate Students in Science and Engineering, by Source of Support, 1969-71

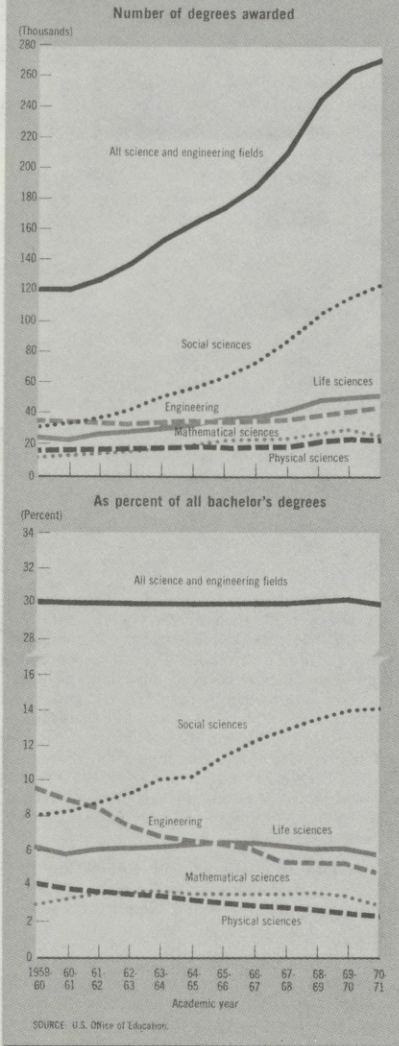


SOURCE: National Science Foundation.

social science degrees increased by a factor of 4.1 over the period, well above the growth (2.2 times) in the total science and engineering degrees awarded at that level. Social science degrees—as a proportion of all first degrees in science and engineering—rose from about one-fourth in 1959-60 to almost one-half in 1970-71. The annual production of graduates in the life and mathematical sciences increased by factors of 2.2 and 2.4, respectively, over the period, whereas those receiving degrees in the physical sciences and engineering rose by factors of only 1.3 and 1.2, respectively.

First degrees in science and engineering, as a fraction of first degrees in all fields, remained essentially constant at some 30 percent between 1959-71. The large increase in the annual recipients of social science degrees was responsible for maintaining the fraction at a constant level; engineering degrees, as a proportion of degrees in all fields, declined continuously from 9.6 percent to 5.1 percent during the period, and the physical sciences fell from 4.1 to 2.4 percent.

Figure 44
**Bachelor's and First Professional Degrees
 in Science and Engineering, 1959-60 to 1970-71**



Annual awards of master's degrees in science and engineering are shown in figure 45. The number of these degrees awarded annually increased by a factor of 2.5 during the period, with the largest increases occurring in the mathematical (3.8) and social (3.1) sciences and the smallest in the physical sciences (1.9). As a fraction of master's degrees in all fields, sciences and engineering degrees declined from a high of 30 percent in 1964-65 to 22 percent in 1970-71. The largest proportional declines were in engineering and the physical and life sciences. This may indicate that relatively fewer persons were seeking advanced degrees in these fields, or that there is a trend toward working directly for the Ph.D.

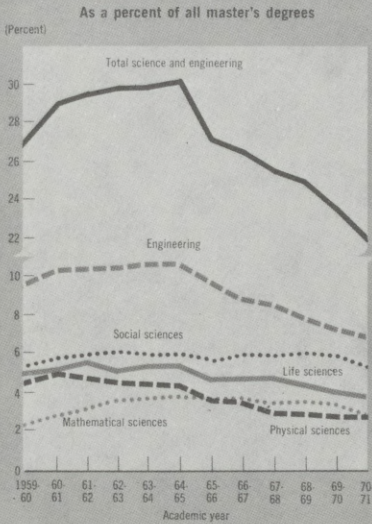
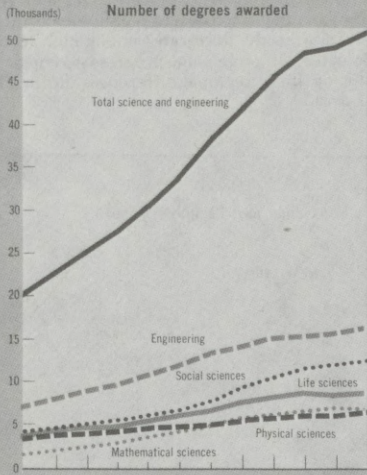
Annual awards of Ph.D. degrees are presented in figure 46. The greatest growth occurred in engineering, which increased by a factor of 4.6, and in the mathematical sciences (4.4), both of which exceeded the 3.0 increase for total Ph.D. degrees in science and engineering. The life and social sciences increased by factors of 2.9, and the physical sciences by 2.4. As a percentage of Ph.D. degrees in all fields, the annual recipients of doctorate degrees in the sciences and engineering declined from a high of 62 percent in the mid-1960's to 58 percent in 1970-71. The largest proportional declines were in the physical sciences.

The rapid growth of recipients of science and engineering degrees is not a development specific to science. Even in the case of the Ph.D. degree, where the growth rate was greatest, the ratio of science to nonscience Ph.D.'s has remained almost constant since the early 1920's. Furthermore, the rapid growth rate is not solely a matter of advanced education. A large part of our modern 20th-century society exhibits the same rapid growth; this appears in such areas as the annual production of books, telephones in use, production of electronic systems, consumption of electricity, and use of raw materials.

While growth rates in science and engineering degrees granted during the 1960's were substantial, they at most kept pace with degrees granted in other fields. Actually, first degrees in natural science and engineering—and nearly all advanced science and engineering degrees—grew more slowly than degrees in all other fields combined. The relative decline has been most pronounced for first and master's degrees in engineering and for doctorates in the physical sciences. Taken as a whole, these indicators point to a relative decline in students

Figure 45

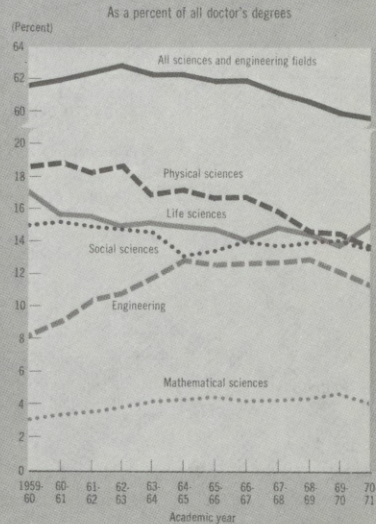
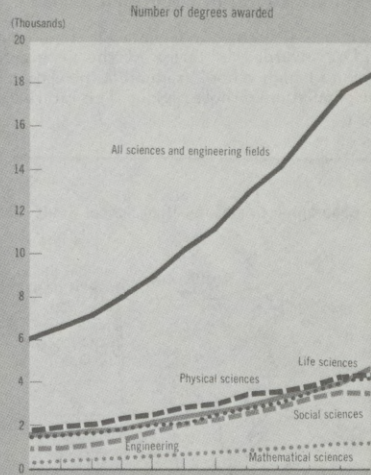
Master's Degrees in Science and Engineering, 1959-60 to 1970-71



SOURCE: U.S. Office of Education.

Figure 46

Doctor's Degrees in Science and Engineering, 1959-60 to 1970-71



SOURCE: U.S. Office of Education.

majoring in science and engineering fields, although the absolute numbers of those who so choose are still increasing.

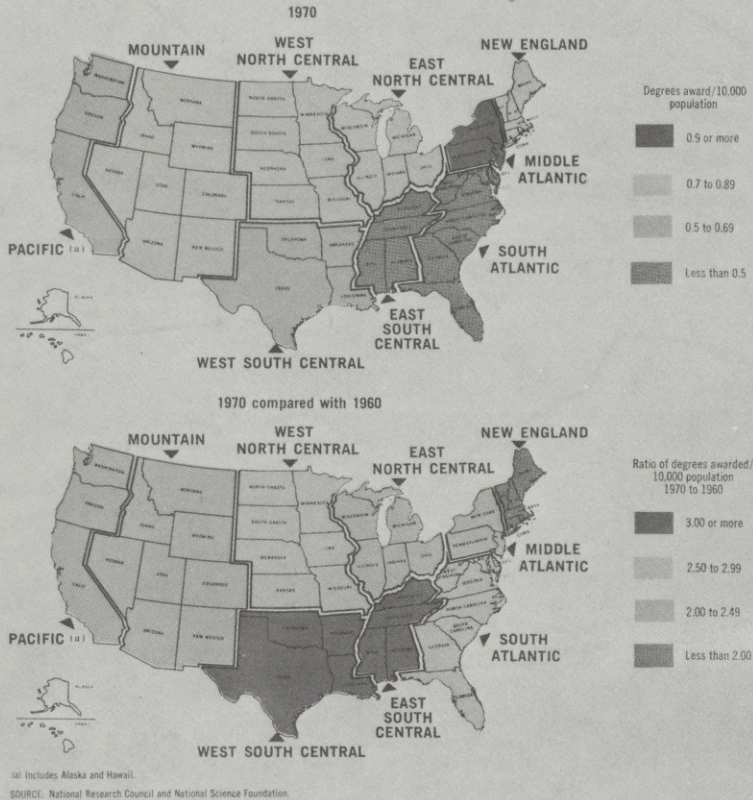
Doctorate Awards by Geographic Region

Figure 47 shows science and engineering Ph.D.'s awarded in terms of the geographic region of high school graduation in relation to the population of those regions. This ratio varies

considerably with New England, the Middle Atlantic, West North Central, and Mountain regions showing larger proportions, while the South Atlantic and East South Central regions are lower by almost 50 percent. This indicator shows an uneven pattern of pursuit of advanced education (to the doctorate) among high school graduates, although some progress was made in reducing these regional differences during the last decade.

Figure 47

Geographic Origins, by High School Graduation, of Ph.D.'s in Science and Technology, 1970



SUPPLY AND UTILIZATION

Unemployment

For most of the 1960's the production of new scientists and engineers could not match the demand for their services. In recent years, however, the demand for scientists and engineers declined as a result of several converging factors: R&D funding (in constant dollars) declined on the average by 1 percent per year between 1967 and 1972, due primarily to an average annual decline of 3.3 percent in Federal R&D funding; concurrently, the Nation underwent a fairly steady period of inflation, reduced economic growth, and less emphasis on space and defense.

However, because of the long timelags in the response of the educational system, the production of scientists and engineers continued in spite of the fall in demand, creating a supply/demand mismatch. Unemployment of scientists and engineers accelerated from 1969, reaching about 2.6 percent for scientists and 2.9 percent for engineers by early 1971 (figure 48). National Science Foundation surveys show that unemployment in 1971 was more severe for engineers than for scientists, as indicated in figure 49; that, generally, those with higher degrees were less likely to be unemployed; and that younger scientists and engineers were most adversely affected. Unemployment rates were more severe in the defense and aerospace areas and in specific disciplines such as physics. Among unemployed scientists and engineers, defense (11 percent) and space-related activities (4 percent) were most frequently cited as the last areas of employment.

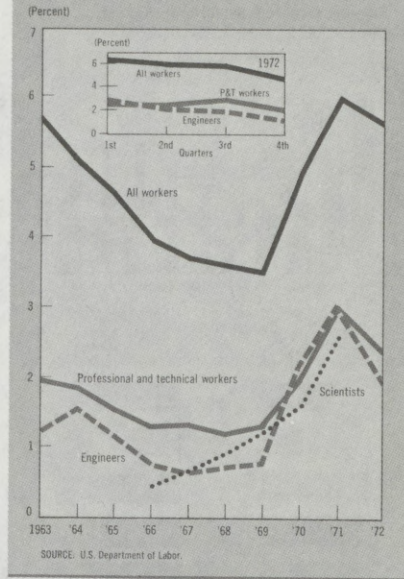
Although there was a relative increase in the unemployment of scientists and engineers, the base level for such a comparison was low. Even with the large relative increases up to 1971 the overall science and engineering unemployment rate was still only about half that for all workers.

The unemployment situation has improved somewhat since then. The unemployment rate for scientists and engineers declined in 1972, as has that for all professional workers, and employment prospects for new graduates were reported as better in 1972, although still not as good as those in the mid-1960's.

Underemployment

Although unemployment has been relatively small, the change from a "sellers' market" to a

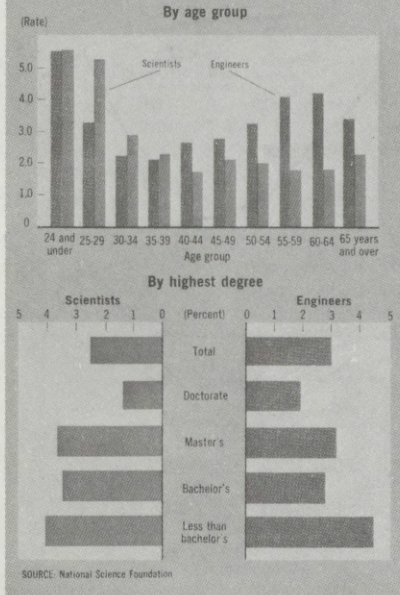
Figure 48
Unemployment Rates, 1963-72



"buyers' market" has tended to produce underemployment—employment that fails to fully utilize the training of scientists and engineers. Although a real problem, underemployment is difficult to assess since "underutilization of training" is a subjective judgment. Some indication of underemployment of new Ph.D.'s can be inferred from a survey of university department chairmen conducted by the National Research Council.⁴ The survey found that in January 1971, 1.2 percent of new (1968-69) Ph.D.'s were listed as employed in positions that did not make appropriate use of their graduate training, and that this percentage was double that reported the year before.

⁴ National Research Council, *Employment of New Ph.D.'s and Postdoctorals in 1971*, Washington, D.C., 1971.

Figure 49
Unemployment Rates for Scientists and
Engineers, by Age Group and Highest
Degree, 1971



Holding Actions

Several other factors should be considered in a review of employment. For most of the 1960's, the percentage of those who planned to continue their training immediately upon receipt of their science and engineering Ph.D.'s remained essentially constant, except for those in the life and physical sciences, who showed a steadily increasing tendency toward postdoctoral study (figure 50). Then, in the late years of the decade, the fraction of all Ph.D.'s taking postdoctoral study increased somewhat.⁵ This may, in part, have been an early indicator of the shrinking employment market for scientists and engi-

⁵ The sharp increases shown in figure 50 between 1968 and 1969 are misleading because of changes in definitions in postdoctoral study. However, analysis of the data indicates increases in the proportion over earlier years.

neers. The number of science and engineering Ph.D.'s in temporary postdoctoral study was still increasing in 1971. The availability of postdoctoral study thus provides a number of new Ph.D.'s with an alternative to employment competition and at least temporarily helps relieve pressure on the labor market.

A related matter is the length of time between receipt of the bachelor's degree and the doctorate. The median time had been decreasing in almost all fields when, in 1968-69, it started to rise again in the physical sciences, mathematics, engineering, and the life sciences (figure 51). This may be due in part to graduate students attempting to prolong their study because of the scarcity of jobs.

Age Distribution

Without a flow of young people into science and engineering, creativity in these fields would tend to decline overall, as would be the case in any profession. In the last decade or so, the number of scientists or engineers, particularly the doctorate population, has grown substantially. Therefore, with this large flow of new entrants the average age has not risen; for doctorates it has actually declined.

Based on current and projected degree production and projected growth in employment, it appears that the average age of the science and engineering population will not rise substantially in the coming decade. However, even though the overall average age may not change markedly, the proportion in the younger age groups will decrease significantly unless recruitment of new young talent continues.

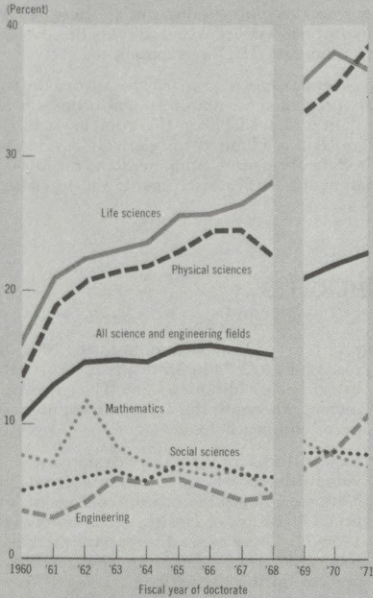
Other Changes

As mentioned previously, the deployment of doctorates into nonacademic, non-R&D activities increased during the 1960's. This trend increased during the most recent years, as supply expanded relative to demand. Similarly, increased employment of doctorates was evident in junior and community colleges, as well as in 4-year institutions. The number of doctorates employed full time in the former institutions increased nearly twice as fast as all science and engineering staff between 1969 and 1971, with the result that the proportion of full-time staff holding doctorates increased from 8.8 to 10.6 percent in 2-year institutions.⁶

⁶ National Science Foundation, *Resources for Scientific Activities at Universities and Colleges, 1971*, NSF 72-315.

Figure 50

Percent of New Science and Engineering Ph.D.'s Planning to Engage in "further education or training" or "postdoctoral study," by Field, FY 1960-71^(a)

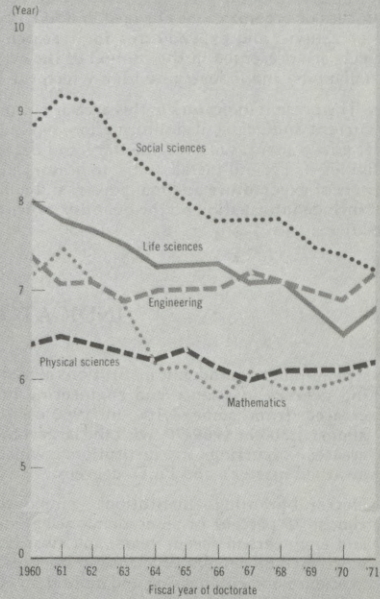


(a) Due to a change in definition, 1969 through 1971 data are not strictly comparable with earlier years.

SOURCE: National Research Council

Figure 51

Median Number of Years from Baccalaureate to Doctorate of Doctorate Recipients in Science and Engineering, by Field, FY 1960-71



SOURCE: National Research Council

Institutional Capabilities

This chapter presents indicators of the state of the institutional system of science and technology. The indices include aspects of the infrastructure involved in training scientists and engineers; types and numbers of organizations engaged in R&D; composition and patterns of concentrations among these organizations; and expenditures for research equipment and facilities. Indicators of these several aspects are presented in the context of the system of institutions—colleges and universities, Federal installations, and industry—within which the bulk of training and R&D is accomplished.

The present indicators in this area are incomplete in several respects, primarily because of the lack of current and/or detailed information. No indicators are presented for nonprofit institutions or for local government; only fragmentary and dated information was available on the number, size, and activities of Federal installations; indicators of industrial R&D are limited to relatively aggregated aspects of expenditure and manpower; and indices of the state of research equipment and facilities do not include information on the quantity, type, and utilization of scientific instruments and specialized facilities.

INDICATOR HIGHLIGHTS

- The number of academic institutions awarding degrees in science and engineering increased from some 1,100 in 1960-61 to almost 1,300 in 1969-70, with the largest increases occurring in institutions which awarded master's and Ph.D. degrees.
- Doctoral-granting institutions employed almost 75 percent of all academic scientists and engineers in recent years, and awarded more than 80 percent of all master's degrees in science and engineering and more than 50 percent of the bachelor's degrees.
- The 20 institutions awarding the most Ph.D. degrees in science and engineering accounted for a decreasing fraction of all such degrees awarded, down from one-half of the total awards in 1963 to two-fifths in 1971. Science and engineering graduate enrollments in these institutions declined proportionally over the period.
- Private doctoral institutions awarded a decreasing proportion of all Ph.D. degrees in science and engineering, falling from 41 percent of the total awards in 1963 to 34 percent in 1971. Science and engineering graduate enrollments in these institutions peaked in 1969 and declined thereafter, in contrast to the continued growth of such enrollments in public institutions.
- New doctoral programs in existing doctoral departments increased at the net rate of 1 program per 26 departments during 1970-72; plans for 1972-74 indicate a reduction of the ratio of new additions to 1:66. The largest net increases were in the areas of computer sciences and psychology.
- Expenditures for laboratory equipment, provided through research grants from the National Science Foundation and major National Institutes of Health, declined between 1966-71. These expenditures as a fraction of total grant funds, fell from 12 percent to 6 percent during the period.
- Federal obligations to universities and colleges for R&D plant and major equipment declined 75 percent between 1965 and 1971. As a proportion of all Federal obligations for academic science, funds for R&D plant dropped from 8 percent to 1 percent during the period.
- A radio astronomy facility (known as the VLA) authorized and funded in FY 1973 was the first new major research facility started since 1968, although some 30 facilities, in various areas of science, were proposed in recent years and evaluated as technically desirable and feasible.
- Federal intramural R&D expenditures increased throughout the 1961-72 period, with the Department of Defense accounting for the largest share of such funds, followed by NASA, the Department of Agriculture, and

the Department of Health, Education, and Welfare. Together, these four agencies accounted for 86 percent of total such expenditures in 1972.

- Federal intramural R&D expenditures, as a percent of total U.S. R&D expenditures, increased from 13 percent to 16 percent between 1960-72, while the number of scientists and engineers (full-time-equivalent) engaged in such R&D rose from 12 to 13 percent of the U.S. total between 1961-71.
- Large industrial companies (5,000 or more employees) employed an increasing proportion of the total industrial R&D personnel between 1963 and 1971 (up from 79 percent to 85 percent), while the share for small companies (less than 1,000 employees) declined from 10 percent to 6 percent.
- The R&D intensiveness of U.S. industry, as measured by the ratios of R&D expenditures to net sales and R&D scientists and engineers to total employment, increased

between 1960-64 but declined thereafter to a level in 1970 which was lower than in 1960. The largest declines occurred in the most R&D intensive industries.

- The R&D intensiveness of manufacturing industries declined by some 25 percent between 1964-70 in the five most R&D-intensive industries, and remained essentially unchanged in other manufacturing industries during the 1960-70 period.
- The R&D intensiveness of nonmanufacturing industries increased by 50 percent between 1960 and 1966, but remained constant thereafter through 1970.
- Industrial R&D is concentrated in relatively few manufacturing industries and in a small number of companies within these industries. In 1970, five industries had 81 percent of the total industrial R&D expenditures, while accounting for only 48 percent of total manufacturing sales, and 100 companies had some 80 percent of the total expenditures.

■ Scientific and technological activities are performed through a mutually complementary system of institutions and associated human resources. The system of institutions consists principally of colleges and universities, which both train scientists and engineers and perform research; Federal laboratories, which focus primarily on research and development directly related to their respective missions; and private industry, which conducts research and development leading to new and improved technology, processes, and products. The characteristics and capabilities of this system can be described in terms of the types of institutions involved, the activities they perform, and the effectiveness with which the education and/or R&D functions are carried out.

SCIENCE AND ENGINEERING EDUCATION

General Institutional Capabilities

Higher education in the sciences and engineering grew rapidly throughout the past decade. The number of colleges and universities awarding science and engineering degrees in each year between 1961-71 is shown in figure

52. The major growth was in institutions which granted the master's and Ph.D. degrees; their numbers increased by 57 and 45 percent, respectively. Institutions at the bachelor's degree level failed to show the same systematic growth, in part because of the widespread evolution of these colleges into higher level institutions.

Scientists and engineers employed by universities and colleges are concentrated in doctoral-granting institutions. In 1971 these institutions employed almost 75 percent of all academic scientists and engineers, a fraction which remained essentially unchanged during recent years¹ (figure 53). The institutions awarded more than 80 percent of all master's degrees in science and engineering and more than 50 percent of the bachelor's degrees during the 1964-70 period (figure 54).

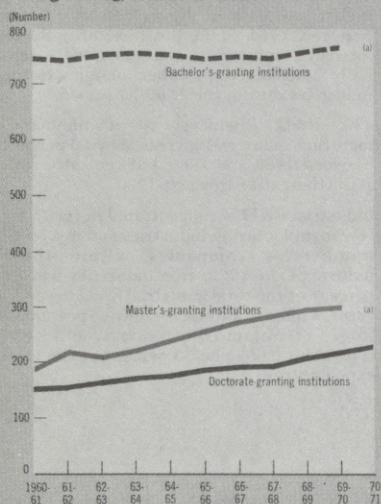
Patterns of Growth in Doctorate Institutions

Institutional capabilities for graduate education in science and engineering grew in

¹ Two-year institutions and other institutions which do not grant science or engineering degrees are not included.

Figure 52

Number of Institutions of Higher Education by Highest Degree Awarded in Science and Engineering, 1960-61 to 1970-71



two ways: the number of graduate-level institutions increased and existing graduate institutions expanded their graduate programs. Some aspects of the growth pattern of doctoral institutions are shown in the following tables.

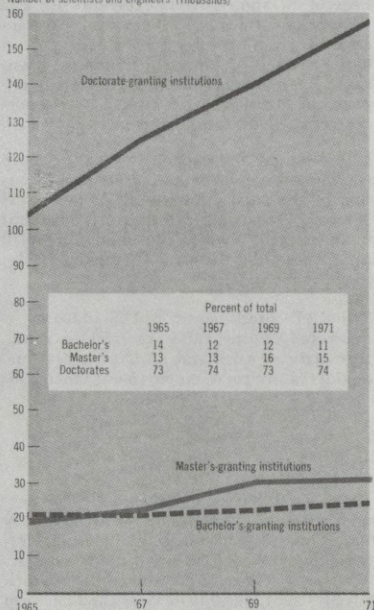
The first table shows the growth in the number of Ph.D.-level institutions and the division of doctorate awards among them. The increasing number of institutions are divided into three groups, in terms of the number of Ph.D. degrees awarded.

Institutions granting	Number of institutions granting Ph.D.'s			
	1962-63	1965-66	1969-70	1970-71
First one-third of Ph.D.'s	11	13	15	16
Next one-third of Ph.D.'s	24	28	35	36
Last one-third of Ph.D.'s	127	146	172	177
Total number of institutions	162	187	222	229

Figure 53

Scientists and Engineers^(a) Employed by Universities and Colleges, 1965-71

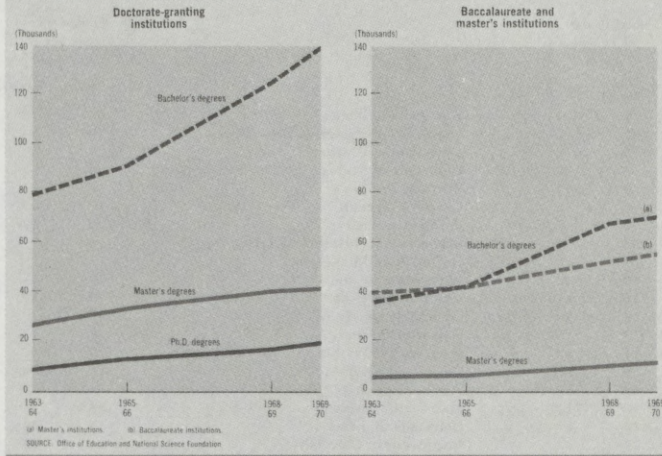
Number of scientists and engineers (Thousands)



The table shows that the number of institutions in each group increased, with the largest increase occurring in institutions which awarded the smallest number of Ph.D.'s. Growth in the last group of institutions, however, was matched by the expansion of graduate programs in the larger Ph.D.-granting institutions. Thus, in 1970-71 as in 1962-63, 7 percent of the institutions produced one-third of all science and engineering Ph.D.'s, 15 percent produced the second third, and 78 percent produced the remaining one-third of the Ph.D.'s.

The proportion of full-time graduate students enrolled in the three groups of institutions over the 1962-71 period are shown in the following table.

Figure 54
Science and Engineering Degrees Awarded at Baccalaureate, Masters,
and Doctorate-Granting Institutions, 1963-64 and 1969-70



Institutions granting	Percent of total full-time enrollment for advanced degrees			
	1962-63	1965-66	1969-70	1970-71
First one-third of Ph.D.'s	29	29	28	28
Next one-third of Ph.D.'s	29	30	31	31
Last one-third of Ph.D.'s	42	41	41	41

This table shows the close correspondence between the proportion of graduate students in the three groups of institutions and the proportion of Ph.D.'s produced by them.² Similarly, there was little change over the period in the proportional distribution of students among the three groups of institutions. First-year, full-time graduate students shows a similar division and constancy among the groups of institutions.

Institutions granting	Percent of first-year full-time enrollment for advanced degrees			
	1962-63	1965-66	1969-70	1970-71
First one-third of Ph.D.'s	25	25	25	26
Next one-third of Ph.D.'s	27	29	29	28
Last one-third of Ph.D.'s	49	46	46	46

Other patterns of growth are indicated by using a different method of grouping institutions; namely, the first 20 institutions ranked in terms of numbers of Ph.D.'s awarded, the next 20 institutions, and all other doctorate-granting institutions.

The individual institutions included in the first two groups changed in rank considerably between 1962-63 and 1970-71 as shown in the table on page 68. Institutions in these groups generally have the following characteristics: they were usually among the top institutions in terms of Federal funds received, were the choice of the largest numbers of Federal fellowship awardees, and were generally included among the highly ranked graduate departments as categorized by the American Council on Education.³

The increase in Ph.D. degree awards and graduate enrollments among these groups of institutions are shown in figures 55 and 56. Although the number of science and engineering

² The deviation may be due to a greater tendency for students in the last group of institutions to conclude their education with the master's degree, to transfer to larger institutions for the Ph.D., or to discontinue graduate education.

³ K. D. Roose and C. J. Andersen, *A Rating of Graduate Programs*, American Council on Education, 1970.

Changes in Ranking of 40 Institutions Conferring the Largest Number of
Ph.D.'s in the Sciences and Engineering, in terms of Number of Ph.D.'s
Conferred and Amount of Federal Obligations Received

Rank in order of Ph.D. degrees conferred			Rank in order of total federal obligations ¹	
1970-71	1962-63		1970-71	1962-63
1	1	University of Illinois	6	8
2	2	University of California-Berkeley	10	4
3	3	University of Wisconsin	3	11
4	7	University of Michigan	4	2
5	11	Stanford University	7	7
5	15	Cornell University	17	12
7	5	Purdue University	40	27
8	4	Massachusetts Institute of Technology	1	1
9	8	University of Minnesota	2	9
10	20	Michigan State University	30	29
11	14	University of California-Los Angeles	9	10
12	10	Ohio State University	15	19
13	6	Harvard University	8	5
14	22	University of Washington	5	15
15	9	Columbia University	11	3
16	18	Pennsylvania State University	39	31
17	13	Iowa State University	56	45
18	17	University of Texas	38	20
19	23	Northwestern University	44	22
20	12	University of Chicago	20	6
20	16	New York University	18	13
22	25	University of Pennsylvania	16	17
23	49	University of Missouri	22	41
23	2	Case-Western Reserve University	42	2
25	27	University of Maryland	28	33
26	43	University of Tennessee	35	38
27	54	Texas A & M University	46	44
28	40	University of Florida	41	37
28	24	Indiana University	31	34
30	64	University of Arizona	53	62
31	21	Yale University	19	16
32	19	Princeton University	63	24
32	44	North Carolina State University-Raleigh	51	54
34	39	University of California-Davis	52	64
35	34	University of Colorado	23	26
36	77	University of Massachusetts	78	3
37	42	Oregon State University	69	57
38	45	University of Southern California	24	35
38	38	University of Kansas	57	53
40	33	Duke University	26	32
40	28	University of Iowa	37	39
42	30	Louisiana State University	21	55
43	37	University of North Carolina-Chapel Hill	25	40
44	29	Rutgers-The State University	48	51
47	32	University of Pittsburgh	33	18
49	36	University of Utah	32	42
54	31	Johns Hopkins University	14	14
54	26	California Institute of Technology	45	43
57	35 ⁴	Carnegie-Mellon University	90	77 ⁴

¹ Includes funds for medical schools, but not FFRDC's.

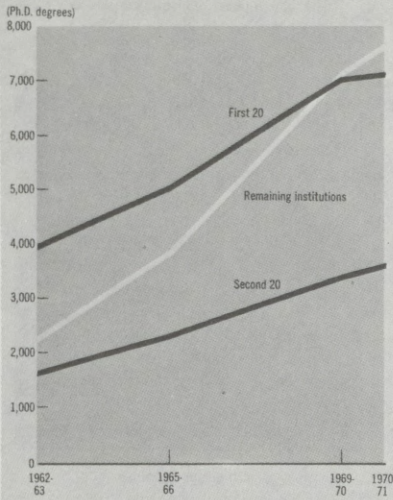
² Ranked below 100.

³ Separate institutions in 1962-63.

⁴ Carnegie Institute of Technology in 1962-63.

Source: National Science Foundation.

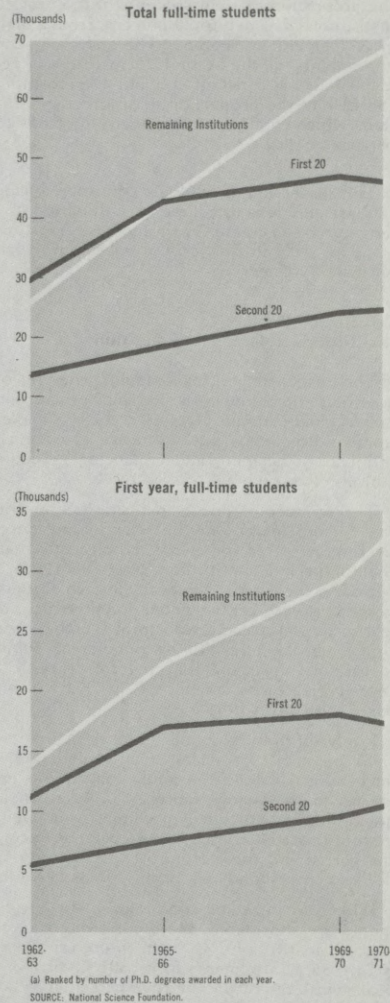
Figure 55
Number of Ph.D. Degrees Awarded in
Science and Engineering by Selected
Groups of Doctorate-Granting Institutions^(a)



doctorates increased in each group of institutions, the smallest growth occurred in the first and second 20 institutions. As a result of this pattern, the proportion of all such doctorates awarded by the first 20 institutions declined from 51 to 39 percent between 1962-63 and 1970-71, as compared with a nearly constant proportion of 20 percent for the next 20 institutions and an increase from 29 to 42 percent for the remaining institutions.

Growth and distribution patterns similar to these occurred for graduate student enrollments, as shown in figure 56. Total full-time enrollments increased overall, although a small decline was recorded among the first 20 institutions in 1970-71. By the end of the period, the share of total enrollments for the first group of institutions had declined to 33 percent, down from 43 percent in 1962-63. The share for the

Figure 56
Graduate Students in Science and
Engineering Enrolled in Selected Groups
of Doctorate-Granting Institutions^(a)



next 20 institutions fell from 20 to 18 percent, whereas the proportion in other institutions rose from 37 to 49 percent.

Shifts in the same direction occurred for first-year, full-time graduate enrollment. By 1970-71, the proportion of such students in the first 20 institutions declined to 29 percent, from a high of 37 percent in 1962-63. The share of such enrollments in the second 20 institutions remained almost constant at about 17 percent, in contrast to the proportion in all other institutions which climbed to 54 percent, up from 45 percent in 1962-63.

This dispersion of graduate education during the last decade is of course a continuation of a long-run trend created by the increase in institutions involved in this level of education in science and engineering.

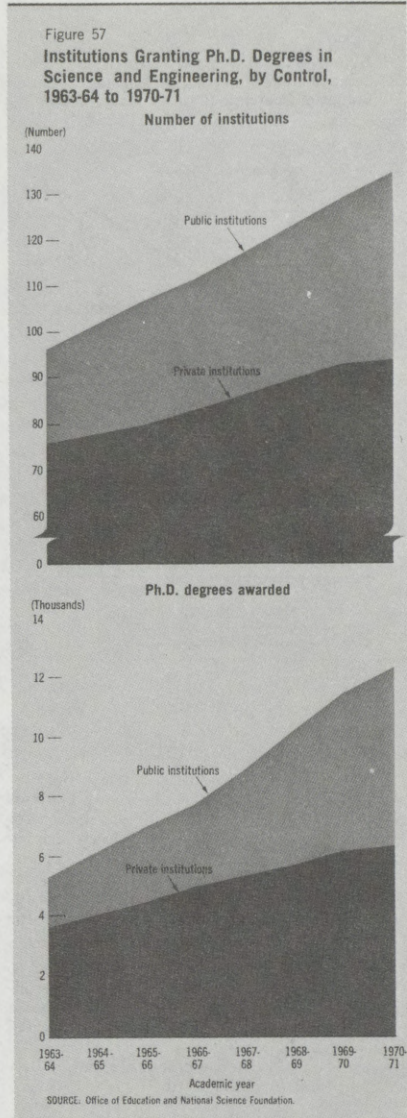
Private and Public Institutions in Graduate Education

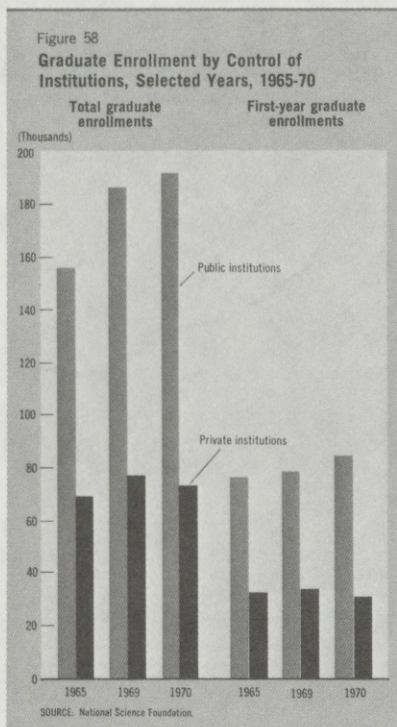
The responsibility for graduate training of scientists and engineers is shared by private and public institutions. Despite their smaller number, private institutions have exerted much influence in shaping and enhancing graduate education as a whole.

The number of public institutions granting the doctoral degree in the sciences and engineering increased somewhat more rapidly than that of private institutions over the 1963-71 period, as indicated in figure 57. In each of these years an average of five public and three private institutions awarded the doctoral degree for the first time. As a result, the number of public institutions awarding the doctoral degree exceeded private institutions by 41 in 1971, as compared with 24 in 1963.

While differences in the number of institutions of each type changed only moderately, doctoral graduates from public institutions increased more rapidly (figure 57). As a consequence, the proportion of graduates from public institutions rose from 59 to 66 percent during the period and those from private institutions declined correspondingly from 41 to 34 percent.

When the level of recent graduate enrollments are considered, the diminishing role of private institutions is even more apparent (figure 58). Enrollments in private institutions peaked in 1969 and declined by 5 percent in 1970, while graduate enrollments in public institu-





tions continued to increase. By 1970, only 28 percent of the total science and engineering graduate students were in private institutions. Most of the decline (some 75 percent) was due to cutbacks in first-year enrollments; these fell by 9 percent between 1969 and 1970, in contrast to such enrollments in public institutions which increased 8 percent.

The largest private institutions, in terms of the number of Ph.D.'s produced, had the largest declines in first-year enrollments. Of the 20 largest Ph.D.-producing institutions, public and private, 6 are private universities. Of the six, only one had an increase in first-year enrollments; as a group, enrollments declined by 12 percent between 1969 and 1970. Such enroll-

ments in the 14 largest public institutions, on the other hand, rose by 5 percent during the same time.⁴

Coincident with these recent declines in private institution enrollments were reductions in Federal R&D expenditures. Such funds declined by 8 percent (in constant dollars) between 1968-70 for private institutions, but remained essentially unchanged for public institutions. The magnitude of this decline is of considerable significance since 85 percent of research in private institutions is federally supported, compared with 65 percent for public institutions.⁴

While there are many factors affecting the growth and capacity of public and private institutions, a fundamental one appears to be the pervasive and worsening financial condition of these institutions.

Growth of Doctoral Programs: 1970-74

A survey was conducted by the American Council on Education of doctoral departments in science and engineering to determine the recent and probable future growth of doctoral programs.⁵ The survey indicated that the ratio of net additions of such programs to existing doctoral departments was 1:26 during 1970-72. Plans for the 1972-74 period, however, indicate a reduction to 1:66, i.e., a net gain of one program per 66 existing departments. The largest net increases in 1970-72 were in the areas of computer sciences and psychology. Plans for 1972-74 indicate the greatest relative increase will again be in computer sciences.

RESEARCH EQUIPMENT AND FACILITIES

Research instrumentation and modern laboratories are basic tools of science. They provide man with his quantitative and most precise window on the real world. They permit the study of phenomena otherwise inaccessible to investigation, provide the means for accurate measurement and observation, and facilitate

⁴ Special tabulation based on data collected for the National Science Foundation report series, *Resources for Scientific Activities at Universities and Colleges*.

⁵ National Science Foundation, *Science Resources Studies Highlights*, "Changes in Graduate Programs in Sciences and Engineering 1970-72 and 1972-74," July 21, 1972 (NSF 72-311).

data collection and analysis. Sophisticated equipment is now a prerequisite for significant research advances in most fields of science. The excellent instrumentation available in the United States is generally regarded as a prime factor contributing to the leading position of American science. Since the requirements for instrumentation are constantly changing with progress in science, a continuing investment is necessary to maintain the quality of this basic tool.

The Federal Government is a prime source of support for research equipment and facilities. This includes basic laboratory equipment, as well as major equipment such as wind tunnels, accelerators, reactors, radio telescopes, etc., which are used for more than a single project, and R&D plant capital grants that fund the construction and maintenance of major R&D facilities.

Research Equipment

A major source of laboratory apparatus for universities and colleges has been the Federal system of research grants, which have often included funds for laboratory equipment as part of the grants. Funds for research apparatus from this source declined in recent years, even though the overall grant funds increased. The extent of the decline is suggested by figure 59 which depicts the proportion of total project grant funds allocated for permanent research equipment. The data presented here are fragmentary in that only the National Science Foundation (NSF) and a part of the National Institutes of Health are included;⁶ they are, however, major sources of research equipment funds and probably typify the situation in general.

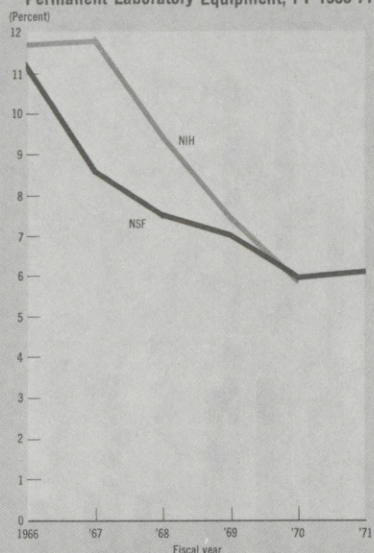
This figure shows that as a proportion of total project grant funds, support for the purchase of permanent laboratory equipment declined by one-half—from nearly 12 percent to 6 percent—between 1966 and 1971. Funds for research grants, on the other hand, increased by about 15 percent over the same period.

In the case of the NSF, the reduced support for research equipment appears to have been absorbed largely by an upward shift in indirect

⁶ National Institute of General Medical Sciences and National Heart and Lung Institute.

Figure 59

Proportion of NSF and NIH^(a) Research Project Grant Funds Allocated for Permanent Laboratory Equipment, FY 1966-71



(a) National Institute of General Medical Sciences and National Heart and Lung Diseases.
SOURCE: National Science Foundation.

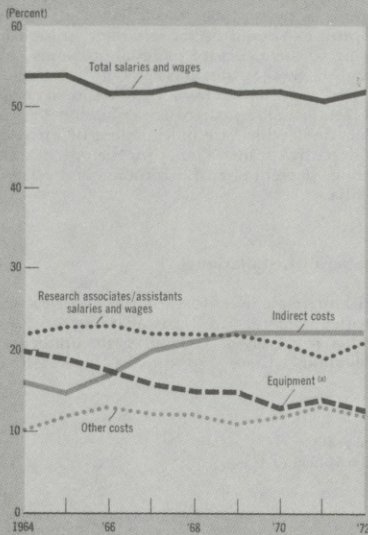
costs, as shown in figure 60.⁷ Salaries and wages, as a fraction of total grant funds, changed little during the period.

R&D Plant and Equipment

The Federal Government has been a prime source of support for major research equipment and R&D plant capital. However, Federal obligations to universities and colleges for new and improved R&D plant declined after the mid-1960's,

⁷ The higher proportion of NSF grant funds for research equipment in figure 60, over that shown in figure 59, is due to the inclusion of funds for both permanent and expendable equipment in figure 60.

Figure 60
Distribution of NSF Research Project Funds,
by Type of Expenditure, 1964-72



(a) Permanent and expendable equipment.

SOURCE: National Science Foundation.

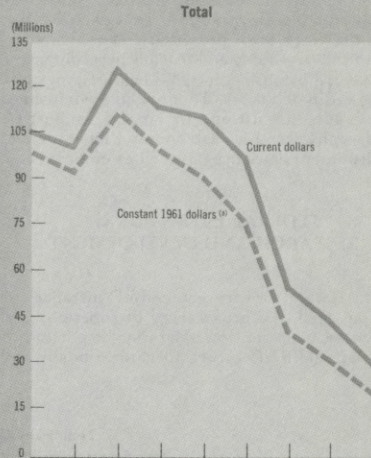
falling by more than 75 percent between 1965 and 1971 (figure 61). Federal funds for R&D plant, as a fraction of total Federal obligations for academic science, declined from 8 to just over 1 percent during the same period (figure 61).

Since the effectiveness and, in many instances, the significance of research depends directly upon the availability of appropriate tools and plant, expenditures for them are as essential as expenditures for the performance of research itself. However, support for these critical items has fallen well behind that for research.

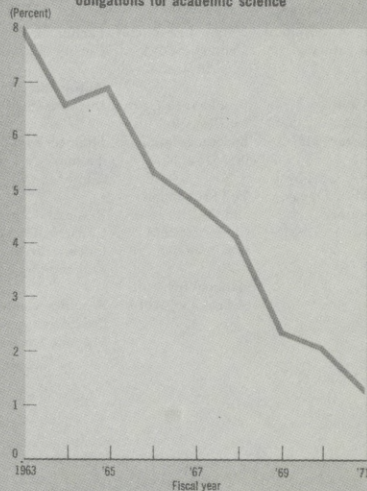
Major Research Facilities

Many fields of science now require large, specialized facilities to achieve significant advances and to initiate research in promising new

Figure 61
Federal Obligations for Academic
R&D Plant, FY 1963-71



As a percent of Federal obligations for academic science



(a) Based on academic R&D price deflator.

SOURCE: National Science Foundation.

areas. Until the authorization of the radio astronomy facility, known as the Very Large Array, in fiscal year 1973, no major research facilities—those requiring \$5 million or more for construction—have been started since the Batavia accelerator in 1968. Yet nearly 30 new facilities have been proposed and evaluated as technically desirable and feasible in recent years. These are listed in the table below along with their estimated costs. There is an evident need for such facilities in many scientific fields—physics and astronomy, biology, and environmental sciences as well as engineering.

FEDERAL INTRAMURAL RESEARCH AND DEVELOPMENT

The Federal Government's R&D installations are engaged in a broad array of functions and activities, representing a significant portion of the national R&D effort. Organizationally and

programmatically, each individual installation's orientation is primarily to the needs and mission of its parent or sponsoring agency.

Both in the Congress and in the general public, there is a perceptible view that the Federal laboratories should be more widely utilized in helping to solve current national problems. Although Federal agency missions, in one way or another, are oriented to meeting national needs and responsibilities, there are no national R&D installations which are independent of a particular executive branch agency for their programs, funding, personnel authorizations, and related essentials.

Number of Installations

Although an inventory of the security unclassified Federal R&D installations in 1969 listed a relatively large aggregate number of installations, there are only a few Federal

Technically Desirable and Feasible
Basic Research Facilities Costing \$5.0 Million or More

<i>Environmental Sciences</i>	<i>Biological Sciences</i>	<i>Engineering</i>	<i>Physical Sciences</i>
Upper Atmosphere Observatory (\$14M)	National Resource Centers (\$50M over 10 years)	Earthquake Engineering Facility (\$30M)	NRAO VLA (\$76M)
NCAR 4th generation computer (\$15M)	Brookhaven Center for Biological Instrumentation (\$5M)	Automation Technology Institute (\$5M)	Neroc 440' dia. Steerable (\$30M)
NOAA: Geophysical and Fluid Dynamics Laboratory computer (\$18M)	Cell Production and Fractionation Centers (\$25M over 5 years)	Engineering Software Technology Transfer Center (\$8M)	Owens Valley Inter- ferometer (\$8M)
	National Institute of Ecology (\$10M)	Resource Center for Construction and Industrialized Building (\$6M)	100" Optical telescope (\$5M)
		Resource Center for Productivity and Machine Design (\$6M)	200" Southern Hemisphere telescope (\$20M)
			NRAO Homology telescope
			Mountain Top Cosmic Ray Observatory (\$5M)
			Calculation Center for Chemistry (\$10M)
			Upgrade Cornell Electron Synchrotron (\$5M)
			Upgrade 184" Synchrotron Berkeley (\$7M)
			Heavy Ion Lab for Nuclear Physics (\$20M)
			Array of Gravitational Detectors (\$5M)
			Storage Ring Brookhaven Isabelle (\$50M)
			Storage Ring Berkeley-Stanford (\$75M)
			Project PEP
			Recirculating Linear Accelerator Upgrade SLAC (\$17M) Stanford

Source: National Science Foundation

agencies responsible for these installations.⁸ A total of 17 departments, independent agencies, and commissions reported nearly 700 installations, over 85 percent of which are within the Departments of Agriculture, Defense, Interior, and Health, Education, and Welfare (HEW), and in the National Aeronautics and Space Administration (NASA).

Another feature of the Federal in-house R&D installations is the large number of small units; approximately one-half of all the installations have nine or fewer professional staff members. The majority of these installations are under the jurisdiction of the Department of Agriculture's Agricultural Research Service and Forest Service. Many of these small laboratories are actually in close juxtaposition to larger installations or are located on the campuses of land-grant institutions. At the other end of the size spectrum, the largest installations belong to NASA, and are staffed by almost 5,000 professionals.

Federal Funding of Intramural R&D

Cost data on Federal laboratories can be approximated from funding data on Federal intramural R&D. Such data have been collected since 1955, and include overall costs of Federal R&D performance as well as costs of administering R&D grants and contracts. In some agencies, such as the National Science Foundation which maintains no Federal laboratories, and the Atomic Energy Commission, which has only three relatively small laboratories, the costs of grant and contract administration represent the great bulk of the intramural effort. In others, such as the Department of Defense, the costs of administering grants and contracts are a minor portion of total intramural costs. This situation would also hold for NASA, and the Departments of Health, Education, and Welfare, Agriculture, Commerce, and Interior. Thus, funding data in this sector must be interpreted with considerable caution.

Between 1961 and 1972 Federal R&D obligations for intramural performance rose by a factor of two and one-third—from \$1.9 billion to \$4.5 billion—as Federal agency programs grew. In constant (1958) dollars the rise was not as steep—from \$1.8 billion to \$3.1 billion in 1972. Each year in the entire period marked a new high

in current dollars, although between 1966 and 1969 the rise was very moderate and, in real terms, actually showed a slight decline (figure 62).

The rate of growth of Federal intramural R&D funding over the 1960-72 period exceeded that of the national R&D effort. During 1960, the Federal Government obligated \$1.7 billion for intramural R&D which represented 23 percent of total Federal R&D obligations and 13 percent of total national R&D expenditures (figure 62). Estimates for 1972 indicate that Federal intramural R&D accounted for 27 percent of the Federal R&D budget and 16 percent of national R&D expenditures. Increases in the Federal intramural shares of R&D totals have resulted not only from higher intramural funding, but also from the fact that Federal funds for R&D in industry dropped in recent years, as the result of reductions in development programs of NASA and the Atomic Energy Commission.

Funding by Agencies

During this time, the Department of Defense (DOD) intramural R&D obligations were the largest of all agencies, although its share of the total of such Federal obligations decreased from 71 percent in 1961 to 54 percent in 1972 (figure 63). While the absolute level of DOD's intramural funding showed an almost continuous increase, the expansion of intramural work on the part of other agencies—notably NASA and HEW—was responsible for the decline in the DOD share.

NASA made up 10 percent of the Federal total in 1961 and rose to a high of 28 percent in 1965, reflecting the buildup of the Apollo program. Thereafter its share declined in most years, falling to 20 percent in 1972.

The Departments of Health, Education, and Welfare (especially the National Institutes of Health), Agriculture, Interior, and Commerce experienced little change over the 1961-73 period in their respective shares of Federal intramural R&D funding. Two of these agencies, Agriculture and Commerce, rely on intramural resources more fully than extramural performers, while the Interior Department does approximately one-half of its R&D intramurally.

The Department of Transportation did not come into existence until 1966, but its attention to problems of ground and air transportation

⁸ National Science Foundation, *Directory of Federal R&D Installations*, NSF 70-23.

Figure 62
Federal Obligations for Intramural R&D
Performance, FY 1961-72

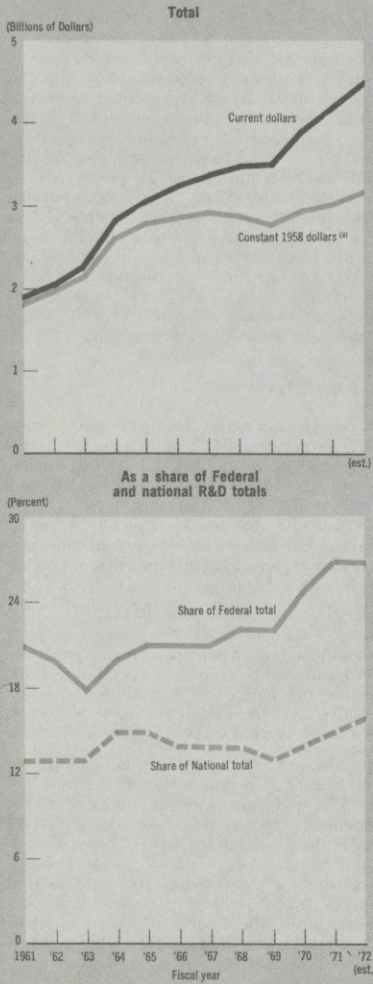
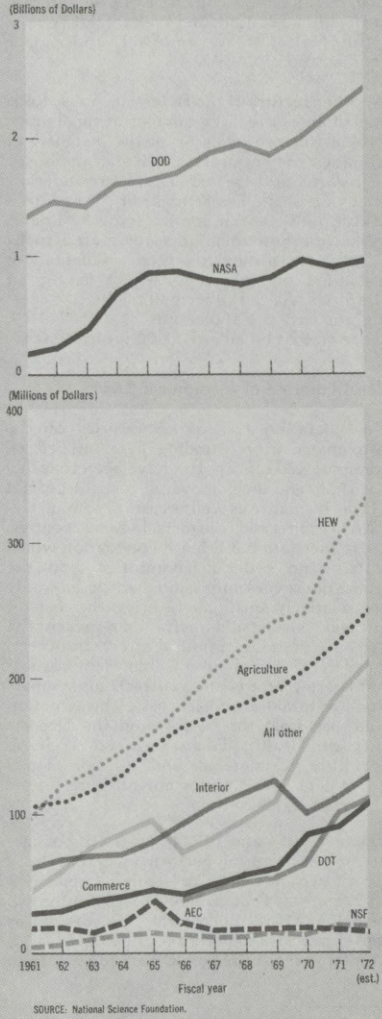


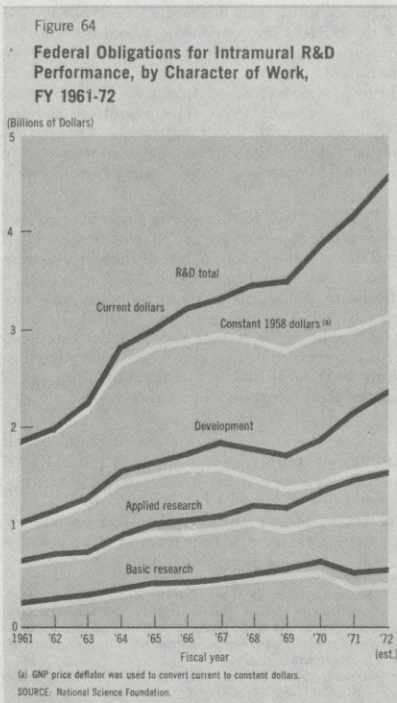
Figure 63
Federal Obligations for Intramural R&D
Performances, by Agency, FY 1961-72



and traffic safety has been represented in increased R&D funding.

Character of Work

While development activities accounted for a considerable larger proportion of the Federal intramural total than either basic or applied research throughout the 1961-72 period, the fraction devoted to development declined from 55 percent in 1961 to an estimated 52 percent in 1972. Part of this decline was due to the Apollo program phaseout. Meanwhile, Federal intramural basic research increased from 11 percent to 13 percent of Federal intramural R&D funds, and applied research rose from 34 percent to 35 percent (figure 64).



INDUSTRIAL RESEARCH AND DEVELOPMENT

Company Size and Research and Development

Research and development is an activity confined largely to large companies. The distribution of industrial R&D among different-size firms—as measured by the full-time-equivalent number of scientists and engineers engaged in R&D—is shown in figure 65. In 1971, 85 percent of all R&D scientists and engineers were employed by firms with more than 5,000 employees, as compared with 70 percent in 1958. Companies with fewer than 1,000 employees accounted for a declining proportion of industrial R&D scientists and engineers, from 20 percent in 1958 down to an estimated 6 percent in 1971. There was little change for companies of intermediate size.

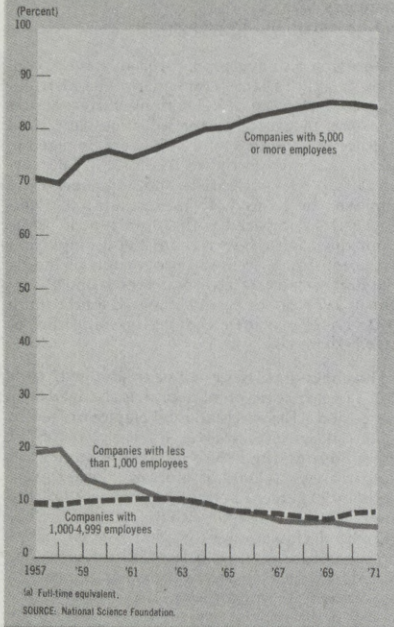
The above statistics must be treated with caution. The structure of industry has changed over this period. "Research and development," as an industrial activity, was in its early stages of growth during the 1950's. While the number of companies with 5,000 or more employees grew by about 50 percent between 1958 and 1967, the number of firms with less than 1,000 employees actually declined slightly. Some small companies naturally grew in size; others were absorbed by larger corporations. A further reason for caution in interpreting these data is the quality of respondent reporting, especially for small companies, during the early years of the survey.

Despite these cautions the rapid apparent decline of R&D in small firms may be a danger signal which calls for further investigation to determine its true significance. There is ample historical evidence to suggest that small firms have produced more than a proportionate share of major innovations, particularly those innovations which have been one of a family of successive innovations whose cumulative effect has been to create an entirely new industry. It is possible that the statistics quoted here do not accurately represent the true situation, but it is also possible that they signal a declining rate of technological innovation.

R&D Intensiveness

An indication of the degree of "R&D intensiveness" of an industry is the proportion

Figure 65
Distribution of Industrial R&D Scientists and Engineers,^(a) by Company Size, 1957-71



of the total human and financial resources which it invests in R&D. A high level of R&D, however, does not necessarily insure that an industry is highly innovative. For example, an industry may direct its R&D activities toward product differentiation, rather than to more basic technological innovation.

Two frequently used indicators of R&D intensiveness are (a) the number of R&D scientists and engineers as a percentage of all employees, and (b) the percent of net sales devoted to R&D. These indicators are used in the following to estimate the level of R&D intensiveness of U.S. industry as a whole, as well as of manufacturing and nonmanufacturing industries, and to determine its relationship to company size.

U.S. Industry. The first of these indicators shows that for U.S. industry as a whole, the number of R&D scientists and engineers increased from 25 per 1,000 employees in 1960 to 30 in 1964-65, but then declined to 24 in 1970. Similarly, the percent of net sales devoted to R&D rose from 4.2 in 1960 to 4.6 in 1964, and then declined progressively to 3.8 in 1970 (figure 66).

The changes between 1960-70 in both indicators show that the R&D intensiveness of U.S. industry, in terms of scientific and engineering manpower, increased by 20 percent between 1960-64 but then declined to a level in 1970 which was lower than 1960. The percent of net sales shows the same trend; the ratio rose by almost 10 percent between 1960-64 and then fell continuously to a level in 1970 well below that of 1960.

Manufacturing Industries. Individual manufacturing industries differ greatly in the extent of their R&D intensiveness. Based on the two indicators, each of the 15 major industries in the manufacturing sector was placed into one of three groups according to the level of its R&D intensiveness in 1970. The resulting groups, each consisting of five industries, are presented in the table on page 79; Group I industries are the most R&D intensive and Group III the least.

The level of R&D intensiveness remained essentially constant for industries in Groups II and III between 1960-70, but declined for Group I industries after 1964 (figure 67). The extent of the latter reduction was approximately 25 percent by 1970, as measured by each of the indicators. The declines in the most R&D-intensive group appear to be due almost entirely to reductions in Federal funding of defense- and space-related R&D in these industries.

Nonmanufacturing Industries.⁹ Only a small number of companies (estimated at 1,100-1,200) in this sector perform R&D. The R&D intensiveness of those which perform any R&D increased by 50 percent between 1961-66, and remained at essentially that level in later years.¹⁰

⁹ These include (but are not limited to) agriculture, mining, transportation, public utilities and sanitary services, wholesale and retail trade, finance, insurance, business services, medical and dental laboratories, and engineering and architectural services.

¹⁰ National Science Foundation, *Research and Development in Industry, 1970* (NSF 72-309).

R&D Intensiveness of Manufacturing Industries

Group I		
	<i>R&D scientists and engineers per 1,000 employees, 1970</i>	<i>Percent net sales devoted to R&D, 1970</i>
Chemicals & Allied Products	38	4.1
Machinery	28	4.2
Electrical Equipment & Communications ..	39	7.5
Aircraft & Missiles	74	18.3
Professional & Scientific Instruments	31	5.9
Mean	42.0	8.0
Group II		
Petroleum Refining & Extraction	18	1.1
Rubber Products	18	2.1
Stone, Clay, & Glass Products	14	1.9
Fabricated Metal Products	10	1.2
Motor Vehicles & Other Transportation Equipment	20	3.5
Mean	16.0	2.0
Group III		
Food & Kindred Products	6	0.4
Textiles & Apparel	4	0.5
Lumber, Wood Products, & Furniture	4	0.4
Paper & Applied Products	6	0.7
Primary Metals	6	0.8
Mean	5.2	0.6

Source: National Science Foundation, *Research and Development in Industry, 1970*. (NSF 72-309).

(Data for the percent of net sales devoted to R&D are not available.) This places nonmanufacturing industries between Groups II and III of the manufacturing industries with respect to R&D intensiveness.

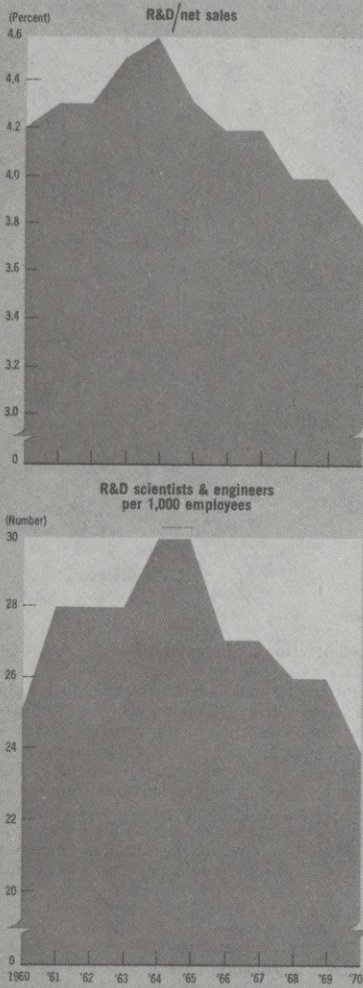
Company Size and R&D Intensiveness. Larger companies invested proportionally more of their resources in R&D than smaller ones over the period for which comparable data are available (figure 68). Very large companies (10,000 or more employees) devoted 4 to 5 percent of their net sales to R&D in 1967 and 1970, as compared with some 2 percent for smaller companies in 1967. The smallest companies (less than 1,000 employees), however, had almost the same ratio of R&D scientists and engineers to total employees as the largest companies in 1967. This ratio declined significantly in the largest companies between 1967-70.

Concentration of Industrial R&D

One of the most salient features of R&D in this sector is its high concentration within a few industries within the manufacturing sector. In 1970, 81 percent of industrial R&D funds were spent by five industries: aircraft and missiles (29 percent); electrical equipment and communications (24 percent); chemical and allied products (10 percent); machinery (10 percent); and motor vehicles and other transportation equipment (8 percent). Yet together these industries account for less than one-half of total manufacturing sales. This pattern of concentration developed in the 1950's and continued with little change through the 1960's. Since 1963, however, there has been a continuous but small (5 percent) reduction in the concentration. This shift is primarily due to declining expenditures for R&D related to aircraft and missile development, and

Figure 66

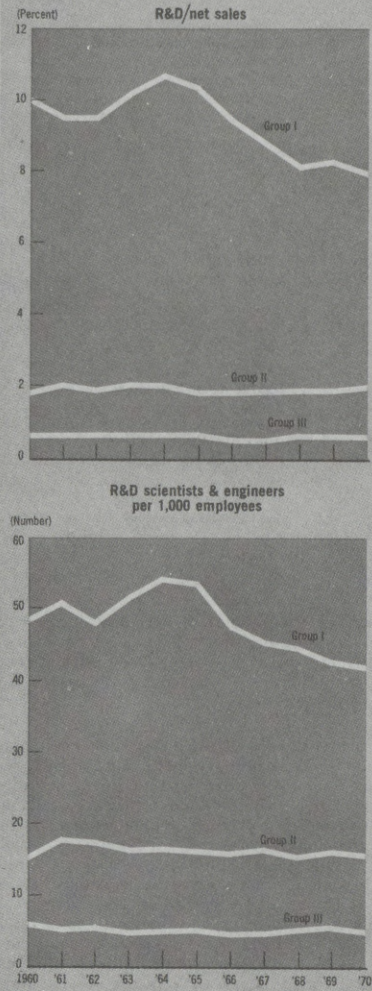
R&D Intensiveness of U.S. Industry, 1960-70



SOURCE: National Science Foundation.

Figure 67

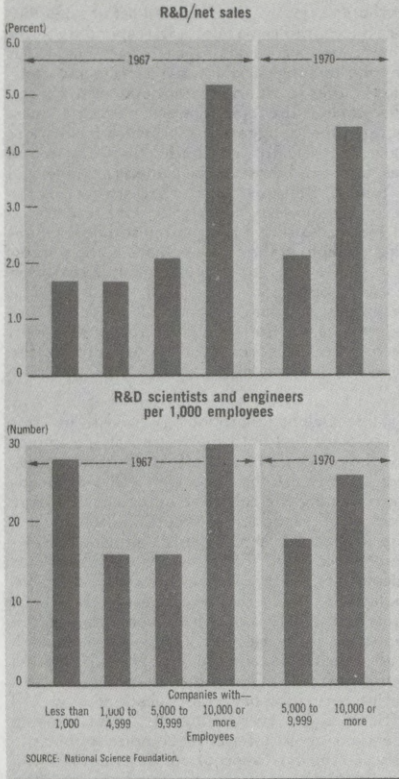
R&D Intensiveness of Groups of Manufacturing Industries, 1960-70



SOURCE: National Science Foundation.

Figure 68

R&D Intensiveness in Manufacturing Industries, by Company Size, 1967 and 1970



to a lesser extent, to the increasing R&D in industries other than the five noted above.

Industrial R&D in these manufacturing industries is also heavily concentrated in a relatively small number of companies. The four companies having the largest R&D investment spent 18 percent of all industrial R&D funds in 1970; the largest 20 spent 55 percent; and the largest 100 spent 79 percent. Some 300 companies spent 91 percent of all funds for industrial R&D. This pattern changed little over the past decades. This concentration, however, partially reflects the fact that certain industries, particularly some of those which are most R&D intensive (e.g., aircraft and missiles), are largely comprised of a relatively small number of large companies. R&D in such industries tends, perforce, to be concentrated in these large companies.

A Delphi Experiment

■ Various aspects of the scientific-technological enterprise and external conditions that influence its capabilities and performance are not amenable to purely quantitative treatment. Some of these were explored through a public opinion survey, the results of which are summarized in the following section of this report. Others involve considerations of a predominantly scientific or technical nature. Several of the latter aspects and conditions were investigated on an experimental basis, using a Delphi technique to solicit and synthesize the judgments and opinions of a cross section of the scientific and technological community. The study was carried out over the period of July-August 1972.

The topics explored in this experimental effort were:

- Panel 1—The future role of science and technology in areas of high public concern;
- Panel 2—Impacts of recent R&D funding changes on science and technology;
- Panel 3—Technological innovation including current impediments and measures for enhancement;
- Panel 4—Basic research including criteria for support and means for improving its effectiveness;
- Panel 5—Allocation of financial resources among fields of scientific research; and
- Panel 6—Future directions for graduate education in science and engineering.

Participants in the Delphi exercise, who are listed in Appendix B, were selected for their extensive experience and knowledge in science and technology and the interaction of the two with society. Panels, ranging in size from 10 to 42, were composed of participants encompassing the disciplines, experience, and institutions relevant to the specific topics. Panelists represented a broad spectrum of disciplines (physical, life, and social sciences and engineering); experience (management, research, teaching); and institutions (colleges and universities, foundations, government, and industry).

The Delphi technique used in this experiment solicited the judgments of the participants

through a relatively structured set of questions organized into two rounds. In responding to the first round of questions each participant was invited to suggest additional aspects and questions either to attain greater detail or to expand the scope of the topic. The second round incorporated these suggestions, provided feedback to each participant of both his first-round responses and those of the panel as a whole, and extended the questions. Participants in the second round responded again to the first-round questions—altering their initial responses if desired, in light of the group responses and suggestions—as well as to the questions added between rounds one and two. The second-round responses to panels reported hereafter are aggregates of the individual responses, with each participant contributing equally to the collective judgment.

The Delphi methodology used in this experiment had both merits and shortcomings for the purposes of this effort. On the positive side, it proved to be a relatively efficient means for obtaining the collective judgment of a large number of respondents, under conditions which encouraged the expression of individual viewpoints free from the pressures of face-to-face encounters. As used here, however, the technique had some serious weaknesses: the size of some of the panels may have been too small to represent the variety of viewpoints associated with some topics; and the controlled and limited nature of the inquiry may have resulted in misinterpretation of certain questions, as well as difficulties in responding to them. Posing questions about inherently complex and subtle issues in the most appropriate way was often the most difficult, and least successful, aspect of the experiment.

Finally, it should be noted that panelists responded to three different kinds of questions: questions soliciting cause or effect *interpretations*; questions soliciting *predictions*; and questions soliciting *recommendations* about possible future policies. Although expert judgment is involved in each case, interpretations and predictions differ from recommendations in that the latter involve normative considerations to a greater extent. Furthermore, in the absence of comparable previous studies the results should be

interpreted with caution. They are presented in this report in the same spirit as that in which they were obtained: as experimental findings.

The judgments of the panelists are summarized in the following pages. Only those judgments expressed by the panels as a whole are presented. This omits the many interesting comments and suggestions provided by individual participants but which were not reviewed by the entire panel.

DELPHI TOPICS

Panel 1—42 Panelists

National Problems Warranting Greater R&D

Panelists judged the extent to which science and technology could help ameliorate several

problems of high public concern and identified the areas in which expanded R&D was warranted. These judgments are presented in table A.

Although R&D was viewed as essential for alleviating many of the Nation's problems, it was rarely regarded as sufficient in itself. The full effectiveness of science and technology was seen as dependent upon appropriate social, economic, and political policies.

A number of problem areas identified by the Delphi panelists as warranting expanded R&D were the same areas as those chosen by the general public for applications of science and technology.¹ The areas in common which were most favored by the public were health care, pollution control, drug abuse, and crime.

¹ See the following section, "Public Attitudes Toward Science and Technology."

Table A—National Problems Warranting Greater R&D Effort

Problem area ¹	Areas which could benefit from science and technology (percent of panelists)	Areas warranting major increases in R&D (percent of panelists)
Pollution (including water pollution, solid waste disposal, land pollution)	97	92
Power/energy resources (including greater conservation and more efficient use of power resources)	97	86
Industrial productivity	81	70
Adequacy of natural resources	80	82
High cost and ineffectiveness of health services	79	86
Deterioration of international economic position of the United States	66	68
Population growth	56	53
Inappropriateness and expense of education	50	62
Magnitude, quality, and delivery of information	47	40
Drug abuse	46	70
Inadequate urban planning	45	63
Poverty	43	56
Breakdown in efficiency and innovativeness of public sector services	36	48
Inadequate employment opportunities	28	47
Nuclear war	27	34
Urban crime	23	46
Disrespect for established institutions	8	17
Group conflict and alienation	8	33
Irresolution of international conflict	8	32
Changing values (sex mores, work ethics, etc.)	3	12
Racial discrimination	3	31

¹ Items in italics were suggested to panelists as examples; others were added by panelists and presented in the second round.

Panel 2—16 Panelists

Impacts of R&D Funding Changes

Delphi panelists identified and assessed certain R&D funding changes which had occurred since 1965 in terms of their beneficial or detrimental impacts, and identified some of the major consequences—both positive and negative—of these changes. Funding changes, which a majority of panelists believed to be either beneficial or detrimental, are presented in table B.

Table B—Funding Changes Assessed as Beneficial or Detrimental to R&D

Beneficial changes ¹	Percent of panelists assessing change as beneficial
<i>Increased spending for health related R&D</i>	69
<i>Increased support for social sciences</i>	67
<i>Increasing percentage of total R&D funded by industry rather than Government</i>	65
Detrimental changes ¹	Percent of panelists assessing change as detrimental
<i>Decreased R&D funding (in constant dollars)</i>	100
<i>Frequent rapid changes of programs and directions of funding</i>	100
<i>Decrease (in constant dollars) in basic research funds</i>	95
<i>Allocation of funds by student count</i>	82
<i>Closing down or significantly diminishing support for some large industrial R&D laboratories</i>	81
<i>Decrease in R&D activities of small firms</i> ..	67
<i>Reduction in rate of initiation of construction of "Big Science" facilities</i>	66
<i>Increased allocation to R&D areas with short-term application</i>	52

¹Items in italics were suggested to panelists as examples; others were added by panelists and presented in the second round.

Three changes in R&D funding were viewed as beneficial. Increased spending for health-related research and development was regarded as having been a positive trend because of the likelihood of improved health services for the general community, rather than for basic science

advances in the life sciences per se. Similarly, increased support for the social sciences were deemed beneficial largely because of the possibilities for developing a more scientific approach to social problems; increased R&D funding by the private sector was seen as probably resulting in greater emphasis on efforts which contribute to the economy in significant and immediate ways. Some panelists, however, warned that the latter change produced a shift in R&D toward short-term and low-risk efforts aimed at insignificant technological advances.

Most of the changes regarded as detrimental relate to decreases in R&D funding. In respect to reduced R&D and basic research funding (in constant dollars), the many consequences suggested by individual panelists included: a decrease or delay in developing new knowledge; the loss of scientific manpower and the reduction of the number of future scientists and engineers; increased reliance on Federal administrators for program selection; the demise of significant basic research programs formerly supported by the Department of Defense; and in the long run, a loss of the U.S. leadership position in basic sciences.

As in the case of funding decreases, all panelists judged frequent, rapid changes of programs and directions of funding to be detrimental because of the discontinuities introduced into research programs and the consequent waste of financial and human resources.

The panelists also registered concern about criteria employed in allocating support for research. The group thought that allocation on the basis of "student count" (a funding change identified by the panelists) was detrimental to the scientific and technical enterprise since it results in an ever greater concentration of research in larger institutions. A small majority (52 percent) of the panelists believed that increased allocation to R&D areas with short-term application was harmful because of the resulting reduced support and training in the basic sciences; a slower rate of development of new knowledge; the sacrifice of long-term needs; and increased support of second-rate projects masked as topical and relevant research. In contrast, 25 percent of the respondents thought that increased allocation to areas with short-term application was beneficial because of possibly earlier benefits to society in important need areas.

The R&D efforts of industry were also a prime concern of the panelists, who thought that de-

creased support for some large industrial R&D laboratories were detrimental to science and technology. The panelists related this funding change to decreases in productivity and in beneficial technological advance, and weakening of the international trade position of the United States. The group (76 percent) also rated the effects of a decrease in R&D activities of small firms as detrimental. They warned against the loss of important innovative groups and the technical obsolescence of small firms. However, 40 percent of the panelists believed the unfavorable consequences would be minimal because significant advances require greater capabilities than are usually available to small firms.

Finally, the panel registered mixed reactions to the reduced rate of initiation of construction of "Big Science" facilities. The majority of panelists viewed the change as detrimental, and related it to a decrease in the rate of discovery in the long run, decline in the rate of research activity, and loss of international scientific leadership.

Panel 3—14 Panelists

Changes Needed to Improve Technological Innovation and Diffusion

This examination attempts to identify major impediments to technological innovation and diffusion in this country, and actions which might be taken to improve the situation. The impediments of both types suggested by the panel are presented in table C.

The major impediments to technological innovation which the group identified can be grouped into three areas related to (a) incentives and government policies, (b) industrial management, and (c) research activities and manpower. Some of the suggested factors, however, were regarded as beneficial by several of the panelists, including patent policies which inhibit innovation (25 percent); lack of a government agency to support the introduction of technological innovation (18 percent); and antitrust laws which prohibit cooperative ventures (17 percent).

Major impediments to the diffusion of innovations can be grouped into (a) lack of financial

incentives and characteristics of the market for innovative products and services, (b) policies and practices of industry itself, and (c) human resources. Several panelists evaluated the suggested factors as actually beneficial including: oversized, overorganized industry (22 percent); lack of a government agency to support the introduction of technological innovation (18 percent); and antitrust laws which prohibit cooperative ventures (17 percent).

Panel 4—12 Panelists

Adequacy of Current Basic Research Efforts

This inquiry assessed the appropriateness of the total funding level for basic research in terms of:

- (a) Criteria considered to be important in determining an appropriate funding level for basic research, and the appropriateness of the current level on the basis of these criteria,
- (b) Propensity for "risk-taking" in potentially "high-payoff" areas of research, and
- (c) Factors perceived to be impeding basic research in general.

Criteria for Support of Basic Research

The panelists emphasized the significance of both external factors and the opportunities and needs of the scientific enterprise itself, in determining an appropriate funding level for basic research (table D). Using these criteria, they suggested moderate increases, ranging from 2 to 12 percent, over the 1972 funding levels. The average of the proposed increases would raise the total funding in current dollars to \$4.4 billion in 1973.

High Risk-High Payoff Research

The panelists also evaluated the adequacy of basic research efforts by assessing the propensity to undertake "high risk-high payoff" basic research. "High risk-high payoff" basic research refers to projects which may have a low probability of producing results and yet promise results, if achieved, of such significance that the projects are deemed worth the risk. An example

Table C—Factors Impeding Technological Innovation and Diffusion

Impeding Factors ¹	Percentage of panelists rating factor as impediment to:	
	Innovation	Diffusion
Incentives and Government Policies		
<i>Inadequate profit from innovative work to help social sector problems</i>	100	100
<i>Disaggregated and diffused market in several sectors needing innovation (local government, housing, health services, etc.)</i>	100	91
<i>Inability to obtain venture capital funds for high-risk innovations</i>	92	77
<i>Lack of appropriate tax incentives for R&D and innovation</i>	91	72
<i>Limited Federal support of industrial projects with high social return but low private return</i>	82	73
<i>Negative public attitudes toward technology</i>	82	63
<i>Antitrust laws which prohibit cooperative ventures</i>	75	75
<i>Lack of a government agency to support the introduction of technological innovation (to offset role of regulatory agencies)</i>	55	55
<i>Patent policies which inhibit innovation</i>	33	38
Industrial Management		
<i>Reluctance to abandon commitment to current processes/products</i>	100	100
<i>Limited industrial research budgets</i>	92	84
<i>Lack of orientation of R&D toward needs</i>	91	100
<i>Limited understanding of the innovation process by big company management</i>	91	91
<i>Lack of acceptance of innovations developed elsewhere</i>	91	90
<i>Lack of entrepreneurial spirit</i>	73	91
<i>Oversized, overorganized industry</i>	56	56
<i>Lack of adequate business and marketing efforts (to exploit successful innovations)</i>	56	56
Research Activities and Manpower		
<i>Negative bias of academic scientists toward the value of industrial research</i>	100	80
<i>Insufficient exploratory research</i>	100	60
<i>Education of scientists and engineers inappropriate for innovation</i>	92	75
<i>Lack of national priorities to focus science and technology resources</i>	91	82
<i>Negative attitude of academic scientists toward programmed (goal directed) research and multidisciplinary team research management</i>	89	78
<i>Lack of new ideas stemming from basic research</i>	85	23
<i>Lack of necessary technical skills</i>	75	100
<i>Limitations in the diffusion of technical information (in English and in foreign languages)</i>	67	75

¹ Items in italics were suggested to panelists as examples; others were added by panelists and presented in the second round.

Table D—Criteria for Use in Determining Total Funding Levels for Basic Research

Criteria ¹	Importance				Un- impor- tant (0)	Rela- tive impor- tance ²
	Very impor- tant (4) percent	(3) percent	(2) percent	(1) percent		
Potential for fundamental new insights	58	33	8	0	0	1.00
Science needed to generate technological solutions to major societal needs	45	36	17	0	0	.95
Contributes to maintenance of adequate spectrum of basic research skills as a resource for the future ..	33	42	25	0	0	.91
Availability of resources in society: ratio of total basic research/GNP ..	33	50	0	8	8	.87
Number of qualified researchers	25	33	33	8	0	.83
Proposal pressures: quantity of meritorious proposals in particular areas of basic research	33	17	42	0	8	.82
Predetermined ratio of basic research to total R&D expenditures	33	17	25	25	0	.80
New application of known laws to broader range of problems and initiatives	25	17	25	33	0	.76
Research contributes to education and training of new researchers ..	0	50	25	25	0	.73
Competitive pressure: activity of greater emphasis existing in other nations	17	17	17	33	17	.64

¹ Items in italics were suggested to panelists as examples; others were added by panelists and presented in second round.

² Sum of importance ratings for each criterion (proportion of panelists selecting each importance category times the numerical value of the category), divided by the largest sum.

of such work might be the current search for gravitational waves.

The panelists judged the level of "high risk-high payoff" basic research to be increasingly inadequate over the 1968-72 period. This decline was attributed to overall economic factors, lack of understanding of the process of discovery, and general disaffection with technology, as shown in table E.

Ninety percent of the panelists agreed that the economic recession forced an emphasis on short-term payoffs to the detriment of "high risk-high payoff" research. Sixty percent believed the increasing high cost of basic research ventures heightened these effects. To reverse the trend toward less "high risk-high payoff" research, panelists (64 percent) suggested establishing long-range research objectives, providing incentive risk-support funding (44 percent), and

increasing Federal funding to basic research in universities (38 percent).

Eighty percent of the panelists thought that lack of understanding of the process of discovery caused a change in the ratio of funding for "high risk-high payoff" basic research. They called for making the "hard and unpopular" decision to retain a fraction of resources for high-risk research (67 percent) and for recognizing the role of the scientist—as distinct from the engineer—in industrial research (40 percent).

Relatedly, 89 percent of the respondents believed that public and, therefore, political disaffection with perceived societal effects of technology contributed to the decline in high-risk funding. Similarly, 70 percent thought disappointment with payoffs from previous research investment was partially responsible for the decline. Sixty-three percent also expressed

Table E—Possible Causes for Relatively Reduced Support of High Risk-High Payoff Research

<i>Suggested causes¹</i>	<i>Percent of panelists in agreement</i>
Economic recession forced emphasis on short-term economic payoff, and concomitant retreat of scientists to safe areas of research	90
Public and political disaffection with perceived societal effects of technology	89
Lack of understanding of process of discovery	80
Disappointment with payoff from research investments (i.e., space, high energy physics, etc.)	70
Association of R&D with the Defense Department, and transfer of negative feelings about military expenditures	63
Increasingly high cost of basic research ventures	60
Failure to handle accelerating pace of knowledge acquisition	43
Investment in mission-oriented space research	29

¹ Items were suggested by panelists in the first round, and presented in second.

the belief that association with the Department of Defense results in the transfer of negative feelings regarding military expenditures to all R&D activities. Compensating policies included educating the public about the positive role of science and technology in the solution of societal problems (60 percent); direct funding of payoff areas (i.e., ecology, nuclear fusion, oceanography) (56 percent); administration of all Federal contracts through civilian agencies (50 percent); promoting public awareness of differences between science and technology (44 percent); and operationalizing and publicizing systems of technology assessment (38 percent). Seventy-one percent of the panelists disagreed that investment in mission-oriented space research caused a decline in "high risk-high payoff" basic research.

Impediments to Basic Research

Finally, panelists evaluated factors which may be impeding the effectiveness of basic research

(table F). These factors can be grouped approximately as: (a) *external factors* relating chiefly to funding, including the level of funding, the source and criteria for funding, and knowledge and attitude of the public; and (b) *internal factors* including inadequate long-range planning, "fashions" in research, inadequately trained researchers, lack of equipment, and inadequate industrial participation.

Several panelists thought some of the factors were not impediments. Fifty-six percent of the group judged the current number of researchers to be adequate; 63 percent believed that emphasis on applied research had essentially no effect or actually helped; 50 percent thought the composition of science advisory groups was not an impediment; and 27 percent viewed funding through national defense agencies as beneficial.

Panel 5—33 Panelists

Distribution of Basic Research Funds Among Fields of Science

Under this topic opinions were sought about criteria which might be useful in deciding on relative levels of support for basic research in various scientific fields—life, physical, engineering, mathematical, and social. The several criteria suggested by the panelists (table G) can be separated into four clusters, each reflecting a dominant concern: (a) advancement of knowledge (Nos. 1, 2, 4, 6, 7, 11); (b) effective use of scientific capabilities and resources (Nos. 10, 14, 15, 16, 18); (c) potential application and use of results (Nos. 3, 5, 8, 9); and (d) public understanding and support of research (Nos. 12 and 17). In terms of the importance ratings assigned by the panelists to the criteria in each cluster, allocation of funds among fields should depend primarily upon opportunities for advancement of knowledge and the potential application of this knowledge to practical ends. Of much less importance—but still to be considered—are criteria concerned with effective use of scientific capabilities and resources, and public understanding and support of basic research.

Using these criteria, the panelists evaluated the appropriateness of the present distribution of research funds among fields, with the results shown in the figure entitled "Federal Obligations for Basic Research by Field of Science."

Table F—Impediments to Basic Research

Factors which may be impeding the effectiveness of basic research in the U.S. ¹	Percent of panelists				
	Completely halts basic research	Seriously impedes basic research	Somewhat impedes basic research	Has essentially no effect	Actually helps basic research
Inadequate funding level		80	20		
Lack of long-range scientific planning		75	17		8
"Fashions" in selecting areas for support		73	18	9	
"Fashions" in research		73	18	9	
Emphasis on near-term payoff		73	18		9
Lack of public understanding of role of basic research		73	27		
Inadequately trained researchers	11	55	11	22	
Lack of research equipment		64	27	9	
Inbreeding in the socio- political structure of science advisory groups		40	10	40	10
Emphasis on applied research		36		36	27
Inadequate industrial participation		36	64		
Short-term funding of research projects		36	55	9	
Inadequate number of researchers ..		33	11	56	
Funding by defense agencies ..		27	45		27
Research perceived as socially undesirable		18	73	9	

¹ Items in italics were suggested to panelists as examples; others were added by panelists and presented in the second round.

Federal Obligations for Basic Research by Field of Science

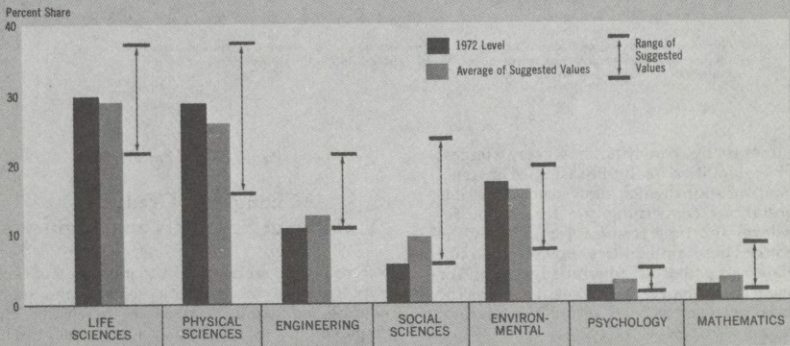


Table G—Criteria for Allocating Basic Research Funds Among Scientific Fields

Criteria ¹	Importance					Relative importance ²
	Very important (4)	(3)	(2)	(1)	Unimportant (0)	
	Percent	Percent	Percent	Percent	Percent	
Potential for major extension of scientific knowledge	42	42	17	0	0	1.00
Basic knowledge to be gained in the field promises to provide new directions for science	8	67	25	0	0	.97
Likely payoff for national objectives, such as health, defense, environmental controls ..	83	0	24	16	0	.92
Extent to which field is ripe for growth	25	42	33	0	0	.88
Field stimulates new technological advances	27	36	27	9	0	.81
Field contributes to progress in other fields ..	8	75	8	8	0	.81
Fields that create new disciplines	0	50	25	0	25	.69
Market mechanism indicates more research is necessary	10	40	40	10	0	.68
Field contributes to national educational objectives	0	42	17	42	0	.66
Field attracts the most able researchers	17	42	8	17	17	.65
Maintaining balance of research competence across fields	0	20	30	40	10	.64
Fosters public understanding of basic research	18	9	54	9	9	.63
Superiority of internal (Nos. 1, 2, 4) over external (Nos. 3, 5, 8) criteria	0	30	10	50	20	.61
Extent of effective use of resources in field ..	0	25	33	25	17	.59
Balance between current and anticipated demands for persons trained in field	0	27	36	27	9	.58
Number of researchers working in field without adequate support	0	18	18	45	18	.58
Packaging of basic research programs so as to enhance political support	0	9	27	54	9	.53
Unit cost of doing research	0	8	42	25	25	.47
Need to match facilities being constructed or in use in other countries	0	17	8	75	0	.35

¹ Items in *italics* were suggested to panelists as examples; others were added by panelists and presented in second round.

² Sum of importance ratings for each criteria (proportion of panelists selecting each importance category times the numerical value of the category), divided by the largest sum.

Comments by panelists, however, suggest certain ambiguities in the phrasing of instructions and questions which allow several possible interpretations concerning the total basic research level and time frame referred to by the questions. These ambiguities, however, do not invalidate the panelists' general suggestion for increasing the proportionate level of funding for the social sciences as well as for engineering, mathematics, and psychology.

Panel 6—10 Panelists

Changes in Graduate Training of Scientists and Engineers

This Delphi study sought to identify and evaluate changes in graduate science and engineering education aimed at increasing the employability of scientists and engineers. The

panel assessed the importance of these changes in terms of their effects on the graduate's ability to find employment and to contribute over a period of time to his profession.

The changes identified by the panelists (table H) emphasized the need for (a) individualized training, (b) integrating work and education, and

(c) reducing the extent of specialization. Better guidance in career development and midcareer education were seen as most important to life-long professional effectiveness of scientists and engineers. As for employability, increased use of cooperative and multidisciplinary research along with independent, practice-oriented programs were rated as possible significant improvements.

Table H—Evaluation of Changes in Graduate Education

Currently or potentially important graduate educational changes ¹	Percent of panelists indicating that change would:		
	Improve employability	Improve professional effectiveness	be implemented by 1980
Increased use of cooperative programs	98	78	67
Increased emphasis on accrediting practice-oriented graduate programs	90	60	60
Increased emphasis on "multi-disciplinary research"	89	70	90
Establishment of personalized or independent graduate programs	89	78	67
Greatly improved systems for assembly and access to current information on science and technology	89	89	50
Better guidance in career development	89	100	55
Inclusion of additional year of "intern" training in a non-academic institution as part of degree requirements	80	50	10
Expansion of programs conferring joint degrees (e.g., M.S. in chemistry; M.A. in business administration)	80	60	50
Establishment of a two-track (practice oriented, research) graduate program with different requirements for masters and doctorate degrees	80	60	50
Relate educational programs and professional experience by encouraging faculty involvement in both	80	67	30
Increased emphasis on "team" research in curricula concerned with highly specialized fields	70	70	60
Emphasis on education-training for university teaching	67	56	44
Mid-career education	66	100	100
Encourage splitting theses between two or more research groups	44	33	22
Establish a curriculum in technological forecasting and social impact evaluation	40	30	33

¹ Items were suggested by panelists in the first round, and presented in the second round.

Public Attitudes Toward Science and Technology

■ Public attitudes affect science and technology in myriad ways. Public opinion sets the general climate—positive, neutral, or negative—for the development and use of scientific knowledge and technology. It influences the choice of ends to which the enterprise is directed, the magnitude and kinds of resources (economic, human, and institutional) allocated for research and innovation, and the selection by the young of careers in science and engineering.

To determine current public attitudes, a personal interview survey was conducted in May and June 1972 among 2,209 persons 18 years of age and more, using sampling techniques which permit the results to be projected to the total adult U.S. population.¹ The chances are 95 in 100 that the survey results do not vary by more than 2 percent (plus or minus) from the results that would be obtained if interviews had been conducted with all persons in this population.

The survey focused on three general aspects of the attitudes of the public: their regard for science and technology, their assessment of its impacts, and their expectations and desires for its future role in dealing with national problems.

The survey results are reported first for the total group, and subsequently for demographic subgroups. Since differences (ranging from 36 to 1 percent) in the frequency of "no opinion" occurred among the subgroups—and were particularly high for the oldest, lower income, lower education, and nonwhite groups—the results are reported for all those polled, as well as for all those expressing an opinion.

TOTAL GROUP RESPONSES

Public Regard for Science and Technology

This aspect of public opinion was explored from three different perspectives: the perceived

effects of science and technology on the quality of life; the affective or emotional reaction to science and technology; and the standing or prestige of scientists and engineers in relationship to other occupations.

Science and technology have changed life for the "better" according to 70 percent of the public. Eleven percent felt that the changes were neither predominately good nor bad, while 8 percent felt that changes were for the "worse."

Do you Feel That Science and Technology Have Changed Life for the Better or for the Worse?

Response	Percent	Percent of those having an opinion
Better	70	77
Worse	8	9
Both	11	12
No effect	2	2
No opinion	9	—

To describe their emotional reaction to science and technology, the respondents expressed either "satisfaction or hope" (49 percent), "excitement or wonder" (23 percent), "fear or alarm" (6 percent), and "indifference or lack of interest" (6 percent).

Which One of These Items Best Describe Your General Reaction to Science and Technology?

Response	Percent	Percent of those having an opinion
Satisfaction or hope ...	49	58
Excitement or wonder .	23	27
Fear or alarm	6	7
Indifference or lack of interest	6	7
No opinion	10	—

A further indication of the public regard for science and technology are the ratings of science and engineering as professions. From a list of nine professions, that of scientist was ranked second only to physicians, while engineers were

¹ The survey was conducted for this report by the Opinion Research Corporation, Princeton, N.J. A complete report of the study is available.

grouped with ministers, lawyers, and architects. Comparison with previous surveys in 1947 and 1963 indicates a decline in ratings for all

professions, although scientists maintained their relatively high position and engineers advanced in relative prestige.

Choose the Statement That Best Gives Your Own Personal Opinion of the Prestige or General Standing That Each Job Has.

Occupation	1972 Ratings (percents)					Total score ¹		
	Excellent	Good	Average	Below average	Poor	1972	1963 ²	1947 ²
1. Physician	66	26	5	1		90	93	93
2. Scientist	59	27	8	1	1	86	92	89
3. Minister	44	36	15	2	1	83	87	87
4. Engineer	40	43	13	1		83	86	84
5. Lawyer	44	36	14	2	1	82	89	86
6. Architect	40	42	12	1		81	88	86
7. Banker	33	47	17	1		81	85	88
8. Accountant	29	46	19	1	1	78	81	81
9. Businessman	20	52	24	1	1	77	80	82

¹ Average of the ratings, where excellent = 100, good = 80, average = 60, below average = 40, and poor = 20.

² Scores from previous studies, which are comparable to present survey (see R. W. Hodge, P. M. Siegel, and P. H. Rossi, "Occupational Prestige in the United States, 1925-63," *American Journal of Sociology*, Volume LXX, No. 3, November 1964, pp 286-302.)

Impacts of Science and Technology

The public assessed several aspects of the impacts of science and technology—the net balance of beneficial and harmful consequences, the relative extent of the problems created, and the pace of change produced by science and technology—and appraised the adequacy of society's control over science and technology.

Fifty-four percent of those responding felt that science and technology do more good than harm, as compared with 31 percent who felt that the effects were about equally beneficial and harmful, and 4 percent who believed the impacts to be more harmful than good.

Overall, Would You Say That Science and Technology Do More Good Than Harm, More Harm Than Good, or About the Same Each?

Response	Percent	Percent of those having an opinion
More good	54	61
More harm	4	4
About the same	31	35
No opinion	11	

Those whose response was either that science and technology did "more good than harm" or "both good and harm" were asked to indicate

"one of the good things." Similarly, those responding "more harm than good" were asked to identify "one of the harmful things." These results are summarized below.

**Beneficial Contributions of Science and Technology
(Cited by Group Responding "More Good than Harm")**

Responses	Percent
Improvements in medicine/medical research	54
Space research/moon trip	12
Atomic research/nuclear science	5
Efforts to improve the environment ...	5
Development of TV, computers, etc. ...	3
Improved methods of transportation ...	3
Agriculture	2
Food research/processing	2
Don't know	4

**Beneficial Contributions of Science and Technology
(Cited by Group Responding "Both Good and Harm")**

Responses	Percent
Improvements in medicine/medical research	50
Space research/moon trip	9
Efforts to improve the environment ...	5
Improved working/living conditions ...	5
Development of TV, computers, etc. ...	3
Improved methods of transportation ...	2
Food research/processing	2
Don't know	17

Harmful Activities of Science and Technology
(Cited by Group Responding "More Harm than Good")

Responses	Percent
Lack of concern for the environment . . .	27
Space program/moon trips	16
Development of weapons for war	9
Destruction of natural resources	2
Development of harmful medicines	2
Harmful drugs (development and publicity)	1
Don't know	23

Forty-eight percent of the public felt that "some" problems were caused by science and technology, as compared to 27 percent who believed that "few" problems were so caused, 9 percent who thought that "none" were produced, and 7 percent who believed that "most" problems were caused by science and technology.

Do You Feel That Science and Technology Have Caused Most of our Problems, Some of our Problems, Few of our Problems, or None of our Problems?

Response	Percent	Percent of those having an opinion
Most	7	8
Some	48	53
Few	27	30
None	9	10
No opinion	9	—

As for the pace of change, 51 percent of those responding felt that science and technology produced a desirable rate of change, whereas the remainder were divided as to whether the change was "too fast" (22 percent) or "too slow" (16 percent).

Do You Feel That Science and Technology Change Things Too Fast, Too Slowly, or Just About Right?

Response	Percent	Percent of those having an opinion
About right	51	57
Too fast	22	25
Too slowly	16	18
No opinion	11	—

Forty-eight percent of those responding felt that society's control over science and technology should "remain as it is," while 28 percent felt that control should be "increased," and 7 percent believed it should be "decreased."

Do You Feel That the Degree of Control That Society Has Over Science and Technology Should Be Increased, Decreased, or Remain as It Is Now?

Response	Percent	Percent of those having an opinion
Remain as it is	48	58
Increased	28	34
Decreased	7	8
No opinion	17	—

Expectations and Directions for Science and Technology

The public expressed confidence in the potential of science and technology to solve major problems. Forty-seven percent believed that it would eventually solve "some" problems, such as pollution, disease, drug abuse, and crime; 30 percent felt that it would solve "most"; 16 percent thought "few" would be solved.

Do You Feel That Science and Technology Will Eventually Solve Most Problems Such as Pollution, Disease, Drug Abuse, and Crime, Some of These Problems, or Few, if Any of These Problems?

Response	Percent	Percent of those having an opinion
Most problems	30	32
Some problems	47	51
Few problems	16	17
No opinion	7	—

The problem areas selected by the public in which they would most like (and least like) to have their taxes spent for science and technology are summarized in the following table.

In Which of the Areas Listed Would You Most
Like (and Least Like) To Have Your Taxes
Spent for Science and Technology?

Response	Percent choosing area ¹	
	Most like	Least like
Improving health care	65	1
Reducing and controlling pollution	60	3
Reducing crime	59	2
Finding new methods for preventing and treating drug addiction	51	4
Improving Education	41	4
Improving the safety of automobiles	38	5
Developing faster and safer public transportation for travel within and between cities	23	14
Finding better birth control methods	20	18
Discovering new basic knowledge about man and nature	19	15
Weather control and prediction	11	19
Space exploration	11	42
Developing/improving weapons for national defense	11	30
No opinion	6	13

¹ Multiple responses accepted.

Preferences are indicated for improving health care, controlling pollution, and reducing crime, whereas space exploration and development of defense weapons received least support. Mixed reactions were expressed for the areas of birth

control, discovering new basic knowledge, and controlling and predicting weather.

On the whole, public attitudes toward science and technology appear to be positive. This is especially evident in their general regard for science and technology, and their confidence in its capacity to ameliorate national problems. Less positive opinions were expressed, however, regarding the impacts of science and technology, and the present uses to which it is put. On the whole, the public attitudes appear to reflect more confidence in the potential of science and technology than satisfaction with its present applications.

ANALYSIS OF RESULTS BY DEMOGRAPHIC SUBGROUPS

The response patterns of demographic subgroups, while similar, are not homogenous. A substantially greater frequency of "no opinion" responses is evident for the oldest, lowest income, least educated, and nonwhite subgroups. Such differences in "no opinion" response rates, while relevant, are not unique to this survey. In effect, they mask differences in expressed opinion toward science and technology. To avoid such ambiguities, comparisons of subgroup opinions are based on percentages of those expressing an opinion. These percentages and the frequency of "no opinion" among all subgroups are reported for selected questions in the following tables.

Overall, Would You Say That Science and Technology Do More Good Than Harm, More Harm Than Good, or About the Same of Each?

Subgroups	Percentage of those expressing an opinion			Percentage of total Group expressing no opinion
	More good	More harm	About same	
All	61	4	35	11
Men	64	4	32	8
Women	59	3	38	13
18-29 yrs.	55	5	39	8
30-39	69	2	29	7
40-49	66	5	29	7
50-59	60	4	35	9
60 +	57	4	39	19
< High school	51	6	43	18
High school	63	2	35	5
Some college	74	4	22	5
< \$10,000	56	6	38	15
> \$10,000	68	2	31	4
White	62	3	35	8
Nonwhite	54	11	35	28

**For The Most Part, Do You Feel That Science and Technology Will Eventually
Solve Most Problems Such as Pollution, Disease, Drug Abuse, and Crime,
Some of These Problems, or Few if Any of These Problems?**

<i>Subgroups</i>	<i>Percentage of those expressing an opinion</i>			<i>Percentage of total group expressing No opinion</i>
	<i>Most</i>	<i>Some</i>	<i>Few</i>	
All	32	51	17	7
Men	36	47	17	5
Women	29	54	18	9
18-29 yrs.	28	55	17	5
30-39	33	54	13	3
40-49	31	53	16	4
50-59	37	43	20	7
60 +	33	46	21	13
< High school	33	47	20	12
High school	29	55	16	4
Some college	35	51	14	3
< \$10,000	31	49	19	10
> \$10,000	33	52	15	2
White	33	51	17	5
Nonwhite	32	50	18	22

The intercorrelations among indicators of socioeconomic status (i.e., ethnicity, income, education) also make it difficult to relate variations to specific subgroups. Some general patterns, however, are evident. Among those expressing an opinion, respondents from relatively high socioeconomic groups indicate more positive attitudes about the contributions of science and technology than do respondents from relatively lower groups.

This socioeconomic difference appears to be overlaid with variation by age. Compared with

other age groups, younger respondents (18-29 years of age) tend to be relatively negative about past contributions of science and technology, but relatively positive in their hopes for the future; middle-aged respondents tend to be relatively positive about both the past and the future; older respondents (over 60) are relatively negative about both the past and the future.

An additional variation appears among the responses of the sexes, as men tend to judge past contributions of science and technology more favorably, and express more optimism about its future.

Appendix A—Indicators

Table 1. R&D expenditures as a percent of gross national product, by country, 1963-71
[National currencies in billions]

Country	1963	1964	1967	1969	1970	1971
R&D expenditures						
United States	17.4	19.2	23.6	26.2	26.7	27.3
France ¹	6.4	(²)	12.4	13.9	15.1	15.8
Germany	6.1	(²)	8.3	10.4	13.9	15.1
United Kingdom	0.73	0.77	0.94	1.02	1.08	1.14
Japan	321	(²)	606	933	1,200	1,500
U.S.S.R.	4.9	(²)	7.2	9.3	(²)	11.6
Gross national product						
United States	590.5	632.4	793.9	929.1	974.1	1,047.0
France	396.0	(²)	573.2	725.6	815.2	903.0
Germany	377.6	(²)	495.5	603.4	682.1	750.6
United Kingdom	30.7	33.3	40.1	46.1	50.5	54.0
Japan	23,628	(²)	43,545	60,242	70,985	82,000
U.S.S.R.	206.8	(²)	282.0	329.6	362.6	386.6
R&D expenditures as a percent of gross national product						
United States	2.94	3.04	2.97	2.81	2.73	2.60
France	1.62	(²)	2.16	1.92	1.85	1.75
Germany	1.62	(²)	1.68	1.72	2.04	2.01
United Kingdom	2.38	2.31	2.34	2.21	2.14	2.11
Japan	1.36	(²)	1.39	1.55	1.69	1.83
U.S.S.R.	2.37	(²)	2.55	2.82	(²)	3.00

¹ Gross expenditures for research and development.

² Not available.

Sources: Organisation for Economic Co-operation and Development, *International Survey of the Resources Devoted to R&D by OECD Member Countries* for 1963, 1967, and 1969; National Science Foundation estimates for 1970 and 1971; U.S.S.R. estimates for all years provided by Dr. Robert W. Campbell, Indiana University.

Table 2. Scientists and engineers¹ engaged in R&D per 10,000 population by country, 1963-71

Year	United States	U.S.S.R.	France	Germany	Japan
1963 ..	25	19	7	6 ²	12
1967 ..	27	26	10	11	16
1969 ..	28	32	11	12	17
1970 ..	27	(³)	12	14	21
1971 ..	25	37	12	15	25

¹ Full-time equivalents.

² 1964.

³ Not available.

Sources: Organisation for Economic Co-operation and Development, *International Survey of the Resources Devoted to R&D by OECD Member Countries* for 1963, 1967, and 1969; National Science Foundation estimates for 1970 and 1971; U.S.S.R. estimates for all years provided by Dr. Robert W. Campbell, Indiana University.

Table 3. Distribution of government R&D expenditures among national objectives, by country, 1961 and 1969

National Objectives	United States	United Kingdom	France	Germany	Japan
Total (millions of dollars)	\$11,089	\$1,078	\$601	\$423	\$235
Percent distribution					
1961					
National defense	65	65	40	22	4
Space	16	1	1	(¹)	(¹)
Community services	7	2	1	(¹)	2
Economic development	4	11	8	(¹)	30
Nuclear energy	7	15	29	16	7
Advancement of science	2	7	20	37	56
1969					
National defense	49	40	31	19	2
Space	24	4	7	6	1
Community services	12	4	3	2	4
Economic development	7	26	16	2	23
Nuclear energy	6	12	18	17	8
Advancement of science	2	13	24	39	61

¹ Not available.

Source: Organisation of Economic Co-operation and Development, *Research and Development in OECD Member Countries: Trends and Objectives*, September 13, 1971.

Table 4. Scientific literature in selected fields as a percent of total literature produced by major developed nations, 1965-71

Selected field and year	Total literature	United States	United Kingdom	Germany	France	U.S.S.R.	Japan	Other and unknown
	Number	Percent of total						
Mathematics								
1965	2,971	23.9	6.6	6.3	5.6	22.4	4.2	31.8
1967	4,298	23.9	4.6	6.4	4.5	26.4	4.7	29.8
1969	3,024	26.9	6.4	6.0	6.9	20.0	5.2	27.1
1971	3,739	27.8	3.9	6.5	6.0	22.2	7.0	26.7
Physics and geophysics								
1965	23,224	41.3	8.2	7.4	4.8	15.7	4.4	18.2
1967	27,121	42.1	8.6	7.5	5.3	13.8	5.2	17.5
1969	29,353	41.0	8.3	7.2	5.4	14.6	5.1	18.4
1971	29,824	42.4	8.1	5.8	5.1	13.8	6.0	18.7
Chemistry and metallurgy								
1965	34,657	25.9	7.7	8.2	3.9	30.9	4.1	19.3
1967	39,730	24.5	7.9	8.4	5.9	28.8	5.3	19.2
1969	43,362	24.2	8.2	7.9	5.7	28.5	6.4	19.2
1971	45,052	23.9	8.4	6.8	6.2	29.0	5.9	19.8
Molecular biology								
1965	24,321	46.6	9.5	4.8	9.4	3.0	4.2	22.4
1967	25,858	48.6	11.0	5.4	7.4	2.1	4.8	20.7
1969	29,359	47.6	9.3	5.5	9.0	1.8	4.9	21.8
1971	30,148	48.7	8.9	5.1	8.9	1.8	5.0	21.6
Systematic biology								
1969	6,101	29.4	6.0	4.9	4.8	9.0	5.0	41.0
1971	7,050	33.3	7.2	5.3	5.2	6.4	4.3	38.2
Psychology								
1965	3,537	79.3	8.1	.5	.2	(¹)	.5	11.4
1967	3,967	79.2	6.4	.5	.2	(¹)	.6	13.2
1969	4,308	76.6	7.8	1.6	.1	(¹)	.4	13.5
1971	4,075	76.5	7.9	.8	.2	(¹)	.5	14.1
Engineering								
1965	10,006	49.9	11.2	4.7	1.4	12.6	2.4	17.8
1967	11,968	48.8	11.3	5.6	1.8	12.5	2.8	17.2
1969	13,222	48.3	11.0	6.2	1.8	12.5	2.9	17.4
1971	13,765	49.7	9.0	6.1	2.2	11.8	3.8	17.3
Economics								
1965	1,299	15.5	7.9	6.0	14.0	7.2	2.0	47.4
1967	1,314	16.5	8.1	6.0	14.0	7.3	3.7	44.4
1969	1,390	20.4	7.4	5.7	14.9	7.4	1.1	43.1
1971	1,138	22.9	6.3	6.1	11.9	4.8	.7	47.3

¹ Complete data not available for U.S.S.R.

Source: Computer Horizons, Inc., *Development of U.S. and International Indicators of the Quantity and Quality of Scientific Literature*, September 1972.

Table 5. Citation/publication ratio¹ of scientific literature in selected fields

Selected field	United States	United Kingdom	Germany	France	U.S.S.R.	Japan	Other
Physics and geophysics	1.25	1.23	.78	.48	.76	.64	.85
Chemistry and metallurgy	1.34	1.22	1.07	.63	.42	.63	.80
Molecular biology ...	1.28	1.14	.60	.37	.50	.67	.78
Systematic biology ..	.97	1.60	1.14	.85	(²)	.91	.80
Mathematics	1.10	1.42	.97	.66	.82	.84	.81
Engineering	1.19	1.03	.82	.63	.62	.84	.84
Psychology	1.05	.92	(²)	(²)	(²)	(²)	.84

¹ Average of 1965, 1967, 1969, and 1971.² Not available.Source: Computer Horizons, Inc., *Development of U.S. and International Indicators of the Quantity and Quality of Scientific Literature*, September 1972.Table 6. Patents awarded to U.S. nationals by foreign countries¹ and to foreign nationals¹ by the United States, 1966-70

Patents awarded	1966	1967	1968	1969	1970
U.S. balance	23,061	21,798	23,226	17,026	14,286
Patents awarded to foreign nationals by the U.S.	9,282	9,662	8,928	11,817	11,961
Patents awarded to U.S. nationals by foreign countries	32,343	31,460	32,154	28,843	26,247

¹ United Kingdom, U.S.S.R., Germany, France, and Japan.Source: World Intellectual Property Organization, *Industrial Property*, Geneva: 1967-71 (December issues).

Table 7. U.S. patent balance with selected countries, 1966-70

Selected country	1966	1967	1968	1969	1970
United Kingdom:					
Balance	11,440	10,877	10,107	9,503	9,776
Awarded to U.S.	14,117	13,676	12,588	—	12,728
Awarded by U.S.	2,677	2,799	2,481	—	2,952
France:					
Balance	8,371	9,353	9,348	5,135	3,932
Awarded to U.S.	9,807	10,911	10,794	6,943	5,664
Awarded by U.S.	1,436	1,558	1,446	1,808	1,732
Japan:					
Balance	3,561	2,008	3,439	2,505	2,149
Awarded to U.S.	4,683	3,432	4,903	4,657	4,774
Awarded by U.S.	1,122	1,424	1,464	2,152	2,625
Germany:					
Balance	—248	—362	362	—40	—1,552
Awarded to U.S.	3,733	3,406	3,804	4,483	2,882
Awarded by U.S.	3,981	3,766	3,442	4,523	4,434

Source: World Intellectual Property Organization, *Industrial Property*, Geneva: 1967-71 (December issues).

Table 8. Productivity in manufacturing industries, by country, 1960-71
[Index, 1960=100]

Year	United States	Japan	France	Germany	United Kingdom
1960 ..	100.0	100.0	100.0	100.0	100.0
1961 ..	102.4	113.3	104.6	105.9	100.5
1962 ..	108.1	118.1	109.3	112.2	103.0
1963 ..	112.6	127.8	114.7	118.2	109.0
1964 ..	117.9	144.7	120.7	127.3	116.1
1965 ..	122.6	150.2	127.4	136.1	120.2
1966 ..	124.1	166.0	136.2	141.7	124.1
1967 ..	124.2	190.1	143.7	150.6	128.7
1968 ..	130.1	218.3	153.2	162.0	136.8
1969 ..	131.9	253.4	161.9	171.4	139.9
1970 ..	133.9	289.4	171.0	175.9	143.5
1971 ..	138.5	309.7	180.6	186.3	149.9

Source: Arthur Neef, "Unit Labor Costs in the U.S. and 10 Other Nations, 1960-71," *Monthly Labor Review*, Washington, D.C.: Bureau of Labor Statistics, Department of Labor, July 1972.

Table 9. Unit labor cost in manufacturing industries, by country, 1960-71
[Index, 1960=100]

Year	United States	Japan	France	Germany	United Kingdom
1960 ..	100.0	100.0	100.0	100.0	100.0
1961 ..	100.7	102.9	105.3	105.9	106.9
1962 ..	99.2	112.6	110.7	112.5	109.7
1963 ..	98.5	116.4	115.5	114.2	108.9
1964 ..	98.3	115.3	118.2	114.2	109.2
1965 ..	97.1	124.5	120.3	117.3	115.4
1966 ..	100.2	123.8	119.9	122.9	123.0
1967 ..	105.0	121.5	123.3	122.4	119.6
1968 ..	107.5	123.3	130.6	120.7	122.4
1969 ..	112.8	125.8	132.9	124.6	129.3
1970 ..	118.5	131.5	137.7	141.4	144.0
1971 ..	121.6	142.2	144.9	153.1	155.1

Source: Arthur Neef, "Unit Labor Costs in the U.S. and 10 Other Nations, 1960-71," *Monthly Labor Review*, Washington, D.C.: Bureau of Labor Statistics, Department of Labor, July 1972.

Table 10. U.S. payments and receipts for patents, manufacturing rights, licenses, etc., 1960-71
[Dollars in millions]

Year	Receipts	Payments	Balance
1960	\$247	\$ 40	\$207
1961	244	46	198
1962	256	44	212
1963	273	51	222
1964	301	60	241
1965	335	67	268
1966	353	76	277
1967	398	105	293
1968	454	106	348
1969	501	120	381
1970	579	114	465
1971	621	126	495

Source: Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, June 1972.

Table 11. U.S. balance of payments for patents, manufacturing rights, licenses, etc., by country, 1960-71
[Dollars in millions]

Year	Total	United Kingdom	Western Europe ¹	Japan
1960				
Balance	\$207	\$31	\$ 74	\$ 48
Receipts	247	40	100	48
Payments	40	9	26	
1961				
Balance	198	31	59	52
Receipts	244	39	93	52
Payments	46	8	34	
1962				
Balance	212	31	64	51
Receipts	256	40	93	53
Payments	44	9	31	2
1963				
Balance	222	31	67	57
Receipts	273	43	102	58
Payments	51	12	34	1
1964				
Balance	241	33	74	65
Receipts	301	50	112	66
Payments	60	17	39	1
1965				
Balance	268	39	89	65
Receipts	335	57	132	66
Payments	67	18	43	1
1966				
Balance	277	32	87	67
Receipts	353	54	132	70
Payments	76	22	45	3
1967				
Balance	293	25	76	94
Receipts	398	56	136	97
Payments	104	32	62	4
1968				
Balance	348	21	86	129
Receipts	454	56	145	133
Payments	106	35	59	4
1969				
Balance	381	17	104	153
Receipts	501	58	170	157
Payments	120	41	66	4
1970				
Balance	465	23	128	198
Receipts	579	58	192	202
Payments	114	35	65	4
1971				
Balance	495	32	126	216
Receipts	621	67	200	221
Payments	126	35	74	5

¹ Except United Kingdom.

Source: Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, June 1972.

Table 12. U.S. trade balance in technology-intensive and nontechnology-intensive manufactured products, 1960-71
[Dollars in millions]

Product	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Technology intensive:												
Balance . . .	\$5,850	\$6,187	\$6,672	\$6,900	\$ 7,887	\$ 8,062	\$ 7,885	\$ 8,686	\$ 9,624	\$10,318	\$11,570	\$11,607
Export . . .	7,517	7,928	8,617	8,864	10,137	10,948	12,015	13,227	15,104	16,732	19,024	19,958
Import . . .	1,667	1,741	1,945	1,964	2,250	2,886	4,130	4,541	5,480	6,414	7,454	8,351
Nontechnology intensive:												
Balance . . .	-88	+137	-301	-411	-438	-1,221	-2,587	-3,434	-6,123	-7,201	-9,062	-11,070
Export . . .	5,073	5,079	5,503	6,005	6,497	6,641	7,270	7,634	8,176	9,395	9,467	10,627
Import . . .	5,161	4,942	5,804	6,416	6,935	7,862	9,857	11,068	14,299	16,595	18,529	21,697

Source: Department of Commerce, Bureau of International Commerce, *Overseas Business Reports* (OBR 67-43, August 1967 and OBR 72-005, April 1972).

Table 13a. U.S. trade balance in technology-intensive products, 1966-71
[Dollars in millions]

Product	1966	1967	1968	1969	1970	1971
Nonelectrical machinery:						
Balance	\$3,972	\$4,079	\$4,126	\$4,624	\$5,343	\$5,023
Export	5,637	6,032	6,400	7,241	8,435	8,516
Import	1,665	1,953	2,274	2,617	3,094	3,492
Aircraft:						
Balance	606	968	1,604	1,528	1,911	2,443
Export	878	1,216	1,887	1,812	2,185	2,741
Import	272	248	294	284	274	298
Chemicals:						
Balance	1,692	1,810	2,119	2,109	2,347	2,174
Export	2,602	2,706	3,177	3,255	3,677	3,673
Import	910	896	1,058	1,146	1,328	1,499
Electrical machinery:						
Balance	853	924	743	680	675	459
Export	1,863	2,059	2,234	2,620	2,934	3,006
Import	1,010	1,135	1,491	1,940	2,259	2,547
Instruments:						
Balance	331	369	379	421	469	471
Export	544	604	640	754	824	850
Import	213	235	261	333	355	379

Source: Department of Commerce, Bureau of International Commerce, *Overseas Business Reports* (OBR 72-005, April 1972).

**Table 13b. U.S. trade balance with other nations in technology-intensive products,¹
1966-71**
[Dollars in millions]

Nations	1966	1967	1968	1969	1970	1971
Developing nations:						
Balance	\$3,659	\$3,916	\$4,544	\$4,595	\$5,102	\$5,313
Export	3,902	4,162	4,877	5,079	5,731	6,119
Import	243	246	333	484	629	806
Western Europe:						
Balance	1,666	1,861	1,897	2,310	3,162	2,697
Export	3,641	3,937	4,351	4,979	6,147	5,919
Import	1,975	2,076	2,454	2,669	2,985	3,222
Canada:						
Balance	1,777	1,691	1,552	1,812	1,559	1,854
Export	2,815	2,914	2,975	3,376	3,388	3,903
Import	1,038	1,223	1,423	1,564	1,829	2,049
Japan:						
Balance	-147	-133	-221	-353	-253	-552
Export	647	754	909	1,151	1,507	1,484
Import	794	887	1,130	1,504	1,760	2,036

¹ Excludes military aircraft.

Source: Department of Commerce, Bureau of International Commerce, *Overseas Business Reports* (OBR 72-001, May 1972).

Table 14a. National R&D expenditures, 1961-72
[Dollars in billions]

Year	Current dollars	Constant 1958 dollars ¹
1961	\$14.6	\$13.9
1962	15.7	14.8
1963	17.4	16.2
1964	19.2	17.7
1965	20.4	18.4
1966	22.3	19.5
1967	23.6	20.1
1968	25.1	20.5
1969	26.2	20.4
1970	26.7	19.7
1971 (prelim.)	27.3	19.3
1972 (est.)	28.9	19.8

¹ GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 14b. National R&D expenditures as a percent of gross national product, by sector, 1961-72
[Dollars in billions]

Year	Total R&D expenditures	GNP	Total R&D as percent of GNP	Federal		Industry		Other	
				Amount	Percent of GNP	Amount	Percent of GNP	Amount	Percent of GNP
1961	\$14.55	\$ 520.1	2.80	\$ 9.264	1.781	\$ 4.749	0.913	\$.539	.104
1962	15.67	560.3	2.80	9.926	1.772	5.114	.913	.625	.112
1963	17.37	590.5	2.94	11.219	1.900	5.449	.923	.703	.119
1964	19.21	632.4	3.04	12.553	1.985	5.880	.930	.781	.124
1965	20.44	684.9	2.98	13.033	1.903	6.539	.955	.867	.127
1966	22.27	749.9	2.97	13.992	1.866	7.317	.976	.957	.128
1967	23.61	793.9	2.97	14.419	1.816	8.134	1.025	1.059	.133
1968	25.12	864.2	2.91	14.952	1.730	8.997	1.041	1.170	.135
1969	26.18	930.3	2.81	14.914	1.603	10.008	1.076	1.254	.135
1970	26.70	976.4	2.73	14.798	1.516	10.541	1.080	1.356	.139
1971	27.32	1,050.4	2.60	14.991	1.427	10.911	1.039	1.418	.135
1972 (est.)	28.94	1,150.5	2.52	15.900	1.382	11.570	1.006	1.470	.128

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 14c. National R&D expenditures, by source, 1961-72
[Dollars in billions]

Year	Current dollars			Constant 1958 dollars ¹		
	Federal Government	Industry	Universities and colleges	Federal Government	Industry	Universities and colleges
1961	\$ 9.3	\$ 4.7	\$.4	\$ 8.9	\$4.5	\$.4
1962	9.9	5.1	.4	9.4	4.8	.4
1963	11.2	5.4	.5	10.5	5.1	.5
1964	12.6	5.9	.6	11.5	5.4	.5
1965	13.0	6.5	.6	11.8	5.9	.6
1966	14.0	7.3	.7	12.3	6.4	.6
1967	14.4	8.1	.8	12.3	6.9	.6
1968	15.0	9.0	.8	12.2	7.4	.7
1969	14.9	10.0	.9	11.6	7.8	.7
1970	14.8	10.5	1.0	10.9	7.8	.7
1971 (prelim.)	15.0	10.9	1.0	10.6	7.7	.7
1972 (est.)	15.9	11.6	1.1	10.9	7.9	.7

¹ GNP price deflator was used to convert current to constant dollars.

Note: Other nonprofit institutions' R&D expenditures ranged from \$110 million in 1961 to \$235 million in 1972.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 14d. National R&D expenditures, by character of work, 1961-72
[Dollars in billions]

Year	Current dollars			Constant 1958 dollars ¹		
	Basic research	Applied research	Development	Basic research	Applied research	Development
1961	1.5	1.5	3.2	3.0	9.9	9.4
1962	1.9	1.8	3.8	3.6	10.0	9.5
1963	2.2	2.0	3.9	3.6	11.3	10.5
1964	2.6	2.4	4.3	4.0	12.4	11.4
1965	2.9	2.6	4.5	4.1	13.0	11.8
1966	3.1	2.7	4.8	4.2	14.3	12.6
1967	3.4	2.9	5.0	4.3	15.2	12.9
1968	3.7	3.0	5.4	4.4	16.0	13.1
1969	3.8	2.9	5.6	4.4	16.8	13.1
1970	3.9	2.9	6.0	4.4	16.8	12.4
1971 (prelim.)	3.9	2.8	6.1	4.3	17.3	12.2
1972 (est.)	4.1	2.8	6.5	4.4	18.4	12.5

¹ GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 15. Scientists and engineers¹ employed in R&D, by sector, 1961-72
[In thousands]

Year	Total	Federal		Universities and colleges	Other
		Government	Industry		
1961	425.2	50.6	312.0	42.4	20.2
1965	496.2	64.2	348.4	53.4	30.5
1968	550.6	68.3	381.9	66.0	34.4
1969	559.4	70.3	385.8	68.3	35.0
1970	549.7	69.8	377.4	68.5	34.0
1971	532.8	68.5	363.4	68.4	32.5
1972 (est.)	525.4	68.0	356.0	67.6	33.8

¹ Full-time equivalents.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 16. Federal R&D expenditures as a percent of total Federal outlays, fiscal years 1961-72
[Dollars in millions]

Fiscal Year	Total Federal outlays	Fed'l expenditures for R&D	Percent
1961	92,136	8,747.9	9.5
1962	101,005	9,831.6	9.7
1963	104,740	11,338.5	10.8
1964	111,651	13,758.9	12.3
1965	111,182	13,811.4	12.4
1966	126,731	14,970.2	11.8
1967	149,602	16,073.0	10.7
1968	169,588	16,333.3	9.6
1969	173,874	15,695.4	9.0
1970	184,656	15,159.3	8.2
1971	199,192	15,300.1	7.7
1972 (est.) ...	221,620	16,007.4	7.2

Source: National Science Foundation, *An Analysis of Federal R&D Funding by Budget Function, 1960-1972* (NSF 71-25) and *An Analysis of Federal R&D Funding by Function, Fiscal Years 1963-1973* (NSF 72-313).

Table 17. Federal R&D expenditures for selected functions, fiscal years 1963-72
[Dollars in millions]

Function	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Current dollars										
National defense	7,273.3	7,999.8	7,179.3	7,199.9	8,133.7	8,592.8	8,321.7	8,067.1	8,161.7	8,702.7
Space	2,429.7	3,832.0	4,638.3	5,409.1	5,168.0	4,576.7	4,119.6	3,596.7	3,207.5	2,960.1
Health	593.8	740.5	662.8	798.5	921.8	1,125.3	1,093.7	1,164.1	1,217.3	1,386.8
Advancement of science and technology	296.4	356.4	371.7	423.4	493.6	544.5	571.4	589.9	619.3	704.6
Environment	171.9	189.7	213.1	235.1	275.2	304.1	331.8	370.4	419.6	509.2
Transportation	112.0	145.9	198.3	264.7	356.2	365.9	377.9	451.0	684.1	607.3
Energy conversion and development	265.3	278.6	281.2	274.6	293.5	344.7	345.6	341.0	336.9	405.2
Agriculture	138.8	150.4	169.0	195.8	214.8	225.9	228.6	239.1	261.8	288.1
Economic security	22.1	27.0	41.6	94.4	86.7	97.5	133.9	144.1	149.1	153.9
Education	9.6	12.7	19.4	37.5	70.0	86.8	93.4	93.7	115.0	125.5
Constant 1958 dollars ¹										
National defense	6,835.8	7,414.1	6,532.6	6,422.7	7,030.0	7,172.6	6,657.4	6,120.7	5,888.7	6,051.9
Space	2,283.6	3,551.4	4,220.5	4,825.2	4,466.7	3,820.3	3,295.7	2,729.0	2,314.2	2,058.5
Health	558.1	686.3	603.1	712.3	796.7	939.3	875.0	883.2	878.2	964.4
Advancement of science and technology	278.6	330.3	338.2	377.7	426.6	454.5	457.1	447.6	446.8	490.0
Environment	161.6	175.8	193.9	209.7	237.9	253.8	265.4	281.0	302.7	354.1
Transportation	105.3	135.2	180.4	236.1	307.9	305.4	302.3	342.2	493.6	422.3
Energy conversion and development	249.3	258.2	255.9	245.0	253.7	287.7	276.5	258.7	243.1	281.8
Agriculture	130.5	139.4	153.8	174.7	185.7	188.6	182.9	181.4	188.9	200.3
Economic security	20.8	25.0	37.9	84.2	74.9	81.4	107.1	109.3	107.6	107.0
Education	9.0	11.8	17.7	33.5	60.5	72.5	74.7	71.1	83.0	87.3

¹ GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *An Analysis of Federal R&D Funding by Function, Fiscal Years 1963-73* (NSF 72-313)

Table 18a. Industrial R&D expenditures, 1961-72
[Dollars in billions]

Year	Current dollars	Constant 1958 dollars ¹
1961	\$10.9	\$10.4
1962	11.5	10.8
1963	12.6	11.8
1964	13.5	12.4
1965	14.2	12.8
1966	15.5	13.6
1967	16.4	13.9
1968	17.4	14.3
1969	18.3	14.3
1970	18.2	13.4
1971	18.4	13.0
1972 (est.)	19.5	13.4

¹ GNP price deflator was used to convert current to constant dollars.
Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 18b. Industrial R&D expenditures, by source, 1961-72
[Dollars in billions]

Year	Current dollars		Constant 1958 dollars ¹	
	Industry	Federal Government	Industry	Federal Government
1961	\$4.7	\$6.2	\$4.5	\$6.0
1962	5.0	6.4	4.8	6.1
1963	5.4	7.3	5.0	6.8
1964	5.8	7.7	5.3	7.1
1965	6.4	7.7	5.8	7.0
1966	7.2	8.3	6.3	7.3
1967	8.0	8.4	6.8	7.1
1968	8.9	8.6	7.3	7.0
1969	9.9	8.5	7.7	6.6
1970	10.4	7.8	7.7	5.8
1971	10.7	7.8	7.6	5.4
1972 (est.)	11.4	8.1	7.8	5.6

¹ GNP price deflator was used to convert current to constant dollars.
Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 19. Scientists and engineers¹ engaged in industrial R&D, by source of funds, 1962-71

Year	Industry	Federal Government
January 1962	172,800	139,200
January 1963	169,500	157,800
January 1964	174,600	165,600
January 1965	180,400	163,200
January 1966	190,300	162,900
January 1967	205,700	161,300
January 1968	219,600	156,800
January 1969	229,500	157,700
January 1970	235,900	148,200
January 1971	229,700	129,600

¹ Full-time equivalents.

Source: National Science Foundation, *Research and Development in Industry, 1970* (NSF 72-309).

Table 20. Industry's own funds for R&D, by selected industry, 1961-70
[Dollars in millions]

Industry	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Current dollars										
Electrical equipment and communication ...	\$887	\$949	\$1,017	\$1,093	\$1,206	\$1,414	\$1,552	\$1,753	\$1,965	\$2,061
Chemicals and allied products	881	939	1,004	1,098	1,198	1,271	1,357	1,458	1,538	1,624
Machinery	588	644	709	788	860	974	1,066	1,197	1,355	1,445
Motor vehicles and other transportation equipment	711	718	799	854	898	995	986	1,106	1,257	1,232
Aircraft and missiles	392	454	452	445	622	753	1,070	1,152	1,276	1,107
Petroleum refining and extraction	280	289	296	338	364	383	409	468	522	565
Professional and scientific instruments	180	202	202	229	257	298	321	388	455	508
Constant 1958 dollars ¹										
Electrical equipment and communication ...	848	897	949	1,004	1,088	1,241	1,320	1,433	1,533	1,524
Chemicals and allied products	842	888	937	1,009	1,081	1,116	1,115	1,192	1,200	1,201
Machinery	562	609	662	724	776	855	907	979	1,057	1,069
Motor vehicles and other transportation equipment	680	679	746	785	810	873	839	904	981	911
Aircraft and missiles	375	429	422	409	561	661	910	942	995	819
Petroleum refining and extraction	268	273	276	311	328	336	348	383	407	418
Professional and scientific instruments	172	191	189	210	232	262	273	317	355	376

¹ GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *Research and Development in Industry, 1970* (NSF 72-309).

Table 21a. Basic research expenditures, by performer, 1960-72
[Dollars in millions]

Year	Total	Universities and colleges	Government	Industry	FFRDC's ¹	Non-profit institutions
Current dollars						
1960	\$1,326	\$576	\$160	\$376	\$ 97	\$117
1961	1,543	701	206	395	115	126
1962	1,886	850	251	488	136	161
1963	2,196	1,036	299	522	159	180
1964	2,559	1,261	364	549	191	194
1965	2,853	1,419	424	592	208	210
1966	3,127	1,601	449	624	227	226
1967	3,362	1,785	478	629	250	221
1968	3,658	2,011	512	642	276	217
1969	3,770	2,087	577	618	275	213
1970	3,946	2,185	658	629	269	205
1971 (prelim.)	3,926	2,281	535	625	260	225
1972 (est.)	4,100	2,335	575	660	285	245
Constant 1958 dollars ²						
1960	1,284	558	155	364	94	113
1961	1,475	670	197	377	110	120
1962	1,783	804	237	461	129	152
1963	2,049	967	279	487	148	168
1964	2,351	1,159	334	504	176	178
1965	2,573	1,280	382	534	188	189
1966	2,744	1,405	394	548	199	198
1967	2,860	1,518	406	535	213	188
1968	2,991	1,644	419	525	226	177
1969	2,941	1,628	450	482	214	166
1970	2,918	1,616	486	465	199	152
1971 (prelim.)	2,772	1,611	378	441	184	159
1972 (est.)	2,812	1,602	394	453	195	168

¹ Federally Funded Research and Development Centers administered by universities.

² GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 21b. Sources of funds for basic research, 1960-72
[Dollars in millions]

Year	Total	Federal Govern- ment	Indus- try	Univer- sities and colleges	Non- profit institu- tions
Current dollars					
1960	\$1,326	\$ 693	\$331	\$215	\$ 87
1961	1,543	841	350	250	102
1962	1,886	1,091	382	293	120
1963	2,196	1,310	414	343	129
1964	2,559	1,595	424	402	138
1965	2,853	1,817	448	445	143
1966	3,127	1,990	496	494	147
1967	3,363	2,179	477	551	156
1968	3,658	2,354	518	621	165
1969	3,770	2,398	519	678	175
1970	3,946	2,474	535	747	196
1971 (prelim.)	3,926	2,416	520	793	197
1972 (est.)	4,100	2,525	545	825	205
Constant 1958 dollars ¹					
1960	1,284	671	320	208	84
1961	1,475	803	334	239	97
1962	1,783	1,031	361	277	113
1963	2,049	1,222	386	320	120
1964	2,351	1,465	389	369	127
1965	2,573	1,639	404	401	129
1966	2,744	1,746	435	433	129
1967	2,860	1,853	406	468	133
1968	2,991	1,925	423	508	135
1969	2,941	1,870	405	529	136
1970	2,918	1,829	396	552	140
1971 (prelim.)	2,772	1,706	367	560	139
1972 (est.)	2,812	1,732	374	566	141

¹ GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 22. Federal expenditures for basic research, by performer,
1960-72
[Dollars in millions]

Year	Federal intra- mural	Indus- try	Univer- sities and colleges	FFRDC's ¹	Non- profit institu- tions
Current dollars					
1960	160	79	299	97	58
1961	206	81	382	115	57
1962	251	143	481	136	80
1963	299	147	610	159	95
1964	364	165	767	191	108
1965	424	186	879	208	120
1966	449	173	1,009	227	132
1967	478	202	1,124	250	125
1968	512	180	1,268	276	118
1969	577	160	1,275	275	111
1970	658	159	1,288	269	100
1971 (prelim.)	535	170	1,336	260	115
1972 (est.)	575	180	1,355	285	130
Constant 1958 dollars ²					
1960	155	76	290	94	56
1961	197	77	365	110	54
1962	237	135	455	128	76
1963	279	137	569	148	89
1964	334	151	705	175	99
1965	382	168	793	188	108
1966	394	152	885	199	116
1967	406	172	956	213	106
1968	419	147	1,037	226	96
1969	450	125	994	214	86
1970	486	117	952	199	74
1971 (prelim.)	378	120	943	184	81
1972 (est.)	394	123	929	195	89

¹ Federally Funded Research and Development Centers administered by universities.

² GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303)

Table 23. Federal obligations for basic research, by supporting agency, 1960-72

[Dollars in millions]

Agency	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972 (est.)
Current dollars													
Total	\$610	\$825	\$1,106	\$1,389	\$1,567	\$1,600	\$1,844	\$2,015	\$2,072	\$2,094	\$2,062	\$2,132	\$2,395
Department of Agriculture ..	34	41	50	56	68	90	94	100	100	107	116	118	138
Department of Defense	168	173	204	231	241	263	262	284	263	276	247	262	265
Department of Health, Education, and Welfare	103	137	190	236	274	303	326	372	397	371	388	397	467
Atomic Energy Commission ..	104	167	192	219	238	258	281	302	282	285	287	277	270
National Aeronautics and Space Administration	97	190	316	447	524	528	559	603	656	678	637	680	750
National Science Foundation	68	77	104	141	155	171	223	239	252	248	245	273	353
All others	35	39	50	59	66	77	98	115	122	129	142	125	152
Constant 1958 dollars ¹													
Total	591	789	1,046	1,296	1,440	1,524	1,618	1,714	1,694	1,633	1,525	1,506	1,643
Department of Agriculture ..	33	39	47	52	62	81	82	85	82	83	86	83	95
Department of Defense	163	165	193	216	221	237	230	242	215	215	183	185	182
Department of Health, Education, and Welfare	100	131	180	220	252	273	286	316	325	289	287	280	320
Atomic Energy Commission ..	101	160	182	204	219	233	203	257	231	222	212	196	185
National Aeronautics and Space Administration	94	182	299	417	481	476	491	513	536	529	471	480	514
National Science Foundation	66	74	98	132	142	154	196	203	206	193	181	193	242
All others	34	37	47	55	61	69	86	98	100	101	105	88	104

¹ GNP price deflator was used to convert current to constant dollars.Source: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXI (NSF 72-317).

Table 24. Estimated expenditures for basic research in universities
and colleges, by field of science, 1964-72
[Dollars in millions]

Field of science	1964	1966	1968	1970	Prel. est. 1972
	Current dollars				
Total	\$1,261	\$1,601	\$2,011	\$2,186	\$2,541
Engineering	162	226	270	280	309
Physical sciences	212	270	296	300	329
Astronomy	15	20	22	16	22
Chemistry	72	82	96	97	112
Physics	111	151	160	156	163
Physical sciences, n.e.c.	13	17	17	31	32
Environmental sciences	52	62	109	105	138
Mathematics	39	48	63	82	79
Life sciences	643	784	940	1,058	1,228
Biological sciences	287	367	433	450	580
Clinical medical	311	360	443	497	571
Life sciences, n.e.c.	45	58	64	111	77
Psychology	36	44	62	64	88
Social sciences	98	131	195	217	275
Other sciences, n.e.c.	18	36	77	80	95
	Constant 1961 dollars ¹				
Total	1,159	1,378	1,584	1,555	1,626
Engineering	149	194	212	199	198
Physical sciences	195	233	233	213	210
Astronomy	14	17	18 ¹	11	14
Chemistry	67	71	76	69	72
Physics	102	130	126	111	104
Physical sciences, n.e.c.	12	15	14	22	20
Environmental sciences	48	53	86	75	88
Mathematics	36	41	50	58	51
Life sciences	591	675	740	752	786
Biological sciences	264	316	341	320	371
Clinical medical	286	310	349	354	365
Life sciences, n.e.c.	41	49	50	78	49
Psychology	33	38	49	46	56
Social sciences	90	112	154	154	176
Other sciences, n.e.c.	17	31	61	57	61

¹ Academic R&D price deflator.

Note: Detail may not add to totals because of rounding.

Source: National Science Foundation, *Resources for Scientific Activities at Universities and Colleges*, 1971 (NSF 72-315).

Table 25. Estimated Federal expenditures for basic research in universities and colleges, by field of science, 1964-72
[Dollars in millions]

Field of science	1964	1966	1968	1970	Prel. est. 1972
	Current dollars				
Total	766	1,009	1,251	1,289	1,409
Engineering	105	151	181	182	196
Physical sciences	164	209	223	237	233
Astronomy	13	17	18	14	15
Chemistry	50	60	70	71	73
Physics	95	122	132	132	124
Physical sciences, n.e.c.	6	10	13	21	21
Environmental sciences	39	47	71	72	95
Mathematical and computer sciences	21	26	34	43	41
Life sciences	371	472	584	591	649
Biological sciences	126	160	204	200	245
Clinical medical	218	279	345	348	372
Life sciences, n.e.c.	27	33	35	43	32
Psychology	24	30	39	40	52
Social sciences	37	53	82	83	90
Other sciences, n.e.c.	5	21	37	41	53
	Constant 1961 dollars ¹				
Total	704	868	985	917	901
Engineering	96	130	142	129	125
Physical sciences	151	180	176	169	149
Astronomy	12	15	14	10	10
Chemistry	46	52	55	50	47
Physics	87	105	104	94	79
Physical sciences, n.e.c.	6	9	10	15	13
Environmental sciences	36	40	56	51	61
Mathematical and computer sciences	19	22	27	31	26
Life sciences	341	406	460	420	415
Biological sciences	116	138	161	142	157
Clinical medical	200	240	272	247	238
Life sciences, n.e.c.	25	28	27	31	20
Psychology	22	26	31	28	33
Social sciences	34	46	65	59	58
Other sciences, n.e.c.	5	18	29	29	34

¹ Academic R&D price deflator.

Note: Detail may not add to totals because of rounding.

Source: National Science Foundation, *Resources for Scientific Activities at Universities and Colleges, 1971* (NSF 72-315).

Table 26. Federal and non-Federal research funds per scientist and engineer in doctorate-granting institutions,¹ 1964-72

Year	Research expenditures (constant 1961 dollars ²)			Number of scientists and engineers
	Total	Federal	Non- Federal	
1964	\$13,138	\$7,673	\$5,465	103,587
1966	13,159	8,040	5,119	125,488
1968	13,484	8,239	5,245	140,163
1970	11,826	6,906	4,920	157,276
1972-est ..	11,424	6,272	5,152	170,000

¹ Includes all scientists and engineers (full-time-equivalent basis) employed in universities

² Academic R&D price deflator

Source: National Science Foundation, *Resources for Scientific Activities at Universities and Colleges*, 1971, (NSF 72-315).

Table 27. Research expenditures per scientist and engineer¹ in doctorate-granting institutions, by selected field of science, 1964-72

Field of science	1964	1966	1968	1970	1972
	Research expenditures per scientist or engineer				
Biological sciences	\$22,107	\$24,066	\$24,140	\$20,594	\$22,636
Physics	24,483	24,722	23,499	19,580	16,073
Engineering	12,728	13,845	15,457	13,405	12,859
Chemistry	14,448	13,200	12,810	11,298	11,272
Psychology	10,425	9,758	9,356	8,174	9,299
Clinical medicine	12,049	11,449	10,676	9,358	8,462
Social sciences	7,718	7,332	8,201	7,490	7,847
Mathematics and computer sciences	7,268	6,966	6,656	7,110	5,630
Total research expenditures (In millions of constant 1961 dollars ²)					
Biological sciences	\$339.2	\$396.2	\$415.5	\$387.3	\$455.0
Physics	113.7	151.4	148.4	131.5	109.7
Engineering	174.5	231.9	254.5	239.3	237.9
Chemistry	76.2	81.0	86.0	78.7	80.6
Psychology	35.5	41.6	53.2	50.7	63.7
Clinical medicine	318.6	388.1	427.1	434.1	426.5
Social sciences	105.1	130.2	176.9	177.4	200.1
Mathematics and computer sciences	39.3	47.0	56.3	66.9	56.3
Number of scientists and engineers					
Biological sciences	15,343	16,467	17,212	18,809	20,100
Physics	4,644	6,124	6,315	6,718	6,825
Engineering	13,709	16,749	16,465	17,849	18,500
Chemistry	5,274	6,134	6,713	6,969	7,150
Psychology	3,405	4,263	5,686	6,208	6,850
Clinical medicine	26,442	33,897	40,003	46,381	50,400
Social sciences	13,616	17,756	21,569	23,683	25,500
Mathematics and computer sciences	5,407	6,747	8,458	9,417	10,000

¹ Includes all scientists and engineers (full-time-equivalent basis) employed in universities.

² Academic R&D price deflator.

Source: National Science Foundation, *Resources for Scientific Activities at Universities and Colleges*, 1971 (NSF 72-315) and Survey of Scientific Activities of Institutions of Higher Education, 1973.

Table 28. Proportion of Ph.D. academic staff in science receiving Federal support and engaged in basic research, by field, 1964-70
[Percent]

<i>Field of science</i>	1964	1966	1968	1970
All fields	69	69	64	57
Physics	84	82	78	74
Biology	77	78	76	71
Chemistry	74	74	66	60
Psychology	67	66	62	53
Earth and marine sciences	54	56	54	51
Mathematics	51	47	43	30
Social sciences	36	39	37	30

Source: National Science Foundation, special tabulations from the National Register of Scientific and Technical Personnel, 1964-70.

Table 29. Proportion of young and senior Ph.D. academic staff in science receiving Federal support and engaged in basic research, 1964-70
[Percent]

<i>Academic staff</i>	1964	1966	1968	1970
Senior	73	74	69	63
Junior	64	63	58	50

Source: National Science Foundation, special tabulations from the National Register of Scientific and Technical Personnel, 1964-70.

Table 31. Total Federal expenditures for intramural basic research, 1960-72
[Dollars in millions]

<i>Year</i>	<i>Current dollars</i>	<i>Constant 1958 dollars¹</i>
1960	\$160	\$155
1961	206	197
1962	251	237
1963	299	279
1964	364	334
1965	424	382
1966	449	394
1967	478	406
1968	512	419
1969	577	450
1970	658	486
1971 (prelim.)	535	378
1972 (est.)	575	394

¹ GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 30. Ratio of young to senior Ph.D. academic staff receiving Federal support and engaged in basic research, by field, 1964-70

<i>Field of science</i>	<i>Percent of senior</i>				<i>Ratio of young to senior</i>			
	1964	1966	1968	1970	1964	1966	1968	1970
Physics	86	86	83	78	95	90	89	86
Chemistry	77	78	70	63	93	91	90	90
Social sciences	37	43	39	34	93	81	87	74
Psychology	70	71	70	62	89	84	80	72
Biology	81	81	80	74	87	90	89	87
Earth and marine sciences	54	56	53	51	81	87	86	91
Mathematics	60	59	56	45	70	64	60	48

Source: National Science Foundation, special tabulations from the National Register of Scientific and Technical Personnel, 1964-70.

Table 32. Federal obligations for intramural basic research, by selected agency, 1960-72

[Dollars in millions]

Agency	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Current dollars													
Department of Defense	\$52.9	\$54.5	\$65.1	\$72.8	\$75.7	\$80.0	\$84.8	\$81.9	\$86.2	\$90.3	\$95.6	\$99.0	\$106.9
National Aeronautics and Space Administration	27.1	48.7	63.2	83.9	127.0	158.2	154.7	163.1	179.3	202.4	238.7	171.5	168.1
Department of Agriculture	22.9	28.1	31.7	36.7	42.5	57.0	62.4	63.3	67.3	76.6	85.4	86.5	97.2
Department of Health, Education, and Welfare	17.8	24.9	30.6	38.9	44.6	47.0	58.6	66.7	69.6	88.3	113.7	67.5	76.7
Department of the Interior	18.7	21.4	22.7	23.9	26.2	30.5	33.7	39.6	41.3	42.9	39.8	41.2	48.0
Department of Commerce	8.6	10.7	15.0	18.7	20.6	21.8	19.9	21.7	23.6	26.4	35.9	35.3	41.8
Constant 1958 dollars ¹													
Department of Defense	52.0	52.8	62.2	68.8	69.6	72.2	74.4	69.6	70.5	70.4	70.7	69.9	73.3
National Aeronautics and Space Administration	26.7	47.1	60.4	79.3	116.7	142.7	135.8	138.7	146.6	157.9	176.5	121.1	115.3
Department of Agriculture	22.5	27.2	30.3	34.7	39.1	51.4	54.8	62.3	55.0	59.8	63.2	61.1	66.7
Department of Health, Education, and Welfare	17.5	24.1	29.2	36.8	41.0	42.3	51.4	56.7	56.9	68.9	84.1	47.7	52.6
Department of the Interior	18.4	20.7	21.7	22.6	24.1	27.5	29.6	33.7	33.8	33.5	29.4	29.1	32.9
Department of Commerce	8.5	10.4	14.3	17.7	18.9	19.7	17.5	18.5	19.3	20.6	26.5	24.9	28.7

¹ GNP price deflator was used to convert current to constant dollars.Source: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXI (NSF 72-317).

Table 33. Industrial basic research expenditures, by source, 1960-72

[Dollars in millions]

Year	Total		Industry		Federal Government	
	Current dollars	Constant 1958 dollars ¹	Current dollars	Constant 1958 dollars ¹	Current dollars	Constant 1958 dollars ¹
1960	\$376	\$364	\$297	\$287	\$ 79	\$ 76
1961	395	377	314	300	81	77
1962	488	461	345	326	143	135
1963	522	487	375	350	147	137
1964	549	504	384	353	165	152
1965	592	534	406	366	186	168
1966	624	548	451	396	173	152
1967	629	535	427	363	202	172
1968	642	525	462	378	180	147
1969	618	482	458	357	160	125
1970	629	465	470	347	159	117
1971 (prelim.)	625	441	455	321	170	120
1972 (est.)	660	453	480	329	180	123

¹ GNP price deflator was used to convert current to constant dollars.Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 34. Industrial basic research expenditures, by field of science, 1967-70
[Dollars in millions]

Field of science	1967	1968	1969	1970
	Current dollars			
Engineering	172	181	171	174
Chemistry	162	191	213	200
Physics and astronomy	146	126	110	97
Life sciences	69	76	74	80
Mathematics	12	14	13	14
Environmental sciences	14	11	12	8
Field of science	Constant 1958 dollars ¹			
	1967	1968	1969	1970
Engineering	146	148	133	129
Chemistry	138	156	166	148
Physics and astronomy	124	103	86	72
Life sciences	59	62	58	59
Mathematics	10	11	10	10
Environmental sciences	12	9	9	6

¹ GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *Research and Development in Industry*, 1970 (NSF 72-309).

Table 36. Natural scientists and engineers in relation to total civilian employment,¹ 1950-70

Year	Scientists and engineers (in thousands)	Total civilian employment (in thousands)	Scientists and engineers per 10,000 civilian employees
1950 ..	556.7	58,920	94
1951 ..	611.8	59,962	102
1952 ..	685.9	60,254	114
1953 ..	748.7	61,181	122
1954 ..	783.7	60,110	130
1955 ..	812.6	62,171	131
1956 ..	873.7	63,802	137
1957 ..	958.9	64,071	150
1958 ..	1,001.2	63,036	159
1959 ..	1,057.9	64,630	164
1960 ..	1,104.0	65,778	168
1961 ..	1,151.5	65,746	175
1962 ..	1,210.3	66,702	181
1963 ..	1,280.8	67,762	189
1964 ..	1,327.0	69,305	191
1965 ..	1,366.9	71,088	192
1966 ..	1,417.5	72,895	194
1967 ..	1,476.7	74,372	199
1968 ..	1,525.0	75,920	201
1969 ..	1,567.7	77,902	201
1970 ..	1,594.7	78,627	203

¹ 16 years of age or over.

Source: Estimates prepared by the National Science Foundation based on data collected by the Foundation and the Bureau of Labor Statistics, Department of Labor.

Table 35. Total scientists and engineers, by broad field, 1960 and 1970

Field	Total		Ph.D.'s	
	1960	1970	1960	1970
Total	1,167,000	1,731,000	89,200	171,800
Engineers	797,000	1,100,000	7,500	25,700
Physical scientists	168,000	253,000	30,400	55,000
Life scientists	98,000	180,000	24,700	42,000
Social scientists	70,000	126,000	22,600	38,400
Mathematicians	34,000	76,000	4,000	10,700

Source: Estimates prepared by the National Science Foundation based on data collected by the Foundation and the Bureau of Labor Statistics, Department of Labor.

Table 37. Natural scientists and engineers in R&D, 1960-70

Year	R&D scientists as percent of total			Relative change (1960=100)		
	Total U.S.	Industry	Universities and colleges	Total U.S.	Industry	Universities and colleges
1960	35.0	34.7	42.3	100.0	100.0	100.0
1961	35.6	35.2	42.8	106.1	105.2	107.8
1962	36.5	36.3	42.2	114.5	113.0	113.6
1963	37.1	37.1	41.9	123.2	121.7	122.0
1964	37.5	37.1	39.5	129.0	124.5	128.6
1965	37.5	37.2	38.4	132.9	127.6	132.7
1966	37.1	36.8	36.8	136.3	131.1	135.0
1967	37.5	36.8	39.7	143.5	136.2	158.6
1968	36.2	36.1	36.6	143.2	137.0	154.9
1969	35.0	35.2	35.7	142.2	137.5	150.4
1970	33.6	33.5	33.2	138.7	131.9	155.8

Source: Estimates prepared by the National Science Foundation based on data collected by the Foundation and the Bureau of Labor Statistics, Department of Labor.

Table 38. Distribution of non-Ph.D. and Ph.D. scientists and engineers, by activity and broad field, 1970

Field	Non-Ph.D.'s			Ph.D.'s		
	Total	R&D	Other	Total	R&D	Other
Total	100.0	31.3	68.7	100.0	52.6	47.4
Physical scientists	100.0	38.9	61.1	100.0	66.5	33.5
Life scientists	100.0	31.7	68.2	100.0	56.7	43.3
Mathematicians	100.0	33.5	66.5	100.0	27.1	72.9
Social scientists	100.0	31.7	68.3	100.0	30.7	69.3
Engineers	100.0	29.7	70.3	100.0	59.1	40.9

Source: Estimates prepared by the National Science Foundation based on data collected by the Foundation and the Bureau of Labor Statistics, Department of Labor.

Table 39. Employment of natural scientists and engineers, by sector, 1960 and 1970

Sector	Percent distribution		Percent increase
	1960	1970	1960-70
Total	100.0	100.0	44.4
Private industry	73.5	69.7	36.8
Federal Government	15.3	15.0	41.8
Universities and colleges	10.4	14.3	98.8
Nonprofit institutions	.8	1.0	88.5

Source: Estimates prepared by the National Science Foundation based on data collected by the Foundation and the Bureau of Labor Statistics, Department of Labor.

Table 40. Public secondary school enrollment in selected science and mathematics courses and total enrollment in grades 9 through 12, 1960-61 and 1969-70

Course	Estimated enrollment (thousands)			Index (1948-49=100)		
	1948-49	1960-61	1969-70	1948-49	1960-61	1969-70
Biology	1,062	1,853	3,197	100	175	301
Chemistry	412	745	1,160	100	181	282
Physics	291	402	482	100	138	166
Economics	255	293	844	100	115	331
Sociology	186	289	495	100	155	266
Psychology	47	140	344	100	298	732
Introductory algebra	1,042	1,607	2,627	100	154	252
Introductory geometry	599	960	1,530	100	160	255
Advanced mathematics	609	1,174	1,756	100	193	288
Total enrollment, grades 9-12	5,399	8,219	12,442	100	152	230

Source: National Science Foundation, *Science Resources Studies Highlights*, "Enrollment Increase in Science and Mathematics in Public Secondary Schools, 1948-49 to 1969-70" (NSF 71-30), Oct. 15, 1971.

Table 41. Percent change in majors declared by junior-year students, 1970 to 1971

Major field	Fall 1970	Fall 1971	Percent change
Physics	7,377	6,759	-8.4
Engineering	66,421	61,575	-7.3
Chemistry	13,949	13,646	-2.2
Mathematical sciences	34,800	34,581	-.6
Basic social sciences	156,446	170,388	8.9
"All other" life sciences	50,212	56,896	13.3
"Other" physical sciences	8,302	9,556	15.1
Preprofessional life sciences	11,303	14,326	26.7
Applied social sciences	16,375	23,552	43.8

Source: ACE Higher Education Panel, *Survey of Enrollment of Junior-Year Students* (Fall 1970 and Fall 1971).

Table 42. Percent distribution of full-time graduate students in doctorate departments, by area of science and type of support, 1967-71¹

Type of major support ²	All areas	Engineering	Physical sciences	Mathematical sciences	Life sciences	Psychology	Social sciences
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Fellowships and traineeships:							
1967	32.4	31.2	27.3	26.0	35.9	42.3	36.5
1968	32.1	29.7	26.4	26.6	36.7	41.9	36.2
1969	29.7	26.2	23.4	23.7	35.7	41.6	33.4
1970	27.6	23.6	20.8	20.6	33.0	40.6	32.6
1971	25.4	22.0	18.5	18.8	30.2	35.0	29.3
Research assistantships:							
1967	22.9	29.0	31.4	9.3	25.4	16.6	11.0
1968	22.1	29.7	30.3	8.5	24.0	15.1	10.5
1969	21.6	29.3	31.6	9.1	22.2	14.5	9.5
1970	21.7	30.0	31.3	9.6	22.2	14.4	9.5
1971	20.9	29.4	30.1	9.1	22.5	13.6	9.4
Teaching assistantships:							
1967	23.0	12.7	31.7	40.5	21.4	18.7	18.6
1968	23.5	13.2	32.9	41.8	21.6	19.1	18.4
1969	24.0	13.8	33.8	42.3	22.8	19.3	18.9
1970	25.2	14.0	36.5	46.2	23.5	20.0	19.6
1971	24.7	14.1	37.4	44.1	23.0	20.4	19.5
Other types of support ³ :							
1967	21.7	27.1	9.6	24.2	17.3	22.5	33.9
1968	22.4	27.4	10.5	23.0	17.7	24.0	34.9
1969	24.7	30.7	11.2	24.9	19.3	24.6	38.2
1970	25.5	32.4	11.3	23.5	21.3	25.1	38.3
1971	29.0	34.5	14.0	28.1	24.2	31.0	41.8

¹ Based on data submitted by 2,236 doctorate departments submitting traineeship applications in each of the years 1967-70 and 2,990 doctorate departments reporting for 1971.

² Major support is defined as a total stipend of \$1,200 or more, exclusive of tuition, during an academic year.

³ Includes principally family or self-support.

Source: Special tabulations from National Science Foundation surveys of graduate student support.

Table 43. Distribution of full-time graduate students in science and engineering, by source of support, 1969-71

Type of major support	1969	1970	1971
Total full-time students	131,923	131,902	129,939
U.S. Government	48,373	45,640	41,263
Institutional support	47,415	48,915	48,298
Self-support	24,123	25,155	28,801
Other sources	11,994	12,192	11,577
Fellowships and traineeships	38,972	36,453	32,988
U.S. Government	26,671	24,070	20,959
Institutional support	6,777	6,740	6,628
Self-support	N.A.	N.A.	N.A.
Other sources	5,524	5,643	5,401
Research assistantships	28,506	28,500	27,249
U.S. Government	18,641	18,451	17,519
Institutional support	7,700	8,034	7,588
Self-support	—0—	—0—	—0—
Other sources	2,165	2,015	2,142
Teaching assistantships	31,221	32,616	32,335
U.S. Government	295	336	384
Institutional support	30,790	32,015	31,729
Self-support	—0—	—0—	—0—
Other sources	136	265	222

Source: Special tabulations from National Science Foundation surveys of graduate student support.

Table 44a. Bachelor's and first-professional degrees in science and engineering, 1959-60 to 1970-71

Field of science	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71
All sciences and engineering ..	120,937	121,660	127,469	135,964	153,361	164,936	173,471	187,849	212,174	244,519	264,122	271,176
Physical sciences ..	16,057	15,500	15,894	16,276	17,527	17,916	17,186	17,794	19,442	21,591	21,551	21,549
Engineering	37,808	35,866	34,735	33,458	35,226	36,795	35,815	36,188	37,614	41,553	44,772	45,387
Mathematical sciences	11,437	13,127	14,610	16,128	18,677	19,668	20,182	21,530	24,084	28,263	29,109	27,306
Life sciences	24,141	23,900	25,200	27,801	31,611	34,842	36,964	39,408	43,260	48,713	52,129	52,640
Social sciences	31,494	33,267	37,030	42,308	50,320	55,715	63,424	72,929	87,774	104,399	116,561	124,284

Source: U.S. Office of Education, *Earned Degrees Conferred*, annual series.

Table 44b. Bachelor's and first-professional degrees in science and engineering as a percent of all bachelor's and first-professional degrees, 1959-60 to 1970-71

Field of science	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71
All sciences and engineering ..	30.6	30.3	30.3	30.2	30.5	30.6	31.2	31.6	31.6	31.8	31.7	30.7
Physical sciences ..	4.1	3.9	3.8	3.6	3.5	3.3	3.1	3.0	2.9	2.8	2.6	2.4
Engineering	9.6	8.9	8.3	7.4	7.0	6.8	6.4	6.1	5.6	5.4	5.4	5.1
Mathematical sciences	2.9	3.3	3.5	3.6	3.7	3.6	3.6	3.6	3.6	3.7	3.5	3.1
Life sciences	6.1	5.9	6.0	6.2	6.3	6.5	6.6	6.6	6.4	6.3	6.3	6.0
Social sciences	8.0	8.3	8.8	9.4	10.0	10.3	11.4	12.3	13.1	13.6	14.0	14.1

Source: U.S. Office of Education, *Earned Degrees Conferred*, annual series.

Table 45a. Master's degrees in science and engineering, 1959-60 to 1970-71

Field of science	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71
All sciences and engineering ..	20,012	22,786	25,146	27,367	30,271	33,835	38,083	41,800	45,425	48,425	49,318	50,624
Physical sciences	3,387	3,799	3,929	4,132	4,567	4,918	4,992	5,412	5,508	5,911	5,948	6,386
Engineering	7,159	8,178	8,909	9,635	10,827	12,056	13,678	13,885	15,188	15,243	15,597	16,347
Mathematical sciences	1,765	2,238	2,680	3,323	3,603	4,294	5,610	5,733	6,081	6,735	7,107	6,789
Life sciences	3,751	4,085	4,672	4,718	5,357	5,978	6,666	7,465	8,315	8,809	8,590	9,738
Social sciences	3,950	4,486	4,956	5,559	5,917	6,589	7,737	9,305	10,333	11,727	12,076	12,364

Source: U.S. Office of Education, *Earned Degrees Conferred*, annual series.**Table 45b. Master's degrees in science and engineering as a percent of all master's degrees, 1959-60 to 1970-71**

Field of science	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71
All sciences and engineering ..	26.9	29.1	29.6	29.9	29.9	30.2	27.1	26.5	25.6	24.9	23.6	21.9
Physical sciences	4.5	4.9	4.6	4.5	4.5	4.4	3.5	3.4	3.1	3.0	2.8	2.8
Engineering	9.6	10.4	10.5	10.5	10.7	10.7	9.7	8.8	8.6	7.8	7.4	7.1
Mathematical sciences	2.4	2.9	3.2	3.6	3.6	3.8	3.6	3.6	3.4	3.5	3.4	2.9
Life sciences	5.0	5.2	5.5	5.2	5.3	5.3	4.7	4.7	4.7	4.5	4.1	3.8
Social sciences	5.3	5.7	5.8	6.1	5.9	5.9	5.5	5.9	5.8	6.0	5.8	5.3

Source: U.S. Office of Education, *Earned Degrees Conferred*, annual series.**Table 46a. Doctor's degrees in science and engineering, 1959-60 to 1970-71**

Field of science	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71
All sciences and engineering ..	6,056	6,531	7,249	8,055	9,025	10,252	11,298	12,759	14,128	15,839	17,639	18,466
Physical sciences	1,838	1,991	2,122	2,380	2,455	2,829	3,045	3,462	3,593	3,859	4,313	4,391
Engineering	786	943	1,207	1,378	1,693	2,124	2,304	2,614	2,932	3,377	3,681	3,654
Mathematical sciences	303	344	396	490	596	688	801	870	983	1,161	1,343	1,327
Life sciences	1,647	1,646	1,804	1,908	2,181	2,474	2,696	2,900	3,445	3,779	4,131	4,746
Social sciences	1,482	1,607	1,720	1,899	2,100	2,137	2,452	2,913	3,175	3,663	4,171	4,348

Source: U.S. Office of Education, *Earned Degrees Conferred*, annual series.**Table 46b. Doctor's degrees in science and engineering as a percent of all doctor's degrees, 1959-60 to 1970-71**

Field of science	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71
All sciences and engineering ..	61.6	61.8	62.4	62.8	62.3	62.3	61.9	61.9	61.2	60.5	59.0	57.5
Physical sciences	18.7	18.8	18.3	18.6	16.9	17.2	16.7	16.8	15.6	14.7	14.4	13.7
Engineering	8.0	8.9	10.4	10.7	11.7	12.9	12.6	12.7	12.7	12.9	12.3	11.4
Mathematical sciences	3.1	3.3	3.4	3.8	4.1	4.2	4.4	4.2	4.3	4.4	4.5	4.1
Life sciences	16.8	15.6	15.5	14.9	15.1	15.0	14.8	14.1	14.9	14.4	13.8	14.8
Social sciences	15.1	15.2	14.8	14.8	14.5	13.0	13.4	14.1	13.7	14.0	14.0	13.5

Source: U.S. Office of Education, *Earned Degrees Conferred*, annual series.

Table 47. Geographic origins, by high school graduation, of Ph.D.'s in science and technology, 1970

Region, division, and State	Population (thousands)		Ph.D.'s in science and engineering by State of high school graduation	
	April 1, 1960 (census)	April 1, 1970 (census)	FY 1960	FY 1970
United States, Total	179,323	203,166	5,128	14,272
NORTHEAST				
New England	10,509	11,842	436	968
Maine	969	992	29	39
New Hampshire	607	738	33	67
Vermont	390	444	10	23
Massachusetts	5,149	5,689	240	543
Rhode Island	859	947	35	73
Connecticut	2,535	3,032	89	223
Middle Atlantic	34,168	37,153	1,499	3,641
New York	16,782	18,191	951	2,058
New Jersey	6,067	7,168	231	586
Pennsylvania	11,319	11,794	317	997
NORTH CENTRAL				
East North Central	36,225	40,252	1,066	2,862
Ohio	9,706	10,652	253	730
Indiana	4,662	5,194	102	320
Illinois	10,081	11,114	403	915
Michigan	7,823	8,875	168	519
Wisconsin	3,952	4,418	150	378
West North Central	15,394	16,319	493	1,415
Minnesota	3,414	3,805	115	301
Iowa	2,758	2,824	98	293
Missouri	4,320	4,677	118	349
North Dakota	632	618	16	49
South Dakota	681	666	23	70
Nebraska	1,411	1,483	50	123
Kansas	2,179	2,247	73	230
SOUTH				
South Atlantic	25,972	30,671	402	1,399
Delaware	446	548	10	36
Maryland	3,101	3,922	59	243
District of Columbia	764	757	36	77
Virginia	3,967	4,148	74	261
West Virginia	1,860	1,744	49	111
North Carolina	4,556	5,082	43	186
South Carolina	2,383	2,591	27	79
Georgia	3,943	4,590	42	156
Florida	4,952	6,789	62	250
East South Central	12,050	12,803	176	602
Kentucky	3,038	3,219	50	143
Tennessee	3,567	3,924	46	205
Alabama	3,267	3,444	46	145
Mississippi	2,178	2,217	34	109
West South Central	16,951	19,321	304	1,149
Arkansas	1,786	1,923	42	81
Louisiana	3,257	3,641	43	203
Oklahoma	2,328	2,559	67	219
Texas	9,510	11,197	152	646

Table 47—Continued

WEST				
Mountain	6,855	8,282	247	714
Montana	675	694	28	71
Idaho	667	713	38	81
Wyoming	330	322	20	38
Colorado	1,754	2,207	55	180
New Mexico	951	1,016	16	88
Arizona	1,302	1,771	28	79
Utah	891	1,059	59	158
Nevada	285	489	3	19
Pacific	21,198	26,523	505	1,522
Washington	2,853	3,409	84	252
Oregon	1,769	2,091	57	147
California	15,717	19,953	344	1,078
Alaska	226	300	2	7
Hawaii	633	769	18	38

Sources: Department of Commerce, Bureau of the Census, decennial census reports and National Research Council, *Doctorate Recipients from U.S. Universities*, annual series.

Table 48. Unemployment rates, 1963-72

Year (averages)	Professional and scientific workers			
	All workers	Professional and scientific workers	Scientists	Engineers
1963	5.7	1.9	—	1.2
1964	5.1	1.8	—	1.5
1965	4.6	1.5	—	1.1
1966	3.9	1.3	.4	.7
1967	3.7	1.3	—	.6
1968	3.6	1.2	.9	.7
1969	3.5	1.3	—	.8
1970	5.0	2.0	1.6	2.2
1971	6.0	3.0	2.6	2.9
1972	5.6	2.4	—	2.0
1st quarter	6.3	2.3	—	2.8
2nd quarter	5.6	2.3	—	2.0
3rd quarter	5.6	2.9	—	1.8
4th quarter	4.9	2.1	—	1.2

Sources: Department of Labor, Bureau of Labor Statistics, periodic reports on labor force and National Science Foundation, *Unemployment Rates and Employment Characteristics for Scientists and Engineers, 1971* (NSF 72-307).

Table 49a. Unemployment rates for scientists and engineers, by age group, 1971

Age group	Scientists	Engineers
	Percent	
Total	2.6	3.0
24 and under	5.5	5.5
25-29	5.3	3.3
30-34	2.9	2.2
35-39	2.1	2.2
40-44	1.8	2.7
45-49	2.1	2.8
50-54	2.0	3.3
55-59	1.8	4.1
60-64	1.8	4.2
65 and over	2.3	3.4

Source: National Science Foundation, *Unemployment Rates and Employment Characteristics for Scientists and Engineers, 1971* (NSF 72-307).

Table 49b. Unemployment rates for scientists and engineers, by highest degree, 1971

Highest degree	Scientists	Engineers
	Percent	
Total	2.6	3.0
Doctorate	1.4	1.9
Master's	3.7	3.2
Bachelor's	3.5	2.8
Less than bachelor's	4.1	4.4

Source: National Science Foundation, *Unemployment Rates and Employment Characteristics for Scientists and Engineers, 1971* (NSF 72-307).

Table 50. Percent of new science and engineering Ph.D.'s planning to engage in "further education or training" or "postdoctoral study," by field, fiscal years 1960-71¹

Field of science	Fiscal year of doctorate											
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
All science and engineering	10.4	13.1	14.4	14.9	14.6	15.7	15.9	15.7	15.4	21.0	22.2	23.0
Physical sciences	13.3	18.7	20.8	21.5	21.9	22.8	24.6	24.8	22.8	33.6	35.5	38.6
Mathematics	7.6	7.2	12.1	8.5	7.0	6.6	6.2	6.9	4.5	8.7	7.9	7.1
Engineering	3.5	3.0	4.1	6.0	5.7	6.0	5.4	4.4	4.6	7.1	8.1	11.0
Life sciences	16.0	21.1	22.4	23.0	23.6	25.7	26.0	26.6	28.4	35.7	38.2	37.0
Social sciences	5.0	5.6	6.1	6.3	5.8	7.0	7.0	6.6	6.1	8.1	8.1	7.7

¹ Due to a change in definition, 1969 through 1971 data are not strictly comparable with earlier years.

Source: National Research Council, *Doctorate Recipients from U.S. Universities*, annual series.

Table 51. Median number of years from baccalaureate to doctorate of doctorate recipients in science and engineering, by field, fiscal years 1960-71

Field of science	Fiscal year of doctorate											
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Physical sciences	6.4	6.5	6.4	6.3	6.2	6.3	6.1	6.0	6.1	6.1	6.1	6.2
Mathematics	7.2	7.5	7.1	6.8	6.1	6.1	5.8	6.1	5.9	5.9	6.0	6.2
Engineering	7.4	7.1	7.1	6.9	7.0	7.0	7.0	7.2	7.1	7.0	6.9	7.2
Life sciences	8.0	7.8	7.7	7.5	7.3	7.3	7.3	7.1	7.1	6.8	6.5	6.8
Social sciences	8.8	9.2	9.1	8.6	8.3	8.0	7.8	7.8	7.8	7.5	7.4	7.2

Source: National Research Council, *Doctorate Recipients from U.S. Universities*, annual series.

Table 52. Number of institutions of higher education by highest degree awarded in science and engineering, 1960-61 to 1970-71

Year	Number of institutions granting—		
	Bachelor's degrees	Master's degrees	Doctorate degrees
1960-61	748	189	153
1961-62	745	212	155
1962-63	754	209	162
1963-64	757	218	172
1964-65	754	233	178
1965-66	745	246	187
1966-67	752	271	194
1967-68	746	281	196
1968-69	756	292	206
1969-70	764	295	220
1970-71	NA	NA	229

Source: Special tabulation by National Science Foundation based on data provided by the U. S. Office of Education.

Table 53a. Scientists and engineers¹ employed in universities and colleges, 1965-71
[In thousands]

Year	Number employed in institutions granting—		
	Bachelor's degrees	Master's degrees	Doctorate degrees
1965 ..	20.3	18.5	103.5
1967 ..	20.9	22.2	125.2
1969 ..	22.4	30.4	140.2
1971 ..	24.3	31.0	157.3

¹ Full-time equivalents.

Source: National Science Foundation, *Resources for Scientific Activities at Universities and Colleges*, biennial series.

Table 53b. Concentration of scientists and engineers¹ employed in universities and colleges, 1965-71

Year	Percent employed in institutions granting—		
	Bachelor's degrees	Master's degrees	Doctorate degrees
1965 ..	14	13	73
1967 ..	12	13	74
1969 ..	12	16	73
1971 ..	11	15	74

¹ Full-time equivalents.

Source: National Science Foundation, *Resources for Scientific Activities at Universities and Colleges*, biennial series.

Table 54. Science and engineering degrees awarded at baccalaureate, master's, and doctorate-granting institutions, 1963-64 to 1969-70

Type of institution and level of degree	1963-64	1965-66	1968-69	1969-70
Doctorate-granting:				
Bachelor's degrees	79,680	90,230	124,191	139,768
Master's degrees	25,582	32,450	39,398	40,107
Ph.D. degrees	8,928	11,298	15,839	17,639
Master's and bachelor's:				
Bachelor's degrees ¹	34,434	41,962	67,424	69,841
Bachelor's degrees ²	39,216	41,279	52,904	54,513
Master's degrees	4,320	5,633	9,027	9,211

¹ Master's institutions.

² Baccalaureate institutions.

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 55. Number of Ph.D. degrees awarded in science and engineering, by selected groups of institutions,¹ 1962-63 to 1970-71

<i>Groups of institutions</i>	<i>1962-63</i>	<i>1965-66</i>	<i>1969-70</i>	<i>1970-71</i>
All institutions	7,947	11,398	17,639	18,407
First 20 institutions	4,040	5,076	7,024	7,125
Second 20 institutions	1,650	2,365	3,456	3,645
Remaining institutions	2,284	3,857	7,159	7,697

¹ Ranked in terms of doctorates awarded in each year.

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 56a. Total full-time graduate students in science and engineering enrolled in selected groups of doctorate-granting institutions, 1962-63 to 1970-71

<i>Groups of institutions</i>	<i>1962-63</i>	<i>1965-66</i>	<i>1969-70</i>	<i>1970-71</i>
All institutions	69,622	105,190	135,123	138,822
First 20 institutions	29,825	43,185	46,465	45,782
Second 20 institutions	13,792	18,820	24,481	24,789
Remaining institutions	26,005	43,185	64,177	68,251

¹ Ranked in terms of doctorates awarded in each year.

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 56b. First-year, full-time graduate students in science and engineering enrolled in selected groups of doctorate-granting institutions,¹ 1962-63 to 1970-71

<i>Groups of institutions</i>	<i>1962-63</i>	<i>1965-66</i>	<i>1969-70</i>	<i>1970-71</i>
All institutions	30,895	47,259	56,858	60,358
First 20 institutions	11,319	17,150	18,039	17,636
Second 20 institutions	5,598	7,784	9,718	10,379
Remaining institutions	13,978	22,325	29,101	32,343

¹ Ranked in terms of doctorates awarded in each year.

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 57a. Number of institutions granting Ph.D. degrees in science and engineering, by control, selected years, 1962-63 to 1970-71

<i>Academic year</i>	<i>Total</i>	<i>Public</i>	<i>Private</i>
1962-63	162	93	69
1963-64	172	96	76
1965-66	187	107	80
1966-67	194	111	83
1969-70	222	129	93
1970-71	229	135	94

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 57b. Number of Ph.D. degrees awarded in science and engineering, by control of institution, 1963-64 to 1970-71

<i>Academic year</i>	<i>Total</i>	<i>Public</i>	<i>Private</i>
1963-64	8,928	5,282	3,646
1965-66	11,298	6,887	4,411
1966-67	12,759	7,785	4,974
1967-68	14,128	8,851	5,277
1968-69	15,839	10,114	5,725
1969-70	17,639	11,471	6,168
1970-71	18,466	12,261	6,205

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 58. Graduate enrollment by control of institution, selected years [Thousands]

<i>Control of institution</i>	<i>Total graduate enrollment</i>			<i>First-year graduate enrollment</i>		
	1965	1969	1970	1965	1969	1970
Total, all institutions	226	264	266	109	112	115
Public institutions	156	186	192	76	78	84
Private institutions	70	78	74	33	34	31

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 59. Proportion of NSF and NIH¹ research project grant funds allocated for permanent laboratory equipment, fiscal years 1966-71 [Percent]

<i>Fiscal year</i>	<i>NSF</i>	<i>NIH</i>
1966	11.2	11.7
1967	8.6	11.8
1968	7.5	9.5
1969	7.0	7.5
1970	6.0	5.9
1971	6.1	NA

¹ Includes National Institute of General Medical Sciences and National Heart and Lung Institute.

Source: National Science Foundation from unpublished data.

Table 60. Percent distribution of NSF research project support, by type of expenditure, fiscal years 1964-72

	Fiscal year								
Type of expenditures	1964	1965	1966	1967	1968	1969	1970	1971	1972
Total (millions of dollars)	\$113	\$120	\$157	\$168	\$171	\$176	\$162	\$175	\$242
	Percent distribution								
Total, salaries and wages	54	54	52	52	53	52	52	51	52
Research associates/assistants salaries and wages	22	23	23	22	22	22	21	19	21
Equipment ¹	20	19	18	16	15	15	13	14	13
Indirect costs	16	15	17	20	21	22	22	22	22
Other costs	10	12	13	12	12	11	12	13	12

¹ Permanent and expendable equipment.

Source: National Science Foundation from unpublished data.

Table 61a. Federal obligations for R&D plant, fiscal years 1963-71
[Dollars in millions]

Fiscal year	Current dollars	Constant 1961 dollars ¹
1963	\$105.9	\$99.8
1964	100.8	92.6
1965	126.2	112.3
1966	114.8	98.8
1967	111.3	91.8
1968	96.1	75.7
1969	54.5	40.9
1970	44.8	31.9
1971	29.9	20.1

¹Based on academic R&D price deflator.

Source: National Science Foundation, *Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, Fiscal year 1971* (NSF 73-300).

Table 61b. Federal obligations for academic R&D plant as a percent of Federal obligations for academic science, fiscal years 1963-71

Year	Total Federal obligations for academic science (dollars in millions)	Percent share for academic R&D plant
1963	\$1,328.5	8.0
1964	1,528.6	6.6
1965	1,816.2	7.0
1966	2,163.5	5.3
1967	2,323.8	4.8
1968	2,349.8	4.1
1969	2,361.4	2.3
1970	2,167.9	2.1
1971	2,335.9	1.3

Source: National Science Foundation, *Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, Fiscal Year 1971* (NSF 73-300).

**Table 62a. Federal obligations for intramural
R&D performance, fiscal years
1961-72**

[Dollars in millions]

<i>Fiscal year</i>	<i>Current dollars</i>	<i>Constant 1958 dollars¹</i>
1961	\$1,874	\$1,800
1962	2,098	1,994
1963	2,279	2,142
1964	2,838	2,630
1965	3,093	2,814
1966	3,222	2,874
1967	3,395	2,934
1968	3,495	2,916
1969	3,498	2,798
1970	3,876	2,941
1971	4,166	3,006
1972 (est.)	4,500	3,136

¹ GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXI (NSF 72-317).

**Table 62b. Federal intramural R&D funds as a share of national and Federal
R&D totals, 1960-72**

[Dollars in millions]

<i>Year</i>	<i>Federal R&D</i>	<i>National R&D</i>	<i>Federal intramural R&D as a percent of:</i>	
			<i>Federal R&D</i>	<i>National R&D</i>
1960	\$ 7,562	\$13,730	23	13
1961	9,059	14,552	21	13
1962	10,290	15,665	20	13
1963	12,495	17,371	18	13
1964	14,225	19,214	20	15
1965	14,614	20,439	21	15
1966	15,320	22,266	21	14
1967	16,529	23,612	21	14
1968	15,921	25,119	22	14
1969	15,637	26,176	22	13
1970	15,330	26,695	25	15
1971	15,550	27,320	27	15
1972 (est.)	16,821	28,940	27	16

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303) and *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXI (NSF 72-317).

**Table 63. Federal obligations for intramural R&D performance, by agency,
fiscal years 1961-72**
[Dollars in millions]

Agency	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972 (est.)
Total	\$1,874	\$2,098	\$2,279	\$2,838	\$3,093	\$3,222	\$3,396	\$3,493	\$3,498	\$3,876	\$4,166	\$4,500
Department of Defense	1,331	1,468	1,435	1,615	1,647	1,720	1,890	1,951	1,867	1,996	2,201	2,418
National Aeronautics and Space Administration	179	213	381	706	863	872	813	791	821	988	909	912
Department of Health, Education, and Welfare	97	121	132	150	161	182	204	222	243	247	298	334
Department of Agriculture	104	109	118	130	153	164	175	182	190	208	227	251
Department of the Interior	62	68	72	73	82	94	109	116	123	100	112	127
Department of Commerce	29	32	39	43	46	42	49	55	58	88	92	109
Department of Transportation	—	—	—	—	—	41	45	52	54	64	101	111
National Science Foundation	5	7	12	13	14	13	12	12	15	14	19	19
Atomic Energy Commission	19	19	14	22	31	20	15	17	17	18	17	15
All other	48	62	77	87	97	74	84	96	110	153	190	212

Source: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXI (NSF 72-317).

Table 64. Federal obligations for intramural performance, by character of work, fiscal years 1961-72
[Dollars in millions]

Year	Current dollars				Constant 1958 dollars ¹			
	Research				Research			
	R&D	Basic	Applied	Develop- ment	R&D	Basic	Applied	Develop- ment
1961	\$1,874	\$206	\$ 634	\$1,034	\$1,800	\$198	\$609	\$ 993
1962	2,098	251	702	1,145	1,994	239	667	1,088
1963	2,279	299	730	1,250	2,142	281	686	1,175
1964	2,838	364	928	1,546	2,630	337	860	1,433
1965	3,093	424	1,030	1,639	2,814	386	937	1,491
1966	3,222	449	1,045	1,728	2,874	401	932	1,541
1967	3,395	478	1,095	1,822	2,934	413	946	1,575
1968	3,493	512	1,199	1,782	2,916	427	1,001	1,487
1969	3,498	577	1,195	1,726	2,798	462	956	1,381
1970	3,876	658	1,375	1,343	2,941	499	1,043	1,398
1971	4,166	535	1,499	2,132	3,006	386	1,082	1,538
1972 (est.)	4,500	578	1,594	2,337	3,136	402	1,108	1,625

¹ GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXI (NSF 72-317).

Table 65. Percent distribution of industrial R&D scientists and engineers,¹ by company size, 1957-71

Year	Total R&D scientists and engineers	Companies with—		
		Less than 1,000 employees	1,000-4,999 employees	5,000 or more employees
1957 ...	229,400	19.5	9.8	70.7
1958 ...	243,800	20.0	9.8	70.1
1959 ...	268,400	14.8	10.1	75.1
1960 ...	292,000	13.4	10.2	76.4
1961 ...	312,100	13.5	10.9	75.6
1962 ...	312,000	11.7	11.3	77.0
1963 ...	327,300	10.4	10.7	78.9
1964 ...	340,200	9.6	10.1	80.3
1965 ...	343,600	9.4	9.3	81.2
1966 ...	353,200	8.5	8.5	83.0
1967 ...	367,200	7.5	8.3	84.2
1968 ...	376,700	7.2	7.9	84.9
1969 ...	387,100	7.0	7.3	85.7
1970 ...	384,100	6.5	8.2	85.3
1971 ...	359,300	6.2	8.7	85.1

¹ Full-time equivalents.

Source: National Science Foundation, *Research and Development in Industry, 1970* (NSF 72-309).

Table 66. R&D intensiveness of U.S. industry, 1960-70

Year	Funds for R&D performance (millions of dollars)	R&D as percent of net sales	R&D scientists and engineers ¹	
			Number	Per 1,000 employees
1960	\$10,509	4.2	292,000	25
1961	10,908	4.3	312,100	28
1962	11,464	4.3	312,000	28
1963	12,630	4.5	327,300	28
1964	13,512	4.6	340,200	30
1965	14,185	4.3	343,600	30
1966	15,548	4.2	353,200	27
1967	16,385	4.2	367,200	27
1968	17,429	4.0	376,700	26
1969	18,318	4.0	387,100	26
1970	17,858	3.8	384,100	24

¹ Full-time equivalents.

Source: National Science Foundation, *Research and Development in Industry, 1970* (NSF 72-309).

Table 67. R&D intensiveness of groups of manufacturing industries, 1960-70

Year	Group I		Group II		Group III	
	R&D funds (in millions)					
	Total	Percent of net sales	Total	Percent of net sales	Total	Percent of net sales
1960	\$ 8,304	10.0	\$1,534	1.8	\$385	0.6
1961	8,610	9.6	1,597	2.0	401	.6
1962	9,079	9.6	1,692	1.9	395	.6
1963	10,059	10.2	1,816	2.0	423	.6
1964	10,682	10.7	2,003	2.0	451	.6
1965	11,167	10.4	2,085	1.8	491	.6
1966	12,228	9.5	2,229	1.8	537	.5
1967	12,886	8.8	2,692	1.9	561	.5
1968	13,579	8.2	2,956	1.9	591	.6
1969	14,192	8.3	3,108	1.9	648	.6
1970	13,731	8.0	2,950	2.0	668	.6

R&D scientists and engineers						
Number	Per 1,000 employees		Number	Per 1,000 employees		
	Number	Per 1,000 employees		Number	Per 1,000 employees	
1960	222,700	48.2	39,700	15.2	15,700	5.6
1961	238,800	50.4	45,800	17.6	16,300	5.2
1962	239,500	48.2	46,600	17.2	14,600	5.6
1963	255,600	51.6	46,400	16.6	14,300	5.0
1964	265,100	54.2	48,900	16.6	14,700	5.2
1965	266,200	53.6	50,300	16.4	15,400	5.2
1966	272,600	47.4	51,000	16.0	15,800	5.0
1967	282,700	45.6	52,000	16.6	16,700	5.0
1968	290,000	44.4	52,300	15.8	17,500	5.2
1969	296,500	42.6	55,000	16.2	18,300	5.6
1970	291,300	42.0	55,200	16.0	18,900	5.2

Source: National Science Foundation, *Research and Development in Industry, 1970*, (NSF 72-309).

Table 68. R&D intensiveness in manufacturing industries, by company size, 1967-70

	1967		1970	
	Funds for R&D			
Size of company (number of employees)	Amount (millions of dollars)	Percent of net sales	Amount (millions of dollars)	Percent of net sales
Less than 1,000	\$ 687	1.7	N.A.	N.A.
1,000-4,999	1,017	1.7	N.A.	N.A.
5,000-9,999	892	2.1	\$ 1,077	2.2
10,000 or more	13,790	5.2	14,890	4.5

R&D scientists and engineers				
	Per 1,000 employees		Per 1,000 employees	
	Number		Number	
Less than 1,000	27,400	28	N.A.	N.A.
1,000-4,999	30,500	16	N.A.	N.A.
5,000-9,999	24,000	16	28,500	18
10,000 or more	285,300	30	299,100	26

Source: National Science Foundation, *Research and Development in Industry, 1970*, (NSF 72-309).

Appendix B—Delphi Panelists

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Senator KENNEDY. The subcommittee stands adjourned.
[At 12:50 p.m., the subcommittee was adjourned.]

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