FOURTH ANNUAL REPORT OF THE NATIONAL SCIENCE BOARD

HEARING

BEFORE THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS HOUSE OF REPRESENTATIVES

NINETY-SECOND CONGRESS

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HEARING ON THE FOURTH ANNUAL REPORT OF THE NATIONAL SCIENCE BOARD

WEDNESDAY, APRIL 26, 1972

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C.

The committee met at 10:10 a.m., in room 2318, Rayburn House Office Building, Washington, D.C., Hon. John W. Davis, presiding.

Mr. DAVIS. The committee will be in order.

I have an opening statement which I would like to present at this time with the permission of you gentlemen

Several years ago the Congress, at the insistence of this committee, amended the organic act of the National Science Foundation. Among other things, the amendments required the submission of an annual report to the Congress from the National Science Board which, as members know, is the policymaking body for the National Science Foundation .

The first Board report, submitted in 1969, dealt with graduate education. The second report, in 1970, dealt with the physical sciences. The third report, in 1971, dealt with environmental sciences.

The congressional charge to the Board with regard to its annual report was that it focus on "the status and health of science and its various disciplines [including] an assessment of such matters as national scientific resources . . . progress in selected areas of basic scientific research, and an indication of those aspects of such progress which might be applied to the needs of American society." The law also stipulates that the report may include such recommendations as the Board deems timely and appropriate.

Certainly, the first three reports have been responsive to the charter and have been useful not only to the committee but to the government at large and the scientific community, not to mention the taxpaying public.

Today, we are receiving the Board's fourth annual report which deals with a national policy for technology.

We are very pleased to have this report presented to the committee, and on behalf of the committee I would like to welcome the Chairman of the Board, Dr. Herbert E. Carter; the Director of the Foundation, Dr. H. Guyford Stever; and five distinguished scientists and engineers, several of whom are also members of the Board, who assisted in the preparation of the report. I will not introduce these gentlemen at this time but will leave that pleasant task to Dr. Carter.

Meanwhile, I would like to call upon my colleague from Ohio and my esteemed and distinguished friend, Mr. Charles Mosher, for a comment if he would like to offer one.

Mr. MOSHER. Well, Mr. Chairman, that is courteous of you.

I am glad to join you enthusiastically in your words of welcome and in your words of anticipation of this Fourth Report. I think these occasions are significant, and I think at this point we should begin.

Mr. DAVIS. Thank you very much.

Dr. Carter, I would like to recognize you at this time, then, and appoint you, if I may, as coordinator of the presentation of the statements to be presented.

(The biographical sketch of Dr. Carter follows:)

H(ERBERT) E. CARTER, CHAIRMAN, NATIONAL SCIENCE BOARD, NATIONAL SCIENCE FOUNDATION

Born: September 25, 1910; Mooresville, Indiana.

Positions: Coordinator of Interdisciplinary Programs, University of Arizona, 1971–Present. University of Illinois, 1933–71. Vice Chancellor for Academic Affairs, 1967–71; Head, Department of Chemistry and Chemical Engineering, 1954–57; Acting Dean, Graduate College, 1963–64; Professor, 1945–71; Associate Professor, 1943–45; Assistant Professor, 1937–43; Associate, 1935–37; Instructor in Chemistry, 1933–35.

Education: DePauw University, A.B., 1930; University of Illinois, A.M., 1931; University of Illinois, Ph. D., 1934; DePauw University, Sc. D., 1952.

Memberships: President's Committee on the National Medal of Science, 1963–66; Member, National Science Board, National Science Foundation, 1964–Present; Member, Executive Committee, Division of Chemistry and Chemical Technology, National Research Council, 1949–55 and 1957–58; Member, American Chemical Society (Director, Associate Editor, Bio-Chemistry, 1961–Present; recipient, William H. Nichols Medal, New York Section); American Institute of Nutrition (Secretary, 1945–57); American Society of Biological Chemists (Editorial Board, 1951–60; Editorial Committee, 1963–66; President, 1956–57); National Academy of Sciences (Chairman, Biochemistry Section, 1963–66; Member of the Council since 1966); Sigma Xi; Phi Beta Kappa; Blue Key; Lambda Chi Alpha; Gamma Alpha; Alpha Chi Sigma.

Publications: Member, Editorial Board, Biochemical Preparations; Editor-in-Chief, Vol. I. Contributor to Technical Publications.

Home Address: 2401 East Cerrada de Promesa, Tucson, Arizona 85715.

Family: Wife: Elizabeth; Daughters: Anne W. and Jean E.

STATEMENT OF DR. H. E. CARTER, CHAIRMAN, NATIONAL SCIENCE BOARD, COORDINATOR OF INTERDISCIPLINARY PROGRAMS, UNIVERSITY OF ARIZONA

Dr. CARTER. Thank you, Mr. Chairman and members of the committee. My colleagues and I are especially pleased to present and discuss with you today the Fourth Report of the National Science Board, "The Role of Engineers and Scientists in a National Policy for Technology."

The concept of an annual report by the National Science Board to the President and to the Congress originated in this committee, as you have indicated.

We are glad that circumstances bring us together with you on the occasion of the issuance of this report.

In conformity with your indicated wishes, we hope that at least half of the time will be taken up by your questions and our responses.

After my introduction there will be a brief overview of the report as a whole, followed by individual statements on each of the five recommendations in the report. It is our hope that we can in that way lead into dialog between the committee and the representatives of the Board.

Permit me to make some introductions. I do not need to introduce to you the new director of the National Science Foundation, Dr. Stever, who participated in the early development of the present report.

I would like also to introduce to you those who are going to speak on the specifics of the report. I believe you have their biographies.

Dr. Thomas F. Jones, Jr., president, University of South Carolina, and member, National Science Board.

Dr. Daniel C. Drucker, dean, College of Engineering of the University of Illinois.

Dr. J. Ross Macdonald, vice president of Corporate Research and Engineering and the director of the Central Research Laboratory of the Texas Instruments Company, Inc.

Dr. William K. Linvill, executive chairman, Department of Engineering-Economics Systems, School of Engineering, Stanford University.

And Dr. Joseph M. Reynolds, Boyd Professor of Physics and vice president for Instruction and Research, Louisiana State University, and member, National Science Board.

Because this is the first meeting of this kind in connection with our annual reports, it seems appropriate to review some of the background. The idea of amending the National Science Foundation Act to include a requirement for an annual report by the National Science Board is usually credited to your Subcommittee on Science, Research, and Development. During hearings on an array of proposed amendments to the NSF Act, held in 1966, there was relatively brief but significant discussion of what is now section 4(g): "The Board shall render an annual report . . ." and so on.

In formal commentary submitted on behalf of the National Science Board by Dr. Eric A. Walker, chairman at that time, the Board expressed the belief that an annual report ". . . would provide a platform for the policy recommendations of the Board and assure adequate 'visibility' to the recommendations."

Subsequent interactions between the Board and your committee resulted in the final language which was enacted in 1968 as section 4(g) of the NSF Act.

I believe it is not too bold for me to assume that the committee is thoroughly familiar with the language of section 4(g), and I will not read it here.

Pursuant to this section the National Science Board has submitted its reports. The chairman has already indicated these and I will not reread them.

The January 31 deadline set by the act for submission of the report to the President and through him to the Congress means, of course, that the preparation has taken place in the previous calendar year. There is no standardized procedure for the preparation, and I think it unlikely there ever will be. Different topics call for different methods. The Board committees immediately engaged—each year sees a new "ad hoc committee on the Board report"—vary in membership from

one report to the next. One common circumstance, however, has been the enlistment of contributory and critical assistance from substantial numbers of people knowledgeable in the field to be treated. The actual acknowledgments in each report—and I am sure you all have copies of this—reflect the magnitude and scope of these contributions.

In general we have sought to provide solid, clearly focused reports of manageable length, on timely subjects. These requirements have sometimes resulted in the publication of supplements containing substantial basic material excluded from the main report, partly because of the size involved.

Thus "Graduate Education—Parameters for Public Policy" was published as a supplement to the First Board Report. A very substantial companion volume to the Third Board Report is currently being prepared under the title, "Patterns and Perspectives in Environmental Science."

Preparation begins with the choice of a topic by the Board after extensive and usually quite lively discussion. This decision is made considerably more than a year in advance of the scheduled date of submission. The Board chairman appoints an ad hoc committee of Board members and designates a chairman. In the case of the Fourth Board Report, now before you, Dr. Stever was named chairman of the ad hoc committee, many months before it became known that there was to be a change in the directorship of the National Science Foundation.

The Committee on the Fourth Report began developing an outline and material late in 1970. The cooperation of the Advisory Committee for Engineering of the National Science Foundation was asked, and given generously. A three-man staff was formed for writing, editing, and production tasks. Continuously from the beginning, the full National Science Board, and its members as individuals, participated in the work. Each meeting of the Board scheduled time for review, criticism, and suggestions. This is a most rigorous process, and it means that the finished document, which is before you today, is truly a document of the National Science Board. In the case of the Fourth Board Report, hard-working meetings in June and just before Labor Day brought together the ad hoc committee, the Advisory Committee for Engineering, and the writing staff. There was a supplementary meeting with the Advisory Committee during its fall meeting at the Foundation. As tentative drafts emerged, each was subjected to critical annotation by the Board and the Advisory Committee. At the November meeting of the Board, a semifinal draft underwent a most rigorous examination, which cleared the way for the final drafting process.

An important step involved review—and this was of the November draft—by interested Federal agencies. The departments and agencies invited to comment were those with mission roles which benefit from or support engineering and technology. (A list of those agencies is in Appendix D.) We appreciate very much the responses to this request which provided both constructive substantive contributions and editorial improvement for the report.

Also, and I think this is an important point, by this kind of interchange the preparation of a report becomes the occasion for fruitful communication between the National Science Board and those persons in the operating agencies having responsibilities related to science and technology. Review of the agency contributions and other responses

resulted in constructive changes in the galleys and this brought us to the final form and, I am delighted to say, to our present meeting with you this morning.

Finally, I should like to say that the Board attaches much importance to this hearing. The previous reports of the Board have been widely distributed and reached a substantial audience. However, it has become increasingly evident that they have not reached many potentially interested people. We hope that these hearings will provide a platform for expanding the usefulness of our reports, and I wish to extend my warm thanks to you, for myself and on behalf of the National Science Board, for giving us this opportunity.

Thank you.

Mr. DAVIS. Thank you very much, Dr. Carter.

I would like to say that this committee also attaches much importance to this hearing. And I would also like to convey to all of you the greetings of Chairman George Miller with whom I just talked over the telephone. He said he was extremely sorry that he couldn't be with you this morning but that he was here in spirit and that he wished he were here in person.

Dr. CARTER. Yes. Please return our regards.

Mr. DAVIS. Mr. Mosher?

Mr. MOSHER. This is a rigorous process that you have gone through, I judge. I think we should all be glad for that, because I think the very discipline of it probably is as useful to you folks as it is to anyone else. That is one of the prime values in it.

Just as a matter of timing, I judge this report is as of January 1. Is that right? I notice that your final draft or your principal draft was completed last November, and we are to look upon this as a report as of around January 1?

Dr. CARTER. January 1, right.

Mr. MOSHER. I guess we are all aware that the situations of this world and particularly in the scientific media are pretty fluid, and we sort of have to have in mind what date you are talking about when you are talking, because lots has happened since January 1.

Dr. CARTER. Yes. This document was in the form in which it is here or very essentially in that form on the January 1 date.

If I may proceed, Mr. Chairman.

Mr. DAVIS. Yes, sir.

Dr. CARTER. Dr. Tom Jones, who played a very important role in the activities of the committee and who has organized the group who will make representations this morning, will carry the proceedings from now on.

(The biographical sketch of Dr. Jones follows:)

DR. THOMAS F. JONES, PRESIDENT, THE UNIVERSITY OF SOUTH CAROLINA

Dr. Thomas F. Jones became President of the University of South Carolina in 1962 after having served four years as Head of the School of Electrical Engineering at Purdue University.

He holds the B. S. degree from Mississippi State and the Masters and Doctorate from the Massachusetts Institute of Technology. He has received honorary Doctorates from The Citadel and Purdue.

Dr. Jones was born in Henderson, Tennessee, July 9, 1916. He is married to the former Mary Butterworth of Somerset, Massachusetts, and they have five children.

During World War II, Dr. Jones served as a physicist for the U.S. Navy and was awarded the Meritorious Civilian Service Award.

In 1947 he joined the MIT faculty where his research concerned computers, nuclear instrumentation and missile systems, and his teaching gave new contributions to standards and practices in electrical engineering curricula throughout the nation.

At Purdue he developed a new curriculum, originated a special undergraduate program for honors students interested in research, and greatly expanded graduate studies and research.

As president of the University of South Carolina his emphasis is on curriculum reform, intellectual environment, special opportunities for honors students, service to the state, and graduate studies. The University has flourished under his leadership.

The Ford Foundation made a significant recognition of Dr. Jones' personal accomplishments at USC in 1971 when the Foundation awarded $250,000 under its Venture Fund Program for his discretionary use in the University's undergraduate educational efforts.

WIS Radio and Television in Columbia named Dr. Jones "1966 South Carolinian-of-the-Year," the fourth person to receive the distinction and following U.S. District Judge Donald Russell, late industrialist Charles E. Daniel and Gen. William Westmoreland. In 1970 the Columbia Sales and Marketing Executives named Dr. Jones "1969 Salesman of the Year."

Dr. Jones is a member of the National Science Board, appointed in 1966 by President Johnson. He has served on the Executive Committee of the National Highway Research Board.

He is a member of the Council on Higher Education in the Americas, the International Association of University Presidents, the Advisory Board of the Southern Region of the Institute of International Education, the Education and World Affairs Task Force on Agriculture and Engineering; is chairman of the Committee on Educational Telecommunications for the National Association of State Universities and Land-Grant Colleges. He was 1969–70 president of the Southern Association of Land-Grant Colleges and State Universities.

In 1969 he was elected to membership in the select National Academy of Engineering, and in 1971 was named a Fellow of the American Association for the Advancement of Science.

STATEMENT OF DR. THOMAS F. JONES, JR., PRESIDENT, UNIVERSITY OF SOUTH CAROLINA; MEMBER, NATIONAL SCIENCE BOARD

Dr. JONES. Thank you.

Mr. Chairman and members of the committee, we, on the National Science Board, are very appreciative of the opportunity to come before you here this morning for this hearing on our report.

We appreciate your giving us and others an opportunity to voice our concerns and our recommendations.

I would like to discuss with you, briefly, the origins and the progression of the main lines of thought leading to the fourth report of the National Science Board: "The Role of Engineers and Scientists in a National Policy for Technology." So these remarks are by way of an overview to provide the general framework for the statements on specific recommendations which will immediately follow.

In our earliest deliberations we thought that we should write about engineers and engineering. This was more or less our assignment. As we progressed we found ourselves led by the stream of our discussions into the broader concept of a report that would deal with technology and the well-being of our Nation.

The realities that emerged from our discussions became the principal bases for our report. The interactions between the larger society and its science and technology components are now more numerous

and complex than ever before. Both are more conscious of these interactions than ever before.

Society is asking more of technology and at the same time society is setting new ground rules within which technology can perform in fulfilling those requirements.

On the other hand, technology requires more awareness of the necessity of meeting the prescriptions of society on society's terms, and at the same time technology is conscious of a greater capability for filling these prescriptions.

The relationship of technological progress to national economic health in both the domestic and international environments is more clearly perceived.

In the light of that perception it becomes more readily apparent that certain parts of our technology are making less than their full potential contribution to the national economic health.

There are problems in both the private and commercial sector and in a kind of "third sector" where public consideration and services depend upon private-sector technology. These demand for their solution the development of unique capabilities of interaction with other elements. Some of the principal problems are noted in the report.

The necessary assistance must be provided by prudent Government stimulus and nourishment of those technologies, including stimulus to self-help to the extent possible.

Every major problem of society today requires some technological input, in most cases substantial technological input, toward its solution.

Every major problem requires technology beyond the capability and resources of any one entity—I emphasize "major" here, of course. Any one corporation, any one industry, any one university, any one discipline is inadequate to handle the major problems which our society faces.

Government must furnish the leadership in providing the means for aggregating the talents, resources, and markets, all of which may be essentially private sector in nature, up to the scale required. And I think we are talking about large-scale commitment.

Technological activities, whether aimed primarily at economic health or more broadly at social well-being, must from now on be monitored as to their consequences. This follows from a point I mentioned earlier, society's heightened consciousness of technology's interactions with it.

We do not yet know how to do all the things required to deal with these realities. Much effort must go into learning how.

The carrying forward of the whole effort, the learning and the doing, must have the support of an informed public.

Gentlemen, I hope I have succeeded in making this brief catalog complete and accurate. I hope you will find in it the roots of each of the recommendations on which my colleagues and I will give you individual statements.

Permit me one personal comment in conclusion. I believe this report to be an optimistic report. I believe that a student of these matters, Sir Charles Snow, who is well known to many members of this committee, holds that the practitioners of science and technology are the real op-

timists in today's world—and I think that we have worked pretty hard at being the optimists in today's world—because more than anyone else, the scientists and technologists sincerely believe they can improve the conditions of mankind; and, I might add, with the help of gentlemen such as yourself who in the end are the trustees in the matter. I share this confidence, and I believe that that kind of confidence underpins our report. It is a pleasure to bring it to you.

I would like to bring to you now one of the participants in the committee which worked up the details of this report, Dr. Daniel C. Drucker, dean of the College of Engineering of the University of Illinois. I would like to present to you Dr. Drucker.

Mr. DAVIS. Thank you. Dr. Drucker.

(The biographical sketch of Dr. Drucker follows:)

DANIEL CHARLES DRUCKER, DEAN OF THE COLLEGE OF ENGINEERING, UNIVERSITY OF ILLINOIS

B. June 3, 1918, New York, N.Y.; B.S. Columbia, 1937, C.E., 1938 (Illig Medal), fellow, Ph.D., 1940; Engr. Asst., Tunnel Authority, New York 1937; asst., Columbia, 1938–39; instr. mechanics of engr., Cornell, 1940–43; Supervisor mechanics of solids, Armour Research Foundation, Illinois Institute of Technology, 1943–45, asst. prof. mechanics, 1946–47; A.F., 1945–46; assoc. prof. engr., Brown, 1947–50; prof. engr., Brown, 1950–68; (Chairman, Division of Engineering, Brown, 1953–59; Chairman, Physical Sciences Council, Brown, 1961–63; L. Herbert Ballou University Professor, Brown, 1963–68).

Member National Academy of Engineering; Member Committee on Public Engineering Policy (COPEP) of NAE.

Tau Beta Pi; Sigma Xi; Phi Kappa Phi; Pi Tau Sigma; Sigma Tau; Fellow, Am. Acad. Arts and Sciences; Guggenheim Fellow, 1960–61; Fulbright Travel Grant, 1968; Nato Senior Science Fellow, 1968; von Karman Medal ASCE (1966); Marburg Lecturer ASTM (1966); Murray Lecturer SESA (1967); Lamme Medal ASEE (1967); Fellow, American Academy of Mechanics; SESA M.M. Frocht Award for 1971.

Registered Professional Engineer, Ill., R.I.; Fellow, Am. Soc. Civil Engr.; Fellow, Am. Soc. Mech. Engr.; Honorary Member Soc. Exp. Stress Anal.; Assoc. Fellow, AIAA; Fellow, AAAS; ASEE; Society of Rheology; N.S.P.E.; Illinois Society of Professional Engineers.

Member, Editorial Board, Quarterly of Applied Mathematics; U.S. National Committee on Theoretical and Applied Mechanics; U.S. Delegate to General Assembly of International Union of Theoretical and Applied Mechanics; National Science Foundation's Advisory Committee for Engineering; Panel 213.00 Advisory to the Mechanics Division of the Institute for Basic Standards, National Bureau of Standards; Advisory Committee on USSR and Eastern Europe of the Office of Foreign Secretary NAS; Honorary Chairman for Third SESA International Congress on Experimental Mechanics; Committee on the Survey of Materials Science and Engineering (COSMAT Project), NAS; Scientific Committee of the International Union of Theoretical and Applied Mechanics Symposium on Photoelastic Effect and its Applications.

Formerly: Technical Editor Journal of Applied Mechanics ASME, 1956–68; President, Society for Experimental Stress Analysis; Vice President and member Executive Committee of Council ASME; President of Providence Section and of New England Council ASCE; Member, U.S. National Committee on Rock Mechanics.

Written over a hundred technical articles.

STATEMENT OF DR. DANIEL C. DRUCKER, DEAN, COLLEGE OF ENGINEERING, UNIVERSITY OF ILLINOIS

Dr. DRUCKER. Recommendation I speaks to a dramatic turn for the worse in a familiar and once comfortable progression. For a long time, innovative new industries developed and grew as mature industries contracted and eventually died away. In turn, the new became mature

and were displaced from center stage by the newer still. Except for some feeling of nostalgia, we were pleased in this country as the automotive industry displaced the horse-and-carriage industry and when, in a series of steps, the computers of today replaced the ledgers and quill pens of yesterday. It is true that regional problems arose as when new textile mills in the South replaced older and less efficient textile mills in New England. Yet we could take comfort in the fact that the country as a whole often did benefit from such changes.

I might say parenthetically here that in my 21 years in Rhode Island, I did not always take as much comfort as I now take in Illinois.

Secure in our faith in the responsiveness of American engineers and the beneficial effects of technology as it advanced, we welcomed this continual replacement of the obsolete old by the vital and essential new.

A change has occurred in the past decade or so. The old that is phasing out no longer represents the obsolete past, but instead is at the heart of the present: Machine tools and other segments of the metal and metalworking industry, shipbuilding, papermills, radios and tape recorders, electron microscopes, low-cost automobiles—a long and distressing list.

We derive little comfort from the knowledge that less developed countries may benefit from these worldwide shifts of location of major and critical industries. We would be more philosophical if the new industrial plants simply deprived us of a share of an ever-growing market abroad. We worry when, instead, their output takes over a fraction of our domestic market which ranges from appreciable in the case of automobiles to almost complete in many consumer electronic products. We are deeply disturbed when our own plants become noncompetitive, not on cost alone, but on quality and versatility of their output of machines and devices.

As we look hopefully to the new and innovative industries waiting in the wings to add vigor and vitality to our domestic economy, we become even more concerned. An ever-increasing number of critical basic inventions seem to originate abroad; in many areas, we appear to be following instead of leading.

The legitimate aspirations of our people for a clean and healthy environment, add great urgency to Recommendation I. We often hear that we have the technology to clean up our air and our water, all we lack is the will. Certainly we can do much to reduce undesirable environmental impact.

However, we do not have nearly enough of the technology we need, because technology can only be said to be available when known techniques permit us to solve the problem within the economic constraints. Unless engineers are given the time and resources to develop more economic procedures, foundry after foundry, papermill after papermill, one kind of factory after another will be shut down. Both jobs and funds will be transferred abroad.

Similarly, without appropriate new technology in great profusion made available to the electric utility industry, the transportation industry, and all of our mature industries, costs will rise to make more of our products uncompetitive in world markets. No longer then will we have the base for increasing the standard of living for those among us now disadvantaged, and maintaining the standard of the rest.

Similarly we slide downhill if new and innovative industries are not developed here.

Two questions arise whenever governmental aid is recommended. One is why the private sector cannot undertake to solve its own problems without help. The other, once the first question is answered in a reasonably satisfactory manner, is how to assist.

First let me state my personal belief that the Government should intervene as little as possible. However, it is clear for mature industries that leaving the problem to the private sector alone will lead to an acceleration of the present trend. Fewer and fewer plants will remain economically viable; employment will drop; the balance of payments will worsen. Therefore it would appear to be in the public interest to aid in an appropriate manner those private industries as well as public utilities requiring such help.

How to assist? Here I must admit to much doubt and uncertainty. Recognition of a need is much easier than designing a system to meet that need. Much experimentation will be required to find means for infusion of basic and applied research activity into mature industries, means which are both effective and satisfactory to industry and the universities, Government laboratories, and research institutes with which industry interacts.

One obvious but long—rather than short—range side benefit of interaction in research with universities is the resulting attraction of a fairer share of the brightest young people into our mature industries and electric utility systems. For too long a time, this extremely important portion of the industrial world has held little attraction for many of our best students who wrongly have viewed it as unexciting.

The stimulation of new and advanced technology poses different but equally difficult problems of policy and procedure. Help for industries in trouble carries more obvious justification than help for industries now doing well. Yet catastrophe would appear to await us on both ends of the spectrum if present trends continue.

It is an encouraging circumstance that interaction of sophisticated science-based industries with universities, Government laboratories, and research institutes is sufficiently frequent today and their in-house research is active enough to permit expansion to whatever level is appropriate. Again, much experimentation will be needed to find the proper replacement for the stimulation provided over the past few decades from defense and space R. & D. In addition some means should be found to aid the small entrepreneur-inventor because the costs of applied research and development are one and two factors of 10 greater than the costs of the basic research itself.

In closing let me state my optimism about finding the means to safeguard the future industrial, economic, and environmental health of our country. My apologies for offering little more concrete at present than the need to try a wide variety of experiments aimed at injecting basic and applied research activity into mature industries and maintaining the high level of such activity in technologically advanced industry.

Thank you.

Mr. DAVIS. Thank you, Dr. Drucker.

Dr. JONES. Mr. Chairman, we would go according to your will. I would suggest we go ahead through these recommendations and then open discussion. But, nevertheless, whatever you wish.

Mr. DAVIS. That is perfectly agreeable.

Dr. JONES. Thank you very much.

Mr. MOSHER. Mr. Chairman, just let me clarify this in my mind. I assume this discussion that Dr. Drucker has just given and his recommendation supports the item in the National Science Foundation budget for 1973 of around $20 million for experimenting to find innovative ways to attract the cooperation of industry and the private sector in general in research and development. Is that true?

Dr. DRUCKER. Yes, sir; it does, and I suppose the National Bureau of Standards is working for the same purpose.

Mr. MOSHER. But this backs up that whole new direction in the administration programs this year.

Dr. DRUCKER. Yes. We hope we have had some hand perhaps in fashioning this.

Mr. MOSHER. Good.

Dr. JONES. Mr. Chairman, I would like to turn now from the academic scientist-engineer-technologist, to an industrial scientist and technologist for a recommendation, too. I would like to present Dr. J. Ross Macdonald, of Texas Instruments, Inc., vice president of Corporate Research and Engineering and director of the Central Research Laboratory, to get a view from an entirely different sector of our economy.

(The biographical sketch of Dr. Macdonald follows:)

DR. J. ROSS MACDONALD—TEXAS INSTRUMENTS, INC.

Dr. Macdonald, who was born in Georgia, received a B.A. in Physics (Williams College) and a S.B. in E.E. (M.I.T.) in 1944. He served as a Navy Radio-Radar officer during World War II and returned to M.I.T. in 1946. He was awarded a S.M. degree in E.E. from MIT in 1947 and then studied in the M.I.T. Physics Department until he received a Rhodes Scholarship in 1948. Oxford University granted him a D. Phil. degree (solid state physics) in 1950 and the D.Sc. degree, based on published papers, in 1967. He worked at Armour Research Foundation and Argonne National Laboratory before joining Texas Instruments in 1953. He served as Director of the TI Physics Research Laboratory for several years and is currently Director of the Central Research Laboratories and Vice President, Corporate Research and Engineering. In addition, he has been an adjunct associate professor of biophysics at the Southwestern Medical School of the University of Texas since 1954 and became an adjunct professor in 1971. His experimental work has been primarily in the areas of ferromagnetic resonance, photo Hall effect, electrical behavior of solids, and electric circuits. He has made theoretical contributions to the areas of dielectric and mechanical relaxation, space charge behavior in solids and liquids, electrical response of electronic devices, electrolyte double layers, equations of state, and numerical analysis of experiments. He has published over 90 papers in more than 30 different scientific and engineering journals.

Main memberships and outside activities: Fellow, The American Physical Society; Fellow, Institute of Electrical and Electronics Engineers; Fellow, American Association for the Advancement of Science; Member, Phi Beta Kappa and Sigma Xi; Member, National Academy of Engineering; Member of NAE Council; Member, NAS–NRC Solid State Sciences Panel; Member, AIP Advisory Committee on Corporate Associates; Member, NSF Advisory Committee for Science Education; Chairman, NAS–NAE–NRC Numerical Data Advisory Board; Member, NAS–NRC Committee on Motor Vehicle Emissions; Member, Visiting Committee, M.I.T. Physics Department; and Achievement Award of the Institute of Radio Engineers.

STATEMENT OF DR. J. ROSS MACDONALD, VICE PRESIDENT OF CORPORATE RESEARCH AND ENGINEERING AND DIRECTOR, CENTRAL RESEARCH LABORATORY, TEXAS INSTRUMENTS, INC., DALLAS, TEX.

Dr. MACDONALD. Thank you, Tom.

Mr. Chairman and members of the committee, I am delighted to participate in this discussion on the Fourth National Science Board Report. It is a particular pleasure to be asked to speak on this report since I had a small part in working on it and its revisions.

Because of this experience, which gave me a close familiarity with the report, but of course no bias, I feel qualified to state that it is the best of its kind I have read, an eminently sensible and practical statement of important national needs and of how technology can be better brought to bear in helping achieve their solution.

Now let me make some specific comments on Recommendation II of the report, which deals with technological support for public goods and services.

The public goods and services sector of the economy presents an opportunity for major innovation and contribution by the Federal Government primarily because it involves needs crucial to modern society. The number of persons providing vital functions such as health care and education, coupled with goods and services "purchased" collectively (for example, clean air, water, fire protection, civic order, city sanitation) has grown to 65 percent of our labor force. As this service sector has become the dominant part of our economy, it has been criticized for achieving a much lower productivity increase than has the manufacturing of capital and consumer goods for the private market. Some of the main characteristics of the service sector, which are relevant to its alleged low productivity and low increase in productivity, are:

1. The structure of the sector consists of many small, uncoordinated, perhaps even uncooperative parts. Often a service is person to person. A good example is food service.

2. A service, such as solid waste disposal, is often taken for granted because its purchase is indirect or collective.

3. Capital costs for providing services—for example, health and education—are often great, creating a high risk for free enterprise development of the service or contribution to it.

4. The indirect, "not for profit" character of a service often permits it to exist without effective resource allocation and without periodic evaluation of its performance and efficiency. The educational enterprise is a prime example.

5. Technology for improving productivity in some areas of the public goods and services sector, such as transportation and housing, already exists, but its application often encounters institutional, legal, or individual barriers.

6. Very few measures exist for quantifying the value of a service. Take local government for example. How can one evaluate the effectiveness of the services provided by local government?

One can identify at least three major problems in applying technology effectively to the public sector. The first problem arises from lack of problem definition and measurement.

Since one can control and improve only what one can measure, let me continue on the subject of measures for a moment to show its present status, the need, and the application of new measures. The President's National Commission on Productivity, headed by George P. Shultz, recognized the need for effort on measurement of productivity.

In a recent release, the Commission said, "adequate measurement of productivity is lacking for major and growing parts of the economy—such as government, the various services, construction, trade, finance, and real estate. Adequate measurement and better information are needed on actual productivity trends and developments in each sector of the economy so that lagging sectors can be more clearly identified and practical efforts can be made to improve their productivity growth."

Hatry and Fisk of the Urban Institute prepared a preliminary report for the Productivity Commission entitled, "Improving Productivity and Productivity Measurement in Local Governments." This report, covering 30 major cities, clearly demonstrates the general absence of measurement and the need for new measures, and it gives preliminary examples of the power of possible new measures in assessing the productivity of the service. Twenty-three out of 30 major U.S. cities record workload data such as tons of garbage collected per year. Only seven of the 30 cities used cost per unit of workload, however, and only four of the 30 had effectiveness data. The Institute found only one case of a city using effectiveness data to prepare time-series information on productivity.

Clearly, the measurement area for public services is both underdeveloped and complex—this complexity is one of the reasons for the need for Government-supported research into the development of measures of effectiveness for operations in the public sector of the economy.

The second problem area of the public sector is "customer" education, where the customer is the diffuse set of public agencies, regional authorities, governing boards, et cetera, who represent the public. In attempting to penetrate public sector markets, industry must attempt to sell to customers who themselves do not really know what their constituents want or need.

Further, companies often approach the customer with inadequate or nonexistent prototype hardware—nonexistent largely because the satisfaction of the need requires a system rather than a component; hence, there is usually an enormous cost and risk involved in engaging in an effective prototype demonstration of the kind really needed.

A second important role of Government-funded R.&D. for the public goods and services sector thus is the development and application of needs analysis and system studies, together with appropriate customer education.

Lastly, the role of Federal technology development for the public sector must include the responsibility of providing answers. The two previous topics I have touched on—measurement and educating the customer about needs—only identify problems and tell us when we are working on the right ones.

We still must get on with the job of developing answers. Because the magnitudes of many of the public sector problems are so large, the governmental role should extend further than R. & D. alone—on into federally sponsored demonstration projects.

In summary, the diffuse, taken-for-granted, not-for-profit, high-risk character of many parts of this sector has largely precluded entrepreneurs and innovators from applying their talents to filling perceived needs. Government-supported research, development, and demonstration could provide the innovative keys essential to providing these services to society in a productive, satisfactory way. I hope my comments show some of the reasons for Recommendation II: namely: "Key technologies essential to the attainment of societal goals, but not presently commercially viable, should be continually developed, strengthened, and renewed through Government-aided research and development."

Thank you.

Mr. DAVIS. Thank you, Dr. Macdonald.

Dr. JONES. Thank you, Ross.

Mr. Chairman, let me just mention that Dr. Macdonald was also a member of the special committee for developing this report, and contributed very greatly thereto.

I would now like to present for Recommendation III Dr. William K. Linvill, executive chairman of the Department of Engineering-Economic Systems of Stanford. And lest this committee become confused, I would like to tell you several things about Bill. He has an identical twin brother of similar accomplishments who is likewise a faculty member at Stanford. This creates no end of confusion for all kinds of people, but I understand this is Bill who is with us this morning and not John.

Bill comes to us with a very special background and expertise in that he has spent the last several years studying the Appalachian Regional Commission and its work trying to gain a better understanding of the way in which large-scale problems are attacked. And so in addressing Recommendation III, he will bring that special expertise to the committee.

(The biographical sketch of Dr. Linvill follows:)

WILLIAM K. LINVILL, EXECUTIVE CHAIRMAN OF THE DEPARTMENT OF ENGINEERING-ECONOMIC SYSTEMS, STANFORD UNIVERSITY

William K. Linvill is concerned with problems of systems analysis and decision-making. The areas of application in which he has been involved range from computer-coordinated systems to long-range planning. Presently he is studying problems of societal choice and technological change.

Following receipt of a liberal arts degree from William Jewell College, he entered the cooperative course in electrical engineering at Massachusetts Institute of Technology where he received the joint Bachelor's and Master's degree in 1945 and the Doctor of Science degree in 1949. Following award of his doctorate, he was on the faculty at MIT from 1949 to 1958. His research interests were in computer control systems for air traffic control and air defense. In 1954, he became more specifically interested in the systems area and in 1956 took a two-year leave of absence from MIT to lead a project of the Institute for Defense Analyses on NATO Air Defenses. In 1958, he became a Senior Staff member of the RAND Corporation. In 1960, he joined Stanford University as a Professor of Electrical Engineering, and in 1963 he became Chairman of the Institute in Engineering-Economic Systems there where he established and continues to develop a systems training and research program featuring field internships for graduate students. In 1967 he became Chairman of the Department of Engineering-Economic Systems. In 1972 he is on sabbatical from Stanford as a Senior Institute Fellow at Battelle Memorial Institute in Columbus, Ohio.

He is a Fellow of the IEEE, a member of the IEEE Systems Science Committee, and has been active in a number of groups and subcommittees including the Advisory Committee of the New Technical Activities Committee, the Systems Science and Cybernetics Group, the Power Engineering Education Committee, and the Awards Board of the Education Medal Committee. He was a member of the Committee of the National Academy of Engineering on the Interplay of Engineering with Biology and Medicine; a member of the National Research Council panel advisory to the Technical Analysis Division of the Institute for Applied Technology; and a member of the Advisory Committee for Engineering of the National Science Foundation.

STATEMENT OF DR. WILLIAM K. LINVILL, EXECUTIVE CHAIRMAN, DEPARTMENT OF ENGINEERING-ECONOMIC SYSTEMS, STANFORD UNIVERSITY

Dr. LINVILL. Mr. Chairman, members of the committee, societal growth and development in response to new technological opportunities is a promising prospect, but it involves large-scale interlocking societal efforts, substantial risks, and complicated transition both in institutional patterns and in individual lives. Many new technological opportunities involve large and diffuse problems, and our society really needs new processes to deal with them.

Recommendation III proposes a major effort to develop such a new process. Through such a process, the society can tackle very large and diffuse problems of national importance, explore their involved relationships to the society, develop alternative exploratory approaches, provide the various levels of societal choice, and consider stages of implementation of solutions.

The objective here is to develop a new process which allows us to launch new initiatives but to leave the men and companies and governmental institutions free.

The problem of the Appalachian Regional Commission represents the kind of societal choice problem with which we are concerned. In a problem such as developing an industrial capability in a given locality, often several separate States must deal jointly with several Federal agencies and several private companies.

The industrial development would influence the local and regional transportation needs, the drain on the region's water resources, its population migration, the health care needs, the vocational and educational needs, the region's resource base, its pollution problem, and so on. The various State and local groups must work jointly on the problem but still as independent agencies. Various elaborate brokerage processes have been established for dealing with such problems.

Just parenthetically, I studied the Appalachian Commission because of the fact that really it is an experiment in that brokerage process. I feel that it has much to do with where we go further.

Now, problems with regard to technological advances are equally complex in terms of the constituencies involved but often include as well uncertainty of technological outcome as well as uncertainty with regard to societal acceptance. Almost all technological change problems involve substantial dynamic effects. The society's problem, then, is to develop this process for societal choice in response to broad new technological responsibilities.

This process is to me a very key point. This process is now not available already designed. That is, we are not proposing a specific process.

But the process must evolve and develop as it is exercised on a set of societal problems. The first step in evolving such a process would be to establish the major outlines, and the next step is to experiment with it and exercise it flexibly on a few specific situations. That is the essence of the proposal.

Now, what about the outlines of the process? There are three essential elements, we believe, in the process for stimulating societal growth in response to technological opportunities.

First, we need a new means for broad, open exploration of problem areas, multidisciplinary in the broad sense involving many professions, many industries, many Government agencies all focused jointly on the same problem.

Second, a chain of initiatives to allow the societal selection of alternative solutions, and then to stage the implementation of solutions, and thus ultimately to link exploration and implementation. In other words, if the explored solutions are not ultimately implemented, the society does not gain anything.

Finally, the implementation must be flexible with modifications provided for as a result of societal feedback.

First, with regard to exploration. The exploration of each important societal problem must be done away from the pressures of the operational world.

The exploratory teams must be multidisciplinary in the broad sense, not only including social scientists as well as physical scientists but, very importantly, a number of industrial practitioners as well as political practitioners and representatives of the people of differing ages, races, sexes, and economic conditions. Such a broadly based team must be sharply focused on a specific problem. The objective of the exploratory process is not to make a decision, not to make a choice for the society, but to illuminate the issues of the problem and then formulate a set of alternative solutions. These alternatives would be analyzed and compared from a number of points of view. It is vital that the exploration be openly carried out and reported, and it is also important that the exploration be separated from the choice or decision process which must follow.

In short, I am not worried about a group doing exploration so long as the choice is left to the people.

Secondly, with regard to choice, a chain of initiatives must be established to carry out one or more alternatives established in the exploration through its various phases of development to implementation. Here the decisions made are the essence of the process. The brokerage process so familiar in the political arena and also in the marketplace is vital here. As the chain of initiatives spans the interval from exploration to implementation, the plans become more specific, the constituency of groups and individuals committed to a given solution increases, and the resources available both public and private increase dramatically. Blockages to the development of the chain of initiatives must be recognized and overcome or the initiative will be lost and the implementation will surely fail.

Finally, because of the newness of many societal problems and the general uncertainty surrounding solutions, great flexibility must accompany any of the implemented solutions. Indicators of success must be developed and means of adaptation must be designed to respond to societal feedback.

What we are proposing now is to experiment with a process. So what might we experiment with? Experiments to develop and exercise the process. Though several necessary characteristics of the process to control technology are clear, the design of the whole process is far from complete, and what we propose is a set of specific experiments in solution of specific societal problems to exercise the proposed process and to perfect it through trial and error. We would propose substantial experiments and not implementation of a permanent process at this point. We would address hard problems of broad scope, but we would not try to work the hardest or the broadest.

There are two general problem areas which appear to be favorable test-beds for evolving the process. The first one is urban and regional design, and second, the question of resources, environment, technology, and population.

The problem of urban and regional design involves interdependencies and interrelationships among several Federal agencies, among Federal, State, and local institutions, and involves both the public and private sectors intensively interacting. Substantial progress has been made with regional development commissions, among which again I cite the Appalachian Commission. Much still remains incomplete; particularly means for extensive exploration of problem areas and chains of initiative to unite public and private sectors in the necessary implementation.

Let me just say, for example, with regard to use of communication technology and computers in education, there is great promise in the Appalachian Commission. But right now exactly what form this will take is not clear. The technological alternatives really need to be explored further.

The problems of resources, environment, technology, and population have similar interesting interactions especially with regard to energy considerations. They received their initial strong attention a little more recently than the urban and regional problem has, and they are not so well laid out at this point.

Thank you.

Dr. JONES. Thank you, Bill.

I think you can see, Mr. Chairman, in putting this report together we had some very exciting times when the many thoughts that were new and at first strange to us were brought to the surface. Ways were pointed out by which we might deal with some of the real issues that face our Nation.

I might say that, when this hearing began to be a real possibility, and we went to work to put together this presentation for you here this morning, we wanted a balance of the private sector, education, and representation from the Board. Of the people who were asked we had only one turndown from a man who could not possibly rearrange his schedule to be with us. I think that for such busy people this is a remarkable attestation to the interest in our Government and in this report.

Because that person could not be with us I have the privilege of presenting Recommendation IV, and I would like to proceed with that at this time.

Mr. DAVIS. All right, sir.

STATEMENT OF DR. THOMAS F. JONES, JR., PRESIDENT, UNIVERSITY OF SOUTH CAROLINA

Dr. JONES. I would like to review the concerns and thinking which led us to Recommendation IV in the Fourth Report of the National Science Board. That recommendation is entitled, "Public Understanding of Technology." It urges as a matter of long-range concern, the promotion of the teaching of the principles and nature of technology at all levels of formal and informal education, in and out of the classroom.

In other words, we see a lack of understanding of technology which exists at this time as a serious limitation to Government and to progress.

The rapid industrial and economic development of our great Nation has not been matched in pace by understanding on the part of our people. We have developed into a technological Nation, a technological society, but there has not been any systematic parallel development within the society of a sound understanding of the implications of a technological world. This development has taken place at different rates in different parts of our Nation. Yet in the last five decades rapid electronic communication and high rates of physical mobility have diffused a variety of concerns and values and problems throughout our society and in almost random fashion. The result for our people is considerable restlessness, dissatisfaction, and confusion.

On the one hand, most of us profit immensely from the output of our vast technological industry. Our material standards of living are very high indeed. Yet this same technology results in crowding, rushing, noise, and other pollution and possibly makes life too easy for some people in some situations. Many feel that important decisions affecting their lives take place without their consent or knowledge. Social instability has, among its many causes, some of its roots in the nature and pace of technological change, particularly because there is an inadequate understanding of the technological world by the people of our Nation. This lack of understanding is compounded by positive misunderstanding generated by those who address our problems loudly and in piecemeal fashion.

This is a major reason for our conclusion and recommendation that education in the principles and nature of technology should be a lifelong process in our Nation. Such education in the potentialities and limitations of this strong component of existence in today's world should ideally begin in the home in early childhood—but that presupposes understanding of the subject on the part of father and mother. So, providing that understanding is part of our task. This education should be prominent in the elementary grades, go forward in middle school and secondary school, and should be a continuing part of life.

Let me make it clear that we all have a part to play in bringing into being an adequate effort in creating public understanding of technology. The Government must take a strong lead. We in education must join with our fellows in industry—management and labor alike—and with teachers and practitioners of science and technology. Together we must develop and maintain adequate educative processes to provide the means of understanding. I do not mean to suggest, of course, that awareness of this need has just now burst upon us. On the

other hand, I hold that awareness has been heightened by developing circumstances which have made the need greater and more pressing.

It is quite generally acknowledged that in the last few years there has been a change in values, and this change has sharpened the public's sensitivity to the impact of technology. One consequence of this has been a tendency to blame science and technology for the problems which now claim our attention. Effective efforts to improve the public's understanding of technology could lead, it is hoped, to a clearer distinction between cause and effect, to a perception that some of today's problems arise not from science and technology, but from their undisciplined exploitation.

It seems to me to be significant and encouraging that strong impetus for the inclusion of this recommendation came from leaders in the community of science and technology. Nor were they moved solely by self-interest—not at all. It is heartwarming to me that their advocacy reflected a belief that public understanding of technology would be of substantial direct benefit to our people in the conduct of their daily lives and their informed participation in public decisions.

Expressions in behalf of the kind of effort we recommend have come also from the general public, the educational world, and persons in Government. We find widespread recognition that, as technology plays an increasing role in society, broadened public understanding of technology is absolutely vital.

Part of the need, then, is to free science and technology to be accepted on their merits, with recognition of both their costs and their benefits. And one of the means of meeting that need is a fuller understanding of technology by the public. It is technology which brings the science-technology system directly to bear upon the public consciousness.

It is often said, and with a great deal of truth, that there is hardly any issue of public affairs today which does not have a technological component. Sometimes that component is conspicuous, sharply in focus. But the influence of our technological activities reaches farther, often in subtle ways, than we readily realize. For example, this country is engaged in a major effort right now to stimulate and assist the innovative process in technology. It is deemed essential to this effort that a favorable "climate of innovation" be achieved. Many steps nontechnological in nature need to be taken to help provide that climate. Whether to take those steps will in some cases present difficult issues for public decision, on matters such as tax policy, patent policy, and Government initiatives backed by public expenditures. In such cases, the technological component may not be conspicuous, may not be in sharp focus. But it will be very much present. The underlying issue is the health of American technology, which has a direct bearing on the health of our economy and the vigor of our competition in international trade. Informed consideration of nontechnological issues, in other words, requires and demands "public understanding of technology."

Near the beginning of my statement I spoke of the team effort involving many different kinds of people which is needed to make this recommendation productive of the results we seek.

The real purpose is to help the people of our Nation to adjust to a way of life into which they have come almost without understanding and preparation, and to enable their informed participation in the decisionmaking which is so much a part of our democracy.

I do not believe that mere exhortation will make that effort effective. It is going to take a lot of thought, a lot of work, and a lot of coopera-

tion. I think we know how to do it, and I believe most deeply that it is an essential undertaking promising very great returns.

Mr. DAVIS. Thank you, Dr. Jones.

Dr. JONES. For our last recommendation, Recommendation V, we have Dr. Joseph M. Reynolds, who is the vice president for Instruction and Research of Louisiana State University, and also an accomplished research physicist.

Dr. Reynolds, will you give us Recommendation V?

(The biographical sketch of Dr. Reynolds follows:)

JOSEPH M. REYNOLDS, VICE PRESIDENT FOR INSTRUCTION AND RESEARCH, LOUISIANA STATE UNIVERSITY

Physicist; born Woodlawn, Tennessee, June 16, 1924; son James J. and Frances (Shelby) Reynolds; married Ruth Anna Heise, September 2, 1950; children, Molly Elizabeth, John Shelby, Wendy Lee.

Student, David Lipscomb College, 1942–44; B.A., Vanderbilt University, 1946; M.S., Yale University, 1947, Ph. D. (Sheffield-Loomis fellow), 1950.

Assistant professor of physics, Louisiana State University, 1950–54, associate professor, 1954–58, professor, 1958–62, head, department, 1962–65, Boyd professor of physics, 1962– , vice president, graduate studies and research development, 1965–68, vice president, instruction and research, 1968– ; visiting professor (Guggenheim fellow), Kammerlingh-Onnes Laboratory, University of Leiden, The Netherlands, 1959.

Member, National Science Board, National Science Foundation; vice president, Gulf Universities Research Corporation. Fellow, American Physical Society, American Association for the Advancement of Science.

Member of the American Ordnance Association, National Council University of Research Administrators, Organization for Tropical Studies (director), Sigma XI, phi Kappa Phi, Omicron Delta Kappa, Kiwanian. Contributor of articles in field to professional journals.

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STATEMENT OF DR. JOSEPH M. REYNOLDS, BOYD PROFESSOR OF PHYSICS AND VICE PRESIDENT FOR INSTRUCTION AND RESEARCH, LOUISIANA STATE UNIVERSITY, AND MEMBER, NATIONAL SCIENCE BOARD

Dr. REYNOLDS. Mr. Chairman and members of the committee, throughout this report it has been taken for granted that technology is a foundation of our economy and of the well-being of our citizens; that technology is built into our national habit pattern and that our economic health and international economic patterns are dependent on a continuous flow of new technical developments. Indeed our quality of life would deteriorate rapidly should technological stagnation persist. Abandonment of our technological culture would condemn millions to starvation and death.

However, we do not contend that technology is the universal solvent and that is its unbridled pursuit is guaranteed to lead to a better life for our people. We recognize that both benefit and injury can and do flow from technology. Certainly, as government takes on new responsibility to develop and promote an expanded peacetime technology, it must also assume the responsibility to explore and evaluate the likely social consequences. For this reason we conclude our report with Recommendation V, which states that:

> There should be formed in appropriate agencies, including the National Science Foundation, or as separate bodies if need so dictates, groups respon-

> sible for the long range analysis and assessment of technological systems of broad public importance. It is urgent that new capabilities be created to evaluate the societal benefits of new technological developments in advance of their wide scale dissemination and call attention to their potential hazards, undesirable by-products or side effects. Such groups should make generally available to the public information regarding comparative costs and values as a basis for decision-making in order that appropriate safeguards may be established. They could call upon all national advisory and research resources to provide the many diverse substantive skills required in assessment.

The report states that we recognize that existing agencies now undertake technology assessment as a part of their missions.

For example, the Environmental Protection Agency, the Food and Drug Administration, and the Federal Communications Commission have technological assessment and regulation among their missions. A major responsibility of the Atomic Energy Commission is that of assessment of the consequences of various uses of fissionable materials, although they also play an advocate role for nuclear technology. Other agencies which are concerned with the impact of technology are the Interstate Commerce Commission, Federal Aviation Agency, Federal Power Commission, Federal Water Pollution Control Administration, the National Air Pollution Control Administration, and the Environmental Impact Office of the Department of Transportation; of course, there are others.

Nor has evaluation of social and other impacts of technology been ignored by the private sector. Many activities relating to technology assessment are being upgraded. Examples are: Product liability precautions, standardization requirements, warranties, industrial hygiene, and antipollution commitments.

Nevertheless, it is apparent that these ongoing programs of technology assessments are inadequate. There is a need for public determination of scientific and technological fact that is free of imputation of advocacy and credible to public and private interests. There is a need for refinement of techniques and methodology of the assessment process. There is a need for a major commitment by our Government to technology assessment with a centralization of responsibility. The most reliable and unbiased professional and technical advice must be made readily available to our elected public officials who bear the burden of decision on technological issues in public affairs.

As we say in the report, we believe that recent action by the House which would provide technology assessment resources for the Congress is a step in the right direction. We commend this committee for its careful study and the leading role that it has shown in this matter.

We caution care that technological assessment not be done in such a way as to imperil the process of healthy technological development. Balances will have to be struck between innovation and restraint, between economic opportunities and social costs, between beneficial accomplishments and harmful side effects.

Technological assessment of the scope and depth required will not be easy because of the inherent difficulties in predicting the behavior of complicated systems. Technological assessment will probably not be a total success, neither will it be a total failure. Technology assessment must be done. It is a responsibility which the Government cannot ignore.

Now, gentlemen, I would like to insert a disclaimer here as follows: That we do not as members of the National Science Board nor as members of its committee on this report purport to be experts on technology

assessment. In fact, we yield that honor to you, members of the committee. You have looked into this matter in greater depth than we have. We feel, however, that we should conclude our report on technology with a support of such activities.

Thank you, sir.

Mr. DAVIS. Dr. Reynolds, I want to say that the committee is very grateful for your having given that honor to the committee. I think I speak for the whole subcommittee. I am not sure we are entitled to it. We appreciate it very much.

Dr. JONES. Mr. Chairman, let me say a few words about the Board's committee for this report.

This committee was chaired actually by Dr. Stever, as has been noted. Obviously in January his new position made it improper that he would continue, although the job was now finished. And that is how I, as vice chairman, have the privilege of guiding this discussion here this morning from the standpoint of the Board committee.

I would also like to mention that in the course of our discussions there were many more recommendations proposed, some very good ones, in fact. But we removed from this report those which clearly had a strong self-serving component from the standpoint of engineers, or the Science Foundation, or other such entities, in order that this report would have the strength and complete credibility which we felt that it must have to do the job that we see to be done and which has been outlined here for you this morning by this group of people, all of whom participated in the preparation of the draft of this report. And we are very pleased to put this before you. You have been most kind to listen patiently as we have gone through the briefing on the major thrust of the report.

And now we place ourselves at your pleasure for further discussion. Dr. Carter has indicated that he would be happy to join in the discussion at this point and be available for a question.

Mr. DAVIS. Well, gentlemen, I want to thank all of you for the great amount of hard work that went into the preparation of this report. And I want to say that as I listened to you I was thinking of the old Aesop's fable of the blind men; feeling this elephant, one thought it was a tree, one thought it was a snake and one thought it was something else. It seems that is sort of the way this discussion has gone this morning. We are all talking about the elephant from a little different point of view or maybe, we are still all discussing the elephant. It has been refreshing, enlightening, and most helpful to this committee.

Mr. BELL. And significant, too.

Mr. DAVIS. Well, Mr. Bell brings up the fact that the elephant is an insignia of the Republican Party. I really hadn't thought about that.

So I will just have to say "touche".

Dr. CARTER. You can't be absolutely sure it is the elephant we are feeling. It might seem that way.

Mr. DAVIS. It might be a jackass.

Mr. Bell?

Mr. BELL. Thank you, Mr. Chairman.

Dr. Jones, I see on page 2 of your statement you refer to the practical application of our developed technology.

I am wondering if you think that enough money was afforded to the program entitled "Research Applied to National Needs," commonly referred to as RANN.

Dr. JONES. Speaking as a member of the National Science Board, and personally, I feel that the development of the RANN program has gone along at the kind of pace demanded by our time. I am very pleased to see it a component of our activity and think it is very important.

It is still, with the level of funding and with the level of experience we have in administering such a program, one which is of very limited scope. It is addressing several classes of major national problems, but it has not branched out into certain other areas of national problems. It has not, for example, addressed the education program here yet. I have to say that in my opinion education is a national need and needs a lot of research in this area. Perhaps we could get to that more strongly a little later on, although it is not yet considered, I believe, other than in speeches.

Mr. BELL. Are you saying that you feel the RANN program is important but that it is your opinion that the educational programs of the National Science Foundation are more important? Is this correct?

Dr. JONES. I do not believe that is what I am saying. I think what I am saying is that the RANN program is a great program and it is addressing certain categories of national needs. It has not yet been directed toward educational needs which up until this time, as far as the Foundation is concerned, have been carried in a different area with, of course, a considerably smaller budget.

I do think that we, as a matter of national policy, need to address education in science and technology but with emphasis on the understanding of technology, because this is the part that has the great impact on the life of the individual. This is a new thrust which is needed and one which I am sure is being studied in the Foundation, but which has neither been funded nor really adopted yet as a policy matter.

Mr. BELL. Well, the report that you came out with addresses itself to the rapid change in the science and engineering manpower situation from one of chronic shortages to apparent surplus.

Do you expect that such changes will be common in the future as the Nation's priorities change in response to the political pressures? How can we dampen these oscillations and put more stability to the supply and demand situation for scientists and engineers?

Dr. JONES. Mr. Chairman, I am presently a member of a commission of the National Academy of Engineering that is addressing this problem. I sincerely hope that, with the attention that this relatively new phenomenon is getting from a number of different sources such as that commission, we will be wise enough and careful enough in the future to plan major changes of national direction in such a way that we will avoid what I consider to be acts of God brought about by Government in this case, which have, in effect, brought near disaster to large numbers of people. But I think this is a matter of growing wisdom on our part as we face a new aspect of our society.

Mr. BELL. Dr. Jones, I happen to be in a district where we have large unemployment as a result of aerospace layoffs. We have engineers and scientists driving taxicabs in our district.

I am certainly one that is a strong supporter of education. I supported the education portion of the National Science Foundation bill. But in view of the current high rate of unemployment among scientists and engineers I wonder if we should begin to emphasize the practical applications of science and technology.

Dr. JONES. Mr. Bell, I think there is much in what you say. We do need to turn out from our universities people who are flexible, for example, and can move more readily with the times.

We do need to think through more clearly the management of manpower and the redeployment of manpower than we have in the past. This thing burst upon us just a very few years ago, some two or three, seriously, in your district, and it caught us by surprise, I am afraid, although with a little more study we might have read the handwriting on the wall with regard to the problem.

Mr. BELL. It is difficult, for me to go back to my district and be confronted with highly skilled individuals who are either unemployed or underemployed. They want jobs. This is why I think a program such as RANN can create more jobs while performing its primary function of finding solutions to urgent domestic problems.

Dr. JONES. It will make the technical economy a little more vital, and we have brought out here several times that it needs to be more vital. I would like to mention another point that relates to this that I feel should be in our thinking, and it is this: What we are discussing is the demand for this manpower which, unfortunately, in your district is down and has not yet been brought back up. I think that as a Nation we have to think in terms also of the need for this kind of manpower. Many of the things that have been laid before you this morning indicate that our Nation has some tremendous needs, very vital needs for this kind of manpower. Our job now is to get on with seeing that we absorb those we need, and that the problem basically is in the demand picture.

Mr. BELL. Again you are reinforcing the argument for projects such as RANN.

The other thing I wanted to ask you, Dr. Jones is whether the National Science Foundation policy may be overemphasizing its work with the academic community and perhaps not paying enough attention to the private sector.

I note the National Science Board is heavily balanced in favor of the academic community. I am in full accord with this present makeup of the Board as long as proper consideration is given to the private sector. It is my belief that many of the problems confronting our society can best be solved with the joint participation of the academic community and the private sector.

Again, I repeat, I have great respect for the academic community and their ability to aid in solving the needs of this Nation. I think you will admit, however, that our ability to deal with these problems can be accelerated by a joint effort.

Dr. JONES. Mr. Bell, let me just address that very briefly. Then I would like to turn it over to the Chairman of the Board and to the Director of the Foundation for such remarks as they might care to

make, because I think that this is a very broad question that relates to the entire Foundation.

Historically, the Foundation was essentially a university and science directed unit. It has been broadened considerably recently, and I am quite aware it is looking much more into these areas, with RANN, for example, and looking at the kind of work that is more suited to nonprofit corporations, and, in fact the profitmaking sector itself.

But rather than trying to give you a definitive answer I would like to turn it over to those who, in effect, are giving much more time to the subject.

Mr. BELL. This, I think, is particularly true in light of the Mansfield amendment which changed the makeup of the National Science Foundation to enable it to engage in a wider range of activities.

Mr. DAVIS. If the gentleman would yield, I would just simply like to interpose a small comment at this point. I realize that Mr. Bell, my esteemed colleague, has raised a rather sensitive issue. I don't consider it an issue. I don't think Mr. Bell does. It is a matter at least in my mind of putting an overlay on the National Science Foundation when you say "OK, let's get out and look around for research applied to national needs." I don't think that any of us would want to see the Government of this country reduce its role as that of being a patron to pure science because it is yielding benefits too rich to enumerate. I would not like to think that the pure scientists would feel any sense of unease, because I think their work is invaluable and that it has broad popular support. Nor would I want anybody to think that there was any lessening of enthusiasm for the work that does go on in the area of basic research.

Mr. BELL. Mr. Chairman, I think it would also be a good idea for the committee to address the question of what the effects will be of the President's recent statement stressing the need for NSF funds to go to private industry to act as an incentive for R. & D. development. Do you think this change will have the impact of putting science and technology to work for society?

I appreciate very much the chairman's comments.

Dr. JONES. Mr. Congressman, that question is one which is so new that I think we will turn to our full-time man, the Director of the Foundation, Dr. Stever.

Mr. DAVIS. Well, may I add a small caveat to that question. Maybe it is not a change as much as it is an additional charter, which doesn't necessarily mean that it is a change.

Dr. Stever?

Dr. STEVER. Mr. Chairman and gentlemen, I think first of all, in my opinion, with respect to the interchange between Mr. Bell and Mr. Davis, I like the idea of the RANN program being an overlay in addition to a basic science mission. I do not think Mr. Bell in any sense would like us to interchange unemployment from the applied scientists and engineers to the basic pure scientists.

Mr. BELL. I wasn't trying to say that this was the solution to unemployment.

Dr. STEVER. I realize that, sir. And I really think that our job is twofold with RANN. One is to help along the lines Mr. Bell pointed out; that is, to increase the activity in the application of science in

our society. The second aim to tap the good ideas in the basic science area, hopefully to accelerate the process of strengthening the industries that we are talking about here. So I really think there is a double factor. One is actually to get the people involved in the programs that Mr. Bell is interested in, and the other is to tap the ideas of basic science faster so they flow to give an extra push to the applied area.

Mr. BELL. President Nixon's suggestion will have that effect.

Dr. STEVER. Yes, sir. Exactly right. We would like to use our newfound capability essentially to support both basic and applied research in a broader constituency, and I think we will to the best of our ability. But I do hope that it is understood as Mr. Davis says, as an overlay on our specific job.

Mr. BELL. Would you care to elaborate on that?

Dr. JONES. No, Dr. Drucker was asking for the floor, but go ahead, Congressman.

Dr. DRUCKER. I just want to say that this report was written by a number of people. If you look at the list of names in the front you will find that it is dominated by the academic community, and yet it addresses precisely the concerns that you raise. That is, we address ourselves not to the worries of the academic community itself. Dr. Jones pointed out all those things were taken out. We address ourselves to our concern about society as a whole, in particular a recommendation regarding our mature industries which really are the backbone of our employment in this country. And, therefore, we are concerned I think, and the National Science Foundation, for which I cannot speak, is concerned with that.

Mr. BELL. Here is an item that concerns me. The Director may want to comment on this. The policy exists in the National Science Foundation that requires National Science Board approval of RANN projects involving a commitment of more than $150,000, while for all other National Science Foundation projects the Board approval is required for only those projects in excess of $500,000. Doesn't this policy indicate a greater scrutiny of RANN projects than other National Science Foundation projects? Why does this policy exist, for example?

Dr. JONES. Well, you are right, it does represent greater scrutiny, Mr. Bell. But the fact is it is a new program and we are the trustees as the National Science Board, and we need to be intimately familiar with and understanding of exactly what is happening in the program. Through this process all of these things do get brought to our attention so that we can be aware that we are fulfilling our responsibilities in the matter. This is the way I look at it as a Board member.

Mr. BELL. Wouldn't you feel the same way about the other NSF programs?

Dr. JONES. There was a time when we looked at those at roughly the $100,000, $200,000 level. We raised it as our confidence and understanding improved. I have been on the Board for 6 years and I have seen this change in my time. Such a change will happen in the RANN program, I am quite sure, as it settles down. But it is still so new that we need to be intimately acquainted with what we are trying to achieve: that we are carrying out the will of Congress, that we are carrying out the needs of the people. And this is how I see it as an individual Board

member. I think I would like to turn now to my Chairman who, of course, would have this overview from a little different perspective.

Dr. CARTER. RANN is a new program. It represents a really novel change in some aspects of the Foundation. Whether you call it overlay or whether you call it an extension, I personally feel it will become a permanent and substantial part of the Foundation's activities. But it is like the elphant you were talking about. We are feeling our way. As Chairman of the Board it seemed to me that it was of the utmost importance that the Board be kept informed by the staff of RANN who also are feeling their way, who are setting up new management procedures for effectively developing these new programs. The role of the Foundation in initiating these programs is quite different from what it has been in the traditional programs. So until we get the fullest of interaction, confidence, and understanding of the programs, I do not want the members of the Board to escape having to look at these things. This process will be a stimulating one which will result in a more effective RANN program. When we finally are satisfied on that, then indeed we will be willing to let that go.

Mr. BELL. Well, Dr. Carter, I certainly appreciate your comments. I do not intend to be hostile. As you gentlemen know I am certainly in wholehearted support of the entire program.

I think it is important, however, that we recognize that since the passage of the Mansfield amendment, the direction of the National Science Foundation has changed. This year's NSF authorization bill is substantially larger than ever before. As a result, the programs of the NSF have been revitalized. I think it is important, therefore, to allow the individual programs within the NSF to function as freely as possible without placing undue restraints on any one particular program.

Dr. CARTER. Some of my academic colleagues have criticized me, and some fairly vigorously, for my frequently and strongly stated support of RANN, because I feel that RANN has initiated the kinds of impacts that will indeed lead universities and universities interacting with industry and so on to be in a position better to address themselves to some of these problems. I am going to do the very best I can to see that our evaluation of RANN and its moving along are made as effective as possible.

Now, if I could say a word about the education/manpower situation. I think you put it very well. We are in a deep transition process in this country. The last 50 years have seen development of the traditional sciences, and their graduates have gone primarily into goods producing sectors of the economy and have developed technology which until very recently has been very satisfactory.

In this Board report, a number of the Federal initiatives that have come in the environmental areas, in occupational safety and health, in omnibus crime control, have manpower implications. I think the Foundation has to sit down now, as indeed we are doing, and take a hard, tough look at our educational programs, at our priorities, at how to meet the continuing education program. Your problem is not one that is going to be directly solved, or easily solved, but continuing education effectively provided would help to alleviate it. We have to look at how we educate within the traditional framework the people with an interdisciplinary mode who are going to participate in the

development of these new jobs that this document suggests, although vaguely, I have to say. To educate a man for a job that does not now exist requires courage and imagination. At the same time, Mr. Chairman, I appreciate your statement. It would be an utter catastrophe if we did not make the best effort we can to sort out those imaginative people who have the potential to be the leading, cutting edge of science, to help generate those new technologies in which we will have at least a year or two headstart on some of our competitors. But I do think we will be coming back to you. We are deeply concerned about our educational programs and that we do indeed expand and alter these or supplement them in the ways that are going to help to bring our young and older citizens more effectively into relationship with the problems they face.

Mr. DAVIS. Mr. Cabell?

Mr. CABELL. Thank you, Mr. Chairman.

I was quite interested in the remarks of Dr. Macdonald. I know that he was expressing views of a number of his colleagues. I am sure that he has some good help.

With reference to the application of technology at various levels of government, although we are appropriating vast sums of money on behalf of research and development in the various levels of government, I think that we are overlooking and using less of it than any other aspect of our daily lives.

You mention the necessity for increased productivity. Yet in government, and may I say in education also, there is less applied technology for improved productivity than you will find in any of the private sectors. The private sector couldn't exist on the wasteful practices that we have in government. This affects every man, woman and child in the United States. Now, I would like to throw a question to you if I could, sir.

How are we going to get more from the application of technologies that have been developed in our governmental processes? How are we going to overcome the built-in reluctance and opposition of the labor sector to get into that increased productivity? Do you have any thoughts on that?

Dr. MACDONALD. I wish I could give you a full and definitive answer because you have raised an exceptionally important, difficult problem.

I do feel that in order to improve productivity in the general service sector we need to try to incorporate into this sector more of the discipline that we have in the private sector of the economy. The usual discipline there primarily comes from the profit motive, the pressure for profits. We have limited resources, and we must be responsible to stockholders and other people to use these resources in a way that provides the maximum useful and profitable results.

The resources in the service sector areas are not always so specifically limited, but they are still ultimately limited, and we are seeing more of this problem in the educational area as the costs of education continue to skyrocket. I believe that we must look much more at the discipline there, at how we allocate and use resources. Although we obviously cannot incorporate a profit motive in many of these areas, per se, I think we need, as I said in my talk, to establish more and better measures of productivity. We need to examine the allocation of resources and look at the results, the efficiencies. We need a feedback

as to what is happening and then need to go back in and change things to maximize efficiency.

Now, this is a very incomplete answer to a most difficult problem, but I believe it provides the initial direction that we must try to follow in almost all of these service areas, not just education per se.

Mr. CABELL. Thank you very much. I might for the benefit of the audience say that the former board chairman of Dr. Macdonald's company had for 5 years the experience of trying to get some of that across. I don't know just how successful he might be but I am sure some of his statistics were in your report with reference to their application.

Dr. MACDONALD. Yes. Erik Jonsson is also the former mayor of Dallas. We think he did an excellent job in a very difficult situation. But as you all know, changes in the service sector of the economy are hard to make, and they may take generations to be fully achieved. But one has to start, anyway, even though you cannot necessarily expect that something you start will be complete in your own period of association with it.

Mr. CABELL. I might also add that the present chairman, Pat Haggerty, before this subcommittee last year raised a question in the discussion with reference to the lack of applied technology in our educational system. Instead of increasing the productivity of our instructors and professors, they are less productive and instead of handling more people, they are actually handling less. Consequently, the efficiency of our academic world has not kept pace with the industrial world.

So I know that you have had some good discussions with those men on the subject which you handle so well.

Thank you.

Dr. MACDONALD. They helped me a lot here. And let me say that we are still continuing to look into this general area as a company to see if there are places where we can make a small mark in helping measure and improve productivity in these important areas.

Mr. CABELL. I want to join the chairman in thanking you gentlemen for taking the time and for your very fine efforts on behalf of the report of this committee.

Thank you.

Mr. DAVIS. Thank you.

Mr. Price?

Mr. PRICE. Thank you, Mr. Chairman. I want to apologize, gentlemen, for being held up because of constituents in my office. However, I am interested in the summary of the recommendations that you gentlemen have put forth.

Dr. Carter, you stated that you are looking for people that are innovative and far reaching—looking out into the future. I am wondering if you are familiar with Lerner Lab's activities in the Bahama Islands. Have you ever heard of them?

Dr. CARTER. The general institution I know about.

Mr. PRICE. Yes. Well, I wanted to point out the fact that we are all primarily interested in the survival of mankind on this planet, and I have been shown through their lab there. For instance, the work that they are doing with the shark in the implanting of strontium-90 (10 times the lethal dose that would kill a man) into the shark brain, and yet he is able to throw it off.

Dr. CARTER. I had not heard about that.

Mr. PRICE. If we were to discover a vaccine as to why this shark can throw it off, we can inoculate all of mankind with strontium 90, and the whole intercontinental ballistic missile system could be completely irrelevant to warfare in this area. They also brought up the monitoring of pollution, talking about helping mankind; that every animal in the sea has a monitoring device already provided by our good Lord that can detect when pollution is in their environment. And the thought was that implants of electrodes in these various animals of the seas throughout the world could then be monitored by our satellites and brought down to our computers where we would have an instant evaluation of where pollution is taking place throughout our planet. I would hope that some attention would be given to the Lerner Lab which is a nonprofit organization supported by numerous countries throughout the world. I serve on the International Cooperation Subcommittee. I find this quite intriguing if such efforts could be found. I would hope that the National Science Foundation would consider and look into the possibility of some sort of a grant, not from any—I suppose any more it is construed that you are trying to help somebody for a devious reason. But I think my reason for this is to help mankind if we can find a solution, and these gentlemen who are doctors and scientists, I think have really something on the ball in this area.

Dr. CARTER. The National Science Foundation is always interested in looking at imaginative and potentially creative proposals. And certainly this would not be excluded on that basis.

With regard to your strontium-90 situation. I might just make this comment. The difference in resistance to irradiation between species of animals is quite large. For instance, the carcinogenic compounds that will produce results in rats or other animals have little or no effect on the monkey. In order to produce chemical carcinogenesis in the monkey, you almost have to put something into the bone marrow. That is one of the problems in this area. This is not to say that this is not a very interesting experiment, but the relationship of that to the human would have to be looked at very carefully.

Mr. PRICE. Well, that is what they are trying to determine, if they can find out why and how the shark does throw this off; it might possibly work for humanity also.

Dr. CARTER. Yes. I also would like to point out that the Foundation currently supports two very substantial programs which are aimed at monitoring, not in this rather novel way that you suggested, the components of the oceans. We are interested in that. Certainly proposals from this organization would be looked at very carefully if submitted to the Foundation.

Mr. PRICE. Well, I would hope that someone under your jurisdiction would look into this, because I think these men are learned men as yourselves, doctors, who really believe in this program and, I think, are very sincere in helping find a solution to these problems.

Thank you, Mr. Chairman.

Mr. DAVIS. Mr. Bell?

Mr. BELL. Thank you, Mr. Chairman. I have one more question.

Dr. Macdonald, in the National Science Foundation news release, you made mention of the problems of improving productivity in the service sector and noted that there exist three principal needs. One of these needs is to establish federally sponsored demonstration projects

to help provide answers to the public sector problems of great magnitude.

Could you please explain what you mean by demonstration projects and please comment on the role that the National Science Foundation can play in developing these demonstration projects?

Dr. MACDONALD. Yes, sir; let me try to address that question. Let me take, for example, the area of broadband communications, CATV, and interactive communication between people and information sources.

Now, as you know, there are many "new," totally planned cities springing up around the country these days. Reston, Va., near here, is one of them. There are some in Texas, New York, and other places. And as these new cities come along, the Government could help a great deal if it would provide some support in the demonstration of the possibility of interactive (two-way) communications to the homes of the citizens of these new towns. I believe that this has even been talked about for parts of Washington, D.C., itself. The point is that the more communication we have with and between people, the more they will understand national needs and problems, and the more they are likely to help support work on their solution. If you have only one-way communication, as in ordinary TV, you obviously are not getting the full benefit of the situation. And yet, when you talk about two-way communication, you are talking about more expensive equipment, cables, and so on. You may still use the television set in the home with some subsidiary equipment.

I am raising this example because the Government, through its various agencies, including the National Science Foundation, can and is already, I believe, beginning to think of helping set up such demonstration projects, particularly in the new cities where you can start from scratch. Now, this is just one possible demonstration area in communications. But there could very well be others in transportation, in health services, and in many of the other social-need areas that we hear about so much these days.

Does that help answer your question?

Mr. BELL. Yes. You would not call that, however, a developmental project, would you? You would call that an experimental project?

Dr. MACDONALD. These words, of course, whether one uses developmental, experimental, or demonstration, are hard absolutely to tie down and separate in meaning.

Mr. BELL. I know they are hard to define.

Dr. MACDONALD. Certainly, such projects would be experimental. They could help demonstrate the possibilities, however, and from that point of view they would obviously be demonstrative.

Mr. PRICE. Would the gentleman yield?

Mr. BELL. Yes, I yield.

Mr. PRICE. Along this line, do you believe it is a responsibility of a Government agency to inform the public of the National Science Foundation's work, this whole space program, or is it private industry's responsibility? We get into this bind of an agency promoting itself with taxpayer's money. We find also on the overall space program and the National Science Foundation that we talk among ourselves a good deal but we haven't been able to disseminate this material to the public where they can understand it to justify the appropriations that we have to fight for, and a lot of people say, well, the

National Science Foundation is using tax dollars to promote their programs; is this their function? How do you feel about this?

Dr. MACDONALD. Mr. Congressman, as taxpayers, we are all paying for these activities. Hopefully they are well selected and worthwhile. If they are not, some of us in this room ought to be doing something about it. Even when they are worthwhile, I think it is the responsibility of us all to make sure that the maximum number of people in the country, who are after all paying for the work, know the maximum amount about it. So I see nothing wrong in the National Science Foundation and other agencies spending some tax money to let the people know what is going on. I strongly believe that the proper exercise of democracy requires getting information to the people.

Now, I could say that perhaps the Department of Defense has used more such tax money to tell what they are doing than some of the other agencies, and we could get into a discussion of that. But certainly this is nothing new, is it?

Mr. PRICE. No, it is nothing new. But we have run into this, the use of taxpayers' dollars, especially in the defense area which you mentioned, that a lot of the media have said they are promoting defense in order to enlist young men. Is this a function of these agencies versus private industry selling space technology and the National Science Foundation through the colleges? Maybe they should be doing more in dissemination of what they have actually found rather than the use of—of course, that is taxpayer dollars too, I suppose. But it is a problem, we find. And you see, this is why we have had the budget cut in all areas in science and astronautics fields, is because of the lack of understanding of people even in my district. They say, well, we can put a man on the moon but we can't solve our transportation problem from the airport in New York to my home.

Mr. BELL. Will the gentleman yield?

I detect a strong feeling that at least there should be some results from the research so that people can feel that there tax dollars are being well spent. Is that correct?

Mr. PRICE. Yes. I think we are either going to have to get that over or they are going to keep demanding of the people they elect to come up here and appropriate the money—they want to get that benefit and they want to know how that program is benefiting me.

Mr. DAVIS. Dr. Jones.

Dr. JONES. I feel I am obliged here to point out that our purpose in Recommendation IV, which I talked on, is to try to help people to understand what their needs are. Basically what you are talking about now is that we do have a very serious problem in Government because the people are not apace with the total thrust of our society. We have a very serious educational problem of enabling them to understand well enough to make the judgments and help make the decisions and reelect, for example, those men who are trying so hard to understand and trying to develop the health of our country which depends so strongly on the technological sphere.

Mr. PRICE. This is like last week. I was out, you know, on 20 speaking engagements and invariably they come back and say you spent $28 billion to go to the moon; what good has that done? Well, they don't realize the jobs you created and the economy that came back is esti-

mated at $18 billion. And somehow we are not reaching the public about the benefits that they are receiving from their own tax dollar.

Mr. DAVIS. Well, I will simply make this observation, too. In the first place, the National Science Foundation in its charter is prohibited from having its own facilities. It is more or less a backup as far as deciding what is worthwhile in the way of pursuing knowledge. In the second place, I don't think there is any more sensitive body in the world than the House of Representatives of the United States in responding to public opinion. When the National Science Foundation authorization bill came up on yesterday afternoon there were only 16 votes against it, which I think is a resounding vote of confidence in the National Science Foundation.

Dr. CARTER. Confidentially, we do our best to retain it.

Mr. DAVIS. I hope the reporter got that into the record.

I would like to say this, gentlemen: I am very proud of the five recommendations you came up with in your report concerning government aid in support of industrial technology. It is highly important that the point be emphasized. The President obviously thinks so. He mentioned it first in his August 15 message to the country on nationwide television. It was mentioned before this subcommittee by Secretary Stans toward the end of July. It was mentioned again by the President early in September when he addressed a joint session of Congress. It was mentioned still again by the President in the State of the Union message in January. Then he submitted a separate message on the question of science and technology which I much regret was overshadowed by another message having to do with busing primarily. I thought at the time it was unfortunate for the scientific community, but nevertheless it has come in for quite a lot of attention.

As far as technological support for public goods and services, that is one that I felt for a long time is extremely important. It is a fact that in our country most of the public servants are laymen so far as being technological experts. Therefore, they are better at shaking hands than they are at reading technical journals and keeping up with advances that are being, have been, and can be made technologically speaking. So we have a lot to do in that area. I am awfully glad that you included that.

The exploration of future alternatives I think is a most valuable subject, and I appreciate your having selected that. I might comment that parochially speaking I represent 14 counties in the State of Georgia and 13 of them are in Appalachia. It occurred to me many months ago that actually Appalachia is the only model we have for a regional solution to be applied to a problem. In that regard, I would like to say that I think one of the greatest retarding factors we have in American society today as we try to solve the environmental problems is the fact that the political boundaries don't coincide with the problems. The problems are regional. For example, it was felt a splendid idea, I am sure, to let the Potomac River be the boundary between a colony known as Maryland and a colony known as Virginia. Then the District of Columbia was superimposed on the banks of the Potomac. Now the river is a problem. I guess they thought very few people would be paddling back and forth across it at the time. That is true all over the country. You have a multiplicity of political tax bases and of autonomous mayors, councils, county commissioners and

what not in State governments. Yet most of our problems transcend even State boundaries, not to mention municipal and county boundaries. So I am awfully glad that that subject was brought up.

As for the public understanding of technology, I am so glad to see that. I am glad it came up again in the question and answer period, because that is just one of the most important of all the recommendations. A particular thing came out in our hearings during the NSF authorization hearings, that it is important for the nontechnical man, the nonscientist, or nonengineer to have some comprehension of science, engineering, and technology. Because if you don't have it, then you cannot expect the people to use it. You cannot expect a sheriff to have the best in communications equipment or crime detection equipment if he doesn't have any understanding of it.

The last recommendation concerns technology assessment. I don't need to tell you how this subcommittee feels about that. I think if and when a technology board comes into existence it can prove invaluable. It can save the taxpayers more money than nearly anything I can think of if it develops into a credible team. It will take awhile, I am sure, as every good team does take awhile to develop.

But I want to express to all of you the gratitude of this committee for your refreshing testimony and for the great help you have been, and for the excellence of your work.

Thank you ever so much.

Dr. CARTER. Thank you very much, Mr. Chairman, for this privilege.

Finally, on behalf of my colleagues on the National Science Board, I would like to express our deep appreciation for the sincere interest and warm support evidenced by this committee in the National Science Foundation and the programs it directs in the fulfillment of its mission to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and other purposes.

Mr. DAVIS. Yes, sir. I have two requests to make. One, I would like to request that our subcommittee be permitted to submit additional questions to you gentlemen for the record.

Dr. CARTER. Certainly.

Mr. DAVIS. We would like to ask the committee's approval that the record remain open for 2 weeks to permit submission of additional statements from witnesses on this question.

Without objection, it is so ordered.

The committee will now adjourn.

(Whereupon, at 12:13 p.m., the subcommittee was adjourned.)

APPENDIX A

Response of the National Science Board to Additional Committee Questions

NATIONAL SCIENCE FOUNDATION,
NATIONAL SCIENCE BOARD,
Washington, D.C., June 28, 1972.

Hon. JOHN W. DAVIS,
Chairman, Subcommittee on Science, Research, and Development, Committee on Science and Astronautics, House of Representatives, Washington, D.C.

DEAR MR. DAVIS: I am providing herein responses to the questions presented in your letter to me of May 2, 1972, pursuant to our meeting with your Committee on April 26 to submit and discuss the Fourth Annual Report of the National Science Board, "The Role of Engineers and Scientists in a National Policy for Technology."

As a preface to our responses to your specific questions, it would perhaps be helpful to offer a brief general statement about the Report and its recommendations, in order to assure a common perspective for the Committee and the Board. In this perspective, the Report can be viewed as wholly advisory, an effort to contribute toward a "National Policy for Technology," in the words of its title.

The Committee's attention may be called to paragraph 2 on page 2 of the Introduction to the Report:

> The recommendations mark out one approach, not the only possible approach, toward meeting the needs in the area of technology discussed herein. This approach is subject to further evaluation, along with any alternatives, in the light of pertinent developments in policy or possible changes in the Federal organizational structure or reassignment of missions affecting technology.

In other words, the Board did not wish to claim for itself unique wisdom, nor to prescribe program specifics, nor specify methods by which implementation might be achieved, nor assign tasks to specific agencies. Instead, it was the feeling of the Board that the first steps toward giving effect to its proposals would in each case be steps of exploration.

Inasmuch as the quoted paragraph applied to all recommendations in the Report, we feel it is relevant to most and perhaps all of the responses to the Committee's questions concerning the Report.

Our specific answers to your specific questions follow:

Question 1: What plans does the Board have for following through on its recommendations? What action can it take to stimulate appropriate response throughout the Federal Government?

The answer to this question divides into two parts: (a) Follow-through by the National Science Foundation, and (b) action to stimulate appropriate response throughout the Federal Government.

(a) In pursuance of policies formulated by the Board, the National Science Foundation has a number of activities planned or underway in which there will be substantial steps taken bearing upon the Report recommendations. A notable example is the new Experimental R&D

Incentives Program. Further illustration is provided by the tabulation in Appendix B.

Beyond such specific activities there will be a broader process whereby the new philosophy underlying the recommendations in the Report will have an even more pervasive influence. In the continuing thinking of the National Science Board and the National Science Foundation on projects in research and education in the sciences, that philosophy will provide a reference point and guidance for choices and decisions. We feel that, in this way, important and valuable follow-through can and will be achieved.

(b) We are asked what action the Board can take to stimulate appropriate response to the Report throughout the Federal Government.

By way of preliminary, the Board feels that a productive beginning was made in this regard by circulation of a late draft of the Report to interested Federal agencies with a request for their comment. (A list of those agencies has earlier been made a part of this record.) In addition to evoking helpful responses on substance, this process brought the Report recommendations directly to the attention of persons in those agencies and, beyond question, stimulated thinking as to how their agencies might appropriately respond.

Another approach is provided by the Federal Council for Science and Technology and its numerous committees on which the Foundation is well represented. The Council's special committee on RANN (NSF's program of Research Applied to National Needs) and its subcommittees have demonstrated their worth in acquainting the Federal agencies with NSF activities which have the potential of producing results relevant to agency missions. The National Academy of Sciences, the National Academy of Engineering, and the National Research Council may be called upon to cooperate with the Foundation and other Federal agencies for discussions, studies, symposia, and the like on scientific and technical subjects. Numerous ad hoc committees crossing agency lines exist. The Board and the Foundation, furthermore, are well supplied with informal contacts in all appropriate agencies of the Government through which action may be initiated and arranged.

Question 2: Can the Committee be provided with information about recommendations other than those which finally appeared in the report—that is to say, recommendations which might have been discussed but were not adopted?

Although many recommendations were considered and eliminated by the Ad Hoc Committee on Fourth NSB Report, the National Science Board itself did not consider any recommendations which then failed of adoption as part of the Report. In the accumulation and winnowing of a large volume of draft material from the numerous sources identified in the Acknowledgements, a variety of suggestions was of course put forward. A major criterion of usability applied at that stage has been described by Dr. Thomas F. Jones, Jr., in an earlier part of this record: "We removed . . . those which clearly had a strong self-serving component from the standpoint of engineers, or the Science Foundation, or other such entities, in order that this Report would have the strength and complete credibility which we felt that it must have to do the job that we see to be done."

In that comment, it may be noted, Dr. Jones was speaking, as the context shows, of the procedures of the Ad Hoc Committee. In the drafting process, that Committee possessed an overall view, and bore an overall responsibility, which individual participants in the drafting process did not. In performing its task it applied the criterion mentioned by Dr. Jones, and other criteria such as feasibility, and the relative significance *vis-a-vis* national policy of the suggestions put forward.

Question 3: With regard to technology assessment, the hearing pointed out that assessments (or something like them) are presently being made in a large number of Executive agencies. What would be the views of the Foundation with regard to the possible centralization of this activity through an appropriate single Federal office?

Uncertainty as to how technology assessment capabilities might best be developed within the Executive Branch of the Federal Government is responsible for the Board's belief that in this case the first steps in implementation of its recommendations should be exploratory. Whether to have a single Federal office or take the path of pluralism is a decision requiring intensive exploration.

There is no doubt that, in the formulation of the recommendation on technology assessment, the dominant thinking of the Board was in the direction of pluralism. The root concept was that technology assessment is a *methodology*, not an institution. Moreover, it is a *new* methodology, which assuredly will develop in novel and unpredictable ways. It asks a commitment to look at problems, not with the purpose of deciding to do this or do that on an ad hoc basis, but to permit a careful weighing of alternatives. Every agency with a technological mission should be applying principles of that kind. Considerations such as the foregoing underlie the language in the recommendation: "It is urgent that *new capabilities be created . . .*" (Emphasis supplied).

In view of the many diverse substantive skills required in assessment of diverse technologies, it would be difficult to hypothesize a unitary agency completely self-sufficient in such skills. Even were such an agency to be designed, the design would require internal pluralization to an extent touching, if not overrunning, the limits of workability. Technology assessment should be used by many individuals and groups, both formally and informally. Centralization of such activities would seem premature at this stage.

Question 4: The Board's report, the President's statement which accompanied it, and the commentary of those appearing at the presentation all spoke of the President's March 16 Message on Science and Technology. Among other things, that message emphasized certain utilization of the Foundation's apparatus to promote technology and its application through profit-making organizations. What policies has the Board set, or does it contemplate setting, on the extent to which such a mechanism should be used?

The National Science Board is deeply concerned about internal and external problems of this Nation related to the level of efficiency of technology in the private sector and the improvement of that efficiency as a means of helping in the alleviation of those problems.

The Board recognizes the importance of establishing and improving relationships among academic, industrial, and governmental organiza-

tions so as to promote the expansion of basic research and its application in all areas.

What forms the relationship should take are the subject of current study which will occupy the attention of the Board throughout the year.

Your Committee has received a discussion of the tentative directions in which the Foundation is moving on this matter, in the testimony of Dr. Raymond L. Bisplinghoff, Deputy Director, National Science Foundation, on February 24. At that time Dr. Bisplinghoff said:

> The central problem we face is one of developing recognition and capability by industry in general of the full spectrum of opportunity for the exploitation of R&D throughout the civilian economy in meeting societal needs. This lack of recognition and capability is demonstrated by the concentration of a significant fraction of industrial R&D in relatively few companies. It will be desirable to find the means to extend the advantages of modern science and technology to small and medium industries and to all others that so far have been unable to afford it.

We feel that a good beginning is being made. We intend to look still further.

Question 5: In the foregoing regard, to what extent does the Board expect the Foundation to become an "advocate" of technology? How does it reconcile this with its traditional role of fostering basic research?

In the past two or three years the National Science Foundation has expanded rapidly its support of programs addressed to problems of major national importance. The majority of these problems involve complex interrelations of social, political, and technological factors. Few, if any, of these problems can be alleviated by a single individual or a single discipline. Further capabilities need to be developed for converting interdisciplinary research discoveries to socially useful programs. Furthermore, the dearth of established interdisciplinary units in universities presents difficult problems in developing effective problem-focused interdisciplinary studies. Thus the Foundation has struggled with a variety of management problems both internal and external in developing problem-focused, applied research programs. Because of the attention given to these activities it may have seemed to some that the National Science Foundation has decreased its commitment to the support of basic research. Such is, indeed, not the case. It is of the utmost importance to the welfare of this Nation that creative individuals be given maximum support in advancing knowledge and basic understanding. This has been and remains of highest priority.

In this connection it should be noted that to varying degrees the Research Applied to National Needs (RANN) programs involve elements of basic research, and RANN support is providing a strong stimulus to the development of interdisciplinary research and teaching.

Indeed, programs which involve no element of research or which emphasize simply repetitive activities should not be supported by the National Science Foundation except under the most unusual circumstances.

We support both basic and applied research which are essential to the development of scientific knowledge and its effective application to the advancement of our society. This does not constitute "advocacy" of technology in the abstract but, rather, broadens our focus by recognizing a need not only to seek new knowledge but to find techniques for using it.

Question 6: What criterion, if any, is used to distinguish service industries from manufacturing industries? Does the Foundation have any reliable data on recent relative growth of the service vs. manufacturing sectors?

For many years students of the social sciences have for analytical purposes divided the economy into sectors, the primary being predominantly agricultural; the secondary, manufacturing or industrial; the tertiary, services. It has been argued that there is a trajectory along which every nation will pass, once it has become industrialized, whereby, because of improved productivity of manufacturers and growing demands for health, education, recreation and the like as incomes increase, an ever larger proportion of the labor force will inevitably move out of industry and into the service sector. The United States is the first so-called "service economy," that is, the first nation in which the major portion of the work force is engaged neither in agrarian nor in industrial pursuits. Other nations, particularly those in northern and western Europe, and Japan, are rapidly following a similar course.

This useful classification of enterprises has been incorporated into a Standard Industrial Classification manual, issued by the Office of Management and Budget. Statistics are collected annually in accordance with the criteria of the manual by the Bureau of Labor Statistics of the Department of Labor. Manufacturing industries are included under the manual's classification, "Division D." The service industries include the following categories:

Division C: Construction.

Division E: Transportation, communications, electric, gas, and sanitary services.

Division H: Finance, insurance, and real estate.

Division I: Services.

Division J: Public Administration.

A more complete list of each of these divisions follows.

Annual rates of growth in employment for the manufacturing and service industries as defined by the manual are shown below:

[In percent]

	1950-60	1960-69	1969-71
Manufacturing	1.0	2.1	−4.0
Services	2.6	3.6	+2.1

The manufacturing and service classifications of the Office of Management and Budget manual follow.

MANUFACTURING INDUSTRIES

Division D. Manufacturing.
- Major Group 20. Food and kindred products.
- Major Group 21. Tobacco manufactures.
- Major Group 22. Textile mill products.
- Major Group 23. Apparel and other finished products made from fabrics and similar materials.
- Major Group 24. Lumber and wood products, except furniture.
- Major Group 25. Furniture and fixtures.
- Major Group 26. Paper and allied products.
- Major Group 27. Printing, publishing, and allied industries.
- Major Group 28. Chemicals and allied products.
- Major Group 29. Petroleum refining and related industries.
- Major Group 30. Rubber and miscellaneous plastics products.
- Major Group 31. Leather and leather products.
- Major Group 32. Stone, clay, glass, and concrete products.
- Major Group 33. Primary metal industries.
- Major Group 34. Fabricated metal products, except machinery and transportation equipment.
- Major Group 35. Machinery, except electrical.
- Major Group 36. Electrical and electronic machinery, equipment, and supplies.
- Major Group 37. Transportation equipment.
- Major Group 38. Measuring, analyzing, and controlling instruments; photographic, medical and optical goods; watches and clocks.
- Major Group 39. Miscellaneous manufacturing industries.

SERVICE INDUSTRIES

Division C. Construction.
- Major Group 15. Building construction—general contractors and operative builders.
- Major Group 16. Construction other than building construction—general contractors.
- Major Group 17. Construction—special trade contractors.

Division E. Transportation, communications, electric, gas, and sanitary services.
- Major Group 40. Railroad transportation.
- Major Group 41. Local and suburban transit and interurban highway passenger transportation.
- Major Group 42. Motor freight transportation and warehousing.
- Major Group 43. U.S. Postal Service.
- Major Group 44. Water transportation.
- Major Group 45. Transportation by air.
- Major Group 46. Pipe lines, except natural gas.
- Major Group 47. Transportation services.
- Major Group 48. Communication.
- Major Group 49. Electric, gas, and sanitary services.

Division H. Finance, insurance and real estate.
- Major Group 60. Banking.
- Major Group 61. Credit agencies other than banks.

Major Group 62. Security and commodity brokers, dealers, exchanges, and services.
Major Group 63. Insurance.
Major Group 64. Insurance agents, brokers, and service.
Major Group 65. Real estate.
Major Group 66. Combinations of real estate, insurance, loans, law offices.
Major Group 67. Holding and other investment offices.
Division I. Services.
Major Group 70. Hotels, rooming houses, camps, and other lodging places.
Major Group 72. Personal services.
Major Group 73. Business services.
Major Group 75. Automotive repair, services, and garages.
Major Group 76. Miscellaneous repair services.
Major Group 78. Motion pictures.
Major Group 79. Amusement and recreation services, except motion pictures.
Major Group 80. Health services.
Major Group 81. Legal services.
Major Group 82. Educational services.
Major Group 83. Social services.
Major Group 84. Museums, art galleries, botanical and zoological gardens.
Major Group 86. Membership organizations.
Major Group 88. Private households.
Major Group 89. Miscellaneous services.
Division J. Public administration.
Major Group 91. Executive, legislative, and general government, except finance.
Major Group 92. Justice, public order, and safety.
Major Group 93. Public finance, taxation, and monetary policy.
Major Group 94. Administration of human resources programs.
Major Group 95. Administration of environmental quality and housing programs.
Major Group 96. Administration of economic programs.
Major Group 97. National security and international affairs.

Question 7. Should not emphasis be placed on introducing new technologies to advance service industries since these, presumably, utilize far less in the way of natural resources?

The inclusive purpose of seeking to advance technology is the conservation of both human and natural resources. New technology should be directed to serving both ends, whether the technology is utilized in the service or industrial sector.

Question 8. How should the Federal Government implement and stimulate the domestic R&D field? Can some examples be given? Should we look to methods being used by advanced foreign countries to promote their economic interests?

We do not feel that there can be formulated at this time a detailed answer which would be genuinely responsive to the first part of this question, how the Federal Government should implement and stimulates the domestic R&D field. Such action will take place within a

framework of new elements of national policy which are subject to examination, deliberation, and decision in the governmental and political process before broad scale implementation can begin. Then, assuming a green light is given at the end of that process, exploration and experimentation are required to determine the means of implementation. The National Science Foundation is one of the agencies, but not the only agency, proposing to undertake such programs.

The development of overall policy on the implementation and stimulation of the domestic R&D field requires participation of both the Executive and Legislative Branches of Government and consideration of the views of economists, industrialists, scientists, engineers, and other interested groups. This will take time.

The Board feels, however, that thoughtful people of many backgrounds will agree that there should be a reshaping of the relationship of Government to industry toward their being more effectively supportive of one another and that technology is a field in which such a need is of particular importance at this time. Additional thoughtful study is required with a view to furthering such a partnership relation.

Certain exploratory moves, such as the provision of financial incentives for joint applied research activities between academic institutions and industrial associations, can meanwhile be undertaken within the scope of existing policy. In accordance with the President's message of March 16 on science and technology, efforts are already underway in fiscal year 1973 by agencies such as the National Science Foundation and the National Bureau of Standards to explore strategies.

Testimony has recently been presented before your Committee with respect to the Foundation's Experimental R&D Incentives Program and National R&D Assessment Program. These programs are in the early stages, so that examples drawn from them would not be fairly illustrative of results which may ultimately be expected.

The last part of Question 8 asks whether we should look to methods being used by advanced foreign countries to promote their economic interests. We believe the answer must be an emphatic "yes."

In the preparation of its 1972 Report, the National Science Board gave extensive attention to this subject. If an appreciative observation is in order, we may note that during this period there came into our hands the Report of The Honorable George P. Miller as Congressional Advisor to the U.S. Delegation at the Meeting of the Ministers of Science of the Organization for Economic Cooperation and Development, and we derived much guidance from it. Dr. Harvey Brooks, Member of the National Science Board, was associated with the work of that meeting, and Dr. Raymond L. Bisplinghoff, Deputy Director, National Science Foundation, was among the advisers to the Delegation.

Our interest in this subject arose from our basic conviction that stimulus of American technology is of importance, among other reasons, as a means of alleviating balance of trade problems. Additionally, there was recognition of the desirability of learning as much as possible about how that stimulus might be applied. In testimony before your Committee on February 24, Dr. Bisplinghoff commented on this:

> In recent years Japan and Western Europe have had experience in sitmulating innovation and diffusion of technology by using methods available to, but untried by, the Federal Gov-

ernment. . . . Although the political and social structures are different in the United States, it has been our object in designing the NSF program to build wherever possible on the experience gained by our foreign competitors.

On this same point also, we are submitting for inclusion in your record what we regard as an illuminating discussion on Canadian Government measures of this kind written by Mr. Harvey Picker, former Member of the National Science Board and Chairman of the Board of Picker Corporation.

We can report also that during the preparation of the Fourth Board Report a thorough study was made of documentation describing the French effort in stimulation of science and technology. We feel that a summary might be of interest to the Committee, and it follows:

Experience of France

In 1954 a state secretariat for scientific research was created, and in the light of resulting experience additional steps were taken in 1968–69 to strengthen industrial development as well.

Organizations created for coordination and stimulation of science and technology were:

(a) The Inter-ministerial Committee for Scientific Research and Technology. French title: *Le Comite Interministeriel de la Recherche Scientifique et Technique* (*CIRST*). The mission of this group is to propose to the government measures to develop scientific research and technology suggesting resources and means, inserting items into the budgets of the concerned ministerial departments. Includes the General Delegate, twelve concerned ministers, and members of the CCRST.

(b) The Ministry of Scientific and Industrial Development. French title: *Le Ministre du Developpement Industriel et Scientifique*. This group deals primarily with studies in atomic energy, aerospace, and "informatique." Formulates the budget for research and technology for presentation to Parliament.

(c) The Consultative Committee for Scientific and Technical Research. French title: *Le Comite Consultatif de la Recherche Scientifique et Technique* (*CCRST*). An advisory committee, consisting of twelve eminent scientists, who serve on a rotating basis.

(d) The General Delegation for Scientific and Technical Research. French title: *La Delegation Generale a la Recherche Scientifique et Technique* (*DGRST*). This is the organ through which the minister charged with the research exercises his authority for coordination at the inter-ministerial level. A staff organization (of about 100 persons) to centralize the studies and analyses made by CIRST, CCRST and other bodies.

The "General Delegate," chosen by the government among the most eminent scientists, directs this organization. He may call upon any consultant of his choice and may constitute groups of technical specialists to resolve problems.

French science policy is prepared by the DGRST which is also charged with the execution and direction of the governmental actions in this area. The CCRST contributes its advice, after reflection and study of the issues. The policy is deliberated at the government

level in the inter-ministerial committee (CIRST), and finally decided and put into practice by the Minister for Scientific and Industrial Development.

Aid to Technological Development

Beginning with 1965, the government has been empowered to provide subsidies, never to exceed 50 percent of the total cost of the proposed operation, and reimbursable in case of success in the enterprise. The reimbursement is effected according to a percentage fixed contractually, of the profits realized on the products eventually produced with government assistance. At the beginning of the year 1969, for example, eleven enterprises were in the process of making reimbursements.

Government aid is given for technical developments in certain well-defined sectors, or themes suggested by various study groups and departmental decisions of the ministries concerned.

The sectors benefiting from government assistance (in 1969) were mechanical construction, electrical and electronic enterprises, chemistry, metallurgy, the textile industry, buildings, and transportation. Contract requirements are studied and correlated with the general technical and economic plans and programs of the government. The budget allowance for aid to technological development has been growing rapidly since the initiation of the arrangements.

Question 9. Dr. Macdonald spoke of the high-risk character of R&D and the research difficulties facing entrepreneurs and innovators. What is the Board's position with regard to the effect of the anti-trust laws, as currently interpreted and enforced, in this area?

The Board does not feel that the antitrust laws, over most of their history, have constituted an unreasonable barrier to research efforts in this country, or have necessarily posed a bar to cooperative arrangements. In recent years, however, we have become seriously concerned by problems arising from the rapidly improving technologies in Western Europe, Japan, and elsewhere. The erosion of our competitive position and the constraints of environmental and pollution problems impose major demands on our competency. The results of research tend today to be more generic, and, because the pay-offs therefore are less exclusively beneficial to the entrepreneur, his incentive to pay for research is lessened. The increasing service orientation of the economy poses additional problems in terms of who pays for research and its value to the person who carries it out.

Situations may exist where the potential corporate rewards are insufficient to bring forth the necessary research effort. It is possible that in these and kindred situations joint or cooperative research efforts and scientific information exchanges would be helpful in promoting research necessary for innovations important to society, and that the Foundation can play a stimulative role. The Board does not have a consensus view as to whether such activities can be supported *effectively* within the present bounds of the antitrust laws. Evolving problems in this area must receive thoughtful and continuing study as to how a productive balance between "collaborative" and "competitive" research can best be maintained.

Question 10. With regard to "public understanding of technology" how much of an effort is NSF itself making to achieve this goal, and where does one draw the line at fostering it? Another way of putting

the question might be to inquire when one ceases to be a dispenser of information and becomes a promoter. What principles distinguish the two?

NSF has had a Public Understanding of Science Program since 1960, funded at the average level of $300,000 per year up until the current fiscal year. Science and technology have both been dealt with, but the emphasis in most projects funded has been on the role and uses of science, broadly defined. This approach is considered appropriate in the light of the Foundation's mandate to advance basic research and support education for science.

During the current fiscal year, the program has evolved towards the support of major interdisciplinary groups in both universities and professional scientific societies for a range of activities including films, television programs, conferences, seminars, science exhibits, and publications for nonscientists. Most of the emphasis here, as in past years, has been on communications about science in general; however, one project which received support this year was specifically directed at technology—two one-hour television programs on the role of engineers and the technological sciences in meeting societal problems broadcast locally in Washington over the facilities of WETA-TV.

The problem of informing without advocating has confronted the Public Understanding of Science Program over the years, and NSF has, we believe, successfully avoided an advocacy role. The use of consultative guidance and review of proposals by scientists, communicators, and lay citizens have been safeguards against any unconscious bias toward advocacy. We will face the same problems in connection with public understanding of technology. Admittedly, the line between understanding and advocacy can be blurred, and we must always be on the alert to keep from crossing it.

Even though the boundary is vague, we strongly believe that we must keep working at advancing public understanding of science and technology because of the key role both play in so many issues of public policy today. The citizen as a decision-maker must be the ultimate generalist. He now lives in a scientific and technological age. The purpose of advancing understanding of science and technology is to aid him in a dimension of his life that constantly grows in importance. When he speaks out in public, writes a letter to his legislator, or steps into the voting booth, he should have at least a basic grasp of the facts relevant to the issue that concerns him.

With specific regard to a new program of public understanding of technology, we plan to consult widely with scientists, engineers, lay citizens, and others to construct guidelines for the program and for the review of proposals. This will take place in fiscal year 1973.

Question 11. Recommendation IV stresses activity by both the Foundation and the Office of Education. What is the role of OE here? What is it doing now? What should it be doing, in the Foundation's view, which it is not doing?

The field of "teaching" explicit in Recommendation IV is very broad, contemplating teaching in and out of school, and at all age levels. It was felt the Office of Education could provide expert assistance, advice, and, if feasible, programs of its own, taking into account both the nature of the materials needed, and the channels most suitable, for kinds of teaching adapted to categories of individuals and

groups which NSF programs have not, for a variety of reasons, sought to develop. "Adult Education" is a case in point. In recommending the stated policy "as a matter of long range concern," it seemed helpful to consider such assistance from the Office of Education as an option very much worth keeping open.

Question 12. With regard to the periodic swing between shortages and surpluses of scientific and technological manpower, it appears that there have always been fluctuations of this kind. For the most part these seem to be regulated by the mechanics of a free market. Is there anything really different about the current downswing? If so, is any thought being given to ways to provide more stability in the future? How might this be done?

The flattening and downturn in employment in civilian scientific manpower which for a time were concealed by continuing activity in aerospace and defense do reflect in part some cyclical factors.

However, there are elements in the present situation which have increased the magnitude of the present downswing.

a. Unprecedented expansion of the entire R&D apparatus during the 1950's and 1960's. The magnitude of the upswing, almost continuous for two decades, can be gauged by the fact that scientific and engineering employment nearly doubled in the 1950's and increased by another 50 percent in the 1960's. During this period, research and development activities grew even more substantially—from less than $6 billion in 1953 to about $25 billion in 1970. The science education enterprise, as measured by college and university enrollments in science and engineering, also grew rapidly, and the economy generally grew.

b. An increasing fraction of the R&D scientists are employed or supported (directly, and indirectly through Federal contracts or grants) by the Federal Government. This factor magnifies the effect on manpower of the changes which occur in Federal programs. Federal agencies through funding of research and development activities, science education programs, and technical construction and procurement, profoundly affect the training, career choices, and eventually the employment of a significant proportion of scientists and engineers. About one-quarter of all scientists and engineers are supported primarily by Federal funds, and a majority of these have been involved in space and defense programs.

c. The combination of (b) and the end of a major phase of the space program has been one cause of manpower dislocation.

d. We are approaching the end of decades of continuous growth in college populations. This has uniquely affected employment—adversely—in the academic sector.

e. The problems of the civilian sector mentioned in our response to Question 8 (which bears directly on this discussion) also have contributed to a decline in civilian scientific manpower requirements.

What might be done? It is unlikely that we can completely prevent ordinary cyclical swings of the civilian economy, though in time we may increase our ability to moderate undesirable effects of their extremes. Furthermore, changes in Federal programs will continue to occur, and will affect scientific and engineering manpower. Cases in point are the programs under the Occupational Health and Safety Act (OHSA), and antipollution activities.

However, major thought and effort should be devoted to the manpower aspects of Federal programs, as these change with future developments. It may be possible to anticipate some of the changes that may occur.

Education of scientists and engineers should be more broadly based, and efforts should be made to provide new graduates with better information as to the nature of available opportunities for employment.

Most important is the lesson for engineering education: greater flexibility in the background training for new scientists and engineers. Imaginative diversity rather than uniformity or high specialization should be stressed. The scientists and the engineers of the future will need the thorough grounding in the physical sciences, which they have had up to now, but they must also obtain a broad general view of the humanities, economics, and social sciences. The scientists and the engineers need to acquire a better understanding of societal goals to which their skills may contribute.

It would contribute to stability if large scale, well coordinated efforts were to be made to provide effective interchange of information regarding employment opportunities, new positions available, and retraining programs. Some of the professional societies have been attempting to do this, but the efforts could be strengthened.

As has been noted previously in this record and elsewhere, Administration concern is evidenced by a number of efforts underway or proposed to meet the changing circumstances with new approaches.

Question 13: Dr. Linvill commented that "The exploration of each important societal problem must be done away from the pressures of the operational world." What important societal problems exist today which might be cited as examples (other than the two very general problem areas cited toward the end of his statement)? Do any existing groups fit the category of the "exploratory teams" which are called for?

(The responses to Questions 13 and 14 were written by Dr. William K. Linvill, whose statement in the April 26 hearing is given earlier in this record.)

Examples of present societal problems requiring multidisciplinary exploration away from the pressures of the operational world are: (a) The problem of upgrading education among the disadvantaged and the poor. (b) The problems of new technology, unemployment, and welfare and their relation to the urban problem in central large cities.

A recent and continuing societal problem requiring multidisciplinary exploration away from the pressures of the operational world is: The problem of poverty, unemployment, and lagging industry in Appalachia initially studied by the President's Appalachian Regional Commission (PARC).

Present exploratory teams funded by the Office of Education are making competent efforts to understand the problems of upgrading education among the poor and disadvantaged. The exploratory effort is not tied as closely to the implementing agencies as it must be for really workable solutions. The exploration of the technology-unemployment-welfare problem requires even a broader range of considerations, and the present explorations do not cover all the interlocking issues simultaneously.

The PARC Commission was a good example of an exploratory team. Follow-on implementation in the Appalachian Regional Development Act of 1965 represented a very significant response to the Appalachian problem and a good example of the exploration process with brokerage to lead to implementation.

Though there are several exploratory teams working in various academic research groups and several nonprofit institutes, their studies are not comprehensive enough in relation to any specific problem nor are their results closely enough tied to implementing operations for them to be completely effective.

Discussion

One exploration done twenty years ago was of our air defense problem initiated after the Soviet Union developed nuclear weapons. It was characterized by a rapidly changing technology in radar, guided missiles, nuclear weapons, and high-speed computers; a changing set of roles and missions of the branches of the service largely between army and air force; a new and different military role in a time of tension but not of armed conflict. The air defense problem required a single unified effort by a number of independent governmental agencies, military departments, private industries, and research laboratories on a different problem than any group had faced before and on which all groups must work together. There was an initiating survey exploration done at Project Charles and more detailed follow-on explorations done at Project Lincoln and at the Willow Run Research Center. This problem involved mostly military and scientific issues and had a clearly defined client-sponsor at the outset so it was not as difficult to manage as more completely civilian societal problems involving more agencies and having no client-sponsor.

A more recent exploration and one that meets our criteria more completely was the President's Appalachian Regional Commission established by President Kennedy to study poverty causes and remedies in a nine-state region. There was high unemployment, lagging industry, difficult transportation problems, and inadequate health care and educational opportunity. The Appalachian problem involved the overlapping concerns of a large number of Federal departments and agencies, a set of separate state governments, and a set of local governmental institutions. Ultimately, the private sector must be involved in a majority share of the solution. The number and range of interests of the public sector agencies far exceed that in the air defense problem. There was no single, commonly perceived imminent external threat and no established client-sponsor. A necessary long term cooperation must be built between the public and private sectors. The PARC Commission made a very significant contribution toward formulating the problem and outlining steps for its solutions. The Federal-state partnership and the very strong and consistent bipartisan backing given the Appalachian problem were almost unique examples in our Government. Any serious Federal-state conflicts or partisan political divisions would have seriously weakened the ARC program.

Upgrading education among the disadvantaged and the poor is a problem involving many different entities, many tangled problem com-

ponents such as racial tension and economic hardship, and requiring strongly interactive effort among many independent groups. In many schools, existing teaching staffs who have strong and healthy personal relationships with the community have too remote connections with present technology, recent advances, and new potential employment opportunities of their students. Quick-fix solutions such as busing have grasped too narrow a slice of the problem. New technological advances such as computer-aided instruction and wide use of video cassettes promise a way to provide rather immediate help to the present students and excellent supplementary training and professional advancement to the present teachers in the the disadvantaged schools. Local ownership and control of schools, a changing structure of tax support, difficult personal problems in local administration, fairly large capital investments needed in a technology which is extremely promising but still immature, inadequate experience in broad-scale experiments to determine public acceptance of the new techniques, and a structure of private support institutions which are developing but not yet established are all problems which make the actual implementation of a solution very hazardous and uncertain. Strong Federal action will not be successful unless it is matched by strong support from the local school administrations, strong participation in the private industries which will be needed, and imaginative and flexible innovation by an academic community which must make drastic changes in its structure. Broad scale exploration and a number of large experiments are almost desperately needed.

The problems of new technology, unemployment, and welfare are a set of interrelated problems which cannot be handled meaningfully one at a time. New technological advances such as agricultural mechanization, industrial automation, and clerical computerization have already made massive changes in employment opportunities for the work force. Adequate means for displaced workers to develop new skills, lack of flexibility of labor organizations, and lack of fluidity of industrial capital to develop new areas have led to large-scale inefficiency in the use of the work force and substantial unemployment. Retraining and the development of new job opportunities is preferable to increased welfare. Short term support of displaced workers and their families is essential. An integrated approach should be developed. Welfare is necessary for extreme cases. Rehabilitation and retraining of displaced workers is essential. New industrial opportunities in both manufacturing and service industries must be formulated and stimulated. A new job mobility of the work force is needed. Societal consequences and industrial shifts from new technological initiatives must be better predicted and prepared for. Probably new legislation with regard to tax laws and antitrust laws would be appropriate. The program needs are so comprehensive that a broad scale exploration involving many groups and several societal experiments is badly needed.

Question 14: Again with regard to Dr. Linvill's statement, can examples be given of the "brokerage process" as it might induce the "chain of initiatives" leading to growth through technological opportunity?

The Appalachian Regional Commission involves the most interesting example of the "brokerage process" because it had no single, well

defined client-sponsor. Generally, brokerage is more needed when there is a need to interest several implementers simultaneously. Following the PARC report, a joint response between the Federal Government and the nine governors of the Appalachian states was formulated. This was almost a unique Federal-state partnership.

The $2 billion congressional appropriation to ARC was administered by a three-man committee: A Federal cochairman appointed by the President, a state's representative and an executive chairman of the Commission. All appropriations must be approved both by the Federal cochairman representing the President and a majority of the state governors (or their representatives). By combining ARC funds with other Federal agency funds (such as Federal highway funds, Corps of Engineer funds, HEW funds, etc.), the Commission was able to act as a broker and stimulate unified regional programs of the order of $5–$10 billion. This brokerage process is similar to the familiar political process, but it includes a much wider range of Federal agencies and state and local governments than the more usual programs. Finally, the private sector is stimulated to invest in Appalachia by the more coherent public sector programs. By this process, a chain of initiatives was set up going from a single problem being studied by a group of local leaders and by the Commission staff to an increasing broad participation and funding until a large highway program was built or an extensive functionally based vocational training program was instituted or a demonstration health care program was established.

Though the impact of any of these programs is significant in itself, the *brokerage process* and the *chain of initiatives* involving continuing responsible commitment in the chain from exploration to study, to experiment, to wide-scale implementation is the essential new ingredient. An outright Federal grant of $10 billion might have accomplished the same physical changes in Appalachia as ARC did, but it would not have set up the "brokerage process" which will be useful for this region on many other problems for years to come if it is built upon.

In both the broad education support to the poor and disadvantaged and the technology, unemployment, and welfare questions, broad study involving Federal, state, and local entities and massive participation by the academic and scientific community and many private industries will be required for a meaningful solution. Again, broad exploration and a chain of initiatives finally leading to broad scale implementation is called for but not yet provided. (This concludes Dr. Linvill's comments.)

Mr. Davis, I hope that the foregoing responses to your questions plus the attached appendices provide useful supplements to the discussions during our April 26 hearing.

Sincerely yours,

H. E. Carter, *Chairman.*

APPENDIX B

National Science Foundation Program Activities Which Relate to Recommendations Contained in the 4th Annual Report of the National Science Board

NATIONAL SCIENCE FOUNDATION

PROGRAM ACTIVITIES WHICH RELATE TO RECOMMENDATIONS CONTAINED IN THE 4TH ANNUAL REPORT OF THE NATIONAL SCIENCE BOARD

[In millions of dollars]

	Recommendations					
	I	II	III	IV	V	
	Government aid in support of industrial technology	Technological support for public goods and services	Exploration of future alternatives	Public understanding of science and technology	Technology assessment	Total
FISCAL YEAR 1971 (ACTUAL)						
Scientific research project support:						
Environmental sciences		0.1	0.9			1.0
Biological sciences			.5			.5
Chemistry	0.2					.2
Engineering	.6	.2	.2	0		1.0
Materials research	.6					.6
Social sciences (soc. ind.)	.2	.2	.4			.8
Subtotal	1.6	.5	2.0	0		4.1
National and special research programs:						
Experimental R. & D. incentives program	0	0				0
National R. & D. assessment program					0	0
Subtotal	0	0			0	
Computing activities in education and research:						
Computer assisted instruction		6.2				6.2
Research applied to national needs:						
Advanced technology applications	2.4	1.0	2.0			5.4
Exploratory research and problem assessment			1.5		1.4	2.9
Subtotal	2.4	1.0	3.5		1.4	8.3
Intergovernmental science program		.8				.8
Science education improvement: Public understanding of science				.4		.4
Planning and policy studies: Studies of science resources			1.7			1.7
Total	4.0	8.5	7.2	.4	1.4	21.5
FISCAL YEAR 1972 (ESTIMATED)						
Scientific research project support:						
Environmental sciences		0.3	1.0			1.3
Biological sciences			.7			.7
Chemistry	0.6					.6
Engineering	1.6	.5	.4	0	0.2	2.7
Materials research	7					7
Social sciences (soc. ind.)	.2	.2	.4			.8
Subtotal	3.1	1.0	2.5	0	.2	6.8
National and special research programs:						
Experimental R. & D. incentives program	0	0				0
National R. & D. assessment program					0	0
Subtotal	0	0			0	0
Computing activities in education and research:						
Computer assisted instruction		8.4				8.4
Research applied to national needs:						
Advanced technology applications	3.4	1.5	2.4			7.3
Exploratory research and problem assessment			3.1		2.0	5.1
Subtotal	3.4	1.5	5.5		2.0	12.4
Intergovernmental science program		1.0				1.0
Science education improvement: Public understanding of science				.4		.4
Planning and policy studies: Studies of science resources			1.2			1.2
Total	6.5	11.9	9.2	.4	2.2	30.2

PROGRAM ACTIVITIES WHICH RELATE TO RECOMMENDATIONS CONTAINED IN THE 4TH ANNUAL REPORT OF THE NATIONAL SCIENCE BOARD—Continued

[In millions of dollars]

	Recommendations					
	I	II	III	IV	V	
	Government aid in support of industrial technology	Technological support for public goods and services	Exploration of future alternatives	Public understanding of science and technology	Technology assessment	Total
FISCAL YEAR 1973 (PROPOSED) [1]						
Scientific research project support:						
Environmental sciences		0.3	1.0			1.3
Biological sciences			1.8			1.8
Chemistry	0.8					.8
Engineering	2.0	.7	.7	0	0.2	3.6
Materials research	.7					.7
Social sciences (soc. ind.)	.5	.3	.4			1.2
Subtotal	4.0	1.3	3.9	0	.2	9.4
National and special research programs:						
Experimental R. & D. incentives program	15.0	7.0				22.0
National R. & D. assessment program					2.5	2.5
Subtotal	15.0	7.0			2.5	24.5
Computing activities in education and research:						
Computer assisted instruction		8.6				8.6
Research applied to national needs:						
Advanced technology applications	5.2	2.3	5.0			12.5
Exploratory research and problem assessment			3.7		2.3	6.0
Subtotal	5.2	2.3	8.7		2.3	18.5
Intergovernmental science program		1.0				1.0
Science education improvement: Public understanding of science and technology				.4		.4
Planning and policy studies: Studies of science resources			1.3			1.3
Total	24.2	20.2	13.9	.4	5.0	63.7

[1] Estimates based on President's budget request for fiscal year 1973

APPENDIX C

STATEMENT BY MR. HARVEY PICKER, CHAIRMAN OF THE BOARD, PICKER CORPORATION; FORMER MEMBER, NATIONAL SCIENCE BOARD

The National Science Board asked a former member, Mr. Harvey Picker, to provide for the committee record a comment from the industrial viewpoint on the Board's 1972 report. His response, which follows, includes interesting observations on direct experience with Canadian Government aid in support of industrial technology.

STATEMENT BY HARVEY PICKER, CHAIRMAN OF THE BOARD, PICKER CORPORATION, WHITE PLAINS, NEW YORK, TO THE COMMITTEE ON SCIENCE AND ASTRONAUTICS, HOUSE OF REPRESENTATIVES, JUNE 1972 [1]

Thank you for permitting me the opportunity to furnish additional testimony for your hearings on the National Science Board's Report, "The Role of Engineers and Scientists in a National Policy for Technology." I believe that your Committee and the National Science Board deserve the appreciation of the American public for your foresight in selecting this problem to analyze. How it is resolved probably will vitally affect the quality of life in the United States. By examining the question now, before heated adversary claims cloud rational analysis, you are greatly enhancing the probability that the public will have the benefit of an early intelligent governmental decision based on adequate studies and, if desirable, pilot projects.

I would like to speak on many aspects of the Report. I will limit myself primarily to the pragmatic aspects of some of its recommendations.

Although I have been a Member of the National Science Board, my comments are based on my experience as Chairman of the Board of one of the largest companies in a high technology industry. Picker Corporation develops and manufactures X-ray apparatus, isotope therapy equipment, and clinical nuclear instruments.

Although the major part of our development, engineering, and production is conducted in facilities in the United States, we also carry on these activities in Germany, Denmark, and Canada.

Our experience provides rather dramatic support for the desirability of the National Science Board's Recommendation I, i.e., that the Government aid in the support of industrial technology.

About ten years ago we reluctantly opened a small plant in Canada. The attitude of the Canadian Government toward purchasing from companies with manufacturing facilities in Canada made this appear to be a somewhat poor but necessary risk. A rather small domestic Canadian market led us to anticipate that this plant would depend on our United States facilities for its engineering, would produce simple products, would grow very slowly, and would continuously struggle to be at all profitable.

A few years later the Canadian Government enacted a group of laws and implemented them to support applied research and development in industry. As a result, this small plant has grown to five times its anticipated size and employs many more engineers than we could possibly have expected even at its enlarged size. Our Canadian manufacturing facility has achieved world prominence as a result of having devised radically new types of X-ray apparatus that markedly increase the number of patients which can be examined per machine, while reducing the cost of X-ray examinations as well as the demands on the hospital staff. Far from producing only for the Canadian market, this small plant's Government-aided development program has resulted in its exporting a large proportion of its production. Besides

[1] Effective August 1, 1972, Mr. Picker became Dean of the School of International Affairs, Columbia University.

that, new Canadian laws have enabled this plant to undertake a cooperative applied research project with a Canadian university which has resulted in the increased employment of scientists at the university as well as in our factory. Without the Canadian Government's cooperation, such advanced work would not have been practical for an operation of that size, and the scientists might have had more difficulty in finding constructive employment for their talents.

Thus, four Canadian Government projects—"Program for the Advancement of Industrial Technology," "Industrial Research Development Incentive Act," "Industrial Research Assistance Program," and "Program to Enhance Productivity"—had, in our case at least, caused a more rapid growth of our Canadian facilities than our German or United States plants. These programs, which are similar to those recommended by the National Science Board, have actually led not only to increased worker employment but also to increased employment of engineers, university scientists, and Canadian leadership in an area of technology, with a resulting increase in exports. Indeed, the increased tax revenue alone for the Canadian Government has undoubtedly more than returned to it its costs of the assistance in this research and development work.

Now let me hasten to add that I realize this is just one example. Probably the Canadian programs, as a whole, are not always this successful. Undoubtedly the Canadian Department of Industry, Trade and Commerce and the Canadian National Research Council, who are charged with these programs, must find many cases where manufacturers are inept, programs are not well analyzed or implemented, and manufacturers try to put development costs on the Government that they should bear themselves. Yet, I cite our story to indicate that the proposals of the National Science Board can be highly practical toward reaching the objectives of an improved economy and quality of life. Wisely directed Government partnership in development and applied research in civilian fields can work very well.

A major part of the effectiveness and usefulness of the Report's recommendations, of course, will depend on how they are implemented. For example, encouragement of an industrial development project must be preceded by a careful market analysis. The customer is at least as important in the development process as the scientist, engineer, businessman, or Government official.

I would like to comment quickly on other aspects of the Report. Clearly, there are hazards to each of the Board's recommendations. No group, no matter how sagacious, can avoid errors in providing technological support for public goods and services. Some projects will be failures. Errors of forecasting will occur in the Exploration of Future Alternatives. Technology Assessment will inevitably be more apt to prevent the development of a technology that might prove to be a boon in order to be safely on the side of not creating new unwanted problems. But none of these objections seems to be overwhelming. It seems to me that the evidence is largely in favor of trying to implement the valuable recommendations of this Report.

I would have liked to comment more extensively. However, I hope that I have made my primary purpose clear. It is to praise the Board Report and your hearings, both of which are embarked on an analysis that is vital to the future quality of life in our country.

APPENDIX D

List of Federal Agencies Commenting on Draft Fourth Report of National Science Board

DEPARTMENT OF AGRICULTURE

ATOMIC ENERGY COMMISSION

COUNCIL ON ENVIRONMENTAL QUALITY

DEPARTMENT OF DEFENSE

ENVIRONMENTAL PROTECTION AGENCY

DEPARTMENT OF HEALTH, EDUCATION AND WELFARE

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

DEPARTMENT OF THE INTERIOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NATIONAL BUREAU OF STANDARDS

DEPARTMENT OF STATE

DEPARTMENT OF TRANSPORTATION

PART II

FOURTH ANNUAL REPORT OF
THE NATIONAL SCIENCE BOARD

The Role of Engineers and Scientists in a National Policy For Technology

REPORT OF THE NATIONAL SCIENCE BOARD

NATIONAL SCIENCE BOARD
NATIONAL SCIENCE FOUNDATION
1972

80-251 O - 72 - 5

My colleagues in the Congress, America can be her true self only when she is engaged in a great enterprise.

To build a full generation of peace is a great enterprise.

To help the poor and feed the hungry, to provide better health and housing and education, to clean up the environment, to bring new dignity and security to the aging, to guarantee equal opportunity for every American — all these are great enterprises.

To build the strong economy that makes all these possible — to meet the new challenges of peace, to move to a new prosperity without war and without inflation — this truly is a great enterprise, worthy of our sacrifice, worthy of our cooperation and worthy of the greatness of a great people.

President Richard M. Nixon
Before a Joint Session of the Congress, September 9, 1971

LETTER OF TRANSMITTAL

January 31, 1972

My Dear Mr. President:

I have the honor of transmitting to you, and through you to the Congress, the Fourth Annual Report of the National Science Board in accordance with Section 4(g) of the National Science Foundation Act as amended by Public Law 90-407.

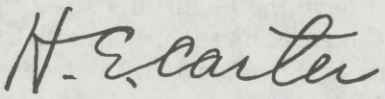
In this Report, the National Science Board carries forward an exploration of one of the most important questions of our time: how science and engineering, through technology, may be brought to bear more effectively on societal problems. The Report reflects the conviction also that changes in emphasis in the requirements for technology, and changes in the pattern of demands for technological talent, provide a strong basis for major Federal initiatives.

There is a need for the strengthening and updating of American industrial technology for the purpose, among others, of reinforcing the national economic base upon which our efforts to deal with societal problems must rest. A parallel need exists in respect to technologies in the public service sector in order to heighten performance in functions indispensable in the everyday life of our communities.

Beyond these findings of action there is now an exciting new capability for the direct use of advanced methods and instruments of technology in seeking solutions to major problems confronting our people. New kinds of institutions are required to gain the full benefit of the Nation's intellectual resources in science and engineering for these enterprises.

Making the most of this new capability, and meeting the needs we cite, are hard tasks calling for new departures in Federal executive and legislative action. The National Science Board is confident that making the required effort will bring commensurate reward.

Respectfully yours,



H. E. Carter
Chairman, National Science Board

The Honorable
The President of the United States

ACKNOWLEDGEMENTS

The National Science Board has been greatly aided by the many contributions of members of the engineering, scientific, educational, and industrial communities in the discussions which culminated in this, its fourth report to the Congress.

The Board is especially grateful to the members of the Advisory Committee for Engineering of the National Science Foundation which met four times to discuss the report and which in addition spent a great deal of time offering specific language and reviewing text. These are:

Dr. Lynn S. Beedle, Director, Fritz Engineering Laboratory, Lehigh University;
Dr. Donald A. Dahlstrom, Vice President for Research and Development, Envirotech Corporation, Salt Lake City, Utah;
Dr. Daniel C. Drucker, Dean, College of Engineering, University of Illinois;
Dr. Harry C. Gatos, Professor of Metallurgy and Materials Science, Massachusetts Institute of Technology;
Dr. Arthur E. Humphrey, Director and Professor, School of Chemical Engineering, University of Pennsylvania;
Dr. William K. Linvill, Chairman, Institute of Engineering Economic Systems, Stanford University;
Dr. Rustum Roy, Director, Materials Research Laboratory, The Pennsylvania State University;
Dr. Robert E. Uhrig, Dean, College of Engineering, University of Florida;
Dr. M. E. Van Valkenburg, Professor and Chairman, Department of Electrical Engineering, Princeton University;
Dr. Max L. Williams, Jr., Dean, College of Engineering, University of Utah.

The industrial viewpoint was effectively presented by the following distinguished persons who advised the Board on the future role of science and engineering in the Nation's industries:

Dr. Robert W. Cairns, Deputy Assistant Secretary for Science and Technology, Department of Commerce (former Vice President, Hercules, Inc., Wilmington, Delaware);
Dr. Thomas C. Kavanagh, Vice President, Praeger Kavanagh Waterbury, New York, New York;

Dr. J. Ross Macdonald, Vice President of Corporate Research and Engineering and Director, Central Research Laboratory, Texas Instruments, Inc., Dallas, Texas.

Officials in those Federal departments and agencies with mission roles which benefit from or support engineering and technology have reviewed this report and have made many valuable contributions.

Finally, the Board is deeply indebted to the "Writing Group" composed of Dr. John M. Ide, Mr. Frederic W. Collins, and Dr. Michael Modell. This group did all the major writing and spent endless hours in drafting original text and incorporating recommendations from members of the Board and from consultants. The Board is also grateful to the staff of the Board Office who have provided administrative and secretarial assistance throughout the entire process of preparation of this report.

CONTENTS

INTRODUCTION

AND SUMMARY OF RECOMMENDATIONS

For three decades the Nation has maintained a strong commitment to the technologies of war and defense. In the Sixties a second major commitment was made to the technologies of space. On both we have concentrated in massive ways the talents, energies, and physical and economic resources that have been required.

The Nation now needs an equally strong commitment to the technologies of peace, suffused with a sense of national purpose. We confront a variety of complex problems throughout the American society. We must broaden and intensify our efforts to deal with them. This is opportunity as well as need. We believe there is now a bright promise that American scientists and engineers can indeed help to meet our material and social requirements and help to solve major societal problems.

New circumstances make possible a different marshaling of knowledge, thought, and energies in science and engineering. To convert that potential into reality, and to move effectively toward the national commitment we seek, two major changes are required:

First, the principle must be accepted that the Federal Government has a new role and responsibility with respect to American industrial technology. It must undertake as a conscious mission the stimulation and support of research and, where desirable, development in order to promote continuing technological health. As a balance for that stimulus, it must provide adequate means of technological assessment.

Second, there must be designed and created institutional mechanisms to deal with societal problems in their complex entirety instead of piece by piece in traditional ways. Major efforts so organized must be coupled with existing governmental and private capabilities, both to enlarge and to focus the contributions of American science and engineering toward finding solutions for major problems.

We have developed a series of recommendations to suggest the ways in which these two fundamental changes can be achieved.

Their attainment will be difficult, and the efforts will be costly. Progress must rely on team efforts joining science and engineering with other professions and other fields of knowledge, in industry, the universities, and government. In carrying out a new mission, the Federal Government will face hard choices on priorities and detailed objectives, and progress will depend on the society's collective wisdom expressed through its processes of government.

The recommendations mark out one approach, not the only possible approach, toward meeting the needs in the area of technology discussed herein. This approach is subject to further evaluation, along with any alternatives, in the light of pertinent developments in policy or possible changes in the Federal organizational structure or reassignment of missions affecting technology.

The propositions stated are large. Yet on both the domestic and international scene we see no realistic alternatives. In a society as large and technologically advanced and complex as ours, there is a circle which cannot be broken. The improvement of our technology through broadened and intensified research and development is needed for continuous strengthening of the economic base. This in turn is essential if we are to meet the prospectively extraordinary costs of solving the complex problems of the American society.

The principal missions of the National Science Foundation (NSF) are to support basic scientific research and programs in education to strengthen scientific research potential. To this has been added more recently the mission of supporting a combination of basic and applied research on major national problems, and in pursuance of this mission NSF has launched a program called Research Applied to National Needs (RANN). Accordingly, Foundation programs embrace the entire science-engineering-technology-society sequence through which new scientific understanding is translated via engineering and technology into products and services for the uses of society.

This report deals with the role of engineers and scientists within a changing national policy wherein technology is reoriented from military application toward greater effectiveness in meeting the needs and aspirations of American society.

In the development of our theme, and the formulation of the recommendations which are summarized below, certain considerations are of first importance.

During the long interval in which so much of our national effort has been commandeered to meet threats and challenges from outside, parts of our technology became hardened in forms inappropriate to the domestic economy. In the same interval there was insufficient opportunity to realize the tremendous potential of science and engineering for innovative contributions to the national well-being. The present need is to achieve flexibility and growth in all parts of our technology so as to realize its potential for social benefit.

Technology has flourished because it is recognized as a foundation of our economy and of the well-being of our people by performance going back to our very beginnings. Its preeminence is attributable in part to the demands which were imposed by the tasks of developing a continent. Technological change is built into our national habit pattern. A continuous stream of new developments nourishes our economic health and growth and helps support our international economic position.

Yet, this progress has faltered. The economic strength of certain industries, particularly long established, basic industries, has diminished in domestic and foreign markets partly because of lagging effort in research and development. In turn, this reflects, inter alia, neglect by executive managers; the enticement of bright young minds to fields of greater glamor; shrinkage of profit margins from which both support of research and the wherewithal for installing expensive new technologies are drawn; adverse economic developments, including factors leading to intensification of foreign competition; and expedient decisions to buy technology abroad.

Ahead lies the possibility that technologically alert industries may drift into premature aging for the same reasons, or from overconfidence, absence of close competition, or retrenchment during economic downswings. Already in prospect is a diminution in the technological dividends from the large Government defense and space programs, which have provided some industries with ready-made research and development.

An additional phenomenon also accounts for the decreasing investment in research and development in some enterprises. As technology becomes more sophisticated and based more on theory and general principles, the results of research tend to become more generic. Since this reduces the competitive advantage accruing to

the entrepreneur, it has dampened the incentive of some to invest in research and development. Thus, the general social benefit of generic results provides the rationale for public funding of such research and development.

All of these considerations point to the emerging need of a new role for the Federal Government: a responsibility for substantially increased support and stimulus for research and development in many areas of the private economy.

The stimulus to technology which we advocate must be balanced by effective forms of credible public technological assessment. Society has reached a stage of such complexity, and the impact of technology is so great and so diverse, that new technology must be closely correlated with the strategies of a mixed society with neither pure *laissez-faire* nor rigid central direction. The means of assessment must not imperil the processes of healthy technological development. It will remain essential to balance innovation and restraint, economic opportunities and offsetting social costs, beneficial accomplishments and harmful side effects, to take advantage of the tremendous spontaneity of science and engineering as focused in technology while, recognizing the growing disinclination of society to be subject to unwelcome and unexpected consequences of new technological departures, preparing the public for desirable change. There is need for public determination of scientific and technological fact as free as possible of either the actuality or the imputation of advocacy — for competent assessment credible to the public and private entrepreneurial interests.

The evident interest of the public in some form of technological assessment reflects new orderings of values in our society. There is a tendency to regard these changes as imposing severe restraints upon scientists and engineers. There is an opposite view that the new order of values opens new horizons for the scientist and the engineer by bringing criteria of social desirability into better balance with economic constraints.

In advocating new Federal encouragement and support for technology, we recognize the necessity of maintaining at full strength support for basic and exploratory research in science and engineering. Federal programs in this field, notably those of the National Science Foundation, expand the vital "knowledge base," thus providing options for technological advance. Failure to maintain those programs would be partially to defeat the purpose of

augmented effort in support of research and development in technology.

Beyond the technology mentioned thus far, largely that generated in industry, there is a class of technological research which society needs but which is not pursued with sufficient vigor with only a market stimulus. Many of these technologies relate to the performance of public services. Fire protection, waste collection and disposal, and noise control are examples. The incidence of such needs typically is localized, but they add up to large national problems. Their financial cost represents, as well, an economic burden running into many billions of dollars in the national aggregate. These is no question that this burden can be significantly reduced by improving the technologies involved. Federal support for such progress is clearly appropriate, and both Federal and State efforts to help in aggregating markets and to effect broader and more rapid technology transfer are desirable.

An important aspect of our times is the rising awareness of the size and complexity of problems which have arisen in our society. Fortunately at this juncture there are emerging highly promising, sophisticated new methods for analyzing them, particularly systems analysis, computerization, and the mathematical simulation in "models" of the dynamics of complex problems. This combination — awakened perception of the boundaries of societal problems and the acquisition of means of their analysis — both urges and makes possible the devising of institutional arrangements, meriting description as "social inventions," to focus on the formulation of alternative solutions, and the planning of their implementation. If this is done, an immensely constructive step will have been taken in the analysis of complex problems in their entirety, going to causes rather than going at symptoms, searching for solutions with long range validity instead of settling for short term, palliative measures.

Consideration of the role of engineers and scientists in our society makes evident a signally important reality of contemporary life: the unremitting multiplication of technological considerations in the issues concerning which the public must make decisions. As the technological components of issues of public policy grow in number and complexity, public ability to evaluate alternative courses must necessarily be severely strained.

There exists, therefore, need for an effort to enhance the public's understanding of technology and its role in our society so that we may more adequately confront the issues on which sound public judgments have to be made. The Federal Government should assume the initiative in launching programs to provide that understanding.

The summary of recommendations follows:

SUMMARY OF RECOMMENDATIONS

Recommendation I. GOVERNMENT AID IN SUPPORT OF INDUSTRIAL TECHNOLOGY

Government policy should encourage the injection of basic and applied research activity into mature industries, and the maintenance of a high level of such activity in technologically advanced industries. Page 19.

Recommendation II. TECHNOLOGICAL SUPPORT FOR PUBLIC GOODS AND SERVICES

Key technologies essential to the attainment of societal goals, but not presently commercially viable, should be continually developed, strengthened, and renewed through Government-aided research and development. Page 24.

Recommendation III. EXPLORATION OF FUTURE ALTERNATIVES

There should be established, on a continuing basis, substantial groups of full-time professionals of outstanding competence to develop the capability (methodology and manpower) to explore specific large problems of national importance, and to explore alternatives for dealing with those problems. The groups would develop alternative exploratory approaches, lay out several possible trials, and devise appropriate experiments. So equipped the decision-making institutions of our country may better guide its future. Page 34.

Recommendation IV. PUBLIC UNDERSTANDING OF TECHNOLOGY

The National Science Foundation and the Office of Education should as a matter of long range concern seek to promote the

teaching of the principles and nature of technology at all levels of formal and informal education. The existing NSF program on Public Understanding of Science should undertake, within its existing field of responsibility, efforts to enhance public understanding of technology and how it differs from science. The Federal Government and industry should mount parallel efforts to convey that understanding through channels outside the classroom. Page 40.

Recommendation V. TECHNOLOGY ASSESSMENT

There should be formed in appropriate agencies, including the National Science Foundation, or as separate bodies if need so dictates, groups responsible for the long range analysis and assessment of technological systems of broad public importance. It is urgent that new capabilities be created to evaluate the societal benefits of new technological developments in advance of their wide scale dissemination and call attention to their potential hazards, undesirable by-products or side effects. Such groups should make generally available to the public information regarding comparative costs and values as a basis for decision-making in order that appropriate safeguards may be established. They could call upon all national advisory and research resources to provide the many diverse substantive skills required in assessment. Page 42.

PART I

POLICY IN SUPPORT OF TECHNOLOGY

In our society today, knowledge and discovery are attaining preeminent roles in the never-ending effort to better the human condition. Science, engineering, and technology are needed across a broadening front and in increasing measure if we are to achieve balanced growth. New discoveries in science are required to broaden the knowledge base. Strengthened and increasingly more versatile engineering is needed to extend this knowledge and apply it to human needs. Technology, the application of knowledge to practical purposes, continually guided and strengthened by research and development, must be built into our industries to keep them productive and competitive without wasting natural resources or destroying the environment, and must be adapted to new functions in meeting nonmaterial needs of society.

The discovery of new knowledge is primarily the function of science. No one can say from which of the sciences the next new transforming concepts will come. Progress in research must therefore be sustained across the board. Physics, chemistry, biology, astronomy, geology, and mathematics have enormously expanded our understanding of the world around us, from the fundamental nature of atoms and molecules to the kinds of matter and the transformations which occur in the universes surrounding us. Knowledge of the basic processes of life is rapidly expanding through exciting new successes in science, as witness those in molecular research. Knowledge of materials and how they may be put to use is increasing by dramatic steps exemplified by new understanding of the solid state, transistors, composites, and new alloys. The complexities of human behavior, including such fascinating mysteries as the learning process, are beginning to yield to systematic study.

Engineering is the bridge between science and society. New knowledge in the physical sciences and mathematics is translated through engineering into new products and services for mankind. Similar bridges with the biological and social sciences are now "under construction."

The work of engineers is, stated broadly, the translation of all available information into forms useful to man, which might mean a method, a process, a design, or a device or "object." Engineers are trained to be problem solvers, drawing upon whatever background is necessary to obtain an answer for the job in hand. This background includes scientific data and theories if they are available; and, when reliable data are insufficient, there is recourse to empirical correlations, hypotheses, approximations, and assumptions. Where more must be learned about basic phenomena to permit solution of the problem, engineers perform research.

Engineers are the keystone of our industrial structure, having the primary role in our society of generating and applying technology, and of innovating, and thereby sustaining the effectiveness of industry. They perform functions of planning and directing, research and development, design, production and operation, and consultation on technological matters. Their range of functions thus extends from basic research through production engineering to technical management. Engineers are largely responsible for the development of the technologies which have made American industry the most advanced in the world. The industrial greatness of this country rests heavily on engineering accomplishments.

Today, new engineering explorations bring new accomplishments. Biomedical engineering provides better replacement parts for human bodies. Holography is leading to sono-radiography for diagnosis. Enzyme engineering is making these unique catalysts more broadly applicable.

It is a fact of substantial importance in considering new roles for scientists and engineers that the overwhelming majority of engineers, four-fifths of them, and many applied scientists are employed in private industry, both manufacturing and nonmanufacturing. The actual number of scientists and engineers employed in industry exceeds one million. Engineers make up one of the very largest American professional communities. One of the meanings of this statistical reality is that a changing policy for technology must find acceptance and support among policy makers in the industrial sector where most of the engineers, and significant numbers of scientists, will no doubt continue to be found.

TECHNOLOGY

Technology is the science of the application of knowledge to practical purposes. Technology can be thought of as a tool, as a body of knowledge developed for a specific purpose, or as a methodology which can be brought to bear on a problem. A technical method of extracting petroleum from shale is technology, as is automated production of engine blocks, or the use of the basic oxygen process in making steel.

Each field of engineering has characteristic technologies it develops, explores and utilizes. In chemical engineering these include chemical transformations in the making of synthetics, polymers, and plastics; separation processes such as distillation; and the design of chemical plants, including automatic control. Civil engineering uses the technologies of building design and construction; and hydrology and hydrodynamics, involving the flow and fall of water, droughts, floods, and runoff.

Much of the promise of progress in technology grows out of the acquisition by today's scientists and engineers of powerful new tools, such as the systems approach and computers. Developed for use in strictly technological problems, they are proving to be increasingly more helpful as wider applications are explored, and perfected, and are being adapted to the study and analysis of at least some of today's socio-technological problems. Possessing what only quite recently seemed incredible capabilities in speed and in mastery of complexities, they have brought into the realm of the possible many tasks formerly regarded as impossible because of the time and aggregations of brain power required to achieve a successful result. The computer, properly employed, can help in any situation requiring analysis of complex interactions. Used as an auxiliary in the modeling of problems, it can provide insights into the consequences of an almost limitless variety of changes in cause-and-effect relationships within them.

Different fields of technology vary in the extent to which they utilize science. In the newer fields, such as aerospace, communications, integrated circuits and electronic industrial process control, technology is closely coupled to the basic sciences, and applicable new science is translated into engineering terms soon after it is generated. In some older fields, such as metal processing and building construction, the science-engineering relationship is

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more remote, and new science enters into the technology, if at all, only with difficulty and after a lapse of time.

The requirement for science varies with differing technologies; and, inasmuch as technology predates science, clearly there was a long interval of human history when technology's base in science was minimal. From the earliest times, man has used observation and ingenuity to shape tools, make pottery, mine metals, and construct roads, bridges, and buildings. This was done, and on the whole done well, by trial and error, hypothesis and experiment, with no scientific idea why the materials behaved as they did. Metals were refined for use without the chemical knowledge that metal oxides were being reduced by the removal of oxygen. This kind of technology evolved through more advanced stages such as those embodied in the Industrial Revolution, the work of Samuel F. B. Morse, Thomas A. Edison, and Alexander Graham Bell, and indeed the "practical arts" characterizing some industries even today. But increased knowledge of science has brought increased infusions of that knowledge into technology, and at the very least may be said to have brought the trial and error process to a higher level of sophistication or a lower level of empiricism.

TECHNOLOGY AND INDUSTRY

Apart from actual requirements, industries vary widely in their individual attitudes toward science and technology. Some have been solidly science based from the outset. Their managements, often technically trained, have a keen perception of how tightly their fortunes are "skewered" to further scientific advances. Some industries, once science based, have as they matured lost contact with the results of recent research, have failed to innovate, and have become obsolescent. Some are content with relatively unsophisticated technology built up by experience and practical art. All are, or ought to be, important elements in the economic strength of the country. A few examples will illustrate.

Mineral extraction technology grew in sophistication as long as the mining industry both supported the associated research and development and continued to offer employment to engineers graduating from the mineral industries departments of engineering colleges. As this industry decreased its proportionate investment

in research and development, and as the greater interest in new sciences and technologies drew the bright technical minds away, the associated departments in the engineering colleges dried up, and the technology soon stagnated. The electric power industry has had a somewhat similar history, although it now enjoys some revival because of critical shortages and the environmental challenge. Of course, in both cases there has been competition from new, rapidly growing industries like aerospace and electronics, offering more glamorous careers to the graduating engineers.

The chemical, synthetic fibers, and petroleum industries, on the other hand, have succeeded better than power and mining in maintaining a reasonable balance between research and development and the other functions of the industry. Their technologies have become more sophisticated as the industries have matured.

Recent examples of new technologies closely associated with science are nuclear energy, transistors, integrated circuits, and lasers. These technologies are already the basis for the modern electronic industries, yet they were made possible only by advances in solid state physics within the last two to three decades. The time delay between the gain of new knowledge from physics and its development into major engineering technology suitable for industrial exploitation was only a few years. The work of the physicists and electrical engineers was also much closer in content to the resulting technology than was the case with earlier inventions.

Research and development, whether performed in universities or industrial laboratories, often lead to technologies of increased vigor. Much new technology results from the gradual accumulation of small gains in science, rather than from scientific breakthroughs on the scale of that which underlies the laser.

TECHNOLOGY AND THE FEDERAL GOVERNMENT

Within the last 30 years the Federal Government has become a major factor in the development and evolution of technologies, directly by funding of academic and industrial research and much development as well, and indirectly by building up the industries to produce vast quantities of material. For the past two decades, approximately one-half of the total industrial research and development spending has been funded by contracts from the Federal Government (see Appendix A). Major industries involved are

aircraft and missiles, electrical equipment and communication, chemicals, motor vehicles and other transportation equipment, and machinery. Total industrial research and development spending by Government and industry together had risen from about $4 billion in 1953 to an estimated $18.3 billion in 1971. The Government has underwritten this in order to carry out its own clearly defined missions and responsibilities for needed advances, particularly in space, defense, and atomic energy.

Another important contribution of the Federal Government to a new science-based, high technology industry is made when the Government exercises its role as the first and biggest customer of the new industry.

Among the Federal contributions, in addition to the evolution of some technologically advanced and sophisticated industries, such as computers, aircraft, and electronic instruments, have been spin-offs of major proportions. New technologies — ranging from semiconductor technology, integrated circuits, and advanced computer capabilities to improved communications and transport aircraft — have been widely applied in other industries.

These advanced technological industries are tomorrow's mature industries. In the process of maturing, a number of our earlier industries have underinvested or gradually reduced investment in technological research and development. The Nation should be forewarned not to let this deterioration affect currently maturing industries.

PROBLEMS OF MATURE INDUSTRIES

The mature industries in the United States (e.g., mineral extraction, primary metal processing, basic chemicals, paper, glass, machine tools, cement, brick, and building materials, construction, motor vehicles, and rail transportation) are the economic backbone of this country. Only if most of these industries continue to be successful can this Nation have a strong economy which, in turn, can sustain important societal programs.

If a mature industry turns stagnant for any one of several reasons, including a failure to remain strong in its research and development, it cannot contribute well to a strong economy.

In considering reasons for letdown in research and development, the general observation seems valid that, as technology becomes more sophisticated and based more on theory and general principles and less on empiricism, the results of research, and even of development, tend to be more generic and therefore less uniquely appropriable by the particular organization making the original investment. What this means is that the private returns of research and development tend to go down, even while the social returns of research and development are going up. As a result the incentives acting on the individual firm become weaker. Consequently, the more efficient and productive research becomes from the social point of view, the more individual firms will tend to underinvest in research because it benefits their competitors as much as themselves. This contributes to the rationale for public support of industrial research and development.

Research and development provides flexibility and leads to growth. It is a necessary step in the development of new technology, and of key importance in the innovative process leading to new products. A growing and more affluent population requires new technology and needs and wants new products of many kinds. The economic constraint on engineering design is still with us and will be a major factor for years ahead. A reconciliation of the need for improvement with acceptable cost must be made with respect to products for which demand exists throughout our society, including construction materials, automobiles, and home appliances. As one illustration, homes constructed with more effective built-in insulation would be more comfortable, quieter, cheaper to heat in winter and to air condition in summer, and generate less pollution from both heating and cooling.

Higher efficiency and productivity in our industries, which can be one dividend of research and development, can help to free a larger fraction of our total resources for the tasks of solving pressing societal problems. Only a productive and flourishing American industry can provide the strong tax base needed if the Government is to underwrite costly programs of social gain.

In response to new emphasis on "the quality of life," many products will have to be reengineered for improved durability, safety, and environmental "cleanliness." Because meeting these new criteria will mean added costs for the producer, conventional

products must be made more efficiently to provide offsetting economies.

Technological obsolescence in production is considered by some to be a factor in the decreasing economic viability of certain American industries in international markets, and in competition in domestic markets with products from abroad. Michael Boretsky of the Department of Commerce has classified the manufacturing industries as "nontechnology intensive" and "technology intensive," depending on the ratio of research and development to sales and the ratio of technological manpower to total employment.[1] These factors are more closely related to the rate of generation of technology than to the "intensity" of technology employed.

Trends in imports and exports within these categories are shown in Appendix B. Many of the mature industries — or, more accurately, industries employing mature technologies — fall within the nontechnology intensive classification (i.e., steel, textiles, paper, nonferrous metals). In many of these cases, there is much evidence to suggest that an infusion of basic and applied research and development could substantially improve the competitive position of these industries.

In some cases industries and their leaders have deliberately held down investment in research and development. Again, certain of the same mature industries would rather rely on trade barriers than have the Federal Government assume a greater role in the stimulation of their research and development. It is essential, however, for our national well-being that the Government and these industries, as a joint responsibility, take the proper steps to insure their continued technological growth. If first-class technical minds could be attracted to those industries which are a substantial component of our economy but are facing technological obsolescence, rewarding results could be confidently expected. Such minds will be attracted, as a minimum but not necessarily in itself a sufficient condition, only if research and development opportunities are increased.

It is recognized that technological advances alone are insufficient and that economic rearrangements and legal questions are involved as well.

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[1] *Technology and International Trade,* Proceedings of the Symposium Sponsored by the National Academy of Engineering at the Sixth Autumn Meeting—October 14 and 15, 1970.

NEEDS OF ADVANCED INDUSTRIES

For much the same reasons as those applying to mature industries, we must also insure that the advanced technology industries, such as computers, aircraft, and electronic instruments, maintain their flexibility and growth potential.

Within recent decades, particularly since World War II, we have seen the development of those strongly science-based industries in which research (basic and applied) has been from the outset integrated into the organizational structure. These industries are characterized by the systematic development of applicable new technology from research, e.g., industries concerned with polymers and plastics, electronics and lasers, chemicals and synthetic textiles, aerospace and communications. By keeping very close to the pertinent science and by applying a large volume of resources in engineering manpower and facilities to their technological goals, these industries have achieved a veritable explosion of new products and materials. Thus a direct and immediate relationship between science and technology, deliberately introduced by these industries, has paid off heavily in economic growth and productivity. "Technology, as we now know, is the basis of increased productivity, and productivity has been the transforming fact of economic life in a way which no classical economist could imagine." [2]

Many of the advanced technological industries fall within the technology intensive category. The overall trade balance in these manufactured products has remained steady at about $9 to $10 billion a year since the mid-1960's. The fact that the fractional surplus has decreased in the last decade is a cause of increasing concern to many people. To other observers, the faster growth rate of technological capability in some other countries and increased imports of their products to the United States are natural results of the general recovery from World War II and the fact that a lower base enables higher rates of increase. Factors other than technological advance are also important.

The range of technical spin-off into advanced industries from Government-supported missions, such as defense, may be consid-

[2] Daniel Bell, Chapter 5: *The Measurement of Knowledge and Technology*, "Indicators of Social Change," Russell Sage Foundation, 1968.

erably narrowed as new objectives emerge. For example, Government involvement in new undertakings in health care delivery will not provide as broad a field of new industrial departures. In general, it is unlikely that Government initiatives in the service industries will provide as much spin-off as they have in the goods industries.

There is a real danger that, without Federal incentives for research and development, we shall witness a spreading of technological enervation and obsolescence in industry. Special attention should be given by the Federal Government to those areas of applied research which give promise of leading to new industries but which are of such high risk or require such long term investment that single industrial groups are unable to pick up the challenge. It is not clear, to be sure, that incentives for research and development will save some industries.

The scale of the investment required for needed research is often so large that many United States industrial companies are at a severe disadvantage in competition with government-industry combines abroad.

As to the immediate future, the relationship of international trade and the success of our technology is of profound importance. There is danger of a deterioration of trade balances in technologically intensive products, such as computers, aircraft and electronics, and also in general manufactures, such as minerals and feeds. If we are to compete successfully in the future, we must maintain a continuing tradition of technological innovation supported by a strong scientific base and engineering competence.

This country would benefit from small scale efforts — seemingly mere beginnings — as well as large ones to stimulate industrial innovation. Therefore, appropriate agencies like the Small Business Administration should continue to encourage and support ventures where technological innovation is vital. It has been found that individuals and small technologically based industries are responsible for making far more than their proportionate share of important new technological innovations. Examples of this are rockets, Xerography, the gyrocompass, the jet engine, and the Polaroid camera (see Appendix C).

We should like to point out, however, that governmental incentives intended to stimulate small technical enterprises or individual inventors are likely to cost little but may yield large benefits.

That small industries merit attention does not mean, however, that the large industries can be neglected, because they provide by far the greatest volume of the research and development which is indispensable to technological and economic progress. They also make a fair share of the important innovations. Inventions which have come out of the laboratories of large corporations include nylon, the transistor, Freon refrigerants, television, polyethylene, neoprene, Plexiglass, fluorescent lighting, and the diesel-electric locomotive.

Both large and small industries are necessary to a strong economy, although their requirements and contributions may be quite different. Among the small industries of today are some which will be the large ones of tomorrow.

NEW FEDERAL ROLE WITH RESPECT TO TECHNOLOGY

We believe that the foregoing discussion points up a newly emerging and enlarging role and responsibility for the Federal Government: that of maintaining and developing the technological base of United States society, and that of assuring the rapid translation of new knowledge into the products and services needed by the Nation and its people.

Therefore, we recommend:

RECOMMENDATION I. GOVERNMENT AID IN SUPPORT OF INDUSTRIAL TECHNOLOGY

Government policy should encourage the injection of basic and applied research activity into mature industries, and the maintenance of a high level of such activity in technologically advanced industries.

The Federal Government should encourage essential research activity through direct and indirect financial incentives on a trial basis through both traditional and new modes of cooperation among industrial, governmental, nonprofit, and academic institutions. Such activities might include, but not be limited to:

Providing financial incentives for joint applied research activities between academic institutions and industrial associations.

Providing matching funds for special cooperative efforts for applied research organized within or alongside universities, non-

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profit, and governmental installations for those industries so fragmented as to be unable to act effectively alone or in concert.

Exploratory grants and contracts are desirable immediately as much trial and error is required before large scale funding of research can be most effective. Some NSF programs in applied research might be used for this purpose. With careful management, valuable models could be provided for larger scale operation. Existing national laboratories should be utilized to the extent practicable, consistent with their areas of competence.

The Federal Government should assume responsibility to insure adequate and continuing development of new technologies to upgrade mature industries, maintain the present edge in technology advanced industries, and generate new industries.

As one way of discharging this responsibility, the missions (used in this Report in an informal rather than strict statutory sense) of appropriate agencies might be expanded to provide greater research and development capability, including support, when public interest warrants, of industry research and development.

The Department of Commerce already has responsibility for such technical agencies as the National Bureau of Standards and the National Oceanographic and Atmospheric Administration. Close liaison should be maintained between the Department of Commerce and the research components of other mission-oriented agencies including the Departments of Transportation and Housing and Urban Development.

With experience, a need may become evident for an additional center or locus of concern — such as a National Foundation for Technology — to identify areas requiring innovation and stimulation and to catalyze new initiatives (e.g., industry-wide centers of research and development, associated in some instances with universities).

Decisions as to which industries need assistance, and how much, should be made, after careful study, by those Federal agencies most concerned. The Government role should focus on but not be limited to applied research. As to development, while there may be a special burden of proof as to the Government's taking this role, there will be cases where a justification exists.

There will doubtless develop gray areas in which the Government mission is vague or controversial. Choices will be difficult, and hard decisions must be made among the possible options. The proper role of Government with respect to technology has never been more difficult to define and implement than it is today, and this task will become even more difficult as the future unfolds.

Beyond this, policy decisions will need to be made as to how far the Government should go in most areas, as, for example, in the encouragement of research and development and new technology in certain industries for the sake of the general economy. Consider industries which for one reason or another are content to import their technology or are unwilling to engage in the necessary research and development to advance their own technology. Is it not in the long range public interest that no major industry should be allowed to stagnate for this reason? It is possible that the Federal Government may be justified in undertaking initiatives in such situations, even though no Federal mission is directly involved.

Government involvement must, however, become a stimulus and a catalyst for developing continuing growth without becoming a crutch. If mechanisms can be devised whereby the Government can stimulate or initiate new research and development, especially in fields which are broadly applicable to a number of industries, stagnation can be avoided, overall productivity can be increased, and industry should be able to continually reinvest.

SCIENTIFIC AND ENGINEERING MANPOWER

The research-technology-productivity sequence will be successful only if highly trained scientific and engineering manpower is available to staff it. The educational system required to produce this manpower must be able to furnish instruction in a wide spectrum of the basic sciences and advanced engineering skills as well as to provide experience in research. Engineers and scientists must also be motivated during the educational process to take serious interest in potential contributions of their subjects to societal needs.

As national objectives shift toward societally oriented goals, engineers are heavily affected by the resulting dislocations. For

example, current technological unemployment is obviously related to changes in national priorities for defense and space. The present crisis entails dislocation and reemployment for many. One hopes that the situation is only temporary and can be resolved by a combination of measures such as retraining, centralized exchange of information on employment opportunities, and flexible adjustment among fields of science and engineering. Many of the professional societies, among them the American Institute of Physics, the National Society of Professional Engineers, and the Institute of Electrical and Electronics Engineers, are taking active steps in these directions. There is a responsibility on the part of Government to do its utmost, on occasions of major shifts in priorities, to make provision to cushion the impact upon persons affected by consequent changes in employment patterns.

The science and engineering manpower situation has changed rapidly from one of chronic shortage to apparent surplus, at least in certain fields. The immediate job market is confusing, influenced as it is by changing factors such as Federal budgetary cuts, transitory business recessions, and inflow of technical manpower from abroad. Long range manpower forecasts are somewhat more reliable because they depend on population trends and estimates of economic growth. Some authorities (Reports of the Engineers Joint Council, also article by Wallace Brode in *Science*, July 16, 1971) suggest that shortage rather than surplus of technical manpower may characterize this century from the late 1970's or early 1980's on. This is most likely to occur if the Nation continues strong in technology, and particularly if it really works at finding solutions to its societal problems.

None of the projections has attempted to take account of the employment requirements for attaining an improved social structure, enhanced quality of life, or strengthened technology. Considerable redistribution of scientists among fields may be expected to occur, and if fewer may be employed in graduate education, more may be needed in other roles. If this Nation were not to produce enough scientists and engineers to carry forward our "knowledge society," our national life would suffer with respect to standard of living, competitiveness in world markets, national security, and, most serious of all, manpower resources for coping with our socio-technological problems.

TECHNOLOGY FOR PUBLIC GOODS AND SERVICES

We have discussed what we see as a newly emerging role for the Federal Government for continuing analysis and strengthening of technology in the private sector of the economy. We believe there is emerging also a comparable role for the Government with regard to that technology which applies primarily to the public sector.

The national economy is rather rapidly approaching what is sometimes described as a "postindustrial" phase. Thus, there is occurring an economic transition in the sense of moving from a manufacturing-intensive to a service-intensive national economy. At present, for example, approximately two-thirds of the employed labor force are in the service sector (including education, health care, recreation, the professions, and clerical functions). The service sector also includes goods "purchased" collectively (e.g., clean air and water, fire protection, civic order). Housing and urban mass transportation are other examples of services that benefit individuals but are believed to have sufficient "external benefits" for society to be publicly subsidized. But "productivity" in almost all these areas has lagged behind productivity in the manufacture of capital and consumer goods for the private market. The need for injection of existing and advanced technology in the production of public goods and services is substantial, but obtaining the transfusion is made supremely difficult by a common characteristic — a market large in the aggregate but composed of a multitude of small, scattered pieces. Thus, Federal policy should be increasingly directed to improving the productivity in these fields and establishing objective criteria of performance.

The opportunities for applying existing technologies and developing new ones in the public goods and services sector are enormous, examples being housing, transportation, and health care. Further discussion of those fields occurs in Part II and includes consideration of their interrelationships as themselves constituting an area in which technological approaches can be helpful. Another kind of example is presented by the need for research and development on the causes and prevention of fires, and fighting fires.

There are other areas where public needs could be met by technology which already exists or would not be difficult to acquire, but where at present the profitability to private firms is ques-

tionable. In other words, there is no present commercial market to pay for the development of the technology, but the stakes for society may nonetheless be of great importance. An example is earthquake engineering. Under a National Science Foundation program, data are being acquired which should lead to design of economically feasible shock-resistant structures in earthquake zones. This program also involves the development of means of assessing seismic risks, and study of the social and economic aspects of earthquakes.

This discussion, in our opinion, points to a need for considerably greater governmental support in those areas where research and development may otherwise be expected to lag for want of cohesive concern or hospitable environment.

Therefore, we recommend:

RECOMMENDATION II. TECHNOLOGICAL SUPPORT FOR PUBLIC GOODS AND SERVICES

Key technologies essential to the attainment of societal goals, but not presently commercially viable, should be continually developed, strengthened, and renewed through Government-aided research and development.

Some of these problems would be more appropriately dealt with by state or municipal government elements, but the Federal Government should provide leadership through initiatives, incentives, and setting of standards.

This responsibility for the stimulation of technology primarily associated with social needs may be met in part by expanding the missions of existing Federal agencies and particularly by substantially strengthening their research and development capabilities. With few exceptions, these agencies now concentrate on relatively short term, quick-payoff projects. A much stronger commitment is needed to enable them to build longer range research and development capabilities in their areas of responsibility, to which universities as well as industry may contribute. The full spectrum of research and development is required, looking toward exploration of alternative possibilities. The commitment should be on a scale to solve the problems.

PART II

POLICY FOR TECHNOLOGY IN SUPPORT OF SOCIETY

Part I advocated the enlistment of public support for development of new technologies for private and public goods and services. This chapter discusses the means of enlisting technological support in approaching broad societal problems.

There is now occurring a clear-cut transition in our society's approach to technology: in its development by engineering and science, in its deployment by the private sector, and in its support and utilization by the public sector. This transition is exemplified by a movement from the long-time predominance of our concern with industrial technology and the technologies of war and cold war toward a concern for a heightened and broadened use of technology in solving the problems and meeting the needs and desires of society. Profound adjustments are under way, in response to radically new patterns in society's desires as to what its technology should do and to the sometimes abrupt decisions as to what technology should not do. This is a period in which a new relationship must be developed between the American society and the technology which pervades so much of its existence. The ultimate nature of this relationship is a major issue to which a public policy for technology must be addressed.

The development of new social attitudes toward technology presents new challenges and opportunities for technology. Environmental and aesthetic requirements have been given new stature comparable to that of the traditional economic constraints. Developments which were undertaken in good faith under one set of considerations are being judged by new criteria, and years of conscientious and honest effort are suddenly condemned and suppressed on grounds which few could have anticipated when the initial development was undertaken. But once this time lag of technology behind society (the opposite of the conventional wisdom) is understood, it seems clear that the new criteria increase rather than decrease the technological options available. Hosts of technological opportunities which were excluded years ago for reasons of uneconomic competitiveness or the preferences

of society suddenly become open for reevaluation (e.g., electric automobiles, coal gasification, high-speed trains). Thus, from the standpoint of the engineer, previously restrained by narrow economic criteria, new ground rules which everybody must meet greatly broaden his opportunity and enhance the importance of his role. Suddenly, many different types of automotive power plants have to be reassessed. New methods of generating and transmitting electrical energy have to be studied. Hundreds of empirically honed industrial processes are suddenly up for reexamination from a more searching and analytical viewpoint. Thus, the commitment to problem solving, which is inherent in engineering, has the beneficial consequence of transmuting requirements into incentives and, thus, challenges into opportunities. There can be justifiable confidence that from just that process of transmutation there will be derived effective new technological performance in meeting the needs and desires of society. The forecast is optimistic, not pessimistic.

But it is realistic, not pessimistic, to acknowledge that the new pressures are powerful and as moving forces have developed great momentum. It is realistic, not pessimistic, to recognize that, in the absence of a public policy for technology within which the constructive potentials of these forces are accepted and given their legitimate functions, the consequences to technology could be damaging. It is as important to society as to technology, for example, that their evolving relationship leave room for the play of those faculties of innovation, intuition, creativity, and on occasion sheer genius, which always have so much to say about where the leading edge of technology is located.

Many of the problems facing us today are the result of the increasing size, complexity, and affluence of our society. Over the last 30 years, during which time our population has increased by 50 percent, the population of automobiles has increased by 350 percent. In 1940 the automobile was considered to be no more a source of pollution than the horse-drawn wagon which it displaced. Over the last 50 years, during which time our population has doubled, our requirements for energy have quadrupled. Today our scale of use is so large that the by-products of energy utilization are noticeable and significant. U.S. per capita energy consumption now is about a million BTU per day, enough to boil 125 gallons of water for every American each day. For every

calorie we consume as food, 80 calories must be expended to provide the goods and services we require. But, on the other hand, to achieve our standard of living in a technologically primitive society would take well over 80 servants for each man, woman, and child.

There is one car for every two Americans today, not in spite of society's desires, but because we continue to buy them and to depend on them. Nor is our vast energy consumption counter to society's desires for air conditioning, washing machines, and the like. If we have failed at all in our utilization of technology, it is because we have overlooked or neglected to look at long range consequences prior to widespread development and use.

As the size of our society has grown, so too has the complexity. We now appreciate that energy, resources, population, and environmental quality are all interrelated elements which cannot be dealt with individually and independently. Similarly, transportation, housing, health care, education, and communications are all elements of the broader urban and regional system, to be dealt with in the totality of the living environment. A program aimed at one element can have subtle repercussions in other sectors; programs aimed at symptoms rather than causes may be ineffective or even detrimental.

The large systems to which we refer present major and seemingly intractable problems. The effort required to examine them in their totality is so vast and the time required so long as to discourage the attempt, at least up to recently. In the near term, we shall continue to formulate programs aimed at solving portions of these problems. But the question is whether we can continue to do so without exploring on a large scale the long term consequences and opportunities of our near term actions.

EXPLORATION OF SOCIETAL ALTERNATIVES

Above the clamor of the ongoing debate to define the "quality of life" and to develop programmatic specifics to improve it, there can be ready agreement on a number of broad societal purposes of a long range nature. For example, we would all like to see:

A living environment conducive to the development of present and future generations. For at least the remainder of this

century, this environment for an overwhelming majority of Americans will be urban-suburban complexes which are interrelated in regional patterns.

Job opportunities in concert with the capabilities of the population. To reach and sustain full employment, we will require 35 to 45 million new jobs over the next three decades. These must offer not only attractive careers in performing skilled functions to an increasing number of college-educated young, but attractive opportunities in unskilled and semi-skilled employment for those who do not attain high levels of education or training.

Continued enhancement of the standard of living. In addition to making more broadly available in the population the goods and services now largely within reach of only upper incomes, it is essential to provide better education, health care, and housing for those at the lower end of the economic spectrum. Continued enhancement of productivity, especially in the service sector, is required to meet this need.

Balanced international exchange of knowledge, goods, and services. As we continue to help developing nations, we must also compete effectively with the increasing number of developed nations while seeking to move toward the elimination of restrictions in the international exchange of knowledge, goods, and services.

Enhancement of environmental quality and preservation of natural resources. In addition to continuing the effort to achieve and maintain a cleaner physical environment, we must face the fact of limits on the earth's resources, and recognize that exhaustion of a resource narrows the choice of options of future generations.

The means of attaining each of these goals includes a high technological component and each, therefore, presents challenge to the engineer and scientist. The order of priority which society chooses for undertakings of such magnitude will deeply influence the future directions of technology in all its aspects.

It is not supposed that such goals can be reached quickly, or even that major efforts can be made simultaneously with respect to all of them. The resources required to eradicate slums or repair our environment overnight simply are not available. We do not

have adequate mechanisms to reeducate or retrain rapidly people displaced by foreign competition or changing priorities. To develop fully the techniques, facilities, and personnel to upgrade health care services will require many years of extensive effort. Thus, in the near term, trade-offs must be made. At present, Government is so beset by immediate problems and crises that too little time and energy remain to devote to longer term opportunities.

On the other hand, we do have sufficient flexibility in the long term to bring the objectives stated above into concert with one another. We should seek the rationale for turning short term conflicts into long term opportunities. For example, let us strive to develop job opportunities in goods and services which will aid in renewing our cities *and* increasing our exports. Let us strive to develop educational patterns which will permit displaced workers to *upgrade* skills to more productive job functions.

The problem of urban and regional development, as an example, illustrates two concepts which have special importance in following the labyrinthine path toward the goals just stated. One is the recognition of the interdependencies and interrelationships among different categories of activity in society which have tended in the past to be viewed as separate problems, their internal dynamics insulated in each case from the others, but are now perceived more and more clearly as parts of larger entities, the "systems" referred to before. The other stresses the need for avoiding to the extent possible, in dealing with immediate problems, measures which later might interfere with progress toward broad and sustained fulfillment of our society's aspirations. First aid is often an inescapable requirement, but its consequences must not be detrimental to the restoration of full well-being.

The continuous process of reviving and renewing our cities and their environs is a problem which illustrates the need for exploring the long term as a guide to near term action. It is also a field of opportunity in which technologists can make significant and varied contributions.

An urban area or region can be viewed as a complex pattern involving the interchange of goods and services which are needed

or desired by its inhabitants. These goods and services include, but are not limited to, the following:

- Housing
- Transportation
- Employment opportunities
- Education
- Health care
- Public safety
- Power
- Environment
- Communications

In the past most sectors of society — academia, industry, and government — have been compartmentalized along the lines of these categories in order to organize and direct efforts to deal with them. In the process we have traditionally reacted sequentially to those sectors which appear to present the most pressing problems. But as our cities and regions have become more complex, we have begun to appreciate the interdependencies of the various components. Traffic congestion is not due simply to inadequate roads, but is partly the result of high population density and large distances between homes, stores, and jobs. Crowding cannot be relieved simply by high-rise housing without taking into account the socio-economic processes which generate incentives for rural-to-urban migration. Urban poverty does not present simply a humanitarian obligation to be met by welfare and higher taxes, because the mismatch between people and jobs will be worsened by rising taxes and the resulting outward migration of industry and the wealthy and inward migration of the poor.

Thus, it is clear that the components of urban life are interrelated in a highly complex *system*. If one part is modified, other parts are affected. Decisions must be made in terms of the total effect rather than of partial ones and made with some understanding of long term consequences.

By the same token, the suburban-urban complex is part of a larger regional system whose components must be viewed in proper perspective. For example, transportation systems can no longer be viewed as a dependent variable to be based on only *10 to 20 year* projections for housing, industrial sites, educational and health care facilities, and so on, because, once built, a transportation system can have a powerful effect on placement of

housing and other structures for the next *50 to 100 years.* The magnitude of the investment required for a transportation system greatly reduces the flexibility for future options in other subsystems. Thus, transportation options for the distribution of goods, services, and people must be based on *long term* analysis of potential placement of homes, jobs, schools, hospitals, etc. Alternatives to direct transport of people — such as two-way cable TV for shopping or for conferences — need to be explored as options to new roads. The environmental impact of roads, highways, and motor vehicle power plants must be considered. Furthermore, alternative transportation systems which may not appear feasible by today's standards require research on a continuing basis so as to enhance future flexibility.

Similarly, an analysis of new methods of providing health care — the costs, benefits, availability, and utilization — must account properly for the interfaces with other components such as communications, education, and environmental quality. Advanced communication systems offer numerous opportunities for remote diagnosis and information retrieval; new educational programs are necessary to foster public acceptance.

There are numerous other examples which attest to the need for a concerted view of our complex social system. The engineer trained in systems analysis can make significant contributions to the understanding of long term consequences and future opportunities within such a system. In the 1950's and 1960's engineering methods such as systems analysis and technological forecasting were developed with a view to refining decision making to improve the effectiveness of research and development in the defense and aerospace fields. Although those developments represented a major innovation, their proponents perhaps sought to extend their use too rapidly into fields beyond those purely technological, involving nonscientific value judgments. But as more and more social and behavioral scientists participate in their development, these methods will undoubtedly reach high usefulness in the analysis of social systems and the development of strategies for coping with societal problems.

Over the last few years, there has emerged a serious attempt to apply the systems approach to complex social problems. It is termed systems dynamics and is an outgrowth of the established and successful approach to analysis of industrial dynamics. The

technique involves development of models which represent the motivation and behavior of groups of people and institutions. For example, migration to an urban area is related to the perceived "attractiveness" of that area relative to other locations. Components of attractiveness involve job opportunities, housing availability, and kindred factors. An effort is made to quantify these elements. The dynamic behavior of the model is simulated on a computer.

The systems dynamics approach is in an embryonic stage. Models developed to date are regarded as naive and incomplete. But it represents the beginnings of a framework — a way of organizing information in an analysis so that we can properly account for multivariable interactions and interdependencies. An intensive effort is needed to refine models and quantify parameters such as social values.

There have been many criticisms of the systems approach to societal problems, notably from social and behavioral scientists themselves. The translation of usually nonquantified values (such as aesthetic, behavioral, or cultural choices) into numerical units for ease of application to computer usage generally has not been very successful. The "pseudo" cost-benefit analysis derived from this process has been invalid more often than not. However, we must navigate these areas of ignorance if we are to convert our thinking on societal matters to more effective forms. The entire value-methodology process is an area in which large scale research and development appears to be warranted, and the social and behavioral scientists should be encouraged to participate with engineers in this pursuit.

The lack of adequate knowledge and methodology should not be viewed as an insurmountable barrier to developing models in the systems context. Jay W. Forrester, a proponent of systems dynamics applied to social systems, presented a forceful argument for the use of models in testimony before the Ad Hoc Subcommittee on Urban Growth, House Committee on Banking and Currency. His point is that we all use models constantly for decision making. Any mental image of the world around us is, in a way, a model in which selected concepts and relationships are used to represent the real system. "All executive actions are taken on the basis of

models. The question is not to use or ignore models. The question is only a choice among alternative models." [5]

Complex systems have many special and unexpected responses which cause many of the failures and frustrations that are experienced in trying to improve their behavior. What may intuitively seem appropriate to a situation may actually be the wrong approach; cause and effect may not be closely related. The cause of a difficulty may lie far back in time from the symptoms or in a completely different part of the system. One may find a plausible cause near in time and space to the difficulty, but sometimes the apparent cause is only a coincident symptom moving in time with the problem. There is the possibility that a symptom is treated and not a cause, with an outcome which lies between ineffective and detrimental. The conflict between short term and long term consideration is another contributing factor. Very often the actions that seem easiest and most promising in the immediate future can produce even greater problems at a later time.

These considerations — to overcome "counterintuitive" obstacles, to avoid the pitfalls of the "quick fix," and to avail ourselves of the benefits of long term opportunities — lead toward Recommendation III which calls for a major effort to *explore* future alternatives to define the options, opportunities, dangers, and costs. Required is an integrated and orchestrated examination of the problems and opportunities within every component of the complex societal system. The exploration must be comprehensive; it must be multidisciplinary in the academic sense — involving technological, economic, sociological, and political viewpoints — and in the broader sense of involving public and private institutions and representatives of major groups of society.

Exploration is vital to define an expanded range of alternative opportunities and make them as specific as possible. The search for objectives implies a new approach that would systematically attempt to relate problems emerging from new societal demands to actual and predictable techno-economic possibilities. It is no easy task — indeed, many doubt that even the best minds are up to it — but there appears to be no other way. Hence, the effort must be made, and immediately begun, to develop the techniques and capabilities that will be necessary.

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[5] *Hearings*, October 7, 1970.

Specifically, this recommendation is offered:

RECOMMENDATION III. EXPLORATION OF FUTURE ALTERNATIVES

There should be established, on a continuing basis, substantial groups of full-time professionals of outstanding competence to develop the capability (methodology and manpower) to explore specific large problems of national importance, and to explore alternatives for dealing with those problems. The groups would develop alternative exploratory approaches, lay out several possible trials, and devise appropriate experiments. So equipped the decision-making institutions of our country may better guide its future.

Initially, the energies of these groups would be concentrated on achieving as a first product the required development of capabilities, methodologies, and manpower. In the long term, with the aid of this process, our Nation would be better equipped to establish priorities and implement national goals.

The immediate formation of three exploratory groups is suggested, each to concentrate on one of the following clusters of major problems:

A. *Urban and Regional Design.* It would be the responsibility of this group to develop a flexible methodology for understanding the dynamics and interactions of urban and regional systems, the results of which could be applied to specific localities; to identify and develop means of quantifying parameters describing social values and societal aspirations; and to develop strategies for local economic, legal, and political arrangements, which can provide incentives for long term enhancement of the living environment. The explorations of methods and of courses of action would seek to embrace all major elements or subsystems such as housing, transportation, health care, education, communications, and the like.

B. *Resources, Environment, and Population.* The responsibility of this group would be to develop methods for understanding and beneficially influencing the impact of man upon the environment and of the environment upon man; to develop an expanded knowledge base of the subsystems of air, land,

water, energy, and life that surround man; to establish, for varying levels of population, the relationships of resource limitations and pollution generated by man's activities to the quality of human life, and to evaluate how technological advances may modify those relationships.

C. *The Techno-economic System.* The explorations of method and action by this group would seek to define the relationship between research and development on the one hand and innovation on the other and, in turn, between innovation and productivity; to assess the distribution of employment activities necessary to support progressively more satisfying standards of living; and to explore the educational patterns needed to match work with intellectual capabilities and psychological needs.

The size of these bodies would be commensurate with the size and complexity of the problems. It is anticipated that the scope of the problems, as described above, may be redefined in the process of formation of the exploratory groups or at a later time. We realize that there are significant interrelationships among the components of these three tasks; they are all elements of our "national system." The suggested clusters represent an attempt to define major subsystems for which broad, mission-oriented objectives can be defined. It is recognized that a group might, when desirable, "subcontract out" subsets of the work to any institutions of the required capability. In some cases, there might be recourse to an existing Federal agency possessing the in-house capability to deal with a problem of major dimensions.

In the exploratory stage, the need for dedication to the public interest cannot be overemphasized. Objectivity with a minimum of interest-group bias is essential to insure responsiveness to the best interest of the public. Thus, exploration should be protected from direct "pressures" from any sector of society, including those resulting from the periodicity of the political process. On the other hand, feedback from the Legislative and Executive Branches is essential.

It is essential that the exploratory groups work closely with existing and any new institutions or agencies which are concerned with important elements of these massive problems.

It is specifically intended that existing agencies should be enabled to strengthen themselves to the point of possessing in-house

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capability to perform research and development in behalf of the exploratory groups, or obtain it outside by contract.

Although the comparison is less than exact, such agency functions would resemble that of the Advanced Research Projects Agency (ARPA) in the Department of Defense.

The results of techno-economic exploration would be expected to contribute to an understanding of the innovation process and, thereby, aid existing and new institutions concerned with setting priorities for Federal support of applied research for technology.

Coupling the exploratory effort to the public sector is also essential. Provision should be made for periodic reports to the Nation to stimulate widespread and intensive debate.

It cannot be predicted in advance when such exploration will yield insights pointing the way toward new applied research directed at concrete solutions or which may indicate reformulation or reorganization of initial objectives. It will be necessary to wait, recognizing that this is the inherent nature of the exploratory process. There will often be temptations to proceed on the basis of incomplete data and partial insights. These temptations sometimes must be followed and other times rejected.

Although the exploratory groups would be expected to propose methods of implementing each alternative, their responsibility would not extend to selecting the options for implementation.

Their main function would be to develop methodology and manpower, and to put forward a menu of alternative solutions from among which choices can be made by the established decision-making processes of Government. Choosing options for implementation must remain the responsibility of the citizenry as a whole, acting through their elected officials. In no way should the exploratory groups impinge on the sovereignty of the political process as the means of establishing priorities.

The strength of the free enterprise system shows up most forcefully in the implementation phase. In many respects, institutions already existing in this country may be well equipped to handle implementation when exploration has been completed and choice of alternatives decided. Once the requirements for implementation are established, the conventional market forces and the free enter-

prise system may be expected to operate effectively, as they have in the past.

THE INTERFACE OF TECHNOLOGY AND SOCIETY

Just as the scientist and engineer must take greater cognizance of the emerging social requirements of technology, there also should be greater emphasis placed on public understanding of technology. As the ultimate decision maker in our society, it is necessary for the public to appreciate what technology can do and what it cannot do; what it must do and what it must not do.

A critical factor in trying to anticipate potential dangers of a new technology is knowledge of how the technology will be deployed and what safeguards will be instituted to control its use. In many cases, there are legal and economic arrangements — at the discretion of society — which govern the availability and control of technologies. These have been referred to as the *supporting systems.*[6]

Whereas the automobile and road building are technological developments, the supporting systems include rules of accident law, automobile insurance schemes, traffic police, and policies to determine where roads should be built.

Long range analysis might have led on past occasions of important decision to choice or encouragement of different technologies (e.g., bioenvironmental pest control rather than chemical insecticides); however, the engineer alone has not had the background to predict the types of supporting systems society would devise to govern the use of technology. In a large number of cases, if not most cases, a higher sophistication in societal decision-making processes might point to different supporting systems rather than different technologies. These might include, for example, different revenue sources for the television industry, different cost-accounting procedures for pollution, or different formulations of building and zoning regulations.

Along with the lack of analysis and forecasting, a factor which has contributed significantly to the abuse of technologies is the

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[6] *Technology: Processes of Assessment and Choice,* National Academy of Sciences, July 1969.

scale of use adopted by society. Prime examples are per capita consumption of energy, pesticides, and automobiles. Sixty years ago it would have been simple to predict that the internal combustion engine would chemically pollute the atmosphere more than steam or electric engines, but few would have predicted that in 1970 there would be one car for every two people. Since the number of horse-drawn carriages was small in relation to the population, it is unlikely that more than a few prophets would have foreseen the scale of use of the "horseless carriage." Similarly, over the years there have been periodic predictions of per capita energy consumption and, in almost every case, it was hypothesized that consumption would level out after ten years. After all, how much more energy could we consume? And yet, consumption continues to rise at a steady rate.

In the future an endeavor must be made to assess more accurately the potential scale of use. In striving to enhance the standard of living of the entire population, it might be anticipated that everyone will want and be able to afford "a good thing." If there are upper limits to the scale of use beyond which a good thing is harmful, we must devise equitable means for limiting its use, or find alternatives to satisfy the function or need. Although our society has been reluctant to "ration" supply, in many cases it may be the only alternative to the development of a national consensus for limiting population.

The previous subsection discussed the need to develop a process for exploration of future alternatives. A beginning must be made now in providing the public with sufficient background to make rational choices among such alternatives. It is not suggested that people at large should be taught how to do engineering. There is need, however, that they be given a grasp of some basic concepts and the process by which association of various observations produces an idea. For example, to generate electricity, a fuel must be consumed and, thereby, *a resource depleted;* waste-heat generation and the need for its disposal at a power station using a heat cycle is a fact of life *imposed on us by nature;* all of the electricity we consume is eventually converted to heat by *irreversible processes.* The mean temperature of the earth is set by a *heat balance,* an element of which is the amount of energy consumed by man. Local and global climate is related to man's activities through the heat balance and man-made contributions to the composition of the atmosphere, although the exact nature of these perturbations to

climate has yet to be fully understood. These are but a few of some basic concepts which are important facts of life in today's technological society. In a democratic society, the public must have a voice in decisions concerning population control, power plant siting, air pollution control, and weather modification; therefore, they must be given a basic understanding of some technological concepts.

The public must also appreciate the capabilities and limitations of the technological process. Engineering is far less an exact science than is physics or mathematics. Empiricisms, extrapolations, and assumptions, which are required when data and theories are lacking, necessarily introduce uncertainties in proposed solutions. In many cases, there are alternative solutions lacking quantified criteria as guides for chosing the best one. Thus, many decisions are based on subjective judgments of individuals, and an informed public will not expect open and shut decisions in all cases.

It has usually been assumed — by scientists and engineers as well as the lay public — that technological subject matter is too complex for those not majoring in it. In an attempt to disprove that notion, the Engineering Concepts Curriculum Project was undertaken in 1965, under the sponsorship of the National Science Foundation, to devise a high school level course on systems and computer technology. A text has been published,[7] and the course is now taught in many high schools. Although the level of the subject material may still be too sophisticated for the entire high school population, this first effort has demonstrated that some concepts of technology can and should be made available to a broader cross section of the populace.

Much of the effort in public enlightenment must be addressed to persons outside the formal processes of education, for the simple reason that there are generations of Americans in that group who are enfranchised to participate in, and criticize, complex policy making and decision making involving technological alternatives. We look with favor on suggestions that industry should generate programs to enlarge public understanding of the technology it places in the public hands. Such an undertaking would be far more than quixotic. It can be supposed that a society like ours

[7] *The Man-Made World*, McGraw Hill Publishing Co., 1971.

which has been fascinated by technology from earliest days would provide a receptive audience.

For the generation now within the formal processes of education, and its successors, the means of fostering such understanding are available, but need to be developed so that ultimately it will be general within the society.

For the foregoing reasons, we recommend:

RECOMMENDATION IV. PUBLIC UNDERSTANDING OF TECHNOLOGY

The National Science Foundation and the Office of Education should as a matter of long range concern seek to promote the teaching of the principles and nature of technology at all levels of formal and informal education. The existing NSF program on Public Understanding of Science should undertake, within its existing field of responsibility, efforts to enhance public understanding of technology and how it differs from science. The Federal Government and industry should mount parallel efforts to convey that understanding through channels outside the classroom.

TOWARD BALANCED TECHNOLOGICAL GROWTH

Although Recommendations III and IV are offered for immediate action, arriving at major findings or results will take time. The exploratory groups will probably take several years to establish methodology and develop the requisite manpower; they will be doing well to produce any major recommendations within the first five years after their inception. Public understanding of technology and its bearing on major policy issues facing society will undoubtedly take longer. Recommendations III and IV are designed for longer term impact. But decisions cannot be postponed on the multitude of matters requiring near term action until all the facts are in hand and the public has had a chance to digest them and express its informed voice.

Of these near term technology-based concerns, one of the most pressing issues for Government is how to achieve a balance between opposing forces: between unhampered evolution of new technologies and constricting controls; between innovation and restraint; between rapid growth and no growth. The task is one

of finding a path between two extremes: the position of a highly vocal segment of society which wishes to impose the strictest kind of restraints upon technology, and the position of an opposite group which fears that restraints can mean only the stifling of innovation, leading to technological stagnation and the most deleterious effect upon our economic performance, domestically and internationally, and upon the quality of life of the American society.

Part I dealt with the need for Government initiatives to stimulate innovation through direct and indirect support of research and development. The imperatives for Federal responsibility — to update aging technologies and to bring forth new ones — are imposing. A continuous stream of new developments is essential if we are to compete effectively with growing technological capabilities abroad; new technologies are a prime source of the new industries we look to for expanding employment; increased efficiency in producing conventional goods and services is necessary to free scarce resources for eliminating poverty and cleaning up the environment, while enhancing our standard of living. In addition, there are the intangible benefits of researching and developing technologies which do not appear economically viable today, but which are necessary to have at hand to preserve the options for future generations; hence, the recommendations in Part I.

On the other side of the ledger, there is perceptible among public attitudes toward technology a potential tendency to throw a strong bridle upon it and hold it on a tight rein. "There is now even a severe case of antipathy toward technology that was expressed in the recent past only by a few romantics," said the 1970 report of the President's National Goals Research Staff, "Toward Balanced Growth." Whether justified or not, there are many who attribute some of our major contemporary problems to ill-considered exploitation of technology: the tensions and frustrations of congested cities; the dangers of a polluted and despoiled environment; the potential of thermonuclear destruction, the hazards of surveillance and manipulation of private thought.

Adjusting to these new pressures presents unfamiliar difficulties to the engineer, who historically has been primarily concerned with the so-called "economic constraint" and had learned to live with it. The new environment is more difficult to deal with, partly because there have been introduced into it new social attitudes

which are not easy to define, analyze, and measure, and partly because these have shown themselves so suddenly as to constitute a surprise, a changing of rules in the middle of the game. They have been given focus and force by legislative enactments, executive actions, and judicial determinations, which up to now have occurred for the most part in not far from random fashion.

The existence of that school which would strictly restrain technology is only the extreme reflection of a reality. Short of the extreme, there is a substantial segment of the American society which, while acknowledging the vital role of technology in the economy and while eager to enjoy its contributions to the quality of life, is disquieted by some aspects of technology's impact on society and seeking some means of controlling it while preserving its full usefulness. This disquiet is what underlies the movement for mechanisms of technology assessment, by which the attempt would be made to screen out such newly emerging technologies as seem to have a potential for adverse social effects if broadly introduced without adequate safeguards.

Recommendation V includes a purpose of allaying that disquiet, which in a range of intensities from vague to acute can indeed have an inhibiting effect upon technological progress, by answering questions and removing (or, on occasion, confirming) causes of concern in the society. It would enhance the public interest by providing a point of recourse — a "credible group" — for independent determination of the probable consequences of technological departures. By experience and learning, it is hoped, such bodies would evolve into an institutionalized function of technical analysis and assessment.

The recommendation:

RECOMMENDATION V. TECHNOLOGY ASSESSMENT

There should be formed in appropriate agencies, including the National Science Foundation, or as separate bodies if need so dictates, groups responsible for the long range analysis and assessment of technological systems of broad public importance. It is urgent that new capabilities be created to evaluate the societal benefits of new technological developments in advance of their wide scale dissemination and call attention to their potential hazards, undesirable by-products or side effects. Such groups should make generally available

to the public information regarding comparative costs and values as a basis for decision-making in order that appropriate safeguards may be established. They could call upon all national advisory and research resources to provide the many diverse substantive skills required in assessment.

It is recognized that some existing agencies and institutions undertake analysis and assessment as a major part of their mission. These include, but are not limited to, the Environmental Protection Agency, the Food and Drug Administration, and the Federal Communications Commission. The Environmental Impact Statements required by the Environmental Policy Act of 1969 provide an example. The Council on Environmental Quality has already received some 2,500. It is not meant to imply that existing mechanisms should be weakened or transferred.

It is recognized also that bills to establish a congressional Office of Technology Assessment have been offered in recent sessions, and we believe this to be a step in the right direction.[8]

Recommendation V is offered with full realization of existing and pending efforts. But two points may be emphasized that have been made in recent study reports on technology assessment.[9] The first is that we must begin immediately to define and refine the techniques and methodology of the assessment process. The second is that the scope of the need is so vast that nothing less than a major commitment will suffice.

The burden of decision on technological issues in public affairs falls squarely upon the shoulders of our elected representatives. Government will undoubtedly be inundated with enthusiastic requests for support of new technologies and with predictions of peril from equally convincing experts. Attempts to compute social benefits and social costs may yield only rough approximations. Choices among options will be difficult, decisions will be controversial. Although those charged with governance are accustomed

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[8] Legislative Report No. 92-469, *Establishing the Office of Technology Assessment and Amending the NSF Act of 1950.* U.S. House of Representatives, Committee on Science and Astronautics, 92nd Congress, 1st Session.

[9] *Technology: Processes of Assessment and Choice,* National Academy of Sciences, July 1969; *A Study of Technology Assessment,* National Academy of Engineering, July 1969; *A Technology Assessment System for the Executive Branch,* National Academy of Public Administration, July 1970.

to being the focal point of such debate, they will have an increasing need for professional and technical advice. The distinction between tentative technical judgment and established fact can be very subtle, requiring cross-examination by highly skilled experts. Thus, officials will require more and more professional assistance to assess the assessors.

It may be pointed out that there already exists a large and complex "machinery of advice," including scientific and engineering advice, in the Federal Government. It works through literally hundreds of technical committees, contributions by specialist consultants, and *ad hoc* technical studies. Until recently, this machinery addressed itself chiefly to relatively narrow, highly specific, subjects — technical issues related to coal mine safety, for example, or isolated issues within the technology of nuclear reactors. Lately, there has been some broadening. The point is, the existence of this machinery establishes the principle that such advice is wanted and used in Government.

But we believe that the participation of engineers and scientists should be formalized, that their professional thinking and judgments should enter into deliberations on the broadest questions presenting technical issues *at the very beginning;* that the numbers participating should be increased to the levels needed at the various points of policy making and decision making where they are assigned; that their participation should be full time in a greater number of instances; and that the places where they are needed should be carefully identified. In fact, an adequate "in-house" capability is essential to make use of and couple the judgments of outside advisory groups to decision-making. It is desirable that the Legislative Branch be strengthened in this respect, to reinforce its coordinate and equal role in our system.

CONCLUSION

This Report, while recognizing the problems facing technology in this country today, has sought to concentrate on positive steps by which the great capabilities of American science and engineering may be helped to attain their fullest effectiveness in meeting national needs. Progress on that path can bring strengthening of the industrial base of our economy, reinforce the domestic and international economic position of the United States, and provide direct assistance toward the solution of major societal problems and enhancement generally of the quality of life. These are the purposes of the technologies of peace, the employment of the discoveries of science in the service of man. Their achievement is within our power.

APPENDIX A

Federal and company share of industrial R&D spending, 1953-1972

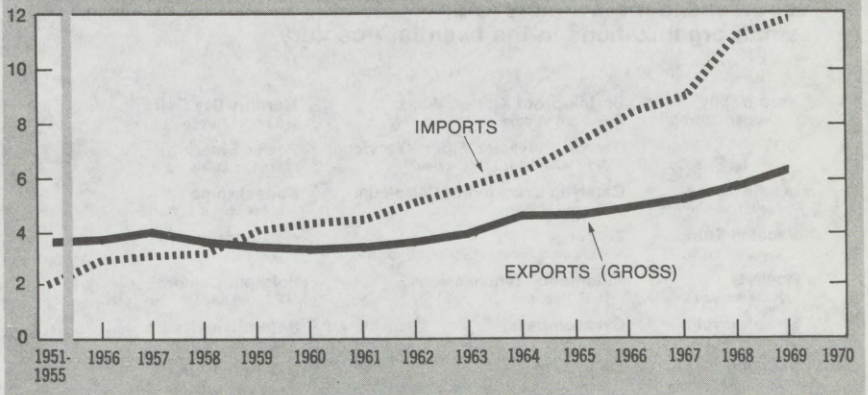
Excerpt from Research and Development in Industry, 1969—Surveys of Science Resources Studies, National Science Foundation—April 1971 (NSF 71-18)

SOURCE: National Science Foundation

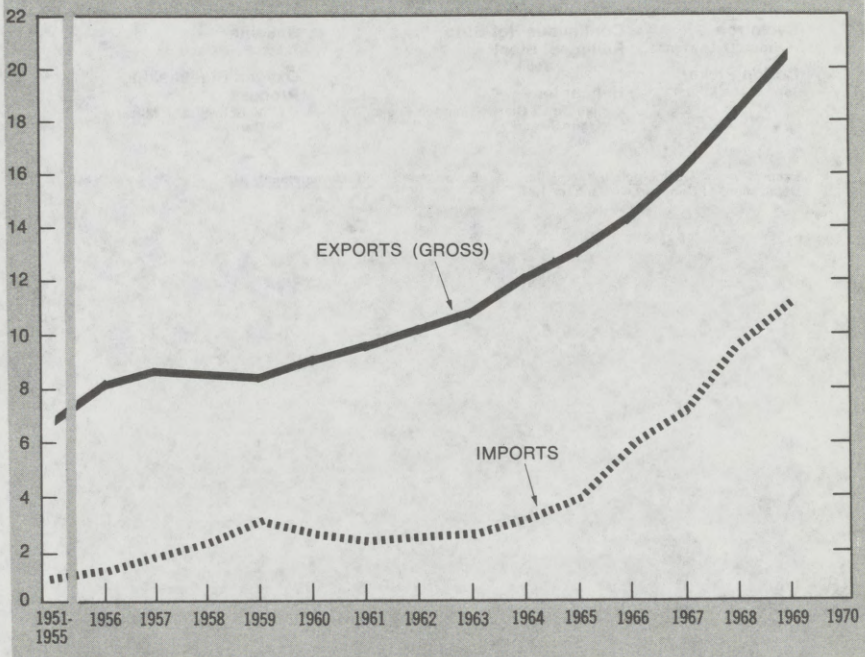
APPENDIX B

Trends in U.S. trade

Not "Technology-Intensive" Manufactured Products



"Technology-Intensive" Manufactured Products



Excerpt from Technology and International Trade, Proceedings of the Symposium Sponsored by the National Academy of Engineering at the Sixth Autumn Meeting—October 14 and 15, 1970.

APPENDIX C

Some important inventive contributions of independent inventors and small organizations in the twentieth century

Xerography
Chester Carlson

DDT
J. R. Geigy & Co.

Insulin
Frederick Banting

Vacuum Tube
Lee De Forest

Rockets
Robert Goddard

Streptomycin
Selman Waksman

Penicillin
Alexander Fleming

Titanium
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Shell Molding
Johannes Croning

Cyclotron
Ernest O. Lawrence

Cotton Picker
John & Mack Rust

Shrink-proof Knitted Wear
Richard Walton

Dacron Polyester Fiber "Terylene"
J. R. Whinfield/J. T. Dickson

Catalytic Cracking of Petroleum
Eugene Houdry

Zipper
Whitcomb Judson/Gideon Sundback

Automatic Transmissions
H. F. Hobbs

Gyrocompass
A. Kaempfe/E. A. Sperry/S. G. Brown

Jet Engine
Frank Whittle/Hans Von Ohain

Frequency Modulation Radio
Edwin Armstrong

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John Harwood

Continuous Hot-Strip Rolling of Steel
John B. Tytus

Helicopter
Juan De La Cierva/Heinrich Focke/
Igor Sikorsky

Mercury Dry Cell
Samuel Ruben

Power Steering
Francis Davis

Kodachrome
L. Mannes & L. Godowsky Jr.

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Willis Carrier

Polaroid Camera
Edwin Land

Heterodyne Radio
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Karl Schroeter

Bakelite
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C. V. Schwartz/J. Miles/
R. Durrer

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