DOCUMENT RESUME

ED 255 367 SE 045 453

TITLE	An Agenda for a Study of Government Science Policy. Report Prepared by the Task Force on Science Policy Transmitted to the Committee on Science and Technology, U.S. House of Representativ s, Ninety-Eighth Congress, Second Session, Serial MM (December 1984).
INSTITUTION	Congress of the U.S., Washington, D.C. House Committee on Science and Technology.
PUB DATE	85
NOTE	67p.; Prepared by the Committee's Task Force on Science Policy.
PUB TYPE	Legal/Legislative/Regulatory Materials (090)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	Engineering Education; *Federal Aid; *Federal Programs; *Financial Support; *Government Role; Labor Force; Policy; *Policy Formation; Science Education; *Sciences; Scientific Research; Social Sciences
IDENTIFIERS	Congress 98th; *Science Policy

ABSTRACT

This report contains a proposed agenda for the comprehensive study of United States science policy which the Committee on Science and Technology expects to perform during the 99th Congress. The proposed agenda was developed by the committee's Task Force on Science Policy in response to the charge to focus on the issues of maintaining America's leadership in science in view of the changing environment facing the nation during coming decades. The proposed agenda is broad and raises questions about both the basic purposes of federal funding for scientific research and the specific practices of the governmental agencies for the expenditures of those funds. Topics included in the agenda are organized under 10 major subject categories (and subcategories, when applicable). These categories are: goals and objectives of national science policy; the institutional framework for the conduct and support of research; education and manpower (including the past, present, and future government role in science education); impact of the information age on science; role of the social and behavioral sciences; the regulatory environment for scientific research; funding levels; support of science by the mission agencies (including the Department of Defense); funding mechanisms; and the role of the congress in science policy making. (JM)

[COMMITTEE PRINT]

AN AGENDA FOR A STUDY OF GOVERNMENT SCIENCE POLICY

REPORT

PREPARED BY THE

TASK FORCE ON SCIENCE POLICY

TRANSMITTED TO THE

COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

NINETY-EIGHTH CONGRESS

SECOND SESSION

Serial MM

DECEMBER 1984

Printed for the use of the Committee on Science and Technology

U.S. GOVERNMENT PRINTING OFFICE
40-560 O
WASHINGTON : 1985

COMMITTEE ON SCIENCE AND TECHNOLOGY

DON FUQUA, Florida, *Chairman*

ROBERT A ROE, New Jersey
GEORGE E BROWN, JR., California
JAMES H SCHEUER, New York
RICHARD L OTTINGER, New York
TOM HARKIN, Iowa
MARILYN LLOYD, Tennessee
DOUG WALGREN, Pennsylvania
DAN GLICKMAN, Kansas
ALBERT GORE, JR., Tennessee
ROBERT A YOUNG, Missouri
HAROLD L VOLKMER, Missouri
BILL NELSON, Florida
STAN LUNDINE, New York
RALPH M HALL, Texas
DAVE McCURDY, Oklahoma
MERVYN M DYMALLY, California
PAUL SIMON, Illinois
NORMAN Y MINETA, California
RICHARD J DURBIN, Illinois
MICHAEL A ANDREWS, Texas
BUDDY MacKAY, Florida
TIM VALENTINE, North Carolina
HARRY M REID, Nevada
ROBERT G TORRICELLI, New Jersey
FREDERICK C BOUCHER, Virginia

LARRY WINN, JR., Kansas
MANUEL LUJAN, JR., New Mexico
ROBERT S. WALKER, Pennsylvania
WILLIAM CARNEY, New York
F JAMES SENSENBRENNER, JR., Wisconsin
JUDD GREGG, New Hampshire
RAYMOND J. McGRATH, New York
JOE SKEEN, New Mexico
CLAUDINE SCHNEIDER, Rhode Island
BILL LOWERY, California
ROD CHANDLER, Washington
HERBERT H BATEMAN, Virginia
SHERWOOD L. BOEHLERT, New York
ALFRED A. (AL) McCANDLESS, California
TOM LEWIS, Florida

HAROLD P HANSON, *Executive Director*
ROBERT C KETCHAM, *General Counsel*
DAVID S JEFFERY, *Minority Staff Director*
JOHN D HOLMFELD, *Science Policy Staff*

SCIENCE POLICY TASK FORCE

DON FUQUA, Florida, *Chairman*

GEORGE E BROWN, JR., California
DOUG WALGREN, Pennsylvania
HAROLD L VOLKMER, Missouri
STAN LUNDINE, New York
MERVYN M DYMALLY, California
NORMAN Y MINETA, California
BUDDY MacKAY, Florida
HARRY M REID, Nevada
FREDERICK C BOUCHER, Virginia

LARRY WINN, JR., Kansas
MANUEL LUJAN, JR., New Mexico
JUDD GREGG, New Hampshire
JOE SKEEN, New Mexico
HERBERT H BATEMAN, Virginia
SHERWOOD L. BOEHLERT, New York
ALFRED A (AL) McCANDLESS, California
TOM LEWIS, Florida

LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC, December 4, 1984.

To the Members of the Committee on Science and Technology:

We submit herewith the report of the Science and Technology Committee's Task Force on Science Policy. The report contains a proposed agenda for the comprehensive study of U.S. science policy which the Committee on Science and Technology expects to perform during the 99th Congress.

The proposed agenda was developed by the Task Force in response to the charge to "focus on the issues of maintaining America's leadership in science in view of the changing environment facing us over the coming decades." In developing the proposed agenda, the Task Force was conscious of the importance which science has come to play in our national life and in our international relations. At the same time, the Task Force was acutely aware of two factors which inevitably will affect American science in the future: the growing international strength in science and the urgent need to ensure that science expenditures, as an important component of a seriously unbalanced Federal budget, be provided at optimum levels and be expended in the most effective manner. As a result, the proposed agenda is broad and raises questions about both the basic purposes of Federal funding for scientific research and the specific practices of the governmental agencies for the expenditure of those funds.

On the occasion of the completion of the work and the submission of this proposed agenda, we express to all the members of the Task Force on Science Policy our thanks for the contributions made by each member. In the three formal meetings held on August 2, September 13, and September 26, and in the numerous informal contacts and exchanges which occurred between meetings, many factors and concerns came to light. This final report is the product of all of those contributions, and we are grateful for the care and thoughtfulness which the members of the Task Force brought to this endeavor.

It is not the intent of the Task Force that the agenda outlined in the following pages be considered final. Additions, changes, or deletions may well be called for when the committee begins its study in January 1985. But we believe that the report provides a solid foundation on which a careful, in-depth, and effective study of U.S. science policy can be based.

LARRY WINN,
Ranking Minority Member.

DON FUQUA,
Chairman.

CONTENTS

	Page
Letter of Transmittal	iii
Contents	v
Introduction	1
Science Policy and the Congress	1
Scope of the Study	2
Bipartisan Approach of Task Force	3
The Past and the Future	4
Longer Term Objective	4
Data Based Study and Analysis	5
Structure of Agenda	5
A Proposed Agenda	7
I. The Goals and Objectives of National Science Policy	7
A. Goals of Federal Science Policy	7
B. History of American Science and U.S. Science Policy	9
C. The Future of U.S. Science	10
D. The Pay-Off from Scientific Research	11
E. Accountability in Research	12
II. The Institutional Framework for the Conduct and Support of Research	15
A. The Role of the Research Universities	15
B. The Role of Government Laboratories	17
C. Basic and Applied Research in Industry	19
D. Government Responsibility for the Research Infrastructure	21
E. International Cooperation in Big Science	23
F. Coordination and Management of Federal Research Programs	24
G. Role of the National Academies	27
III. Education and Manpower	29
A. Past, Present, and Future Government Role in Science Education	29
B. Effects of Long-Range Population Trends on Science Manpower Policy	30
C. The Government's Role in Professional Education	31
D. Equity of Opportunity	32
E. How Should the Education of Scientists, Doctors, and Engineers Be Paid For?	32
F. Engineering Education	33
G. New Educational Technologies	34
IV. Impact on Science of the Information Age	36
V. Role of the Social and Behavioral Sciences	38
VI. The Regulatory Environment for Scientific Research	40
VII. Funding Levels	41
A. History of Science Funding since 1945	41
B. Is There an Optimum Level of Federal Support of Science?	42
C. Financial Health of Universities and Medical Centers	43
D. Priorities for Science Funding	44
VIII. Support of Science by the Mission Agencies	46
A. Support of Science by the Department of Defense	46
B. Support of Science by the Other Mission Agencies	47
IX. Funding Mechanisms	49
A. Alternate Systems of Funding Scientific Research	49
B. The Selection Process and the Role of Peer Experts	50
C. Styles of Research Support in Different Fields of Science	51
D. Secondary Effects of Present Funding Mechanisms	52
E. The Costs of Research	53

	Page
X. The Role of the Congress in Science Policy Making	55
A. Science in the Political Process	55
B. Priority Setting by the Congress	56
C. Oversight and Evaluation of Federal Science Programs	58
D. Multi-Year Funding of Science Programs	59
E. Review of Science Policy Reports to the Congress	60
F. Background Reader for New Members	62

INTRODUCTION

The last major Congressional review of American science policy took place in the mid-sixties, almost twenty years ago. Since that time, the relationship between science and government has undergone a number of significant changes, and there is every indication that further changes in that relationship are in prospect. In addition, the wider environment in which both government and science must function is expected to change in ways that will affect both science and the science-government relationship.

It is therefore timely that the Science and Technology Committee conduct a careful review of American science policy. Such a review will enable the members of the Committee, and the wider membership of the House of Representatives, to discharge their legislative and oversight responsibilities on the basis of a deeper understanding of past policies, present problems, and future needs and choices.

The proposed agenda presented in this report by the Science Policy Task Force represents our recommendations about the ground such a science policy study should cover. In our view, all of the individual items and questions we propose for consideration and study are closely related and together form the fabric of our science policy. We realize that the list of agenda items is long and may be difficult to cover in depth even with the expected two-year duration planned for the study. Nevertheless, the importance of this subject for the future of the country compels us to recommend that the entire subject be given the most careful and thoughtful study so that we can emerge with a deeper understanding and enhanced wisdom about the Federal Government's role in keeping America strong in science.

SCIENCE POLICY AND THE CONGRESS

The Federal Government's role as the principal source of the resources needed to advance science is comparatively new. Prior to 1945 it was limited to peaks of effort in support of major wars and specialized activities by those agencies of government which saw science as a way to acomplish their primary missions such as the Department of Agriculture. This limited role for the Federal Government gave way to a much stronger, ultimately dominant, role in the years following the end of World War II.

During the war years large numbers of scientists performed research directly related to the war effort. Funds were provided through the Manhattan Project for work on the atomic bomb, through the Office of Scientific Research and Development for work on a wide range of other military weapons, techniques, and medical problems, and through the military services to the universities for both training and R&D activities. This resulted in the development of a spectacular array of science-based technologies which contributed significantly to the winning of the war. They included, in addition to the atomic bomb, the proximity fuze, radar, mass-produced penicillin, scientific techniques for anti-submarine warfare, and psychological methods for the selection and training of personnel.

As a result, public and Congressional support for the continuation of government support of science was strong, and the view that it should be broadened to include research with potential applications to the civilian sector of society was introduced. A number of new government agencies were created to continue and strengthen the close relationship with the universities. They included the Office of Naval Research and the National Science Foundation. Other established departments and agencies such as the National Institutes of Health and the Department of Agriculture also saw their science programs expanded and strengthened.

In the late Fifties, the launch of the Soviet earth satellite Sputnik, provided further impetus for public and Congressional support of science leading to rapidly growing budget allocations for science. A new emphasis on science education at all levels emerged, based on the need to train more scientists and engineers.

The resulting series of annual budget expansions lasted into the mid-seventies when a period of uncertainty and abrupt changes, began a period that is still with us. After a series of annual budgets in which the science component was essentially level, there has been a resumption of budget growth. That growth in science expenditures has been at rates equivalent to a doubling time of less than six years. It is unlikely that such rapid increases can be sustained, especially in view of the urgent need to close the deficit gap in the Federal budget.

The shift from a limited government role in providing support for science to a dominant role has of necessity meant a heavier involvement by the Congress in all aspects of that process. The Congress early recognized the importance of science to improved health, technological advance, and economic growth. The Congress has provided the institutional framework of new or augmented government agencies to administer those programs, and has responded to international developments, Executive Branch initiatives, and scientific opportunities with the allocation of substantial and frequent budget increases.

Yet, as in numerous other areas, there has been a strong tendency to make extensive changes in policy only under the conditions of crisis. Absent such conditions, debate on questions of resource allocation is normally restricted to the incremental increases proposed by the President in the annual budget. In our view the Science Policy Study offers a welcome opportunity to stand back in a non-crisis atmosphere and take the measure of our federal science policy in terms of both its relevance to national goals and its effectiveness in allocating sufficient resources to support science.

Scope of the Study

The scope of a study of science policy could vary widely, and would be interpreted quite differently depending on the time, the circumstances, and the interests of the individuals involved. The term "science policy" itself is subject to differing interpretations, but in common practice is frequently used to cover policies for government support and encouragement of science and technology, ranging from basic research through applied research, advanced development, concept demonstration, and product development. When interpreted to encompass that broad range of activities, science policy includes such issues as patent policy, anti-trust policy, tax policy, and industrial innovation policy generally.

After a careful consideration of the appropriate scope for the Science Policy Study, and an evaluation of the advantages and disadvantages of a wide scope versus a more circumscribed scope, the Task Force recommends that the scope be limited to the issues of science policy in the narrow sense of government policies for the support of basic and applied research. This means excluding from the present study the issue of technology policy and the many policy questions which fall into that broad category. Our conclusion in this matter of the scope of the Science Policy Study is based on the following considerations.

We believe that any study to be done by the Committee should be of the highest quality. To achieve this will require extensive data gathering, careful probing of many issues and their correlated subjects, and in-depth analysis of each issue. Such a study can only be done if the scope is limited to a manageable number of issues, all of which preferably are related to each other. Science policy in the narrow sense constitutes, we conclude, such a group of issues. Furthermore, many of the issues in the wider interpretation of science policy are themselves as large, or larger than, the more narrowly defined study contemplated here and could therefore easily divert attention from the focus on basic and applied research policy. Consequently, we recommend that the Science Policy Study be limited to the role of the Federal Government in conducting and supporting basic and applied research.

Similar considerations were brought to bear in considering the extent to which the Science Policy Study should cover education and manpower issues in the area of science and engineering. While the Task Force fully recognizes the importance which mathematics and science education have at the high school and undergraduate college levels, it was concluded that only those aspects of science and engineering education which are directly related to research activities should be covered in the Study. In part this is due to the fact that several recent reports have dealt with the issues related to pre-graduate science education. In part this is also due to the great scope which a study of all science and mathematics education would entail, and the desire of the Task Force to keep the proposed Study within manageable boundaries. We therefore recommend that the Science Policy Study include science and engineering education and manpower issues as they are related to graduate and post-doctoral education in these fields.

Bipartisan Approach of the Task Force

From the time that the idea for a comprehensive science policy study first emerged, there was wide agreement that it should be done on a fully bipartisan basis. That was the view of the several members who proposed the initiation of such a study as well as of the Chairman and the Ranking Minority Member of the Science and Technology Committee. We all share the view that the importance of science to the nation's future is high, and the need, therefore, to provide a strong leadership role by the Federal Government is not in dispute. The composition of our Task Force reflects that view.

A bipartisan approach to the work of the Task Force, and subsequently to the Science Policy Study itself, will not preclude that differences will arise on individual issues which form part of this study. Nevertheless, we recommend that the Science Policy Study be conducted in the same bipartisan manner as the work of the Task Force, an approach that proved workable and which we believe to be in the best interest of the nation.

THE PAST AND THE FUTURE

We recognize that science policy is dynamic, ever-changing, and has a past and a future. That past, although comparatively short, is replete with changes that range from adjustments in the nuances of policy to major redirections in program orientation. Similarly, the future of science policy calls for sensitivity to important, but hardly detectable, emerging developments as well as the anticipation of major trends in the factors affecting science and science policy. In the conduct of the Science Policy Study an awareness of historical developments coupled with an acute sensitivity to emerging future needs will be cruci. to the achievement of both wise judgments and sensible relevance. The Task Force recognizes that, in designing and conducting the Science Policy Study, a balance should be sought between attention to historical developments in American science policy over the last forty years and awareness of potential developments in science, in science policy, and in society as a whole.

LONGER TERM OBJECTIVE

The Task Force is well aware that studies of important policy issues frequently have as their only result the drafting and publication of a huge report which is read by few and which accomplishes little. We urge therefore that, in the conduct of the Science Policy Study, the longer term objective of achieving a deeper understanding by members of the Committee should be a major objective.

This is not to suggest that an over-all report should not be produced, bringing together the conclusions and recommendations arising from the Study. But rather than a voluminous final report written without the active participation of the members of the Committee, we recommend that the Committee's final report be short and succinct and that it be considered only one of the several end products of the Science Policy Study.

DATA BASED STUDY AND ANALYSIS

A prominent anomaly of past and current science policy making has been the very limited use of quantitative information. In neither the evaluation of past programs nor in the development of new initiatives has the arena of science policy formulation seen the use, to any significant extent, of hard data and quantitative analysis. In this respect science policy differs in a noticeable way from policy-making in such fields as defense policy, social security policy, and many others.

The Task Force believes that in many areas of science policy the data is available and the policy making process could potentially benefit from its use in the associated analysis. We recommend therefore that in the conduct of the Science Policy Study, particular attention be given to the definition of the issues, the formulation of the questions, and the enunciation of the recommendations in a manner which will permit quantitative approaches to be brought to bear when possible. Equally important, a concerted effort should be made to evaluate existing programs with the prominent assistance of such quantitative methods.

We are conscious of the limitations of such quantification, especially in a field of public policy which is characterized by a high degree of uncertainty and a noticeable degree of reliance on individual insight and creativity. Nevertheless, we believe that the time has come to supplement, although certainly not replace, the traditional science policy process with a strong component of quantitative analysis, an approach which has proven so successful in science itself.

STRUCTURE OF AGENDA

In considering the wide range of topics which must be included in the agenda, even under the agreed narrow scope for the Science Policy Study, we have sought to arrive at a reasonable degree of coherence. The topics have therefore been organized under major subject categories and subheadings. However, some duplication was found unavoidable. For example, the focus on accountability in research will be found both in the initial chapter on goals and objectives and in the concluding chapter on the role of the Congress. Where it occurs, such repetition is intentional.

A PROPOSED AGENDA

I. The Goals and Objectives of National Science Policy

Beginning with Vannevar Bush's 1945 report to the President, "Science—The Endless Frontier," certain goals and objectives for American science policy were set forth. These initially emphasized research for national security, technological advances, and the training of scientists. Subsequently, other goals and objectives were added, such as international prestige and cultural relevance. The Task Force recommends that these goals and objectives, the assumptions underlying them, and how well they are being achieved be carefully examined as part of the Science Policy Study.

A. GOALS OF FEDERAL SCIENCE POLICY

As with any other area of government policy, it is important that the goals of Federal science policy be well defined and articulated. Such a set of goals enables both members of Congress and the officers of the Executive Branch to consider individual initiatives and particular budget proposals in a larger framework in which their merit can be judged. The Task Force recognizes that a set of goals for the nation's science policy can not be static. They will change over time. Thus, the goals established forty years ago may or may not be relevant for today and for the coming decades.

We also recognize that there have been times in the recent past when the goals of Federal science policy were neither well defined nor well articulated. In our view that makes it that much more important that the Science Policy Study devote particular attention to this part of its task. We recommend that the Study carefully review present and past statements and other expressions of Federal science policy together with the future requirements that emerge from the many other facets of the Science Policy Study, and on that basis develop a statement which, with some degree of specificity, states the goals of Federal science policy for the coming decades. Among the questions to be explored are the following:

1. What Are We as a Nation Aiming for in Providing Support for Science?

In the most general terms, the aim of science policy is to "strengthen American science" or "maintain the world leadership position" of U.S. science. Such general statements are, however, not particularly helpful in judging the merits and priorities of science programs, science budgets, and the organizational arrangements for science.

While a strong case can be made for the support of science for its own sake at modest levels, the bulk of the science efforts supported by the Federal Government must have as its objective the accomplishment, directly or indirectly, of other social goals such as the prevention and cure of disease, industrial innovation, military strength, international prestige, or education of new generations of scientists. (See "The Pay-Off from Science Research", below.)

The needs in those areas of pay-off from science should therefore be carefully reviewed and forecast to the extent possible, and the goals tailored to the result of that analysis.

We recognize that the rapid advances of science and the accelerating changes within society make such a forecast difficult to develop and fraught with uncertainty. Nevertheless, we conclude that the effort to better define our national aims in supporting science must be made if the growing level of resources going into science is to be used in an optimum manner.

2. How Do Our Goals for Science Relate to Our Other National Goals?

In reviewing and formulating our goals for science we urge that the immediate goals to which science can be expected to contribute, such as improved health, a cleaner environment, and enhanced technological innovation, not be considered in isolation. Broader societal goals, such as full employment and economic growth, are frequently closely linked to the more immediate goals of science, and they should be taken into consideration when formulating the goals for science.

3. Are the Goals for Science Internally Consistent?

If the goals established for the Federal Government's science program are not characterized by a reasonable degree of consistency, one result could well be that individual science programs will be working at cross purposes. It is perhaps not reasonable to expect, nor even necessarily advantageous in the longer run, that such consistency become an overriding goal. Yet in the interest of effective utilization of the resources available for science, and in the interest of serving the goals for which these programs are conducted, the goals should themselves, insofar as practicable, be consistent.

4. How Does a Statement of National Goals for Science Relate to Science Policy Issues, and, Given a Set of Goals, What Is Needed to Achieve Them?

Just as a statement of goals for national science policy should be related to broader national goals, so our science policy should also be related to the more specific, sometimes shorter-term, science policy issues which constitute the daily agenda of science administrators.

This need to ensure that the goals of science policy relate to practical questions suggests first of all, as we have already noted, that the goals should avoid the high level of generality which is easier to develop but less useful as a guide to decision making. It also means that the statement of goals should be developed in full awareness of what the nature of current operating problems are so that the goal statements have a greater chance of being relevant. We therefore recommend that the development of a statement of the goals for government support of science be developed in the course of the Science Policy Study and be completed only toward the conclusion of the Study when a fuller appreciation of the entire subject and the feasibility of achieving such goals has been achieved.

5. Have Our Goals Changed, and to What Extent Do the Policies for Government Support of Science which Have Evolved over the Last Forty Years Apply to the Next Forty Years?

The formulation of a set of goals for American science policy will benefit notably from a careful review of past goals. These goals have, as we noted, evolved over time, and they will continue to need adjustment as some goals are achieved and as conditions in the surrounding society change. Yet it is probably characteristic of the value of science to society that in many ways the goals remain basically unchanged. This continuity should, in our view, be recognized, and changes in the goals that have evolved since 1945 should be made only after the most careful consideration of their implications for our nation's future over the next forty years.

6. To What Extent Must Changes Now Be Made in Those Policies to Achieve the National Objectives and Goals?

In the conduct of the Federal programs of support for scientific research we are guided by a set of policies which are expected to help achieve our goals for science and the nation. While the goals may gradually be subject to changes, the policies are more flexible. They will have to be adjusted as the available level of resources go up or down, as successive Administrations place emphasis on different aspects and approaches, and as international and domestic factors and needs change. We must also be prepared to accommodate unpredicted developments. We therefore recommend that the current policies for Federal support of science be closely scrutinized in the light of current and future circumstances, and that changes be recommended wherever necessary.

B. HISTORY OF AMERICAN SCIENCE AND U.S. SCIENCE POLICY

The point of departure for the proposed Science Policy Study should, we believe, be a thoughtful review of the developments that have brought American science and science policy to where they are today. We recognize that many of the policies and practices that are in place today are based on developments in our national history and the efforts to fashion policies that meet the needs arising from those developments as well as to meet developments within science itself.

Proposals for new initiatives, new directions, or new emphases to be included in future science policies will be more effective and more likely to succeed if they are shaped against a background that includes an understanding of the forces and factors that shaped past policy developments. To achieve this the Task Force recommends that the Science Policy Study commission a history of American science and U.S. science policy for use by the members.

1. What Historical Steps Have Occurred over the Last 100 Years which Have Led U.S. Science from a Position of Insignificance on the World Scientific Scene to a Position of Leadership?

The remarkable advance of American science over the last 100 years is not due to any single factor. Undoubtedly many events, many ideas, and many individuals produced that startling advance. The history should, within the confines of the relatively short document envisaged here, sum up those influences.

2. How Has Federal Science Policy Evolved since the Bush Report Was Written in 1945?

The proposed history should have as its major theme the evolution of government science policy since 1945. The interaction between the scientific community and the Federal Government and the specific episodes that led to new directions in science policy should be covered. Of particular interest and relevance to the members of Congress will be the role which the legislative branch played in the development of American science policy during this period. In addition, some attention should be given to past proposals to create a cabinet-level department of science.

3. How Are the Policies Proposed in the Bush Report Being Implemented Today?

Federal science policy in the last four decades has been based heavily on the rationale, proposals, and plans included in the Bush Report. Moreover, the Bush Report has come to occupy a unique role as the document often referred to as the starting point for many current agencies and policies, and as the foundation of American science policy. Thus it would be particularly useful to have an analysis done of the proposals and recommendations found in the Bush Report and the extent to which they have and have not been followed and implemented.

4. What Is the Size of the U.S. Scientific Community Today in Comparison with Other Nations?

An important factor in the rise of American science is undoubtedly the growth in the number of scientists who perform the research that constitutes the substance of science. The historical study should provide data that will permit an overview of this growth and enable a comparison to be made with the comparable growth in other countries.

C. THE FUTURE OF U.S. SCIENCE

The future of U.S. science policy will be linked inextricably to the future of American science itself. The most elaborate policy apparatus, the most thoughtful policies, and the most generous provision of resources in the form of funds, facilities, and manpower will have little effect if science, as an enterprise resting on new ideas, does not itself prosper.

1. What Are the Future Prospects and Needs of U.S. Science?

The historical development of science has been characterized by a constantly shifting emphasis from one discipline to another. At any given time some fields of science are advancing rapidly, others have reached a settled state, while a few are clearly less lively. For example, the biological sciences have seen an acceleration of new ideas and techniques over the last 25 years, beginning roughly with the discovery of the double helix structure of DNA, by Watson and Crick. The Science Policy Study should seek the best possible advice about the expected and potential developments across a broad front of all the disciplines of science. This will serve to assist the Committee in developing its recommendations about the future policy needs for American science.

2. Can the U.S. Maintain a Strong Leadership in Most Fields of Research or Should a Division of Leadership with Other Countries Be Accepted?

The United States, until recently, led the world in a large number of fields within science. One of the better indicators of this was the fact that the best young scientists from other countries sought to obtain all or part of their training by studying in this country.

However, in recent years there has been a reversal of this phenomenon in a small but growing number of fields. In certain areas of physics, for example, the availability of specialized research machines in Europe has led American researchers to do both part of their training and some of their research in Europe. The fact that these machines were built elsewhere has permitted resources in the U.S. to be concentrated in other fields, but has also meant that U.S. science no longer is preeminent in those fields. Limits on available resources in the Federal budget may not permit U.S. preeminence in science and engineering across the board. The advantages and disadvantages of such a limitation in the longer term should be reviewed by the Science Policy Study.

D. THE PAY-OFF FROM SCIENTIFIC RESEARCH

Society, through the Federal Government, began four decades ago to accept the view that it has a responsibility to foster science. That responsibility arose because it was realized that the pay-off from science was of direct benefit to society. The nature of the pay-off from science has, however, been differently perceived at different points in time. Furthermore, the pay-off from science has always been surrounded by a certain degree of rhetorical vagueness. There is a need, as total governmental resources become scarce and the fraction devoted to science becomes more significant to understand much more precisely what the pay-off from society's support of science provides in terms of specific benefits.

1. How Has the Rationale for Federal Support of Science Changed since 1945, and What Should It Be during the Coming Decades?

In order to articulate the rationale for future Federal support of science, the Science Policy Study should perform a detailed review of the various reasons advanced for expending government funds on scientific research beginning with the 1945 Bush Report. The review might include the major studies in this field performed since the Bush Report, the statements of the successive Science Advisors to the President and comparable officers of the government, and thoughtful individuals in the private sector and at academic institutions.

2. To What Extent Is Government Support of Science Comparable to Government Support of the Arts and Humanities?

Apart from the value of science as a major contributor to technological innovation, it is frequently noted that government should support research for the same reasons it supports the arts and humanities. This rationale notes that any advanced society has an obligation, and finds it valuable, to advance beauty, truth, and understanding of the human condition, and that science, like the arts and humanities, performs the same function. The applicability of this concept should be examined, and the feasibility of determining how much of the total funds devoted to basic research can and should be justified on this basis should be explored.

3. What Are the Effects on Science from the Changing Rationales Advanced to Justify Government Support of Scientific Research?

Recognizing that the rationale given for Federal support of science has shifted noticeably over time, and may continue to evolve in future years, it would be helpful to assess whether these shifts have, in turn, had a feedback effect on how science is conducted. These rationales have included support of research to achieve payoffs such as cures for disease and technological innovation, to enhance national image and prestige, and to advance the training of new generations of graduate students in science. Each may give impetus to particular emphases and approaches in the conduct of research, and we recommend that the effects of each be determined insofar as practicable.

E. ACCOUNTABILITY IN RESEARCH

Generally, accountability is defined as the process for measuring performance and comparing it to standards of expectation and legislative intent. This was given new vigor for science policy when the Comptroller General of the United States, Mr. Elmer Staats, devoted a major address to the subject in 1979. Accountability in research was subsequently the subject of a separate report by the National Commission on Research.

The Task Force is conscious of the high regard in which science is held by the public and by the Members of Congress. There is widespread and well justified acceptance, which we share, of the fact that science has made great contributions in this century to advances in health, space, defense, and technological innovation. As a result some would, at least initially, question whether it is appropriate and worthwhile to ask if the traditional question of accountability applies to the field of scientific research.

We have concluded that this question should be examined by the Science Policy Study, and we do so for several reasons. One decidedly lesser factor is the growing but still minuscule problem of scattered cases of scientific fraud by a few individual scientists. We believe that this is principally an internal problem for the scientific community, but one that receives extensive public attention. An expression of Congressional interest in and concern for accountability may serve to strengthen those scientists who are making an effort to eliminate this problem. More importantly, Federal support of science has now reached very large proportions. The funding levels for some of the agencies supporting science is tenfold in comparison with what it was twenty years ago, a growth which is large even taking inflation into account. In recent years the growth rates have been at levels which, if continued, would produce a doubling in less than six years. It seems reasonable to ask whether all of the activities that are now being supported are, in fact, of the highest quality or whether these programs now also support lower quality and marginal work. We therefore recommend that the Science Policy Study devote a significant effort to the question concerning the applicability of accountability concepts to scientific research.

1. How Well Are the Federal Government's Science Programs Performing in Relation to National Objectives to Be Reached through Federal Support of Science?

The concept of accountability applies at several levels. One can speak of accountability at the financial level, which is focused on whether the funds provided are properly expended and accounted for. At the next major level one can speak of project accountability, which is focused on whether a research project or program of research is yielding the results in terms of findings and papers for which it was undertaken. Finally, one can speak of accountability in terms of national objectives; this focuses on whether such objectives as cures for diseases and opportunities for technological innovations, the training of new scientists, international prestige, and cultural enhancement are being achieved by the research programs of government agencies. At this latter level it is widely agreed that government supported scientific research contributes, but the specifics of this contribution are vaguely understood and chiefly based on scattered, anecdotal evidence. The Science Policy Study should include an effort to understand and determine in depth how accountability for the expenditure of Federal funds for scientific research at the level of national objectives can be strengthened.

2. Can Federal Funding for Science Be Viewed as an Investment and Be Measured in a Way Comparable to Other Forms of Economic Investment?

Members of Congress frequently have been urged, during the annual hearings on the Federal Science Budget, to view the proposed expenditures not as current operating funds, but as an investment, with emphasis on long term pay-off. However, little analysis or testimony specifically aimed at this question has come to the attention of the Committee. A review of the economic models and other approaches used by economists to evaluate capital investments generally, and in particular investments made under comparatively high levels of uncertainty, should be performed for the use of the Science Policy Study.

3. Are the "Outputs" from Science Programs Measurable in Terms of How Research Activity Benefits Society?

Much of the analysis of Federal science policy has been focused on the resources of funds and manpower being devoted to the support of science. These "inputs", in particular the funds, are the focus of the budget-making process in the executive agencies, and of the authorization and appropriations process in the Congress. But very little is done to measure the outputs, that is, both the immediate research results and the longer term, more indirect effects resulting from the input of funds and manpower. In this area, while illustrative examples and other anecdotal evidence are available, little has been done to measure quantitatively the outputs. This should be given serious attention as part of the Science Policy Study.

4. Are the Nobel Awards and Other Awards for Scientific Accomplishments Useful Measures of National Strength in Science?

Much attention has been given to the strong representation of American scientists among the recipients of the Nobel awards in recent years. On more than one occasion all the science prizes have been awarded to U.S. scientists. This has frequently been taken as an indicator of the current strength of U.S. Science. It has been pointed out, on the other hand, that care must be exercised in using the Nobel awards as an indicator of strength or weakness. The differences in time between the work done and the time of award, the fact that many scientists were educated and trained in other countries, and perhaps most significantly, the very small numbers involved, may be misleading. This question should be carefully and thoroughly explored so that the Nobel awards can be viewed in the proper perspective.

5. What Other Measures Are There to Gauge the Strengths of Science Apart from the Nobel and Other Prizes?

It is highly desirable to determine if measures other than honorific awards such as the Nobel prize are available to measure the strength of science. Such measures could provide an important supplement to the more subjective judgments expressed by individual scientists. Such judgments will undoubtedly continue to be important, but should be complemented by less subjective measurements. Furthermore, measures of the strength of science are needed not only for the purpose of national comparison, but also to evaluate the strength of individual disciplines, of individual programs, and of individual institutions. The evaluation of possible measures should include the quantitative approaches already proposed, such as publication and citation counts, changes in the incidence of death and illness and in the Gross National Product, as well as new measures that could be developed.

II. The Institutional Framework of National Science Policy

Today science in America is conducted within a framework of institutional structures consisting of research universities, industrial firms, and government agencies that evolved in part by purposeful design and in part by historical accident. This institutional framework has served science and government well. But some parts of it are showing signs of strain. As a result, questions must be raised about the adequacy of these institutions to meet the needs and demands they will face in the years and decades ahead. The Task Force concludes that the institutional framework for the support and conduct of basic and applied research should be carefully reviewed, and recommends that such a review be included in the Science Policy Study.

A. THE ROLE OF THE RESEARCH UNIVERSITIES

In the United States the largest single group of institutions to carry out the nation's basic research is universities. In this respect, America differs notably from most other countries where universities place a much greater emphasis on teaching and where research is done in separate research institutions, in government laboratories, and in industry. Furthermore, while the U.S. has approximately 1,500 colleges and universities, 33 percent of the Federally provided research funds go to these institutions. The American approach, while unique, has also proved extraordinarily successful, and it is being emulated on a growing scale. It means, however, that the nation is relying on a group of private and state supported institutions which are subject to a certain amount of instability due to fluctuations in enrollments, variations in levels of support, and turnover of faculty. These are problems which the universities themselves are highly aware of and frequently convey to the Congress and government agencies. This raises important questions about the future role of the universities as performers of basic research, and the Task Force urges that these questions be placed high on the list of issues to be analyzed by the Science Policy Study.

1. What Has Been the Growth in the Number and Size of Research Universities and Academic Medical Research Centers since 1900?

It will be useful and highly relevant for the work of the Science Policy Study to have available an analysis of what constitutes the complex of research universities and academic medical research centers and their evolution and growth since the turn of the century. These are the institutions which currently perform most of the nation's basic research and train most of the Ph.D. and M.D. level researchers.

2. To What Extent Is Basic Research Done outside the Universities?

In order to understand with some degree of precision how research done at the nation's research universities fits into the total picture of all scientific research done throughout the country, we should know how much and what type of research is done in places other than the research universities. Such a review will indicate if certain areas or disciplines of science are significantly covered in environments and in circumstances other than universities, such as, for example, industrial research laboratories. This in turn could have significant implications for the Science Policy Study as a whole.

3. With the Fluctuations in Enrollments and the Resulting Limits on New Faculty Hiring, Should Alternative Institutional Mechanisms for Research Be Sought to Supplement the Universities?

In the event that it becomes desirable to expand further, in a significant way, the research base, the ability of the universities to do so may be in question. Of primary importance is whether Federal policies can assist in reducing the degree of instability experienced by existing research universities. One feasible alternative would be the establishment of research institutions with weak or no links to the universities. Such research institutes would be chiefly characterized by the absence of a teaching function and therefore the absence of a need to tie the number of the research staff to the number of students in need of instruction. Various forms of such research institutes now exist on a very limited scale, but are more prevalent in other countries, especially in Western Europe. The Science Policy Study should carefully weigh the need for such institutes and review the experience gained elsewhere with this kind of arrangement for the performance of research.

4. Should the Number of Research Universities Be Significantly Expanded?

A massive expansion of the nation's research base involving large growth in the number of graduate students, both domestic and foreign, large growth in the number of faculty, and broad-based widening of undergraduate education could also be accomplished through a significant expansion in the number of research universities. This could be accomplished by a concerted effort to strengthen the research role of those universities which are not currently sharing in the Federal research support programs. In considering this possibility the interest of many sections of the country in the geographical distribution of research funds, and the advantages and drawbacks of that criterion for research funding should be weighed. On a more modest scale we can visualize that universities devoted only to graduate training, and thus with a heavy research orientation, might be needed, perhaps focused principally on certain fields of science. The Rockefeller University in New York and certain medical research centers perform research on this model. Whatever the need, we recommend that the Science Policy Study be alert to the wide range of alternatives that should be considered.

5. *What Should Be Expected in Terms of the Comparative Institutional Productivity in Research and in Graduate Education of the Different Institutional Alternatives?*

An examination of possible alternative institutional structures to supplement the research universities should be mindful of the need to consider the importance of research productivity at such institutions. Research productivity should be interpreted here in the broadest sense to mean that both the highest quality science and a reasonable number of publications would be expected.

6. *What Should Be the Contribution of the Primarily Educational Institutions to the Strengthening of Science?*

At the two-year and four-year colleges, headway has been made toward improving the science programs. Instructional equipment has been provided and modest efforts have been made to involve the faculty at these institutions more in actual research. Yet the longer term goals of these efforts to strengthen science at these institutions need to be more clearly focused and better articulated.

7. *What Should Be the Federal Government's Relationship to the Four-Year Educational Institutions?*

With the current strong emphasis on expanding Federal science resources on high-quality, frontier research and graduate education, the role of the Federal Government in science education at the college level is unclear. In our view, the Science Policy Study should devote some attention to this question.

8. *How Should the Various Levels of Higher Education Be Encouraged to Interact to Maintain Quality and Sufficient Numbers in Science?*

The Task Force is well aware that the Federal Government can not do all, or perhaps even most, of the things that are needed to resolve the matter of the future role of the research universities. Those institutions themselves and the many vigorous associations through which they share their concerns and give voice to their views should be encouraged to interact closely with the work of the Science Policy Study.

B. THE ROLE OF GOVERNMENT LABORATORIES

A large proportion of the basic and applied research conducted with Federal funds takes place within the extensive system of government laboratories. Most of the agencies involved in the support of scientific research are directly or indirectly supporting one or more such government laboratories. Because of their significant role in the conduct of research and because of the questions which arise in connection with their operation, the Task Force recommends that their future role and functions be carefully examined as part of the Science Policy Study.

1. *How Has the Large Number of Government Laboratories Evolved over Time and What Are Their Present and Future Roles?*

In some mission agencies which rely on scientific research to perform their functions, such as the Departments of Energy and Defense, government laboratories have long played a significant role. As a result, their number has grown and their managements have vigorously pursued new functions and opportunities. At the other end of the spectrum, some semi-independent government laboratories, such as the Fermi National Accelerator Laboratory, have limited their scope to a single function which they have pursued to the exclusion of adding new activities. In order to fully evaluate the present and future role of the government laboratories, we recommend that an analysis be made of how their structure and function have evolved up to the present time.

2. What Should Be the Policy with Respect to the Establishment of New National Laboratories and the Reorientation of Existing Facilities?

Most national laboratories were originally established for the purpose of achieving a particular goal or to develop solutions to particular problems Because of the large number of such goals and problems to which scientific research has been considered the answer, the number of government laboratories has proliferated. Moreover, while many of these laboratories have continuing missions which justify their continued existence, a certain number do, in fact, complete their assigned task. However, the policy of how to deal with requests for the establishment of new laboratories and of when to reorient existing laboratories which may or may not have completed their original mission has not been clearly spelled out, and, in our view, this is urgently needed. This matter should be taken up by the Science Policy Study.

3. How Are Decisions Made with Respect to the Science Programs to Be Done in the Government's Own Laboratories versus Their Conduct through Grants and Contracts?

A subject of frequent discussion has been the extent to which the research now being done within government laboratories could more effectively be done through grants and contracts with firms and institutions in the private sector, including the research universities. Proponents of a continued strong role for the government laboratories have noted that some types of research should be done under the direct supervision of the government, that having a strong in-house research capability is the best way for the government to be able to judge and evaluate related research in the private sector, and that the existing capacity represented by the people and facilities, frequently of a unique type and size and with singular computer capacity, which constitute the laboratories should be fully utilized. Those favoring a reduced role for the government laboratories have argued that the quality of research done in the laboratories does not measure up to the best research work done outside government, that government laboratory research is more expensive, and that as a matter of policy greater reliance should be placed on private sector research performance. We recommend that these questions be extensively examined with due regard for the many differences in objectives, operating styles, and funding modes that exist.

4. *What Is the Record of the National Laboratories in Attracting and Retaining Highly Qualified Research Personnel?*

A significant factor in assessing the capabilities and future capacity of the government laboratory system must necessarily be its scientific staff. This has been the subject of a number of studies, including several in recent years. We recommend that the Science Policy Study's review of the future role of the government laboratories include a study of the ability of these laboratories to attract and retain highly qualified research personnel, and ways to improve that ability.

C. BASIC AND APPLIED RESEARCH IN INDUSTRY

Several recent estimates seem to agree that industry performs about 50% of the nation's basic and applied research of which 95% is industry-funded. Generally the distinction between research and development expenditures in industry is readily apparent. It is possible to distinguish between the advancement of knowledge and its systematic application. Many industrial laboratories are process and product development facilities linked to production. The work of such laboratories may be classified as development, even though new knowledge sometimes results from this work.

The definition of industrial research is somewhat more difficult. In discussing research activities with various corporations, one can find programs ranging from basic, fundamental studies to improvements in productivity and operating safety. With the elimination of technical innovation projects, the remaining activity is basic and applied research. It is believed that applied research is much more heavily funded in industry than is basic research. It is reported that current emphasis is on turning out new products based on earlier research.

A significant occurrence in the recent past is the formation of multi-company entities to conduct and sponsor basic research. There have been two examples of companies banding together in computer hardware research, and one group devoted to software research. The threat of government intervention, with anti-trust justification, remains, but early federal encouragement has been perceived. The consortia claim that joint, generic research efforts provide program flexibility, elimination of fragmented approaches, and funding leverage. It appears that these research groups will perform research themselves but will look for major contributions by universities.

All of these trends, claims, and relationships should be explored. The industry-university activities appear to have both advantages and disadvantages. There may be an increasing role for government in basic research if industry concentrates on application. Manpower training and utilization in industry should be reviewed and evaluated. Industry is involved in joint ventures, research limited partnerships, university grants, fellowships, and international relationships. Attention should be given to the needs of each, and to the benefits and pitfalls arising from the development of each.

1. How Much Basic and Applied Research Is Done in American Industry and How Much Is Supported by Industry in Cooperation with Universities?

An observed trend, over the last twenty years, is the shift of basic research from industry to the colleges and universities. It has been argued that basic research is properly performed for industry in the nation's universities, which are responsible for educating the scientists, engineers, and managers employed in industry. Despite significant annual increases in funding by industry, the universities still receive less than five percent of their total basic research support from industry. On the other hand, some critics claim that industry-sponsored research in the universities is still directed to near-term payoff at the direction of the sponsors.

2. What Are the Current Trends and Future Prospects for such Research?

Over the last five years a number of industrial firms, both domestic and foreign, have entered into agreements with universities for the conduct of research. This appears to be done by the universities to augment badly needed financial resources and by the firms as a long-term investment in ideas and people. Although still constituting a small fraction of the total funding available to universities, the magnitude should be determined and possible trends ascertained. The possibility of providing incentives for additional developments of this nature should be evaluated.

3. To What Extent and in What Ways Should Government Policies Provide Stronger Incentives for Industry to Conduct and Support Research, both In-House and at Universities?

Industry's ability to conduct research is influenced not only by its perception of the potential for new product development, but also by the extent to which financial resources are available. It is not well known precisely what role particular tax incentives for research play in the decision-making process of individual companies. For example, there has been a good deal of discussion about the effects or lack thereof of the R&D tax incentives included in the 1981 Tax Act. This entire question should be reevaluated as part of the Science Policy Study.

4. How Many of the Scientists Graduating from U.S. Universities Are Employed in Industry, and How Many Foreign Nationals Perform Scientific Research in American Industry?

Sporadic, anecdotal evidence surfacing in recent years suggests that the manpower situation in industry is under strain. There have been suggestions that industry increasingly prefers to hire bachelor-level engineers and provide additional education within the firm on the basis that graduates with degrees at the master's and doctoral levels are not suited to industry cond[illegible]s. There have been suggestions that in order to hire enginee[illegible] in certain fields some firms have had to recruit from abroad. And, with respect to the university engineering schools, there have been suggestions that in certain of the newer disciplines of engineering, academic jobs go begging because the universities cannot match the salaries offered by industry. This entire cluster of issues should be carefully examined as part of the Science Policy Study.

5. What Are the Future Demands by American Industry for Scientists and to What Extent Should Industry Contribute to Their Education?

Industry employs large numbers of scientists but the magnitude of future needs has not been determined. Much concern has been expressed about the ability of present graduation rates to meet that demand. Particular concern has been expressed about the ability to meet the need for scientists in industry, and this naturally raises the question of whether industry should take an expanded degree of responsibility for the education of scientists, as has already happened in a small number of cases.

6. To What Extent Do Industry Scientists Contribute to the Advancement of Science by Publishing in the Open Literature?

It is understood that scientists performing research in industry do so principally in the expectation that new products will eventually result. Hence most companies place various restraints on the free or immediate publication of some research results pending patent application, product development, or other steps to protect their competitive position. This factor has led some government science agencies to show reluctance in funding research at industrial firms. We recommend that, as part of the Science Policy Study, an effort be made to determine the extent to which industrial researchers do or do not publish in the open, scientific literature, and the degree of lag in publication as compared with university publication.

D. GOVERNMENT RESPONSIBILITY FOR THE RESEARCH INFRASTRUCTURE

The research infrastructure is, in the most general terms, the supporting surroundings which enable the scientist to accomplish his or her tasks. It includes buildings, facilities, laboratories, computers, and libraries. It also includes the technicians, research assistants, administrators, and other support personnel who perform the support and management functions that allow research institutions to function. In recent years the spotlight has been focused on two components of the research infrastructure: the needed research instrumentation and, more recently, the "brick and mortar" needs. The Science Policy Study should review the entire question of the future infrastructure needs and the role of the government in providing and maintaining it.

1. How Well Did the Institutional Grants Programs of the National Institutes of Health and the National Science Foundation Work in the Post-World War II Period?

During the twenty-year period after 1945, several of the science agencies, most notably the National Institutes of Health and the National Science Foundation, conducted several programs which had as their sole purpose the provision of funds for the construction of new laboratory buildings and other large research facilities. These programs were initiated in recognition of the urgent need for expanded space at the nation's research institutions. These programs were phased out, however, when it was concluded that a certain capacity had been achieved. With the reemergence of a concern about the need for extensive and costly renovation of obsolescent buildings and for new research and laboratory buildings, it would be highly useful to obtain a careful analysis of the experience gained in those earlier programs, their effectiveness, the pitfalls they faced, and other relevant aspects.

2. What Is the Current Status of and Needs of the Research Infrastructure at the Research Universities?

Scattered, anecdotal evidence has recently emerged to indicate that there is a particularly urgent need at American universities for funds to construct new buildings and facilities. However, little systematic information is available. In the late seventies a similarly urgent need for research instrumentation surfaced. But little hard data was developed to indicate and circumscribe the nature and magnitude of this need. Thus, although the government took steps to provide some resources aimed at solving the instrumentation problem, it is not known to what extent these resources have helped ameliorate the shortage. Furthermore, this experience suggests that in future years, similar, specific issues concerning other parts of the infrastructure may well occur, leading to requests for categorical assistance targeted at such problems. This suggests that it would be most helpful to conduct a comprehensive review of the current status and future needs of the infrastructure as a whole. Such a review might well provide guidance to the formulation of future policy initiatives. It might also serve to alert officials in the research institutions and in the funding agencies to the need to view this area as a whole rather than on an *ad hoc*, piecemeal basis.

3. Should Government Support for Laboratory Construction, Libraries, and Instrumentation, Rely on Direct, Categorical Grants, Research Grant Indirect Costs, Loans, or Loan Guarantees?

A number of mechanisms can be used in the event the Federal Government decides to provide support aimed at meeting the infrastructure needs of the research universities and other research institutions. They include direct, categorical grants under which the funds would be provided to the research institutions in response to applications aimed at particular, well-defined needs, such as a building or a laboratory. It also has been suggested that funds could be provided by allowing all such infrastructure costs to be included in the indirect cost category associated with research grants. Under this approach, both direct purchases and depreciation charges would be allowable, and would thus permit the institutions to obtain the funds to defray infrastructure costs on a continuing basis. Loans or loan guarantees would involve the government in reviewing the institutional needs but would not require the commitment of Federal funds. The institutional needs, however, would also be subject to evaluation by private lenders and would be tied to capital availability and interest costs. The Task Force recommends that the advantages and disadvantages of the various mechanisms for providing assistance with infrastructure needs be reviewed carefully and that their applicability under different circumstances be determined.

4. Should the Government Facilitate Alternative Forms of Financing Infrastructure Needs such as Debt Financing?

The financing of that portion of the infrastructure which involves substantial sums on a one-time basis, chiefly the construction of new buildings or facilities, has in the past mainly been through grants from major foundations, private gifts, or through direct government grants. In other sectors of the economy, however, a range of different financing methods for such buildings and facilities is used, including loans, revenue bonds, loan guarantees, and lease-purchase arrangements. The reliance on, and the applicability of, such alternate methods of financing for research institutions should be carefully examined, and the question of providing special financial incentives for those methods found promising should be studied.

5. How Should the Government Promote Industry-University and University-National Laboratories Sharing of the Costs of Infrastructure?

With the rapid growth in the cost of maintaining, replacing, and providing new infrastructure for the research institutions, the potential for sharing these costs with industry and the national laboratories takes on added importance. We recommend that this question be viewed in the broadest terms. It should not be limited simply to the question of obtaining funds for infrastructure costs at the universities, but also include such questions as the sharing of research and other facilities and their support staffs, innovative ways of financing the acquisition and operational costs of infrastructure items, and ways to obtain increased utilization and benefits from the existing infrastructure.

E. INTERNATIONAL COOPERATION IN "BIG SCIENCE"

"Big Science" involves the provision of large, very expensive research facilities such as astronomical observatories, magnetic fusion devices, oceanographic vessels, and particle accelerators. All indications are that the future requirements for continued advances in science will require a growing number of such facilities and that their use will spread into areas of science where they have not been needed in the past.

The cost of the initial construction and subsequent operation of these big science facilities will undoubtedly continue to mount. At a time when the federal budget is severely unbalanced and may continue to be in difficulty, and when comparable budgetary pressures exist in other countries, it is natural to ask whether international collaboration and support for big science research facilities should be sought in the future.

It is well known that such international cooperation has succeeded spectacularly in a small number of cases. The best known example is the European Center for Nuclear Research (CERN) located outside Geneva, Switzerland. On the other hand, CERN has not led to widespread imitation possibly due to factors such as scientific and political nationalism. The Task Force recommends that the subject of joint international construction and operation of future big science facilities be included in the Science Policy Study.

1. How Many Big Science Facilities Now Exist around the World?

Any review of the policy for the funding and operation of big science facilities should be based on a solid foundation of information about the number of such facilities existing in the United States and around the world. This should include not only the number of facilities in each country, their research activities, purpose, and cost, but also an analysis of the extent to which each has been jointly funded and operated, and a comparison of the success of their scientific research activities. The Task Force recommends that an inventory of these facilities, accompanied by an analysis of their activities, be obtained for use in the Science Policy Study.

2. What Are the Advantages and Disadvantages of Sharing with Other Nations the Cost of Big Science Facilities?

A number of assumptions about the advantages and disadvantages of joint support for our big science facilities are often expressed or assumed. These should be carefully explored in terms of their validity and future applicability. A frequent but unstated assumption is that by sharing the cost of construction and operation of big science facilities, each nation participating will incur less cost while obtaining many of the same benefits it would obtain if it had its own national facility. A careful analysis of this question should be made. Another, also unstated assumption, is that significant, rather than token, cost sharing can be obtained for a given big science facility. As noted above, the financial pressures existing in many other countries may place very real limits on what can be achieved in the way of international participation. Concern about American dominance in such projects also may produce reluctance to participate. The scientific productivity of jointly operated big science facilities in comparison with national facilities is not well known and should be carefully considered.

3. Should the U.S. Seek to Develop Some or All of Its Future Big Science Facilities on the Basis of International Cooperation?

Even if it is concluded that there are advantages in joint international participation in future big science facilities, there may well be special factors affecting each individual case. For example, it may be easier to obtain international agreement about collaboration on facilities for astronomy than for physics. The site for such facilities, especially whether a particular device is to be located in the United States or elsewhere, could well affect the support the project would have both at the scientific and at the political levels in all the participating countries.

F. COORDINATION AND MANAGEMENT OF FEDERAL RESEARCH PROGRAMS

The size and diversity of the Federal Government's science activities requires that careful management and extensive coordination be exercised. But the nature of scientific research, with its reliance on individual insight and initiative and its search for breakthroughs, does not easily lend itself to such management and coordination in the traditional sense. Strong central direction from the nation's capital may be applicable in procurement policy, but may be counterproductive if applied to the government's science programs. On the other hand, the magnitude which these science programs now have reached means that waste and unnecessary duplication must be avoided no less than in other large government programs involving the expenditure of the taxpayer's moneys. The Task Force recommends that the management and coordination of these programs be studied in some depth, taking into account the special needs and unique nature of scientific research.

1. How Is the Federal Government Organized for the Conduct and Support of Rese ?

The organizational structure of the many Federal agencies engaged in the support of basic and applied research varies widely. Some agencies, such as the National Bureau of Standards, employ, almost exclusively, in-house laboratories with a large staff of civil service scientists to perform research. Others, such as the National Science Foundation, rely mainly on private non-governmental scientists whom they provide with funding through grants and contracts. In some cases an agency is even prohibited by law from establishing its own laboratories. Yet other agencies, such as the National Institutes of Health and the National Aeronautics and Space Administration, use a combination of in-house laboratories and external grants and contracts to perform the needed research.

In some agencies research is closely integrated with the mission of the agency, and research and research training is performed with the aim of advancing the primary mission. This is the case, for example, in the Department of Transportation. In other agencies there exists a mixture of mission-related research closely tied to the work of the agency, and research which is basic in nature and related to the agency's mission only in the most general way. At the National Institutes of Health and the Department of Defense this combination of the two modes of research is prevalent.

A further characteristic of the Federal Government's organizational structure is that some of the agencies are organized internally along the lines of the scientific disciplines while in other agencies the disciplines are subordinate to a group of diseases, or a group of environmental problems, or a similar set of topics. This wide range of organizational arrangements for the government's conduct of scientific research reflects, at least in some instances, the optimum organizational structure for the various types of governmental roles that must be performed. It undoubtedly also reflects, at least in part, an historical evolution and individual or Congressional preferences. We recommend, therefore, that the Science Policy Study review the organizational structures used under various circumstances to organize the government's science programs with a view toward developing recommendations for improvements where it is found necessary.

2. Is the Pluralism of Many Support Agencies Working Effectively in Practice?

It is well known that for any particular area of scientific research more than one Federal agency, and frequently three or four, can provide financial support. This "pluralistic" structure of the Federal Government's system of providing support is said to be advantageous because it helps to ensure that worthwhile research can be funded. If one agency initially turns down a particular research proposal, another agency may later be able to provide the necessary support. In the aggregate, this is said to ensure that few worthwhile areas and subdisciplines of science go unexplored. Little is available in the way of definitive data about whether the pluralistic system functions in this manner. Nor is it well known whether the pluralistic system is effective from the point of view of efficiency, the avoidance of unjustified duplication, and over-all administrative costs. We therefore recommend that the advantages and disadvantages of a pluralistic form of government organization for the support of science be carefully evaluated as part of the Science Policy Study.

3. What Are the Roles of the Office of Science and Technology Policy and the Office of Management and Budget in Coordinating Federal Science Programs and Funding and in Avoiding Wasteful Duplication?

Beginning with the onset of World War II, a succession of Presidents have found it necessary to establish or reestablish a series of offices and committees to bring coordination and advice to bear on national problems which have a strong science component. Similarly, in the budgetary process, the President's Budget Office gradually found it necessary to strengthen its role in overseeing the various science budgets. Following the abolishment of the Office of Science and Technology (OST) by President Nixon in 1973, the current Office of Science and Technology Policy was reestablished on a statutory basis in 1976 after extensive Congressional hearings and in close cooperation with President Ford. In addition, a number of closely related councils and committees have functioned with varying degrees of success as adjuncts to the White House Science Office. Some of these were intended to perform coordination functions perceived to be urgently needed. However, several have not been operative in recent years. Whether this is because the need is being met through other means or is being neglected is not well understood. The Task Force believes that while some of these questions are not being prominently raised and debated at this time, they are of continuing importance.

The importance of the Office of Science and Technology Policy and the Office of Management and Budget cannot be overemphasized, since it is in these agencies that all Federal science issues and requests meet. It is only in these agencies that a comprehensive evaluation of Federal science can be made on a continuing basis. The role of these agencies therefore should be included in the Science Policy Study and given careful attention.

4. How Well Is the Extensive System of Advisory Committees with Members from Outside Government Working?

It has long been a particular characteristic of government science policy that advisory committees play a strong role in the formulation and execution of policy for science. Because of the highly specialized knowledge and understanding which science embodies, few of the government's own, full-time officials can be fully aware of developments in every field and subfield within science and their potential future direction and application. Advisory committees permit the government to obtain the most well-informed judgments of scientists with such specialized, up-to-date knowledge. They typically consist of scientists who donate their time and are reimbursed only for their expenses attendant upon their participation in the meetings of the committees. The effectiveness of these advisory committees has not been studied extensively. The Task Force therefore recommends that evaluations of various advisory committees be made, including, but not limited to, member background and experience, extent of information provided, benefits and disadvantages of volunteer participation, extent of implementation of committee recommendations, and the degree of continuity of service experienced.

G. ROLE OF THE NATIONAL ACADEMY OF SCIENCES

The National Academy of Sciences was chartered by the Congress well over one hundred years ago to provide scientific advice to the Federal Government. Under this charter the Academy has produced a growing number of reports on a wide range of scientific and technological subjects. These reports have been commissioned and funded by the agencies of the Federal Government, and in rare instances by the Congress. Within the last several decades it has been supplemented by the National Academy of Engineering and the National Institute of Medicine. The operating arm for all three academies is the National Research Council which was established under an Executive Order of President Woodrow Wilson during World War I. Although the Academy in recent years has sought to expand its endowment resources, the overwhelming source of funds for the many valuable studies of science and technology related issues continues to be the agencies of the Federal Government. Thus the Academies constitute a major, influential, and highly respected source of advice in the fields of science and technology policy.

1. How Well Is the Academy's Advisory Function to the Federal Government Being Performed?

Although the Academy increasingly has been called upon since 1945 to provide advice on a broad range of science and technology issues, there has been no review of this function by the Congress during that period. The manner in which the advice is used, both within the Executive Branch and the Congress and in the wider scientific and technical community, and its impact on national policy should be reviewed. Such a review should focus on the impact, quality, and cost of the advice.

2. *Is the Financial Structure Supporting the Academy's Advisory Functions Adequate?*

As is the case with the government's support of basic and applied research, where the individual project grant has come to predominate, the government's requests for advice from the Academy is also tied to individual projects. The advantages of this approach are many, but it also leads to a good deal of administrative work, and, more importantly, it means that the Academy rarely addresses issues on which its advice is not specifically sought. It might well be worthwhile to determine if the project system of obtaining advice from the Academy should be supplemented with a form of support which would give the Academy greater freedom in initiating self-selected projects on topics it judges of importance. The Task Force recommends that the financial arrangements for supporting the Academy's advisory functions be reviewed.

III. EDUCATION AND MANPOWER

The close relationships between scientific research, the education and training of new scientists, and the demand for scientific manpower is well known. It led to our conclusion that the many issues associated with science education at the graduate and postdoctoral levels, and manpower utilization and demand should be included in the Science Policy Study. We outline below the specific issues in this area which we believe merit particular attention as part of the Study.

A. THE PAST, PRESENT, AND FUTURE GOVERNMENT ROLE IN SCIENCE EDUCATION

During the last 40 years, the government has engaged in a number of science education programs at the advanced levels. Some of these have been highly successful, others have not met the expectations held for them. We recommend that a careful look be taken at the successes and failures in the light of future circumstances and demands.

1. What Has Been the Federal Role in Science Education?

The major Federal role in education began with the G.I. bill immediately after World War II. Its role in science and engineering education began with the National Defense Education Act, which was followed by the fellowship programs of the National Institutes of Health and the National Science Foundation, the traineeship programs of the National Aeronautics and Space Administration, and any other programs for supporting advanced education should be carefully reviewed to determine how well they met the goals for which they were designed, how well their selection and administrative aspects worked, and whether any significant factors affected the careers of those individuals who received their education through the assistance provided.

2. Which of the Past and Present Science Education Programs Should Be Continued and What Modifications Should Be Made?

If it is concluded that direct stipends for advanced science education are desirable, a number of questions about their most effective administration should be examined. For example, the differences between traineeships, which are given to a university for graduate students at that institution, versus fellowships, which are given to graduate students for use at a university of their choice, should be scrutinized and the advantages of each evaluated.

3. What New Initiatives Are Needed?

In addition to the careful examination of past and present science education approaches, it may well develop that future needs dictate that new and different approaches be pursued. Innovative approaches to the support of advanced science education could well be needed.

4. What Is the Proper Federal Role in Funding and Setting Policy for Science Education at the Advanced Levels?

A central question in determining the Federal role in the advanced education of scientists is whether the government should seek to anticipate the future demand in each field of science. Such forecasts would then lead to decisions about the number of stipends to be offered, thus influencing the intake of beginning graduate students. The alternative to this forecasting approach is to place the main reliance on the marketplace; that is, to let the students themselves judge the future opportunities for employment in each field of science and tailor the allocation of stipends to this expression of demand. These alternative approaches, along with the success or failure of past approaches, should be considered as part of the Science Policy Study.

B. EFFECTS OF LONG-RANGE POPULATION TRENDS ON SCIENCE AND ENGINEERING MANPOWER POLICY

A recurrent phenomenon in recent decades has been the shifts in the levels of student enrollments and the resulting impact on faculty hiring. This impact has been augmented by Congressionally mandated prohibitions against age-related, forced retirements. These factors have, at many institutions in the early eighties, led to situations where very few faculty members were leaving the institutions. Consequently, little expansion in total faculty size took place, and, as a result, institutions were able to add few younger scientists to their faculty each year. In addition, both as faculty members and as students at the graduate and undergraduate levels, foreign nationals are growing in numbers.

1. What Are the Relationships between Future Demographic Trends and University Enrollments, the Need for Science Faculty, the Number of Advanced Graduate Students, and the Need for Scientists, Medical Doctors, and Engineers in the Private Sector?

It is clear that many of the changes in educational and manpower demands are related in a significant way to general developments in the rates of births and retirements. These broad, demographic changes, if prudently used in connection with other data, might well provide insights that help anticipate future changes in enrollments and related developments. The Task Force concludes that a stronger effort to anticipate these fluctuations in university enrollments should be made so that the effects on the size and composition of science faculties can be anticipated and mitigated.

2. In the Longer Term, What Fraction of the Needed Number of Scientists and Engineers Can Be Expected to Be Made Up of Women and Minorities?

With a growing interest on the part of women and minorities in pursuing opportunities as professional scientists and engineers, and with the government and others actively seeking to encourage such careers, what can the expected impact of these developments be? As part of the demographic analysis proposed above, we recommend that this question be examined, along with the identification of barriers to such participation and the means for the lowering of these barriers.

C. THE GOVERNMENT'S ROLE IN PROFESSIONAL EDUCATION

Closely related to the education of research scientists is the question of the education of engineers and medical doctors. These professions are research intensive, yet they both involve aspects that lie beyond the training in and practice of research. Both professions involve the application of the results of research in professional practice. Both include a strong scientific component in their educational structure, and in both a small but significant number elect to make careers in research rather than in professional practice.

1. What Should the Future Role of the Government Be in the Professional Education of Engineers and Medical Doctors?

Unlike advanced education for a career in science and medicine, some other types of professional education have traditionally seen less government involvement. This has been due, at least in part, to the perception that individuals entering these professions would receive substantially higher levels of compensation upon entering a career. As a consequence, loans by educational institutions rather than outright Federal stipends have been provided. The Science Policy Study should review the present modes of financing professional education in engineering and medicine, and, if needed, make recommendations for the appropriate role of the Federal Government.

2. What Programs for Postdoctoral, Doctoral, and College Education Have Been Used in the Past to Support Professional Education, and to What Extent Have They Achieved Their Goals?

The Science Policy Study would benefit from a review of past governmental programs which have been carried out in support of engineering and medical education at all levels. Such a review should include particular attention to the objectives of these programs and how well those objectives were achieved.

3. Among the Various Methods of Providing Stipends for Such Students, Which Have Proved the Most Effective?

The review of past progams in support of engineering and medical education should pay particular attention to the comparative effectiveness of fellowships, traineeships, and other mechanisms through which such support has been provided.

4. What Implications Do Changing Demographics Have for the Form that Federal Support of Science Education Should Take?

The longer term changes in demographics should be carefully weighed and taken into account in structuring Federal support of science education. Incentives and disincentives that would in the longer run result in a significant unbalancing of supply vis-a-vis demand should be considered with the greatest care. The necessary flexibility and alertness to evolving trends in both supply and demand should be encouraged, and the Science Policy Study should attempt to develop the necessary statistical data to improve our capability in this area.

D. EQUITY OF OPPORTUNITY

An important objective in all Federal education programs is to ensure that the resources being made available provide an equal degree of opportunity to all qualified students. This is particularly important in science because an untapped reservoir of highly competent individuals may exist which have not in the past entered careers in science.

1. Have Federal Efforts Promoted Equity of Opportunity for Education and Careers in the Sciences?

The success of past efforts to provide equity of opportunity for education and careers in science should be carefully evaluated. The results of this evaluation may permit corrective recommendations to be made with respect to future science education programs.

2. How Might Future Programs Allocate Educational Resources More Equitably to All Groups of Potential Scientists and Engineers?

In addition to assuring that equity of opportunity exists in terms of such steps as preparatory work and entrance examinations, it is also important to assure that available educational resources be equitably distributed to all groups with individuals that have high potential for careers in science and engineering. The review should address this important question.

E. HOW SHOULD THE EDUCATION OF SCIENTISTS, DOCTORS, AND ENGINEERS BE PAID FOR?

A number of instruments have been used to channel Federal funds to those individuals who are to receive the support of the Federal Government during their graduate education. The most prominent has traditionally been the provision of some form of stipend to the individual to help him or her defray educational expenses. In more recent years emphasis has reverted to a more indirect method of providing such support by channeling it through research grants. In this mode the student is selected by the research professor, and works on, and is paid by, the research projects awarded to the professor.

1. What Is the Relationship of Federal Funding to Doctoral Production?

When stipends of some form are provided to individual graduate students, it is easily feasible to determine the number of such students being supported at a given time and thus relate the degree to which these government programs will meet expected needs, insofar as they can be predicted. However, when stipend support is replaced by funding via research grants, few if any attempts appear to have been made to establish the number of students expected to benefit and the numbers which have been graduated. This gap should be closed by the gathering of sufficient statistical information.

2. What Is the Optimum Mix of Funding for Graduate Science Education?

There are undoubtedly distinct advantages to be gained from the several methods used to provide Federal support for graduate and postdoctoral education and training. These advantages and disadvantages may possibly be related to different disciplines, different institutional settings, and other factors. In order to assist in evaluating the comparative advantages of these methods and their applicability, we recommend that this question be examined as part of the Science Policy Study.

3. To What Extent Should the Production of Scientists, Engineers, and Doctors Be Related to Demand?

In determining the number of graduate students which should be supported at any given time, several approaches have been taken. Using a "demand approach," decisions are made within the government at two levels: first, what is the expected over-all demand, and, secondly, what fraction of that number should government funding seek to support through various forms of financial assistance? Another approach that has been taken might be termed the "market approach." In this approach, government disassociates itself from any attempt to predict society's need for scientists, engineers, and doctors, and instead arrives at the number to be supported by determining how many students are applying for stipends. In a sense this approach transfers the judgment of future needs from the government to the prospective graduate students. The Task Force recommends that the Science Policy Study evaluate the comparative merits of these two approaches and make recommendations about when each should and should not be used.

F. ENGINEERING EDUCATION

Engineering education serves a need which is as important as the need for science education. It has many aspects and problems that are quite similar to those of science education, but it also differs in several significant respects. Although technology development as such is beyond the scope of the Science Policy Study, engineering education, which takes place in the universities, is closely related to the subject of science education insofar as the relevant support and funding issues are concerned. This, combined with the intrinsic importance of the subject, led the Task Force to recommend that engineering education, and the Federal Government's role in its support, be included in the agenda of the Science Policy Study.

1. What Are the Needs of Industry and the Universities for Engineering Graduates at the Various Levels?

A good deal of anecdotal evidence has suggested that the training provided by some engineering colleges may be drifting away from the type of training demanded by industry. At the same time the faculties at engineering schools are said to be short of qualified members, in part because of frequent requirements that such individuals have Doctoral degrees and be oriented toward research careers. Although most of these questions are matters for the institutions themselves to decide and establish policies for, we recommend that the Science Policy Study obtain a factual base of information about these important factors.

2. Should Government Support for Engineering Education Be Focused Solely on the Research Component of Professional Education?

The major, current initiative in the area of engineering education has been the National Science Foundation's move to establish a group of engineering research centers to supplement the existing program of research grants for engineering faculty. Both thrusts are, however, principally research oriented and it is not clear that all our national needs are well served by an approach which thus deemphasizes other important aspects of engineering education. We recommend that the Science Policy Study review these questions of what a well-balanced program of support for engineering education should involve.

3. What Should Be the Role of Foreign Nationals in Engineering Education?

Both as faculty members and as students at the undergraduate and graduate levels, foreign nationals are growing in numbers. Such individuals are frequently among the best and the brightest, and their contributions are unquestionably significant and important. In the shorter term such individuals pose questions arising from the desire of some to remain in the United States rather than return to their native lands where their contributions may be needed. The difficulty in industry and in the university of employing foreign nationals in defense work is also of growing concern. In the longer term the presence of foreign nationals in the American engineering community raises questions about the future capability of U.S. engineering and American engineering education. The role of foreign nationals in American engineering should be reviewed as part of the Science Policy Study.

G. NEW EDUCATIONAL TECHNOLOGIES

The very rapid advances in those technologies that communicate, store, manipulate, and display information will unquestionably impact all of education, including science education, at all levels. This revolution in information technology in turn will affect the way science is taught and also will affect the way in which scientific research is conducted and research training done.

1. How Can Modern Educational Technology Best Be Utilized to Enhance Science Education at All Levels?

The indiscriminate introduction of modern educational technology into the educational process would in all probability not be desirable. These technologies require the thoughtful consideration of the many factors that have an impact on good education. In order to enhance their effective use in science education, those factors should be evaluated carefully so that the best utilization of the vast potential which they represent is achieved.

2. How Can Non-Academic Routes, such as Television and Home Computers, Be Utilized for Science Education?

One of the notable possibilities which has materialized in connection with the new information technologies is their use in education apart from the traditional academic routes. This may include new approaches to adult education, education in the home and workplace, degree programs for Americans stationed abroad and in the military services, and scientific literacy education for all citizens. These opportunities should be explored with due consideration of the limits imposed by both the technology and by the learning process.

3. What Should Be the Role of the Federal Government in These Endeavors?

The new educational technologies clearly offer an array of opportunities for a broadening of both the scope and reach of education. The principal responsibility for achieving the full potential of these new technologies must necessarily rest with the individual and with local and state educational bodies. However, the Federal Government may also have opportunities and responsibilities to disseminate, coordinate, and encourage the use of these technologies. The Science Policy Study should address the question of what the Federal role should be in bringing modern educational technology to bear on science education at all levels.

IV. Impact of the Information Age on Science

The Information Age, characterized by the widespread introduction and use of modern information technologies such as telecommunications, electronically-stored data bases, and computers, is affecting many sectors of society. The conduct of scientific research is affected on a growing scale. This may lead to new ways of doing research, research on subjects not previously explored, and may in the long run affect the content and scope of science as a whole. The Task Force recommends that this matter be carefully examined as a significant part of the Science Policy Study.

1. How Will the Dissemination and Use of Research Results Be Affected by the Information Revolution?

One of the first ways in which the information revolution is affecting the conduct of scientific research is in the manner of scientific publication. Already much indexing and cataloging has been computerized, certain data resulting from some research projects are issued in electronic form rather than in printed form, and some literature searches are done by means of computerized data bases and computerized bases of footnote citations. This trend will move forward rapidly, and will impact the way in which research is done and the way in which the results are disseminated, the speed of availability, and the cost of dissemination.

2. What Changes Affecting the Individual Scientist and Research Institutions Will Take Place?

The information revolution will affect not only the way science is done but also the individual scientist and the institutions where he carries out his research. The customary ways of collecting, analyzing, and storing scientific information and experimental data may require new institutional support mechanisms and may lead to different requirements for support personnel and equipment and other changes difficult to predict. The introduction of new generations of computers, and the growing interest in the use of supercomputers, science networks and data bases are already raising many questions about changing research styles. These changes should be examined as part of the Science Policy Study.

3. How Should the Government Respond to the Effects of the Information Revolution on Science?

The longer term changes in science itself and the way it is conducted and supported within the institutional frameworks may well lead to different modes for government support of research. Different attitudes and policies for conveying such support and for dealing with the reports and results of research may be required. The Task Force believes that while it may be difficult to predict the nature of such changes in detail, some trends are already visible. Because of the importance of these trends and the ultimate effects of the information revolution on the science enterprise and on the role of government in sustaining it, this subject should be an important item on the agenda of the Science Policy Study.

V. Role of the Social and Behavioral Sciences

The social sciences occupy a special place in the broad spectrum of government science policy. Several factors account for this. Less certainty is possible in achieving scientific findings, in discovering applicable laws, and in predicting future developments; the subject matter of the social sciences frequently borders on matters where social, political, and religious values are important; and the promise of improving human behavior and social life on a substantial scale is offered by these sciences. As a result, the extent to which government support should be provided for scientific research in the various social sciences has been the subject of frequent debate. Reflecting this, levels of support have fluctuated over the years.

The Task Force has in general taken the position that the content and promise of individual scientific disciplines, such as chemistry, astronomy, or oceanography, could not be covered in detail by the Science Policy Study because of the very extensive effort that would be required. However, in the case of the social and behavioral sciences, we recommend that an exception be made. The importance of the social sciences, and the visibility which the question of future government support has achieved, especially the role of the Congress in sustaining past research programs in these disciplines, suggests that the subject should be addressed as part of the Science Policy Study. We therefore recommend that the role of the social and behavioral sciences be placed on the agenda of the Study.

1. In Making Decisions about the Support of the Social and Behavioral Sciences by the Federal Government, what Criteria Should Apply?

We have suggested elsewhere in this report that certain criteria may apply generally to the government's support of science. Because of the special nature of the social sciences it will be useful and relevant to review how well these criteria apply to these sciences, or whether other and different criteria are more applicable.

2. To What Extent Do the Social Sciences Help the Nation Make Informed Use of the Discoveries and Technologies Produced by the Physical and Life Sciences?

It is widely recognized that many of the changes now occurring in society are attributable to the advances taking place in the physical and life sciences. Because the social sciences have for their subject the actions of individuals and their interactions in society, it will be of interest to assess how well these sciences are able, at their current state of development, to contribute to an informed adjustment to such changes.

3. To What Extent Has Past Social and Behavioral Science Research in Any of the Disciplines Contributed to the Formulation of Social and Other Policies, and What Are the Prospects for the Future?

An important criterion for support of research in the social sciences must necessarily be the expectation that the resulting findings will contribute to the formulation of social policies the solution of social problems, or the decision-making process at the judicial or regulatory level. In order to arrive at an understanding of what can be expected from future social science research, the Task Force recommends that an extensive, in-depth analysis of the past record in this area be made so that a sound basis for judgment will be available.

4. What Contributions to National Priority Setting Should the Social Sciences Be Making that They Are Not Now Making?

The deeper understanding of human needs and social processes which is expected to be achieved from research in the social sciences should provide an enhanced level of understanding relevant to national policymaking and priority setting in many areas. It will be useful to determine how much this is already the case, and the extent to which a potential for further contributions exists.

5. What Is the Role of the Government in Facilitating or Inhibiting the Contributions of the Social Sciences to the Resolution of Issues of National Importance?

Research in the social sciences has advanced steadily in the decades since 1945, and many findings have emerged. The use or nonuse of these findings is not, however, automatic, and may or may not be justified in particular circumstances. The role of the government, including the Congress, the Courts, and the Executive Branch agencies, in facilitating or inhibiting the use of these findings in resolving issues of national policy should be examined.

6. To What Extent Should Support Distinguish between the Individual Disciplines within the Field of the Social and Behavioral Sciences?

In making judgments about the budgetary levels of support for the social sciences, the Congress has studied the proposed budgets for the individual disciplines, such as anthropology, economics, and psychology. But it has customarily authorized and appropriated funding in the aggregate, encompassing all of these disciplines in one lump sum. The diversity of the individual social science disciplines and their differing degrees of maturity and relevance to societal problem solving might suggest that the Congress differentiate between the levels of support to be provided. On the other hand, the ability to make such judgments, and the time required to delve into the state and opportunities in each field, might mitigate against such an approach. We recommend that the advantages and disadvantages be evaluated.

VI. The Regulatory Environment for Scientific Research

In various ways societal values have led to the regulation of research. Concerns about safety led to the regulation of research on certain diseases and on Recombinant DNA; concerns about the potential conflict with human values led to the regulation of fetal research and certain types of behavioral research involving human subjects; and national security concerns produced an intense debate about the regulation of publications and other forms of dissemination of research results. This is one of the few areas in which the aims of science and the aims of society are not necessarily congruent. The manner in which these conflicting aims are accomodated is of significant importance to both science and society, and the principles for achieving the needed balance must be carefully developed. The Task Force concludes that this is a subject likely to be of continuing importance, and recommends that it be considered in depth in the Science Policy Study.

1. How Should the Future Regulatory Environment for Science Be Shaped in Order to Obtain All the Benefits from Science while Still Responding to the Need that Science Avoid the Ill Effects Arising from Regulation?

From the point of view of scientists, the ideal situation with respect to externally imposed regulations is that they should be avoided, and in practical terms minimized. Scientists may be prepared to accept a certain amount of regulation of their work in those cases where the effects are clearly detrimental. But they are concerned about what some of them see as an increasing tendency to strengthen regulation where it already exists and to add regulations in new, previously unregulated areas without considering the adverse effects on science.

2. How Can the Legislative and Regulatory Authorities Representing Society as a Whole Achieve the Protection of Health, Safety, and Values while Still Avoiding the Imposition of Unnecessary Restraints on Science?

From the government's point of view, certain dangers to human life, health, safety, and social values should be regulated so as to eliminate, or in practical terms to minimize, such dangers. The government is prepared to balance such regulatory efforts against the desire of scientists to keep research activity and the communication of its results as free as possible. Nevertheless, it is concerned about the growing number of scientific activities where potential adverse effects appear to exist.

VII. Funding Levels

The most prominent manner in which national priorities for science and within science are debated and settled is the budget process. This process involves the Federal science agencies, the President's budget staff, and the Congress. The manner in which funds are allocated to scientific research both by the government and by other providers of such funds is therefore of central importance to a study of American science policy and its future.

A. HISTORY OF SCIENCE FUNDING SINCE 1945

We noted in the introduction to this report that the Federal Government's entry into the support of science on the massive scale it has achieved today began less than forty years ago. To fully understand how this came about and thus be able to make informed judgments about future trends, it will be helpful to have available a detailed analysis of science funding since 1945.

1. *What Have Been the Trends in Science Funding since 1945?*

The trends in over-all funding levels for the government as a whole and for the individual agencies, as well as an analysis of a range of further disaggregations, should be included in the analysis done as part of the Science Policy Study. These disaggregations should include funding trends by discipline and subdiscipline, by the various categories of cost elements, and by other categories which may prove helpful in the course of the Study.

2. *What Have Been the Trends in Non-Federal Support of Science?*

Since 1945 a number of sources other than the Federal Government have also provided support for scientific research. Such support has come both in the form of funding and in the form of donations of equipment, land, and other tangibles. It has come from State governments, from domestic and foreign industrial firms, from private foundations, from individuals in the form of gifts, and perhaps from other sources. An understanding of the strengths, limitations, and unique characteristics of these non-Federal sources of support for science will no doubt be of significance to the Science Policy Study by placing the Federal role in a broader context.

3. *What Have Been the Effects of High Levels of Inflation, and What Will Be the Effects of a Possible Era of Low Inflation?*

The research community, along with most other sectors of society, has had to cope with the high inflation rates which have affected almost all research-related costs. In the course of dealing with those cost escalations over a ten-year period, certain responses and patterns of operation were incorporated into the normal operating mode of many researchers and many research institutions. Annual cost growth has come to be expected and accepted, and appropriate responses have been developed and become routine. However, it now appears that there is a possibility that the rate of inflation is becoming substantially lower and that it may stay comparatively low. The failure to adjust to this new and significant factor in the environment for research could result in undesirable distortions. The Task Force recommends that this question be examined as part of the Science Policy Study.

B. IS THERE AN OPTIMUM LEVEL OF FEDERAL SUPPORT FOR SCIENCE?

The growth of Federal science programs since 1945 has been essentially uninterrupted. Although occasional spurts or periods of level funding have been experienced, there have been no instances of large reductions in the overall level. The annual changes have been largely incremental, involving increases in a range that rarely exceeded 10–15 percent for individual programs. It appears that the level of funding in a given year is as much a function of overall budget size and pressures, and of pragmatic growth rates, as an attempt to come to grips with actual, total funding needs. To the best of our knowledge no attempt has been made to determine if an optimum level of support exists for science, and what it might be. The Task Force recommends that the feasibility of establishing such a benchmark be seriously examined as part of the Science Policy Study.

1. Should All Good Scientists Be Supported?

One basis occasionally advanced for establishing the overall level of support for science is that all scientists capable of doing research should be provided with the resources they need. If this is not done, it is argued, a precious national resource, in which substantial educational investment has been made, would be going to waste. The feasibility and implications of this approach should be explored.

2. To What Extent Should Expected Social Benefits Such as New Technology and New Pharmaceuticals Determine Overall Funding Levels for Science?

Another criterion for establishing total funding levels might be the estimated demand for the technological pay-off which basic and applied research in science can be expected to provide. While we realize the difficulty of predicting such pay-offs in specific instances, we suggest that in the aggregate such predictions could be attempted based on past experience both in government and industry. The feasibility and implications of this approach to total funding levels should similarly be investigated.

3. Can a Base Level of Support for Science Be Established?

Yet another approach to the establishment of the overall level of support for science is the concept that a base or minimum level could be established. Funding below this level would present a clear danger to the national interest, while funding above this level would represent added opportunities that would be provided dependent on the availability of resources.

4. Should Science Funding Be Determined as a Percentage of GNP?

A small, fixed percentage of the Gross National Product has occasionally been suggested as a way to establish the overall level of government science funding. This would automatically increase science funding as the national economy expands. It would, however, also remove any flexibility needed to take into account either developments within science or developments in the total Federal budget situation.

5. Is a Certain Level of Annual Growth a Requirement for a Sound National Science Effort?

Rather than aiming for a fixed level of funding, it has been advocated that a fixed level of annual growth is the optimum way to establish the total level of funding for science. This approach is based on the thought that science itself expands at a fairly constant rate as new frontiers emerge, and the frontiers opened in previous years continue to yield useful results and thus need continuing support. Alternatively, the effects of no or little funding growth and of level funding should also be examined.

6. Is a Stable Number of Research Grants a Useful Target for Determining Funding Levels?

Since 1980 the National Institutes of Health has sought to determine the needed level of funding for research by aiming to award a fixed number of research grants each year. In this case the objective has been 5,000 new and competing awards per year. Because many grants are of two to four year duration, the effect has been that 15,000 to 17,000 grants are in effect at any given time, and the funding levels requested have varied with the needs to support that number of grants including the 5,000 new starts.

7. What Would Be the Effect of a Federal Withdrawal or Curtailment of Funding for Civilian Science?

An effective way of adding perspective to an examination of the feasibility of establishing an optimum level of Federal support for science is to ask what effects would emerge from a large reduction in funding. This might yield insights into the priorities attached to the many programs included in the base as opposed to the customary focus on the priorities attached to the annual funding increases.

C. THE FINANCIAL HEALTH OF UNIVERSITIES AND MEDICAL RESEARCH CENTERS

In the United States the most important institutional unit for the performance of basic research is the research university and the associated medical research centers. As such the group constituting the research universities is a national asset which provides both a home for most of the scientists engaged in basic research and which educates and trains almost all the new scientists. Although most are private institutions or state supported, the Federal Government has a strong interest in their continued performance of those functions.

1. What Are the Prospects for the Continued Financial Viability of the Research Universities and Medical Research Centers?

The rapidly rising costs of operating the modern research university and the difficulties of recovering those costs has raised questions about the longer term financial viability of the research universities. The institutions themselves have been aware of these problems and have sought a variety of solutions, both internally and in the form of augmented financial support from the Federal Government. The Task Force believes that it is timely to look beyond the several interim adjustments in the manner of providing financial support for the costs of operating the research universities. We therefore recommend that the Science Policy Study review the longer term financial prospects of the modern research university.

2. To What Extent Have the Various Sources of University Funding such as Tuition, Research Funds, and State and Private Support Fluctuated, and What Are the Future Expectations for Each?

Recognizing that research funding is only one among the several major sources of operating funds for the university, a review of the future financial viability of the institutions should include an examination of the future prospects for the other major sources including tuition and state and private funds.

3. What Are the Actual Uses of Research Funds?

It is well recognized that when research funds are provided to a research institution they are actually used in many diverse ways. Some uses, such as the costs of assistants and supplies, are directly associated with the performance of research. Others, such as heating, library, and administrative costs, are for supporting activities less directly linked to the cost of research but rather are institutional costs. In order to fully understand and appreciate the nature of institutional research costs, we recommend that the Science Policy Study analyze and determine the actual uses of research funds.

D. PRIORITIES FOR SCIENCE FUNDING

Within the over-all budget of the Federal Government, the priority to be given funding for science rests on a number of factors. One consideration has to do with the goals for science which are embodied in government science policy. Another consideration involves the priorities that apply to the many other non-science programs in the budget. The Task Force recommends that the priorities for science funding be examined and addressed as part of the Science Policy Study.

1. Should Federal Science Funding Include the Aim of Keeping the U.S. First in Every Field of Science?

The merits of maintaining a strong position of leadership in all or most fields of science should be carefully examined. As part of such an examination, the funding levels required to maintain such a position of leadership should be estimated and forecasted for the coming decades, and those funding levels should be weighed and compared with the expected returns from maintaining such broad leadership. Other options, including a selective surrender of leadership in some fields, should be similarly evaluated.

2. What Can Be Done to Eliminate Wasteful Duplication?

Duplication in scientific research can occasionally be useful and necessary because it can serve to validate and confirm other work. Furthermore, in some specialized fields of science, competition between scientists fostered through government support of a number of investigators in that field can serve to stimulate and accelerate advances. However, the incentive to be first with a discovery or other scientific results is strong for most scientists, and in most cases serves to militate against unnecessary duplication. Nevertheless, the size of the scientific enterprise and the pluralistic mode of providing support through many government agencies suggests that wasteful duplication may be occurring. This should be reviewed, along with the important watchdog roles of the Office of Science and Technology Policy and the Office of Management and Budget, as part of the Science Policy Study and appropriate methods of eliminating such duplication should be developed.

3. Has Limited Funding Prevented the Support of Innovative Research Proposals?

It is well known that many more proposals of scientific research projects are developed and submitted to the research agencies than can be supported at any given time. It is also possible that some scientists refrain from proposing innovative but unconventional ideas in the belief that funds will not be made available. The review of government funding policies and levels should seek to determine the extent to which this is a significant problem, and the availability and effectiveness of mechanisms to support innovative research.

VIII. Support of Science by the Mission Agencies

A large and significant part of research conducted with government funding is supported, not by the Federal science agencies such as the National Institutes of Health and the National Science Foundation, but by agencies with missions other than or in conjunction with the encouragement of scientific research. These include such agencies as the Departments of Defense, Energy, Agriculture, and the National Aeronautics and Space Administration. Their science programs, conducted both in government laboratories and through grants and contracts, should be included in the Science Policy Study.

A. Support of Science by the Department of Defense

The Department of Defense is reemerging from a period of reduced levels of support for basic research. The Department has reentered that field with particular emphasis on support of such research in the universities. This is in marked contrast with the late sixties and early seventies, when an amendment to the Defense Appropriations Act, the so-called "Mansfield Amendment", prohibited the Department from supporting research unless it was clearly related to its mission. An additional factor throughout the seventies was the Department's involvement in the Vietnam conflict and the resulting reluctance of some universities to accept Defense Department research funds. The Task ~~Force~~ recommends that the impact of the growing Defense Department research programs on the civilian research community be examined as part of the Science Policy Study.

1. *What Has Been the Track Record of the Department of Defense in Supporting Research in the Post–1945 Period?*

While the degree of support by the Department of Defense for basic and applied research has varied during the period since 1945, it has always been a factor. In the immediate post-war years the Defense Department was the strongest vehicle for providing government support for university science, and some feel that many of the policies for such support can be traced to those early years. A review of the role of the Department of Defense in supporting science should include an analysis of the Department's past performance in this field.

2. *What Are the Strengths and Weaknesses of Having a Stronger Role for the Department of Defense in the Support of Basic Research?*

Looking to the future, it appears that the Department of Defense can be expected to strengthen its support for basic and applied research. From the point of view of both the research universities and the Department, this will undoubtedly entail both advantages and disadvantages, and, in our view, those strengths and weaknesses should be carefully analyzed.

3. To What Extent Does Defense Supported Research Yield Technology which Is Applicable to the Civilian Sector and Vice Versa?

As has been the case in the space program, the research activities conducted by the Department of Defense will unquestionably yield technological advances which have application in the civilian sector. Such pay-off has occurred in the past and can be expected to continue. However, while individual instances have become known, and in some cases have received wide recognition, no over-all analysis of the scale and value of such civilian pay-offs has been done. We recommend that such a review of civilian technology pay-off be conducted.

4. Is It Possible to Determine an Optimum Balance between Civilian and Military Support for Scientific Research?

Scientists and engineers working on military programs have available to them, and can benefit from, research conducted with support by the civilian agencies. Conversely, those engineers and scientists who work on non-defense problems can benefit from basic and applied research supported by the Department of Defense except in those cases where the research is classified. Thus the optimum balance between civilian and defense sponsorship of research need not be tied to the needs of a mission agency such as the Defense Department. Depending on the results from the analysis of the strengths and weaknesses of Department of Defense, support of research suggested in (3) above, it may be possible to recommend an optimum balance between civilian and military support for scientific research.

B. SUPPORT OF SCIENCE BY THE NON-DEFENSE MISSION AGENCIES

The mission agencies of interest here are those agencies, such as the Department of Agriculture and the Department of Energy, which support scientific research as one of the means to assist in the accomplishment of their primary responsibilities. The science done under the aegis of the mission agencies varies widely in scope, quality, and the degree to which it is basic or applied. All of these programs, however, contribute to the total Federally supported scientific effort of the nation. As such, they and their impact on the total should be included in the Science Policy Study.

1. To What Extent Are the Mission Agencies Engaged in the Support of Basic and Applied Research, and How Much Is Done at the Universities?

The magnitude of the research activities supported by the mission agencies should be reviewed, and the degree to which it is concentrated on particular disciplines and particular fields of applied research should be assessed. An important aspect of these research programs is the extent to which they are conducted through grants and contracts with the nation's universities and thus complement the other government programs at these institutions.

2. How Do These Programs Compare with the Science Programs of the Science Agencies in Their Effects on Science and on the Universities?

The science programs of the mission agencies should be specifically compared with the science programs of the science agencies with large science programs, mainly the National Institutes of Health and the National Science Foundation. The extent to which there is overlap, the extent to which the programs of some agencies fill gaps in the programs of other agencies, and the extent to which useful overlaps tied to the training of graduate and postdoctoral students occurs should be evaluated.

IX. Funding Mechanisms

An array of particular funding mechanisms and instruments, such as peer review and grants, are used to provide the government's research funds to organizations and individuals. These mechanisms have a profound effect on all aspects of the scientific enterprise, and are the focus of continuing discussion and debate. The Task Force recommends that the funding mechanisms used to support science be examined as part of the Science Policy Study.

A. Alternative Systems of Funding Scientific Research

A cursory review of the funding mechanisms used by Federal agencies over the last 20–30 years shows that the diversity of instruments and methods of funding scientific research has been gradually narrowed. The variety of these funding instruments included Senior Investigator Grants, formula grants of various types, and block grants of many varieties. In their place, the project grant has achieved growing prominence as the principal method of providing funds for reseach.

1. *To What Extent Should the Present Dominance of the Project Grant System for the Support of Scientific Research Be Gradually Replaced with a More Pluralistic Form of Support?*

The project grant approach has many advantages, chief among which is that it maintains a strong degree of competition. This helps ensure that the available resources are expended on the best projects and that the system is open to new ideas and all researchers. But the system is also under considerable strain. There has long been complaints from scientists that the associated practice of basing project grants on unsolicited proposals involves a disproportionate amount of effort and paperwork. It is also claimed that the practice of judging the relative merits of the proposed projects by means of peer review does not ensure an open system, but introduces instead a strong degree of conservatism and reluctance to support unconventional research ideas. Recently, it has been claimed that the workload required to review proposals and the requirements for disclosures about personal finances have increased to the point that a growing number of scientists, especially among the leading, mature investigators, are declining to serve as reviewers. These points all serve to suggest that the time has come to ask if the trend toward sole reliance on project grants should be reversed in favor of a system which increasingly uses a greater diversity of funding mechanisms that more closely meet the needs of scientific research.

2. What Lessons Can Be Learned from the Mechanisms of Science Support Used in Other Advanced Industrial Countries?

In addition to reviewing alternative funding mechanisms used by various agencies at various times in the United States, it might well be highly useful to determine what funding methods are used in other advanced, industrial countries. While none of these methods may be directly transferable from the particular circumstances found elsewhere, there may be elements of such systems that would be highly useful. We frequently have heard mention, for example, of the Max Planck Institutes in Germany as a form of organizational arrangement outside the university setting which permits high quality research to be conducted. Other modes and practices may be of equal interest and they should all be studied as part of the Science Policy Study.

B. THE SELECTION PROCESS AND THE ROLE OF PEER EXPERTS

Underlying much of the present grant system is the belief that the best results are obtained through competition based principally on potential scientific merit. Because such judgments frequently can be made only by other scientists who are experts in the same field of science, the peer review method of deciding project competitions has become prevalent. But this system also appears to be biased against radical, high-risk research project proposals and against younger investigators. It also suffers from a high degree of centralization and much paperwork. We therefore recommend that the Science Policy Study include on its agenda a careful review of the presently used selection processes for scientific research projects, their advantages and disadvantages, and their relative merits in comparison with other possible selection methods.

1. Should the Present System of Peer Review and Competition Be Modified?

The peer review system operates differently from agency to agency and even within some agencies. Under some operating modes the peers provide their comments by mail and thus never meet face to face, while other systems involve formal meetings and discussions in Washington or elsewhere. As indicated previously, occasional complaints have surfaced to indicate that the workload of those serving as peer reviewers is trending toward a level where some of the better scientists are reluctant to continue their service as reviewers. On a more general level, concern has been expressed that while this system works well in periods of rapid growth, it may be less well suited to periods where a particular field of science is not growing. On the other hand, many have noted the very great advantage which some form of competition yields in comparison with systems in other countries which involve less or no, competition. We are also cognizant of the strong attachment which many, but not necessarily all, scientists have to the peer review system. Thus we recommend that one approach to the reduction of the undesirable aspects of the present project selection method that should be considered is the evolution of changes which would modify the system to reduce its weaknesses without eliminating its basic strengths.

2. What Are the Advantages and Faults of Alternative Systems?

A more far-reaching way of rectifying the known problems of the present project selection system would be the adoption, wholly or partly, of quite different methods of providing research support. Such methods might include junior investigator grants and career development grants, involving support for individuals rather than projects, various forms of block or formula funding which would support institutions or groups, or, alternatively, project awards made on the basis of program manager judgments, geographic distribution criteria, or cost considerations. Any of these alternatives are likely to have distinct advantages as well as faults, and we urge that each be carefully weighed on its own merits and in comparison with the present methods as part of the review of the support selection process.

C. STYLES OF RESEARCH SUPPORT IN DIFFERENT FIELDS OF SCIENCE

A review of the variety of modes or styles in which government support for scientific research is provided, suggests that the degree of centralization or decentralization varies greatly. For example, a high degree of decentralization is found in some parts of agricultural research. The Department of Agriculture supports a comprehensive system which involves, in addition to research, extension and teaching activities. Funds for this system are provided through formula grants to the land grant colleges, the so-called "Hatch Act funds". At the other end of the spectrum, the National Institutes of Health and the National Science Foundation support research chiefly through project grants to individuals. Projects are selected on the basis of nationwide competition and peer review. In recent years, however, competitive grants have been introduced into the agricultural research system to supplement the formula grants. At the National Science Foundation and the National Institutes of Health, small but significant programs of support for limited areas of science such at materials research is being provided in the form of block grants. We recommend that these widely varying styles of research be compared and evaluated as part of the Science Policy Study.

1. Are Differing Styles of Research Support Optimum for Particular Fields of Science?

While we note the wide spectrum of styles used for the support of research in different agencies, little is available to explain why these different styles are being used. Apart from the historical evolution of the program, it is not clear whether certain types of research, for example basic or applied, or certain disciplines, for example biological or physical, thrive better under one style of support or another. In the event a correlation of support style with productivity exists, that should be ascertained and applied more widely.

2. Should Future Funding Systems for Research Mix the Two Styles of Funding?

It appears possible that the optimum mode of supporting scientific research may be a mix of formula or block grants and competitive project grants. The instances where experience with this mixed style of support has been developed should be included in the examination of the effectiveness of the different research support modes.

3. Has One Mode of Research Support a Higher Chance of Yielding Technological Pay-Off?

A basic question in evaluating the various modes of research support is how the different modes contribute to the transfer of research to the users who can apply them in the form of technology or cures for disease. For example, it has long been recognized that the agricultural research system has been highly successful in providing the results of research to the farmer. Whether this is due to the formula mode of research support is not clear. Conversely, the recent lag in technological innovation often is viewed as occurring in areas where research in the physical sciences might have been expected to make major contributions, and these fields of science are largely supported through project grants. The Science Policy Study's review of research support styles should attempt to determine if a relationship exists between such styles and the level of practical application.

D. SECONDARY EFFECTS OF PRESENT FUNDING MECHANISMS

The presently used mechanisms for providing support of scientific research may, on the whole, be achieving the primary aim of advancing science. However, it is becoming evident that these mechanisms also have significant secondary effects on scientists and the institutions in which they do their research. In our view, these secondary effects can not be neglected. They should be identified, both in terms of the effects produced by the existing support mechanisms and in terms of any proposed new or altered support mechanisms that may energy from the Science Policy Study.

1. Should the Federal Government Be Concerned about These Secondary Factors?

Many of the secondary effects arising from the presently used research funding mechanisms occur wholly or partly within the research institutions. As such their impact is chiefly a matter of concern to those institutions. At the same time the funding mechanisms are established by the government, and the government in the long run has an interest in assuring that the research institutions are healthy and viable. The balance between institutional autonomy and government interest should be carefully observed in the view of the Task Force. The cooperative spirit between the government and the research community should, in our view, be preserved and enhanced, and the development of an adversarial relationship should be avoided.

2. Is "Getting Research Grants" Replacing the Actual Conduct of Research as an Incentive for Some University Scientists?

One suggested effect of the present project grant system in its interaction with the universities and their system for rewarding and promoting individual scientists on their faculties is said to be that it has become more important to obtain research grants than to conduct actual research work. The prevalence of this practice should be determined, if feasible, along with its good and bad effects, and the desirability of making adjustments in the funding mechanisms.

3. To What Extent Do the Present Funding Mechanisms Provide Incentives and Disincentives for Research Fund Raising, Industrial Cooperation, Patient Care, and Undergraduate Teaching?

The scientists who are engaged in research at universities, medical research centers, and other institutions have a number of other duties such as patient care and undergraduate teaching. The institutions similarly have duties other than raising research funds from the Federal agencies. These include fund raising from private donors, and cooperation with industrial firms and many other functions. It has been noted that the present mechanisms of providing Federal research funds may in some cases serve as disincentives for carrying out these other activities. This should be reviewed as part of the Science Policy Study, and, if possible, corrective measures should be recommended.

4. Would Growing Institutional Funding Lead to Growing Government Influence in Research Institutions?

Any shift in the use of funding mechanisms which would increase the reliance on funding mechanisms that provide support to institutions rather than to individuals might potentially lead to expanded government influence on the institutions. Past experience with such funding mechanisms should be carefully reviewed in designing new approaches to institutional support research funding.

E. THE COST OF RESEARCH

To a considerable extent the discussions about government funding of university research activities have become centered on a group of technical issues. These are issues having to do with what it costs to carry out research in an institutional setting and how many of the costs less directly related to such research should or should not be borne by the government. Because of their impact on both the financial health of the universities and on the costs to the government, we recommend that these technical issues be included within the scope of the Science Policy Study.

1. What Accounts for the Gradual Increase in Indirect Cost Rates, and Is This Growth Desirable or Undesirable?

For most grants and contracts the direct costs, consisting of salaries, materials, publication costs, etc., are supplemented by the so-called indirect or overhead costs. These presumably pay for such associated costs as building maintenance, heating, and shared clerical support. A slow but steady growth of the indirect cost rate has been noticeable over the last five years. This growth has meant that for every dollar provided to a research institution a smaller and smaller fraction goes to the direct cost of doing research, while a mounting fraction goes to defray general institutional costs. The nature of this shift, if in fact it is widespread, should be ascertained and its longer term implications should be carefully examined.

2. Is It Possible to Replace the Present Complex Indirect Cost System with a Better System?

The present system by which government agencies pay the research institutions for their indirect costs involve the careful and detailed audit of the institution's books after the costs have been incurred. The government auditors must determine whether a given expenditure is allowable under the current rules and how much is allocable to a particular grant. Frequent disagreements occur between the university officials, who seek to recover as much of their costs as possible, and government auditors, who seek to include only those cost items reasonably chargeable to the government projects. Because of differences in institutional accounting practices, the overhead rates vary from institution to institution. It has occasionally been suggested, most recently in a 1984 study by the General Accounting Office, that a fixed overhead be established for all research grants at all institutions. This would eliminate the need for the complex and controversial accounting rules and the extensive auditing needed to ensure compliance with them. However, the research institutions have resisted such an approach, in part because they feel that if the rate were set too low, it would mean a substantial loss of revenue to cover many of their administrative costs. In more general terms, the underlying question is how much of the institutional operating costs should be borne by the agency sponsoring individual research projects at research institutions. Institutional grants for this purpose also have been considered to deal with this question, and we recommend that this entire question be examined as part of the Science Policy Study.

3. Has Cost Sharing Worked in the Past and Is It Feasible in the Future?

In the early postwar years when the Federal Government embarked on an expansion of support for science at American universities, there was a strong belief that this should be done in the form of partial assistance to such research, rather than complete funding. There were concerns that complete funding could lead to undue government interference in the research being done and in the internal operation of the university. There was also a feeling that, while the research being done would benefit the government, it also would benefit the institution and the professor in charge by providing training of graduate students, professional growth for the scientist, and some measure of enhanced status to the university. Based on such considerations, the principle of cost sharing between the government and the university was established for the funding of research. In practice, however, this principle is not widely used. In some cases cost sharing is less than one percent, and it may well have lost both its actual and symbolic effects. We recommend that the principle and practice of cost sharing be reviewed as part of the Science Policy Study and that a clear-cut policy for this practice be sought

X. The Role of the Congress in Science Policy Making

In the Congress the process of policy development for science is not without problems in spite of the many accomplishments that have been achieved over the years. We recognize that the Committees with jurisdiction over science and the members who have played active parts in dealing with the issues of science policy have compiled a notable record of important initiatives and active support. But the process undoubtedly can be strengthened. The Science Policy Study has been proposed with the aim of reviewing all of the relevant steps in the science policy process, including those of the Congress. We share the view that, in the case of the Congress, it is especially important to do so apart from the busy schedule of the regular, annual budget hearings and legislative deliberations. The Task Force recommends therefore that the processes of the Congress for dealing with science policy formation be included in the Study.

A. Science in the Political Process

The days when a prominent politician such as Thomas Jefferson was also thoroughly familiar with science are long gone. Science has become complex, large, and specialized, and in many fields reliant on sophisticated mathematical and instrumental techniques. As a result, few members of Congress are in a position to make judgments about the substantive content of science, its quality, and relevance. Nor are the administrators and managers who serve in the science agencies of the government in many cases close to the research frontiers or their applications in most fields, although many were active scientists at an earlier stage of their careers.

In order to ensure that the most promising scientific research ideas are funded, it therefore has proved indispensable to rely heavily, and sometimes solely, on scientists either in government or in universities or industry for decisionmaking that involves judging the substantive merits of proposed or ongoing programs. But few decisions are one hundred percent scientific. Most involve components from other spheres of society; that is, the outcomes of such decisions, while strongly affecting science, also affect education, institutional vigor, short-term and long-term employment, and local, regional, and national economic growth. For smaller projects of individual scientists, the scientific aspects tend to be dominant. For projects that are large in terms of funding levels and number of people involved, the non-science factors tend to be more important. Thus, for example, the decision about where to locate and build a major new research facility will have important scientific components as well as important economic and political components.

The relative balance between the science component and other factors in making decisions and policy for science is becoming more important. In the last two years this question has received intense discussion as a result of a small number of instances where disagreements arose about the relative weights the several factors should be given in decisions regarding science. The Task Force recognizes that this matter is of wide interest. We believe that the Science Policy Study could make an important contribution to future science policy practice by thoroughly examining the various views and practices in this area and recommending the policy that might guide future action.

1. How Can the Expert Judgments of the Scientists and the Societal Goals-Oriented Judgments of Members of Congress Effectively Interact?

It is worth recognizing that in the last 40-years the expert judgments of scientists and the broader political judgments of members of Congress have, for the most part, interacted successfully. There unquestionably have been cases where disagreements arose, but even in those cases a decision was reached. We recommend that a number of these cases be analyzed as helpful guides to the evolution of future policy.

2. At What Levels Should Decisions Be Made by Scientists, by Members of Congress, and Jointly?

As noted in the introduction to this subsection, the degree of scientific expertise needed for decision-making increases the closer the subject matter is to the detailed project level of a scientific program. Conversely, broader economic, social, and political factors affect the more complex levels where total funding and similar matters are considered. It must also be recognized that an important role is played in decision-making about science programs by the staff and administrators in the agencies of the Executive Branch. We recommend that the general question of the appropriate level for each type of decision-making be explored.

3. Under What Circumstances Should the Congress and/or the Scientific Community Use Criteria such as Regional Economic Growth, Specific Health Needs, and Agricultural Crop Needs in Making Decisions for Science Policy?

The circumstances under which criteria beyond science, such as regional economic growth, specific health needs, and agricultural crop needs, should or should not play a part in decision-making about science are not clear. We recommend that the possibility of explicitly stating such criteria be explored.

B. PRIORITY SETTING BY THE CONGRESS

The Federal science budget is made up of individual agency budgets, and these in turn include proposed funding for individual disciplines, such as physics and the social sciences, and for subdisciplines, such as high energy physics and anthropology. Or, the budget may cover funds for particular disease-oriented institutes, such as the institutes for Cancer and for Heart and Lung, or for other mission agency programs, for competing big science projects, and for individual science education programs. The more specific and detailed the levels reached within the budget, the more expertise is necessary and the more time and effort required by the members and committees of the Congress to reach informed judgments about the validity of the budget recommendations. The time needed to hear witnesses, for example, for each of the subdisciplines funded by the National Science Foundation is probably prohibitive. Thus the question of the appropriate level at which the Congress can and should set priorities must be addressed. The Task Force makes no prior judgment on this matter or on whether the level of priority setting now in use is the appropriate one or whether changes should be made. However, we recommend that this question be addressed.

1. At Whatever Level the Congress Makes Decisions about Funding Priorities, How Can the Process Be Better Informed and Further Improved?

The traditional and recognized method by which the members and committees of the Congress obtain advice about any subject is the public hearing. This is supplemented by analyses prepared by the agencies, by interest groups and individuals, and by Congressional staff. Improvements in these processes and the possible development of additional or supplemental processes should be explored, taking into account the particular characteristics and needs in the field of science policy.

2. In Cases Where the Growth of Resources Does Not Permit All Branches of a Particular Field of Science To Be Supported, Should the Congress Stop Support for One or More Branches in Order to Support Higher Priority Branches?

The Congress is often asked to strengthen support in a particular field or branch of science which is thought to have strong scientific promise or potential for practical pay-off. When this occurs, the choice is usually between providing an increase in the overall budget level or reducing the support for some other branch of science. In such circumstances a further choice is to discontinue support for one or more fields altogether. The basis for reaching such a decision, given the difficulty of predicting future developments in any branch of science, should be considered.

3. Can and Should the Congress Initiate Support for Branches or Fields of Science not Supported Otherwise, but Judged To Have High Priority?

In cases where new branches of science emerge which, for one reason or another are not receiving support from an agency, the Congress may choose to initiate such support. The criteria for the initiation of such support should similarly be explored.

4. Should Research Leading to Potentially Undesirable or Very Expensive Technologies, such as Highly Expensive Medical Technologies, Be Deemphasized by the Congress?

Rapid advances in science and technology frequently have outpaced the conventional capacity of society to adapt to such advances. This has occurred, for example, in the area of health care where kidney and heart transplants have achieved feasibility, but where factors of costs and availability present difficult problems. Furthermore, some advances may yield technologies which on balance may be considered undesirable. For example, some discoveries that may yield technologies for genetic or behavioral modifications may not be acceptable to some segments of society. Similar examples may be found in other fields. Whether the Congress should seek to make judgments about discontinuing government research support in such cases is not clear. This subject should be examined as part of the Science Policy Study.

C. OVERSIGHT AND EVALUATION OF FEDERAL SCIENCE PROGRAMS

In addition to its responsibility to act on proposals for new legislation, the Congress and its committees must also review how well existing legislation is being carried out. In the case of the Congressionally enacted programs in the field of basic and applied scientific research, such oversight presents special difficulties due to the high-level, special expertise required to make judgments about science programs and the uncertainty about the time required to demonstrate practical pay-off from such research.

1. How Much Oversight and Evaluation Should the Congress Do and How Can the Process Be Improved?

Congressional oversight should be conducted to an extent sufficient to ensure that for a given program the Congressional intent, as mandated in the relevant laws, is being carried out. In the case of the Congressionally mandated science programs of the Federal Government, it is not clear whether the present level of oversight is fully adequate or whether it should be expanded. Furthermore, given the special nature of these science programs, it appears to us that new approaches to oversight might well improve the oversight process. We therefore recommend that the Science Policy Study address this important question.

2. How Can the Congress Make Independent Judgments about the Quality of Past, Present, and Future Research?

We have noted on several occasions in this report the fact that the substantive content of modern science is such that few individuals outside the subdisciplines and narrow specialties are able to make informed judgments about the current quality of research. In conducting its reviews and hearings, the Congress therefore relies heavily on alternative means. It seeks the views of experienced scientists and the views of administrators from the agencies supporting the programs. Yet these individuals are typically directly or indirectly involved themselves in the programs, and may therefore not have an entirely detached or independent view of the quality, merits, and need for the programs. Unlike many other fields in which the Congress conducts legislative and oversight hearings, it is rarely possible to identify individuals of opposing views who can help members form their own judgments by weighing the merits of such views. The Office of Technology Assessment, established at the initiative of the Science and Technology Committee to serve the Congress, has in a limited way performed this function, but has more often sought to present a range of options and their probable consequences. We therefore urge that the Science Policy Study include on its agenda a search for means by which independent judgments can be made by the Congress about the quality of past, present, and future research.

3. Can Better Quantitative Methods Be Found for the Evaluation by the Congress of Research Programs?

The evaluation of research programs is an underdeveloped art. At a time when many other fields of government activity, ranging from Defense and Public Works to Medicare and Social Security, have experienced the infusion of imaginative and helpful methods of quantifying all aspects of their activities, science has not seen a comparable development. The Task Force is aware of the useful contribution that has been made by the Science Indicators reports of the National Science Board and some of the evaluation efforts made by the Director's Office at the National Institutes of Health. But we are also concerned that few of these efforts appear to have affected in any significant way the day-to-day management or the year-to-year policy process within the agencies. We recommend that the possibilities for broad, imaginative development and use of better quantitative methods for the evaluation of research programs be studied by the Science Policy Study.

4. How Can Accountability Concepts Be Applied by the Congress to Basic and Applied Research Programs?

In discussions of the application of accountability concepts to government programs of all types, a distinction is usually made between three levels of accountability: 1) The financial level: Were the funds provided properly expended and accounted for? 2) The project level: Did the expected results of a particular project in fact yield most of those results? and 3) The program level: Did the program as a whole produce the benefits to society for which it was initiated and carried out? Financial accountability is naturally expected when the government funds are spent on scientific research, but we do not recommend that this type of accountability be a significant part of the Science Policy Study. On the other hand, accountability at the project and program levels have not, to our best knowledge, received much interest or attention in the field of government supported scientific research. The Task Force believes that in spite of the uncertain and unpredictable nature of research, a strong effort should be made to apply accountability concepts in this field, and we urge that this matter be taken up in the Science Policy Study.

D. MULTI-YEAR FUNDING OF SCIENCE PROGRAMS

Scientific research projects typically ~~take a number~~ of years to complete. Anywhere from two to five or six years, or occasionally longer, are consumed in designing the project, carrying it out, analyzing the data, and publishing the results. The governmental cycle of providing funds for science is, however, annual. The budget for the government, including those agencies with science activities, is prepared on an annual basis, and is considered, amended, and approved by the Congress on an annual basis. It has been suggested that the uncertainty associated with annual budget approvals for the many multi-year projects taking place in science introduces a level of uncertainty that discourages scientists from undertaking longer term science projects. Conversely, it has been asked whether a longer term cycle of planning and approval of the Federal budget would materially help scientific progress by reducing the degree of uncertainty for the scientist. The Task Force recommends that this question be placed on the agenda of the Science Policy Study.

1. What Are the Good and Bad Effects of Single-Year Budgeting, Authorization, and Appropriations for Scientific Research Programs?

An examination of the feasibility of providing multi-year funding for scientific research should establish how important such a changeover would be for science. Because present practices by most of the governmental agencies supporting science recognize the multi-year nature of many research projects, they usually approve projects with that understanding in mind. It is also understood however, that if funds do not become available in future years, support for the project may be reduced or cut off altogether. Data to show whether, in fact, this is happening and, if so, to what degree, is however, not available, and we recommend that the actual impact on science be determined as part of the Science Policy Study's inquiry into this question.

2. Would the Advantages of Multi-Year Approvals Outweigh the Disadvantages for the Federal Agencies and for the Congress?

It is clear that both the single-year and the multi-year methods of funding have both advantages and disadvantages for those involved in the governmental budget process. For example, a changeover to a multi-year cycle for science programs would have the advantage of reducing the work load, thus, in the case of the Congress, providing time for oversight and other activities. But the disadvantage of lessening the close contact with these programs which the annual cycle provides would have to be taken into consideration. We therefore recommend that the study of a multi-year budget cycle for science programs should include, as well, a detailed examination of how the various steps in the budget process would be affected by a switch from the present one-year cycle to some form of multi-year cycle. A particularly important question within this context should be the advantages and disadvantages that would be yielded if some part of the process, for example the authorization process, was done on a multi-year basis while other parts, for example the appropriations process, remained on a single-year basis.

E. REVIEW OF SCIENCE POLICY REPORTS TO THE CONGRESS

Over the years a number of science policy reports have been mandated in various Acts of the Congress. These reports were intended to serve a number of diverse purposes, and attempts have been made from time to time to consolidate, amend, and otherwise change the requirements for those reports in order to improve their usefulness. As part of the comprehensive review to be done by the Science Policy Study, the Task Force recommends that this report structure be evaluated and such changes as are deemed necessary be developed.

1. How Useful Are the Various Science Policy Reports Mandated in Legislation for Submission to the Congress?

The individual reports, and perhaps their predecessors, where such exist, should be individually analyzed to determine how well they serve both their original purpose and current and future purposes. Such an evaluation should be mindful that these purposes include both the value to the responsible agency of government from preparing the report and the associated thinking and rethinking of the purposes and effects of the activities covered, and also the usefulness to the Congress, its committees, and individual members.

2. Can Future Improvements Be Made without Legislation?

For those science policy reports which are judged to be of continued usefulness but in which improvements are found to be needed, two approaches are available. One approach is to amend the legislative mandate for that report, spelling out the additions or deletions that are judged necessary. The other approach is to work directly with the head of the agency responsible for the report in order to achieve the changes found desirable. We recommend that, in developing its recommendations in this area, the Science Policy Study be mindful of both of these approaches.

3. Should the Congress Respond to These Reports in More Formal Ways such as Hearings?

The Task Force recognizes that one factor that has contributed to the deterioration of the content and the lack of attention by some agency heads to the preparation of these reports has been a lack of sustained attention within the Congress to some of them. After initial recognition of the need for the report and its incorporation into law, concerns in the Congress sometimes have shifted elsewhere, and because of this the responsible agency heads have felt less need to devote attention to their content, timely submission, and potential effects. We recommend that, for those reports judged to be of continued usefulness, better ways to maintain Congressional awareness be developed.

4. What Is the Status of Statistics Gathering about Science and Science Education?

The review of the science policy reports and their content should be coupled with a more comprehensive review of one of the most important bases on which such reports must rest, namely the available statistics about science and science education. This review should cover the fluctuations in data-gathering efforts in this area, the degree to which the government's data gathering is coordinated within the government and with private sector efforts, and the areas not now covered, but which present and future data needs dictate should be covered.

5. Do We Have Accurate and Complete Data on the Numbers and Kinds of Scientists, and Output Levels?

It will be particularly important to determine what well-known data needs are not currently being met, and why. We are aware that while the costs of data collection sometimes is a factor in refraining from the collection of some types of data and in discontinuing other efforts, conceptual barriers also exist. For example, data about the "output" from the scientific enterprise has yet to be collected mainly because of a lack of agreement about what constitutes such output. We urge that the Science Policy Study devote careful attention to this matter.

6. What Improvements Should Be Made in Statistics Gathering about Science?

The Science Policy Study will touch upon a wide variety of policy issues affecting science and science education. As we noted in our introduction to this report, past experience has shown that in a surprisingly large number of instances very little statistical information now exists to support, or to evaluate, proposed courses of action. We recommend that, as such areas are identified in the course of the Science Policy Study, they be noted and that the composite needs for additional statistics be given particular attention.

F. BACKGROUND MATERIALS FOR MEMBERS

In the course of reviewing the many issues and topics that should be on the agenda for the Committee's study of science policy, the members of the Task Force again were struck by the great diversity and large number of issues and topics that we deal with. These issues and topics come before the members of the Committee during many of our activities throughout the year. They are, as we have recognized, subject to frequent change because of current and future developments, and many of them are rooted in past decisions. For both new and more senior members alike, it would be very useful to have available some means of getting quickly familiar with each of these issues. We believe that this could be done in several ways: It might involve a modest sized background reader which could include overviews of the questions that have been before the Committee in the past; it might also include shorter, but perhaps more detailed, briefing papers on particular policy issues coming before the Committee. We therefore recommend that the Science Policy Study seek to determine if such background materials would be helpful to the members, what form they might take, and how they could be supplied.

O