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Recent decisions, actions, and program initiatives within the Federal Government that involve science and technology are reviewed and current and emerging issues and problems that require action are examined. Federal research and development programs in national security, space, health, energy, natural resources, environment, transportation, agriculture, education, and international affairs are addressed. The Federal Coordination Council for Science, Engineering, and Technology is discussed and issues recently dealt with by the Council are considered including: minorities in science and engineering; Three Mile Island; radiation research policy; and scientific exchanges with China, Japan, Latin America, and Africa. A chapter on recent developments in risk assessment and management, earthquake prediction, coal consumption, information and communications, and privacy and computer data bases is included.

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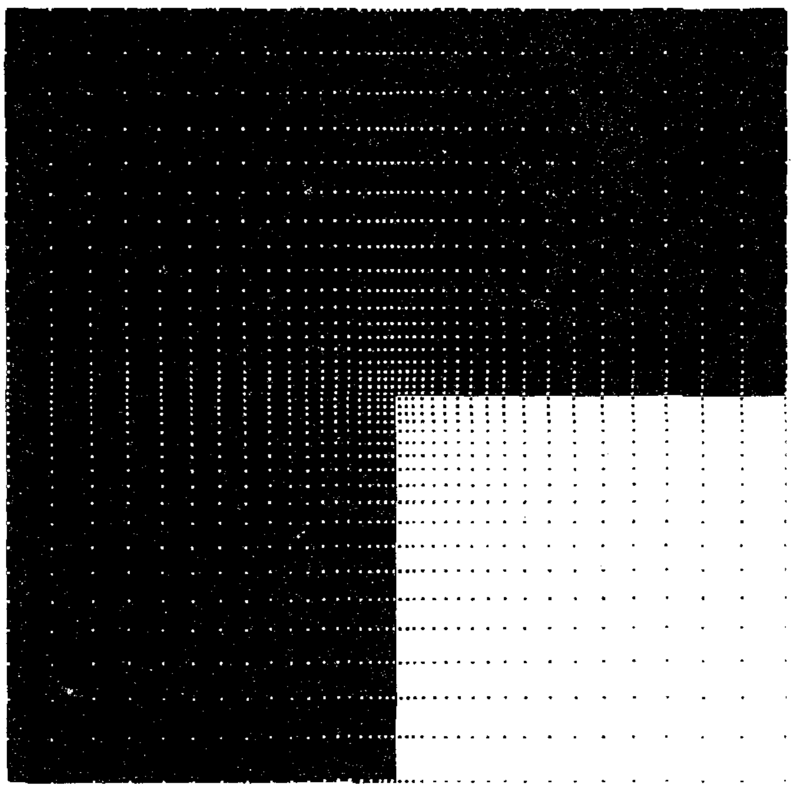

National Science Foundation
January 1981

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FEDERAL DECISIONS, ACTIONS, AND PROGRAMS DURING 1980

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NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
DIRECTOR

January 12, 1981

The President
The White House
Washington, D.C. 20500

Dear Mr. President:

I am pleased to transmit to you, and through you to the Congress, the third Annual Science and Technology Report, as required by the National Science and Technology Policy, Organization, and Priorities Act of 1976.

The objectives of the Annual Science and Technology Reports are to review recent decisions, actions and program initiatives within the Federal Government that involve science and technology, and to examine selected current and emerging issues and problems that require action in the near future. This report should be seen as part of a larger effort by the National Science Foundation to present the information on which a useful science and technology policy agenda can be based. In particular, the Five-Year Outlook on science and technology provides the framework within which the Annual Science and Technology Report defines issues of significant national concern, and the Science Indicators report of the National Science Board provides qualitative and quantitative views of recent trends in science and technology.

Among them, these three reports provide the broad and open discussion of scientific and technological issues essential to determining the possible contributions and limitations which science and technology can make in defining, illuminating and resolving national problems.

Respectfully,

John B. Slaughter
Director

Enclosure

PREFACE

In enacting the National Science and Technology Policy, Organization and Priorities Act of 1976 (Public Law 94-282), the U.S. Congress declared that national policies for science and technology should be based on the "continuous appraisal of the role of science and technology in achieving the goals and formulating policies of the United States." As one means for obtaining information on the relationships of science and technology to other issues of national concern to provide a better basis for the development and implementation of strategies for the Nation's science and technology enterprise, the act required the periodic preparation of two reports: (1) the *Annual Science and Technology Report* and (2) the *Five-Year Outlook* on science and technology. Responsibility for the preparation of both reports has been assigned to the Director of the National Science Foundation (NSF).

Taken together with the National Science Board's *Science Indicators*, which is also prepared by NSF, the *Annual Report* and *Five-Year Outlook* are intended to provide public and private decision-makers, as well as society at large, with well-organized and timely information about science and technology activities and about the condition of the scientific and technological enterprise. *Science Indicators* provides quantitative data about such recent trends as investments in and resources for science and technology and about some quantifiable results of scientific and technological activity. The *Five-Year Outlook*, which provides a framework for subsequent *Annual Science and Technology Reports*, identifies and describes current and anticipated developments in science and technology. The *Five-Year Outlook* also suggests ways in which those developments could contribute to illuminating and resolving problems of national and international significance, and it points out possible constraints on the ability of science and technology to make those contributions. The *Annual Science and Technology Report* focuses on present and near-term future science- and technology-related accomplishments and program initiatives of the Federal Government, and it identifies policy issues associated with emerging developments in science and technology that are likely to merit public discussion and action in the near future.

This third *Annual Science and Technology Report*, transmitted to the Congress in manuscript form by President Carter on January 19, 1981, summarizes major decisions and actions related to science and technology that were taken by the executive and legislative branches of the Federal Government during 1980. The *Report* also describes the status as of January 1981 of significant science- and technology-related programs of executive branch departments and agencies. A supplementary section, published here, consists of a set of short papers, commissioned by the National Science Foundation, that explore the policy dimensions of several of the emerging developments in science and technology described in the body of the *Report*. These papers, prepared by individuals who are experts on these issues, do not necessarily reflect the views of the National Science Foundation or the U.S. Government. This supplement provides notes on recent developments associated with some of the emerging issues discussed in Chapter IX of the second *Annual Science and Technology Report*. Tables listing Federal research and development (R&D) expenditures by functional areas for fiscal years 1979, 1980, and 1981 and a description of President Carter's proposed R&D budget for fiscal year 1982 are appended.

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SUPPLEMENT: SCIENCE AND TECHNOLOGY POLICY ISSUES AND DEVELOPMENTS

APPENDICES

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EXECUTIVE SUMMARY

In a personal statement that served as an overview to the first *Five-Year Outlook* on science and technology, the Director of the National Science Foundation (NSF) focused on six sets of issues associated with science and technology warranting the special attention of the executive and legislative branches of the U.S. Government and the American people.[1] For convenience, the decisions, actions, and program initiatives described in this third *Annual Science and Technology Report* are highlighted below under seven headings, corresponding approximately to the NSF Director's six issue categories, plus national security. References in parentheses cite sections in Chapters I and II that contain more complete discussions of the respective topics. References to the second *Annual Science and Technology Report*[2] *(ASTR II)* or to policy discussions in the supplement to this *Report* appear as footnotes.

1. *Ensuring the Continued Vitality of the Nation's Scientific and Technological Base*

- The year 1980 was one in which U.S. scientific achievements, carried out or initiated in earlier years, received public recognition. Seven of the nine Nobel Prizes awarded in 1980 were given to U.S. citizens. The range of accomplishments for which they were awarded—in economics, medicine, chemistry, and physics—emphasized the diversity of activity that characterizes contemporary science.[3] Perhaps the most dramatic scientific accomplishment of 1980 came from a U.S. space project, when, in November, Voyager 1 transmitted its spectacular data on Saturn back to Earth, which it had left 38 months earlier (II-C).

- From fiscal year 1975 to fiscal year 1980, Federal expenditures for both total research and development (R&D) and basic research, measured in constant dollars, exhibited annual increases. Private industry's R&D investments during fiscal year 1980 were estimated to be 48 percent of the national total. Estimates as of January 1981 indicate that fiscal year 1981 total Federal R&D obligations, measured in current dollars, increased by 11.2 percent over fiscal year 1980, and obligations for basic research increased by 9.4 percent. The Carter Administration's budget for fiscal year 1982 proposed current dollar increases above 1981 estimates of 18.5 percent for total R&D and 14.4 percent for basic research (I-A).

- Both Federal funding levels and funding continuity are important to maintain the research capabilities of scientific laboratories in universities.[4] To ensure stability in funding levels for health research, action was taken in fiscal year 1980 to establish a firm number of competing investigator-initiated grants to be awarded annually by the National Institutes of Health (II-D).

- To provide additional aid to technological developments in microelectronics and computers, the Department of Defense, the National Bureau of Standards, and the National Science Foundation are expanding programs in measurement methods, standards, and technical data during fiscal year 1981 (II-B, F).

- An extensive evaluation of the state of science and engineering education in the United States was submitted to the White House by the Secretary of Education and the Director of the National Science Foundation in August 1980. This report, *Science and Engineering Education for the 1980s and Beyond*, addressed problems and made recommendations in two broad areas: (1) the education of professional scientists, engineers, and technicians;[5] and (2) education in science and mathematics for those who do not intend to pursue careers directly related to science and technology but who require some level of competency and understanding in those fields[6] (I-B; II-F, K).

2. *Stimulating Innovation and Productivity in Industry and Agriculture*

- During 1980, several steps were taken to implement the initiatives stemming from the Domestic Policy Review on Industrial Innovation, the results of which were announced in October 1979.[7] Enactment of the Stevenson-Wydler Technological Innovation

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Act authorized a series of generic technology centers; enactment of uniform patent reform legislation will encourage universities and small businesses to seek commercial use of inventions by allowing them to retain title to most inventions developed with U.S. Government sponsorship; and a guide issued by the Department of Justice clearly defined boundaries, established by antitrust laws, of permissible scientific research cooperation among business firms (I-C).

- Other fiscal year 1980 actions resulting from the industrial innovation review included establishment of a Center for the Utilization of Federal Technology within the National Technical Information Service to facilitate application of research results in technological settings, and expansion of existing small business innovation and cooperative university-industry grant programs within the National Science Foundation (I-C; II-F).

- Detailed planning was initiated for two new programs involving government-industry cooperation in R&D: the Cooperative Automotive Research Program and the Ocean Margin Drilling Program (I-C).

- Increased emphasis was placed on opportunities for government-industry cooperation in the areas of national security and space. The Space Shuttle, when operational, will greatly facilitate private industry involvement in space. The first test flight of the Shuttle Columbia has been tentatively scheduled for April 7, 1981 (I-C; II-B, C).

- The data available from the two experimental remote sensing satellites, Landsat 2 and 3, have been increasingly used in agricultural planning. AgRISTARS, a major fiscal year 1981 interagency initiative, will build on the Landsat system to establish an operational program providing continuous data required for both agricultural and natural resources planning[8] (II-C, J).

- Because of the need to increase agricultural productivity, major current research initiatives are being focused on the use of genetic engineering techniques in agriculture, on integrated pest management, and on determining more clearly plant biophysical and metabolic responses to environmental stresses (II-J).

- Recognizing that American agriculture is highly energy-intensive, two centers have been established, with support from the Department of Agriculture, to carry out integrated programs for research, development, and technology transfer associated with the agricultural use of alternative energy sources[9] (II-J).

- The National Aquaculture Act of 1980 formalized a number of ad hoc arrangements in the executive branch aimed at increasing the production of both fresh- and salt-water aquatic species (I-E).

3. *Improving the Science and Technology Base for Risk Assessment and Regulation*[10]

- During fiscal year 1980, an Acid Rain Coordination Committee was established to coordinate Federal research activities, during the 1980s, on the determinants and the biological and environmental effects of acid rain[11] (I-D, II-H).

- Many potentially carcinogenic organic substances found in ambient air were assessed for their toxic potencies, for their rates of atmospheric transformation, and for the extent to which humans are exposed to them (II-H).

- As part of an increasing focus on developing mathematical techniques for predicting the near- and long-range effects of pollution sources, a model for predicting concentrations of airborne oxidizing agents on a regional scale was completed (II-H).

- Many programs being initiated during fiscal year 1981 are directed both toward improving the identification, analysis, and monitoring of hazardous nonnuclear, solid- and liquid-waste disposal sites and toward determining appropriate remedial actions for uncontrolled disposal (II-H).

- The most dramatic natural disaster to occur in the United States during 1980 was the eruption of Mount St. Helens on May 18. For approximately two months prior to the eruption, a team of scientists monitored the volcano's activity. Since the event, groups of scientists have conducted a wide variety of studies. Together, these efforts qualify as the first systematic observations of volcanic activity using modern techniques. In addition, the Federal emergency coordinator, working with scientists and engineers, issued a series of 32 special bulletins dealing with a range of scientific, technical, emergency recovery, and procedural topics (II-G).

- Many steps have been taken to coordinate Federal risk assessment and management programs. They include creation of a Federal Regulatory Analysis Review Group to analyze the most significant proposed Federal regulations, a Federal Radiation Policy Council, an Interagency Radiation Research Committee, as well as an expansion of the interagency National Toxicology Program (I-C, D; II-D).

4. *Ensuring Adequate Supplies of Energy and Nonrenewable Resources*

- Major new efforts have emphasized increasing the supplies of oil, gas, and coal as energy sources. These efforts include a five-year accelerated leasing program for offshore oil and gas (I-D; II-G).
- The Energy Security Act of 1980 created an independent U.S. Synthetic Fuels Corporation to foster commercial development of liquid and gaseous fuels from coal, shale oil, and tar sand, and of hydrogen from water. At the same time, major research efforts have been directed both at reducing the costs and hazards associated with processing oil shale and at identifying socioeconomic effects on local communities where large-scale processing operations may be established (I-D; II-E).
- The Energy Security Act also authorized accelerated programs to aid commercial production of alcohol and other fuels from crops and crop wastes, timber, timber wastes, and other sources of biomass[12] (I-D).
- To keep nuclear energy a viable present and future option, research has been directed at increasing the safety of light water reactors, in part by focusing on human factors and in part by focusing on clarifying the effects of ionizing radiation. The latter effort is being coordinated within the government by an Interagency Radiation Research Committee. A Nuclear Safety Oversight Committee, established by President Carter, is monitoring the progress of industry, the Federal Government, and the States in ensuring the safety of nuclear power (I-D; II-E).
- In February 1980, the White House issued a Policy Statement on Nuclear Waste Disposal, dealing primarily with low-level wastes. Technical criteria governing disposal of high-level nuclear wastes are scheduled for publication by the end of fiscal year 1981[13] (I-D, II-H).
- Enactment of the Fusion Research, Development and Demonstration Act of 1980 committed the Nation to an aggressive program for the advancement of knowledge on fusion technology. A magnetic fusion test reactor, being built at Princeton University, is scheduled to be in operation in 1982 and could demonstrate the scientific feasibility of fusion power by 1984 (I-D; II-E).
- Fiscal year 1980 actions and programs aimed at more efficient energy use include a provision in the Energy Security Act to establish a Solar Energy and Conservation Bank and cooperative government-industry programs of research, development, and demonstration of a range of options for more energy-efficient industrial processes (I-D; II-E).
- During fiscal year 1980, the National Highway Traffic Safety Administration demonstrated a minicar safety vehicle that satisfies fuel economy and Federal emission requirements and can also meet rigorous safety standards. Safety tests of the Department of Energy's electric and hybrid demonstration vehicles were carried out to determine which components of those vehicles might need modification (II-I).
- Recognition that future supplies of important nonfuel minerals may become limited in the near future has spurred additional public and private sector investments in exploration, mining, and processing. Both the Deep Sea Hard Minerals Resource Act and the National Materials and Minerals Policy, Research, and Development Act were passed in 1980. Related efforts in Federal agencies have been accelerated, including plans for vigorous pursuit by the Department of Defense, in fiscal year 1982, of rapid solidification technologies (I-E; II-B).
- Programs for satellite remote sensing of natural resources have been fortified, including initiation of the National Oceanic Satellite System (NOSS) (II-C, G).

5. *Contributing to the Maintenance of National Security*

- Science and technology have long been important components of U.S. military security and foreign policy. In the face of major technological growth by other countries, including both developing countries and our potential military adversaries, the Nation's security in the broadest sense will rest heavily on the continued vitality and breadth of its scientific research and on the productivity and innovativeness of its technological base (II-B).

- The science and technology programs of the Department of Defense, augmented by those of such other Federal agencies as the Department of Energy and the National Aeronautics and Space Administration, provide the foundation for the technological superiority of U.S. military capabilities. Proposed constant dollar R&D obligations for the Department of Defense have been increasing annually since 1976, reflecting the expanding science and technology programs of the agency. Obligations for fiscal year 1982, as proposed by President Carter, would account for 48 percent of the proposed total Federal R&D budget (I-A; II-B).

- Significant advances are being made that will have considerable impact on the design and operation of both military and civil aircraft in the near future. They include advances in the areas of applied computational research, flight control techniques, and materials technology (II-B).

- The Department of Defense is making use of the most advanced computer and communications technologies to develop integrated systems to improve the ability to control fighting forces, in both broad strategic and tactical systems contexts, through its command, control, and communication program. Testing and evaluation of several advanced systems are scheduled for fiscal year 1981 (II-B).

- The rapid exploitation of space as an arena for potential military functions presents requirements for major new technologies capable of defending U.S. and allied spacecraft against enemy attack. Recent developments, including advances in laser and charged particle beam technologies, will help meet those needs. In addition, the Department of Defense's space surveillance program is focusing on the development of a technology base for optimal use of satellite-borne remote sensing. An advanced experimental sensing system is scheduled to be launched by the Space Shuttle during 1982 (II-B).

6. *Contributing to Improvements in Health*

- Over the past two years, the health agencies of the Department of Health and Human Services have been engaged in a formal planning effort designed to introduce greater cohesiveness into the Department's health research programs. That successful effort has resulted in a number of new interagency initiatives (II-D).

- One such initiative is to exploit opportunities emerging from recombinant DNA and hybridoma (cell fusion) technologies in the development of new and improved vaccines, a program that will require close coordination with research and evaluation carried out by the private sector (II-D).

- Recent investigations in the neurosciences have led to enormous increases in information about the human nervous system and its disorders. In addition, advances in brain research have opened new conceptual approaches to the study of a wide range of behavior patterns, including mental illness, alcohol abuse, drug addiction, and smoking[14] (II-D).

- A national survey of health habits, linking mortality over a 10-year period with specific combinations of health habits, has recently been initiated to illuminate the impacts of lifestyles and environmental factors, such as stress, on health[15] (II-D).

- A new initiative in human nutrition involves coordination of comprehensive programs in science, technology, and public education. This initiative emphasizes the monitoring and assessment of the nutritional status of the U.S. population, and the analysis and establishment of standards for the nutrient composition of foods (II-J).

- Established in 1978, the National Center for Health Care Technology is beginning to implement the methodology and format to be followed in performing technology assessments.[16] Technologies that will be addressed by the center over the next few years include coronary artery bypass surgery, cesarean delivery, electronic fetal monitoring, and the use of ultrasound for cardiac diagnosis (II-D).

7. *International Cooperation in Science and Technology*

- Explicit protocols for cooperation with the People's Republic of China in such areas as agriculture, energy, earthquake studies, ocean sciences, and basic research were signed during 1980, and collaborative work on a few specific projects under the auspices of those protocols was initiated (I-F).

- A United States-Japan Science and Technology Agreement, signed in May 1980, has provided the foundation for planning a broad range of joint science and technology undertakings in areas such as space, environmental protection, health, agriculture, and resource conservation. This agreement complements and builds upon a bilateral United States-Japan agreement for cooperation in large-scale energy R&D projects (I-F).

- Scientific and technical exchanges under bilateral agreements with the Soviet Union were reduced by 75 percent after January 1980, although some joint projects of specific interest to the United States or of humanitarian interest have continued (I-F).

- In fiscal year 1980, new cooperative science and technology agreements were signed with four African countries and several South American and Caribbean countries in the course of official visits by delegations of U.S. Government science and technology officials, headed by the Director of the Office of Science and Technology Policy (I-F; II-L).

- Steps are now being taken to coordinate U.S. energy policy with the policies of other industrialized nations, through both the International Energy Agency in Paris and economic summit meetings (I-F; II-L).

- Cooperation was enhanced in fiscal year 1980 between the United States and Mexico in a broad program to use science and technology to combat desertification along their common border, and excellent headway has been made in a program to develop guayule, a substitute for rubber, which grows in the arid lands along that border (I-F; II-G).

- A contingency agreement regarding pollution of the marine environment was signed with Mexico in July 1980, and a Memorandum of Intent to develop an air quality agreement, with emphasis on acid rain, was signed with Canada in August. Late in 1980, an Interagency Working Group on Hazardous Substance Export Policy completed a report for submission to the White House that aims toward the development of an internationally acceptable program of hazardous waste disposal that would be consistent with U.S. domestic requirements (I-F).

- Worldwide expansion of remote sensing capabilities continued in fiscal year 1980, with Australia, Argentina, and South Africa joining six other nations that have operational ground stations for direct reception of data from U.S. Landsat satellites (I-F).

References

[1] *The Five-Year Outlook: Problems, Opportunities, and Constraints in Science and Technology.* Washington, D.C.: U.S. Govt. Printing Office. (NSF 80-29). May 1980. v-1 pp. 1–7.

[2] *Science and Technology: Annual Report to the Congress (ASTR II).* Washington, D.C.: U.S. Govt. Printing Office. (NSF 80-21). June 1980.

[3] *Science.* v. 210, pp. 619–23 (Nov. 7, 1980); pp. 758–59 (Nov. 14, 1980); pp. 887-89 (Nov. 21, 1980).

[4] Supplement, Chapter I, "The Consequences of Limited University Growth."

[5] Supplement, Chapter I, "Recent Trends in the Education of Scientists and Engineers."

[6] *ASTR II*, pp. 39–44.

[7] Ibid. pp. 6–8; 53–60.

[8] Supplement, Chapter I, "Public Policy Implications of Satellite Remote Sensing Applications."

[9] *ASTR II*, pp. 78–79.

[10] Ibid. pp. 61–64; Supplement, Chapter II-A, B.

[11] *ASTR II*, pp. 70–72.

[12] Supplement, Chapter I, "The Use of Biomass as an Energy Source."

[13] *ASTR II*, pp. 66–68.

[14] Supplement, Chapter I, "Mental Health Policy Implications of Scientific Research on Drugs."

[15] Supplement, Chapter I, "Role of Stress in Physical and Mental Health and Disease: Implications for Preventive Health Strategies."

[16] *ASTR II*, pp. 76–78.

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CHAPTER I

DECISIONS AND ACTIONS CONCERNING SCIENCE AND TECHNOLOGY

Science- and technology-related decisions and actions taken by both the executive and the legislative branches of the Federal Government during fiscal year 1980 and the first months of fiscal year 1981 were concerned with improving the capacity of science and technology to assist in the resolution of issues associated with national security, energy availability, conservation of nonfuel resources, and international relations; and with strengthening the capacity of the U.S. science and technology enterprise to make future contributions to the Nation's social and economic well-being.

Despite high inflation rates, estimates through the end of the fiscal year indicate that the national constant dollar expenditures both for total research and development (R&D) and for basic research were continuing to increase, as they have since fiscal year 1975, following a decline that began with fiscal year 1969. During fiscal year 1980, private industry's total R&D investments grew more rapidly than those of the Federal Government and were estimated at 48 percent of the national total investment. The growth of Federal expenditures, for total R&D and for basic research, reflects explicit policy decisions of both the Ford and Carter Administrations.

The Director of the Office of Science and Technology Policy (OSTP), in hearings before the Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation in September 1980, identified five key factors that he regarded as essential to any strategy to strengthen the capacity of the science and technology enterprise: (1) a stable, balanced Federal R&D budget; (2) enhanced Federal support for basic research, including support to modernize university R&D equipment and facilities; (3) strengthened R&D programs in the Federal mission agencies; (4) attention to science and engineering education and personnel needs; and (5) improved cooperation among the Federal Government, private industries, and universities. Decisions and actions of the executive branch related to the first three factors were implicit in the Carter Administration's original (January 1980) and revised (March 1980) fiscal year 1981 budget proposals to the Congress, and also in its fiscal year 1982 budget, submitted in January 1981. The overall thrust of these budgets is discussed in Section A. Significant actions related to science and engineering education and to the improvement of government-industry-university cooperation are discussed in Sections B and C, respectively, while major Federal decisions and actions in the areas of energy, natural resources, and international science and technology cooperation are summarized in Sections D, E, and F.

A. OVERALL SUPPORT FOR SCIENCE AND TECHNOLOGY

The Federal Government supports a wide spectrum of research and development activities to achieve a variety of goals, as described in Chapter II of this report. The fruits of R&D provide an important means of responding to and addressing many of the problems confronting this Nation and the world, as well as a primary means of building a desirable future. Moreover, since the advancement of scientific knowledge is a cumulative process, expenditures cannot be deferred without risk. Indeed, continued support of R&D is an important and necessary investment in our Nation's future well-being.

Approximately half of our national R&D effort is supported directly by the private sector and the Federal Government's role is to complement, but not supplant, these activities. The budget focuses direct Federal support in areas where the U.S. Government is itself the primary user (as in the case of defense), where there are insufficient incentives for the private sector to invest adequately (as in the case of basic research), or where the government seeks to augment private efforts be-

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cause of overriding national interests (as in the case of energy).

The Carter Administration has made major efforts in all these areas, but particularly with regard to basic research. Such research typically does not directly yield property rights, such as patents, and thus performers cannot be assured that they will be able to reap the commercial benefits of their work. Moreover, the commercial payoff of any particular project is likely to be both uncertain and long term. Thus, the private sector understandably tends to channel its R&D funds elsewhere. Yet, basic research is the foundation for future advance and progress. Indeed, whole new industries—biotechnology, computers, microelectronics—have been spawned by this work. The Federal Government must thus assume a major role in support, a responsibility that it has clearly recognized since the mid-1970s.

The Carter Administration's budget request for fiscal year 1982, which was transmitted to the Congress on January 15, 1981 (Appendix B), included real increases above inflation for all broad R&D activities over fiscal year 1981: in particular, an 18.5 percent increase in current dollar obligations for the conduct of R&D over fiscal year 1981 and a 14.4 percent increase for basic research. These provide growth of 8.0 and 4.3 percent above inflation, respectively, in these important activities. Many of the specific programs are discussed in detail in the remainder of this *Report*.

Estimated Federal obligations for the conduct of R&D and of basic research for fiscal years 1978, 1979, 1980, and 1981 are given in Table 1. These figures reflect congressional actions through December 1980. Table 1 also summarizes the total R&D obligations and basic research obligations proposed by President Carter for fiscal year 1982.

TABLE 1. Federal Research and Development Obligations
(dollars in billions)

	Current Dollars		Constant 1972 Dollars	
Fiscal Year	Total R&D	Annual percentage change	Total R&D	Annual percentage change
1978	26.39		17.36	
		+9.8		+1.1
1979	28.98		17.55	
		+9.3		+0.8
1980[1]	31.68		17.69	
		+11.2		+0.7
1981[1]	35.23		17.82	
		+18.5		+8.0
1982 (proposed January 1981)[2]	41.73		19.24	

	Current Dollars		Constant 1972 Dollars	
Fiscal Year	Basic research	Annual percentage change	Basic research	Annual percentage change
1978	3.70		2.44	
		+13.4		+4.3
1979	4.20		2.54	
		+11.5		+2.8
1980[1]	4.68		2.61	
		+9.4		−0.9
1981[1]	5.12		2.59	
		+14.4		+4.3
1982 (proposed January 1981)[2]	5.86		2.70	

[1]Estimate.
[2]*Note added in proof.* Reductions in the 1982 budget figures as well as some recisions in fiscal year 1981 obligations were proposed by President Reagan in March 1981.

Source: Office of Management and Budget, Special Analysis K. Budget of the United States Government, Fiscal Year 1982. January 1981.

Over the period covered by the budgets prepared during the Carter Administration (fiscal years 1978-1982), support for basic research was proposed to grow by a 12.2 percent average annual rate, and support for all R&D, including basic research, by an average of 12.1 percent per year. This is equivalent to average annual growth rates above inflation of 2.6 percent for both basic research and total R&D.

Federal obligations for total R&D and for basic research for fiscal year 1979 and proposed (March 1980) obligations for fiscal years 1980 and 1981 are broken down according to detailed budget functions in Appendix A. Percentage changes in current dollars in total R&D between fiscal years 1980 and 1981 are summarized, by budget function, in Figure 1.

Taken together, the fiscal years 1980, 1981, and proposed 1982 R&D budgets of the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), the Department of Health and Human Services (HHS), the National Science Foundation (NSF), and the Department of Agriculture (USDA) account for more than 90 percent of proposed Federal obligations for R&D. The combined basic research budgets of these six agencies during these three years account for more than 95 percent of proposed Federal obligations for basic research. Figures 2 and 3, respectively, show the percentage distribution of the proposed total R&D budget obligations and the proposed basic research obligations budget for fiscal year 1982 among the budgets of each of these departments and agencies.

B. SCIENCE AND ENGINEERING EDUCATION AND PERSONNEL NEEDS

In August 1980, the Director of the National Science Foundation and the Secretary of Education submitted a report to President Carter entitled *Science and Engineering Education for the 1980s and Beyond.* It reviewed in both quantitative and qualitative terms the adequacy of science and engineering education for the Nation's long-term needs. The report, which had been requested by the President in February, addressed issues and made recommendations in two broad areas: (1) the education of scientists, engineers, and technicians; and (2) the education in science and mathematics of those who do not intend to pursue careers directly related to those fields, but who require some level of competency in and understanding of them.

Four immediate, critical problems associated with science and engineering education and personnel requirements were identified by the report: (1) there are currently shortages of new graduates at all degree levels in the computer professions, in most fields of engineering, and in some subspecialties of physics, chemistry, and biology; (2) there is some likelihood that some of those shortages could persist for a decade or more, particularly at the Ph.D. level; (3) there are currently severe shortages of university engineering and computer science faculty; and (4) a good deal of the equipment and facilities needed for both university teaching and research in several critical science and engineering fields is obsolete. The latter two problems are closely related and could limit the capacity of universities to provide quality education to adequate numbers of students in engineering and the computer professions. The report concluded, however, that there are now, and will continue to be for the next decade, sufficient numbers of scientists in all broad fields and all degree levels.

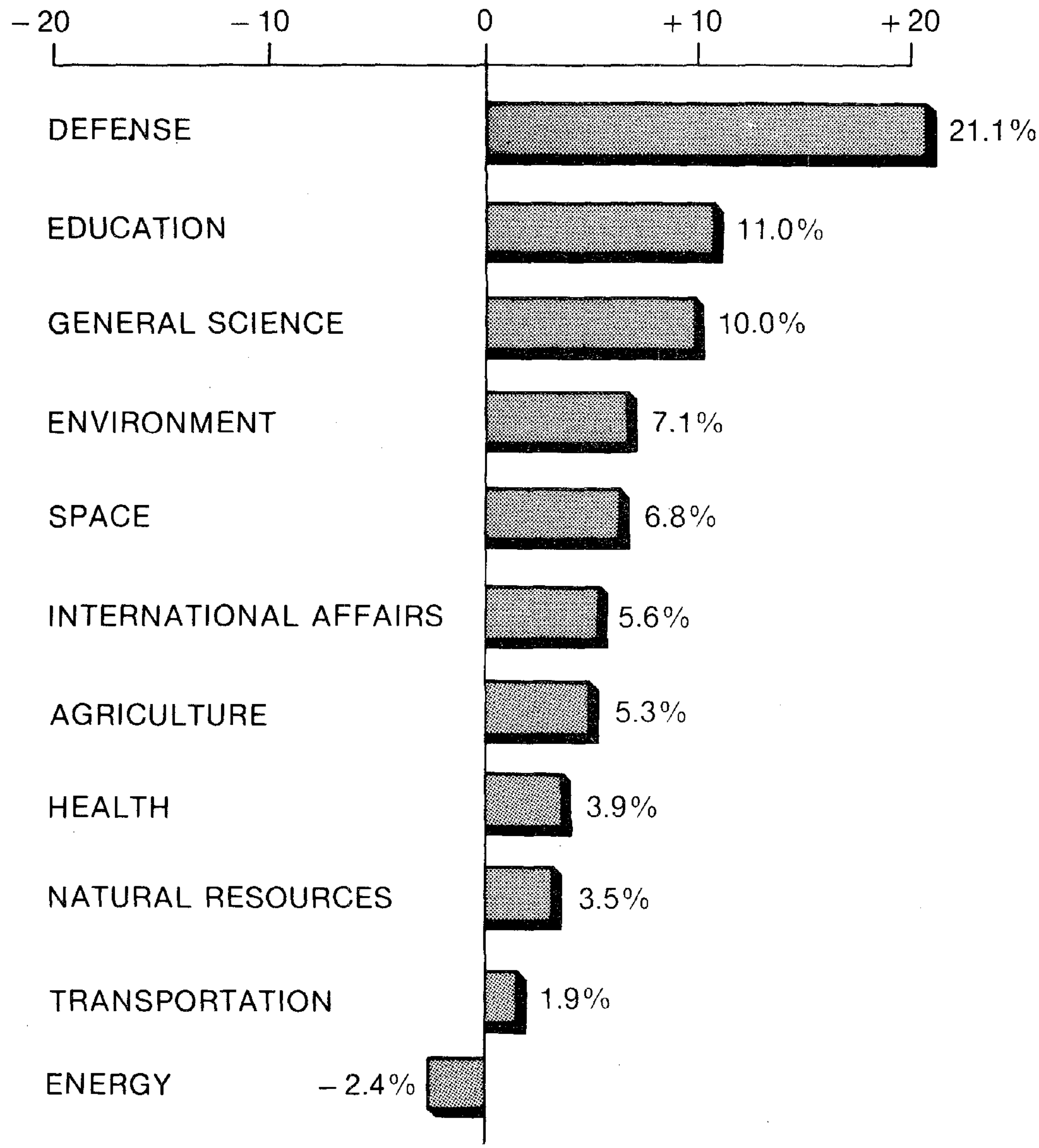
The report made several specific recommendations for Federal action to help resolve the problems: (1) provision of limited numbers of graduate fellowship and traineeship programs in critical fields where serious personnel shortages at the advanced degree level are projected; (2) enhanced, focused support by the Federal mission agencies for university engineering faculty and graduate students in critical fields, to be conveyed through grant and contract mechanisms; and (3) measures to stimulate closer industry-university cooperation to help the educational system maintain its long-term capacity to produce the numbers and types of trained engineers and scientists that industry will require in the future.

The importance of having sufficient numbers of skilled technicians to support the work of professional scientists and engineers was also emphasized, although the report concluded that information about the specific needs of industry for such technicians or about the present adequacy of their training is insufficient to permit recommendations for appropriate Federal action.

Data analyzed by *Science and Engineering Education for the 1980s and Beyond* indicate that the qualifications of secondary school graduates who intend to pursue careers in science and engineering or in such closely related fields as medicine have remained essentially constant for more than a decade. However, achievement levels in mathematics and science for most other students have declined appreciably over the same period. That decline probably stems from several factors, including an overall relaxation in requirements for high school graduation and college admission, shortages of ade-

FIGURE 1

CHANGES IN PROPOSED FEDERAL R&D BUDGET AUTHORITY BY SELECTED FUNCTIONAL AREAS: FY 1980-1981

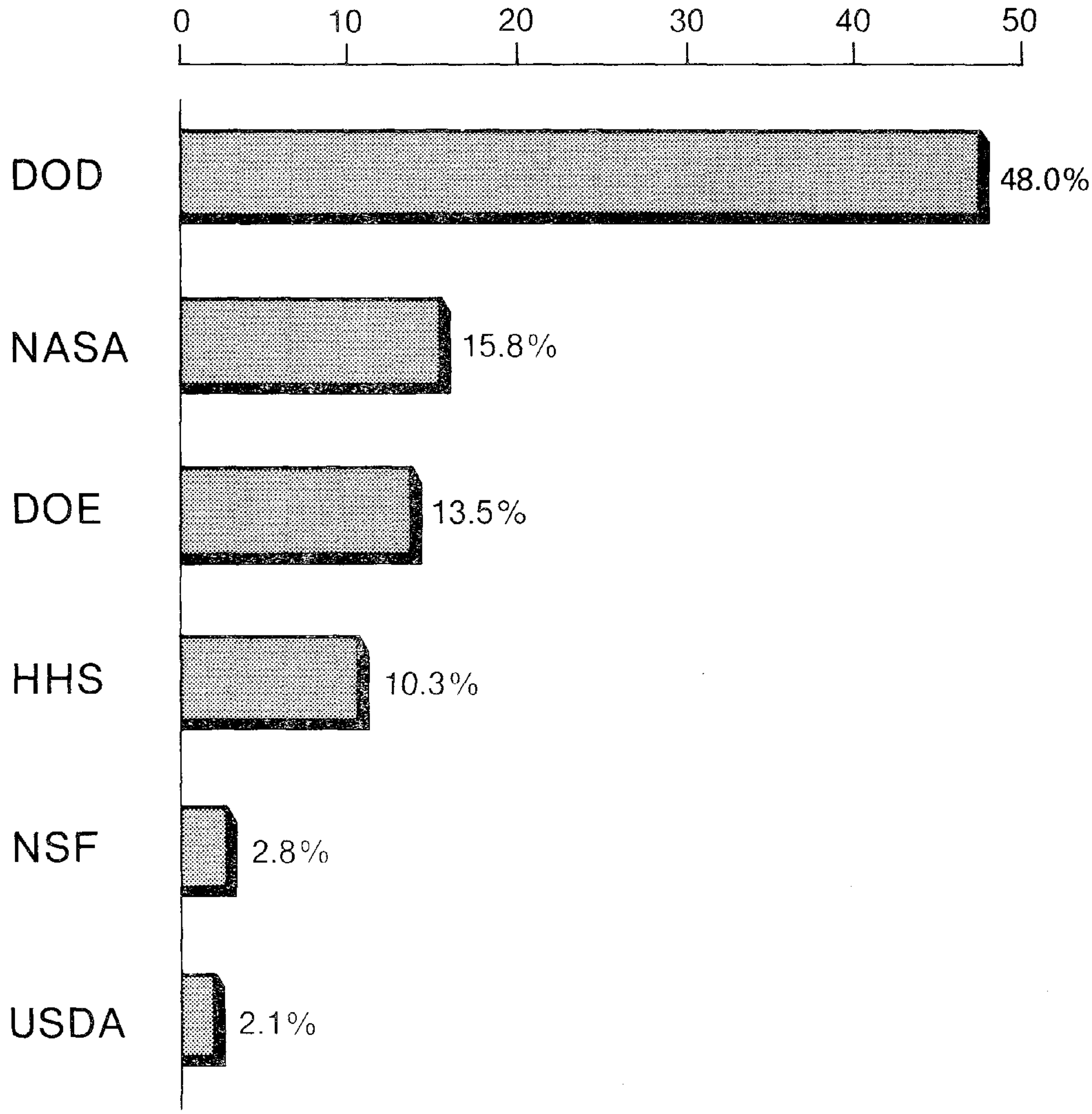


SOURCE: DIVISION OF SCIENCE RESOURCES STUDIES, NATIONAL SCIENCE FOUNDATION, FEDERAL FUNDING BY BUDGET FUNCTION, FISCAL YEARS 1979-81, MAY 1980.

FIGURE 2

DISTRIBUTION OF PROPOSED FY 1982 TOTAL R&D BUDGET BY AGENCY

(JANUARY 1981)

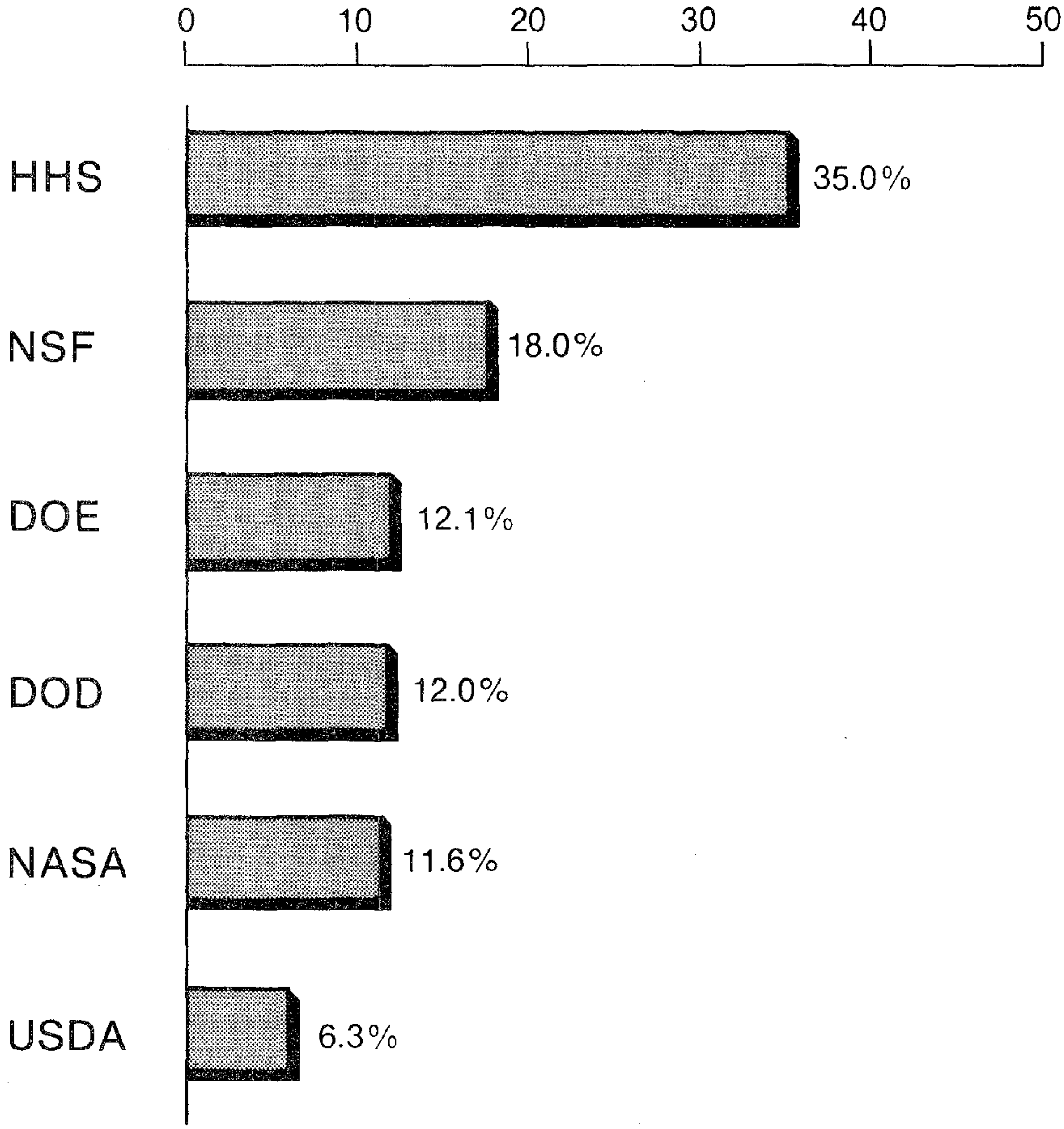


SOURCE: OFFICE OF MANAGEMENT AND BUDGET, SPECIAL ANALYSIS K. BUDGET OF THE UNITED STATES GOVERNMENT, FISCAL YEAR 1982. JANUARY 1981

FIGURE 3

DISTRIBUTION OF PROPOSED FY 1982 BASIC RESEARCH BUDGET BY AGENCY

(JANUARY 1981)



SOURCE: OFFICE OF MANAGEMENT AND BUDGET, SPECIAL ANALYSIS K. BUDGET OF THE UNITED STATES GOVERNMENT, FISCAL YEAR 1982. JANUARY 1981.

quately trained secondary school mathematics and physical science teachers, and the continued use of secondary school science and mathematics curricula that are not tailored to the needs of nonspecialists. Since those factors have persisted for over a decade, the report recognized that long-term efforts would most likely be required to reverse the decline in achievement. Recommendations focused on measures that the Federal Government could pursue to stimulate better interactions among scientists, engineers, educators, and State and local officials who bear primary responsibility for education at the precollege level.

C. GOVERNMENT-INDUSTRY-UNIVERSITY COOPERATION

Several steps were taken during fiscal year 1980 to implement specific initiatives associated with the Domestic Policy Review on Industrial Innovation, the results of which were announced in October 1979, and, more broadly, to expand government-industry-university cooperation in R&D:

- Enactment in October 1980 of the Stevenson-Wydler Technology Innovation Act (Public Law 96-480) established a framework for the industrial technology (or generic technology) centers proposed in October 1979. The act provided a statutory foundation for initiatives previously launched by the Carter Administration. Plans were made to establish five centers by the Department of Commerce (USDC) and one by NSF during fiscal year 1981, at a total cost of $6-8 million. Each center, at a university or other nongovernmental site, would be financed jointly by industry and the Federal Government, with government's share dropping to 20 percent or less in the fifth year. The centers would be devoted to developing generic technologies such as welding and joining, robotics, corrosion prevention and control, powder metallurgy, and tribology.

- The Stevenson-Wydler Act also created a National Medal of Science and Technology, and established a joint USDC/NSF program of personnel exchanges between Federal laboratories, industry, and universities.

- Legislation was enacted in December 1980 to establish a uniform patent policy for universities and small businesses (Public Law 96-517), in which such contractors retain title to most patents developed at government expense, if they agree to commercialize the inventions.

- The Carter Administration's revised (March 1980) fiscal year 1981 budget proposed $15 million for support, by NSF, of high-quality R&D projects to be carried out jointly by industry-university research teams, plus $9 million for another NSF program that supports research and feasibility testing of new developmental concepts by small, technology-intensive firms.

- The Department of Justice issued, in November 1980, a publication entitled *Antitrust Guide Concerning Research Joint Ventures*, which sets forth the analysis it will use to examine the permissibility of collaborative research ventures. These guidelines should help business firms structure and undertake a range of joint research projects. They suggest that permissible joint research may "promote a more competitive market as a whole by enabling the participants to provide new goods and services that would not have come into being except by cooperative effort."

- The transfer of Federal scientific and technical information to the private sector has been facilitated by a merger of the Smithsonian Science Information Exchange (SIE) with the National Technical Information Service (NTIS). The objective is to strengthen NTIS by giving it a wider range of scientific inputs. NTIS also established a new Center for the Utilization of Federal Technology as a focal point for aggregating federally sponsored technical information and assessing its usefulness to other industrial sectors.

Two major programs developed in fiscal year 1980 aim to stimulate government-industry-university cooperation in specific areas:

- The Ocean Margin Drilling Program (OMDP), announced in January, is a proposed 10-year program of research and technological development to study the geology of the world's ocean margins, which lie just beyond the outer continental shelves. The ocean margins are one of the last unexplored areas on Earth. Their potential for large oil and gas resources may be significant. NSF has been given overall management responsibility for the program, whose detailed design phase began in October 1980 and is due for completion in mid-1982. The Federal Government is contributing $5 million to the costs of the first year of the program, with 10 U.S. oil companies contributing the remaining $5 million. The primary objectives of the design studies are to prepare detailed plans for converting the government-owned *Glomar Explorer* into a drillship capable of penetrating 20,000 feet beneath the ocean floor in 13,000 feet of water and to develop a detailed scientific program. If design studies indicate the desirability of the full 10-year program, conversion of the *Glomar Explorer* and procurement of the necessary technical equipment should commence in mid-1982 and be completed by mid-1983. Initial field testing would begin in January 1983, and full-scale operations a year later. An advisory committee, composed of scientists from government, industry, and universities, has selected 10 preliminary candidate sites for a model drilling program. Exploration of those sites would constitute a balanced scientific effort. The total cost of the full 10-year program is estimated at $800 million, with the Federal Government and industry contributing equal amounts. Several other countries, including France and Japan, have also expressed strong interest in contributing to this effort.

- The Cooperative Automotive Research Program (CARP) is intended to increase the level of research underpinning automotive technology. Costs would be shared by the government and by the five major U.S. automotive manufacturers (General Motors, Ford, Chrysler, American Motors, and Volkswagen of America). CARP would operate as a voluntary confederation of relatively autonomous participants—the individual manufacturers, the Department of Transportation, the National Science Foundation, and possibly the Department of Energy. Each participant would select and fund specific research projects consistent with mutually agreed-upon administrative and technical frameworks. The technical framework, completed in September through the combined efforts of approximately 100 scientists in government, industry, and universities, outlines promising directions for research in nine areas. Federal support for the program would be directed primarily to university and other nonprofit research laboratories, and possibly to some research-oriented firms.*

Space is a promising area of future government-industry cooperation. Hearings on the Space Industrialization Act of 1979 were held by the House of Representatives in June 1980. The bill would establish a Space Industrial Corporation to promote, encourage, and assist in the development of new products, processes, and industries using the unique properties of space. The legislation also recognizes the importance of the early involvement of private industry in exploring industrial aspects of space. Completion of the Space Shuttle is, however, a necessary first step toward more active industrial involvement. A new projection of demand for Shuttle services, completed during fiscal year 1980, indicates that the requirements of commercial and foreign government users will be about twice what had been previously anticipated. The Shuttle passed several major technical milestones during the year, suggesting that earlier weaknesses in program planning and control that resulted in considerable delays in its schedule may have been overcome. The present target date for the first test flight of the Shuttle Columbia is April 7, 1981, with the Shuttle's operational era scheduled to begin in 1982.

D. ENERGY AVAILABILITY AND USE

Several fiscal year 1980 science- and technology-related decisions and actions were aimed at implementing components of the National Energy Plan of May 1979:

- The Energy Security Act of 1980 (Public Law 96-294) was enacted in June. This omnibus energy bill, designed to reduce U.S. dependence on foreign oil, authorized $20 billion for a synthetic fuels program. It creates an independent U.S. Synthetic Fuels Corporation to foster the commercial development of liquid and gaseous fuels from coal, shale rock and tar sands, and hydrogen from water, and it establishes a production goal of 500,000 barrels a day of crude oil equivalent by 1987 and two million barrels a day by 1992.
- The same law authorized $1.4 billion through fiscal year 1982 for programs in the Departments of Energy and Agriculture to aid commercial production of alcohol and other fuels from crops, crop waste, timber, animal and timber waste, and other forms of biomass.
- Executive branch agencies, particularly the Department of Energy, continued support of a wide range of other solar energy research and development activities in university, in-

**Note added in proof.* The Reagan Administration has proposed recision of fiscal year 1981 budget obligations for CARP.

dustry, and government laboratories. Support for those activities will amount to approximately $700 million during fiscal year 1981.

- The Ocean Thermal Energy Conversion Research and Development Act (Public Law 96-320), designed to accelerate the commercial development of ocean thermal energy conversion, was enacted in August. The technology it encourages generates electricity by exploiting the temperature differential between surface water in tropical climates (such as Hawaii, Puerto Rico, and the Southern States) and cold water deep in the oceans.

A number of decisions and actions associated with the development of nuclear power also occurred in fiscal year 1980:

- A Policy Statement on Nuclear Waste Disposal, dealing primarily with low-level wastes, was issued by President Carter on February 12, 1980. It focuses on policies concerning waste performance, site suitability, and facility design, operation, and decommissioning, as well as on policies for evaluating alternatives to shallow land burial. The Nuclear Regulatory Commission (NRC) intends to publish technical criteria governing disposal of high-level nuclear waste by the end of fiscal year 1981.

- A Federal Radiation Policy Council charged with coordinating the formulation and implementation of Federal policy on radiation protection was established in February. In addition, a 14-member Interagency Radiation Research Committee was created to coordinate Federal research into the effects of ionizing radiation.

- The Fusion Research, Development, and Demonstration Act of 1980 (Public Law 96-386) was enacted in October. It commits the Nation to an aggressive program leading to a magnetic fusion electricity-generating demonstration facility during the 20th century, with emphasis on engineering and development of technology. A magnetic fusion test reactor at Princeton University is scheduled to be in operation in 1982 and could demonstrate the scientific feasibility of fusion power as early as 1984.

Several significant Federal initiatives were begun during fiscal year 1980 to facilitate an expanded supply of conventional domestically accessible fuels during the remainder of the century. For example:

- The Department of the Interior's Bureau of Land Management initiated a five-year accelerated leasing program for the outer continental shelf lands. That program is being supported by new scientific studies on geological and oceanographic hazards, and it includes biological reconnaissance and endangered species research.

- The Department of Transportation issued proposed regulations on the design, siting, construction, operation, and maintenance of liquefied natural gas pipelines and facilities. Those regulations are the culmination of extensive risk assessment, economic and environmental analyses, and other research into the new technology needed to transport that super-cold, highly flammable material.

- Considerable attention was directed to an improved understanding of the causes, occurrences, and effects of acid rain, a problem that is likely to become increasingly significant in view of the planned expansion in the use of coal and coal derivatives. The Acid Rain Coordination Committee has prepared a Federal Acid Rain Assessment Plan to provide guidance for a 10-year, coordinated Federal effort, as required by the Energy Security Act of 1980. Collection and analysis of weekly rain samples to establish trends and spatial occurrences of acid rain and to assess its biological effects on agriculture and forest products began in fiscal year 1981. The program will be broadened, and substantive research on the effects of acid rain on plants will be initiated during 1982.

E. NONFUEL RESOURCES AND THE ENVIRONMENT

In fiscal year 1980, Congress enacted two laws dealing with the problem of ensuring the availability of nonfuel minerals to meet the future requirements of industry. A third law is intended to encourage commercial aquaculture development, primarily to help meet the growing domestic demand for seafood.

The Deep Sea Hard Minerals Resource Act (Public Law 96-283), enacted in June 1980, established an interim legal regime under which technology can be developed and the exploration and recovery of mineral resources from the deep sea bed can take place prior to the conclusion of an International Law of the Sea Treaty. The principal commercial focus of the act is on nodules, lying on or close to the surface of the deep sea bed, that contain high concentrations of manganese, nickel, cobalt, and copper. The act provides a framework for regulating and licensing exploration of the mineral resources of the deep sea and for the commercial recovery of those resources by U.S. citizens and firms. It also directs the Administrator of the National Oceanic and Atmospheric Administration (NOAA) to expand and accelerate environmental assessments of the effects of exploration and recovery activities, and to conduct a continuing program of ocean research with ecological, geological, physical, and biological components.

The National Materials and Minerals Policy, Research, and Development Act of 1980 (Public Law 96-479), signed into law in October, provides for a national policy for materials research and development. It requires the assistance of the responsible agencies in the development of policies that will ensure a stable supply of materials. In addition, the act calls for the support of basic and applied research and development aimed at the exploration, discovery, and recovery of nonfuel materials. It also requires the Secretary of the Interior to improve the ability of the Bureau of Mines to assess international minerals supplies and report the results to Congress.

The National Aquaculture Act of 1980 (Public Law 96-362), enacted in September, aims to encourage activities and programs in both the private and public sectors that will result in increased aquaculture production, improved coordination of domestic aquaculture efforts, conservation and enhancement of aquatic resources, and creation of new aquaculture industries. There is considerable potential in aquaculture for increased scientific research (in the areas of genetics and closed cycle systems, for example) and for application of existing technologies to increase yields from fresh and salt water species. To this end, the act authorizes the Secretaries of Agriculture, Commerce, and the Interior to use grant and contract mechanisms to promote appropriate scientific research. In addition, the act formalizes several arrangements initiated by the executive branch, including the establishment of a Federal Joint Subcommittee on Aquaculture under the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET); the formulation of a National Aquaculture Plan; and the initiation of studies of the extent to which the growth and development of commercial aquaculture are being impeded by the lack of sufficient venture capital, disaster loans, and insurance and by Federal, State, and local rules, regulations, and procedures.

Significant fiscal year 1980 executive branch actions dealing with the environment included:

- Completion of the first draft of a major study dealing with desertification of arid and semiarid lands in the Western States. Executive branch agencies, congressional offices, State and local governments, and professional groups are participating in the study. A series of hearings on the draft report was held in August.

- Submission to President Carter of the report of the Interagency Task Force on Tropical Forests recommending specific programmatic steps involving research, development assistance, economic analysis, and ecological monitoring and management. The report addresses a serious international issue concerning the rapid disappearance of tropical forests throughout the world. Their disappearance could adversely affect the availability of certain woods in the United States and also lead to global changes in weather. Participating agencies have been asked to identify specific programmatic steps to respond to the recommendations contained in the report.

- Submission to President Carter of *The Global 2000 Report*, prepared by the Council on Environmental Quality and the Department of State with assistance from several other Federal departments and agencies. The report provides a foundation for planning by outlining changes that are likely to occur in the world's population, natural resources, and environment through the end of the century.

- Transmission to Congress, in November, of a five-year plan prepared by NOAA to coordinate Federal climate programs to improve the understanding of, and ability to respond to, natural and human-induced climatic processes. Preparation of this plan was mandated by the National Climate Program Act of 1978.

F. INTERNATIONAL COOPERATION IN SCIENCE AND TECHNOLOGY

Considerable progress was made during the year on developing and implementing a wide variety of collaborative projects with the People's Republic of China. To date, a total of 14 specific protocols to implement the January 1979 umbrella Agreement for Cooperation in Science and Technology have been signed. The protocols provide for project activity in such areas as agriculture, student and scholar exchange, earthquake studies, ocean sciences, hydroelectric power, and basic research. These cooperative efforts are supportive of U.S. interests in building a strong and modern China and also in developing a network of institutional and personal relationships at all levels. The specific scientific agreements reached so far will lead to greater bonds: a Chinese technological leadership in the future will be trained largely in the U.S., and trade will be greatly increased. Examples of cooperative projects carried out or initiated during fiscal year 1980 include these:

- A research ship operated by NOAA joined Chinese ships and scientists studying sedimentation dynamics at the mouth of the Yangtze river. The data collected are currently being studied by combined teams of U.S. and Chinese scientists. Joint work on earthquake studies has also proceeded rapidly with the collection of data that could lead to improved earthquake prediction capabilities.

- Planning and implementation of a program of activities in the hydroelectric power field are well under way. Delegations have been exchanged in a program aimed at assisting the Chinese in their ambitious efforts to develop their extensive hydropower resources. It is anticipated that the involvement of the U.S. Government in the pre-planning stages of this program will provide competitive advantages to U.S. commercial interests once actual design and construction work has begun.

- The Department of Commerce provided an 18-member team of U.S. management experts to staff and develop the teaching program for a new Chinese National Center for Scientific and Technical Management Development in Dalien, China. The initial 120-person student body was drawn from Chinese industrial enterprises and government industrial development ministries. The goal of this long-term program is to assist the Chinese modernization effort through the development of sound management practices for industrial science and technology.

- Completing its second full year, the exchange of students and scholars continues to flourish. The 1980-81 academic year will see 17 advanced students and 36 research scholars from the United States working in China in fields ranging across the humanities, social sciences, and physical sciences. From the Chinese side, some 4,000 students are currently in the United States—approximately half under the auspices of the officially sponsored government program, and the remainder under private auspices.

In May 1978, Japanese Prime Minister Fukuda proposed that the United States and Japan cooperate in energy research and development. After detailed negotiations, U.S. and Japanese representatives signed a bilateral agreement for cooperation in such large-scale energy research and development projects as coal liquefaction, nuclear fusion, and geothermal and solar energy. In late 1979, President Carter proposed to the late Prime Minister Ohira of Japan a complementary program of joint research and development in such nonenergy areas of global importance as space, environmental protection, health, agriculture, and resource conservation. Negotiations culminated in the signing, at the White House, of a Science and Technology Agreement by President Carter and Prime Minister Ohira in May 1980.

The scale of these programs represents a new concept in international science and technology cooperation in which expensive, risky, globally important science and technology projects are undertaken across the entire range of technological possibilities and in both energy and nonenergy fields. These projects are designed not only to benefit the two countries, but also to advance the state of the art in various fields, thus benefiting all nations. Personnel, physical resources, and financing of these large-scale projects will be shared. Agreement has been reached with Japan on several joint projects in the space area, and program development continues in a number of additional areas.

The United States and the U.S.S.R. participate in 11 bilateral programs in basic and applied science fields. These agreements all date from the early 1970s when the interest in a general improvement of U.S.-Soviet relations was high. As a result of the Soviet invasion and continued occupation of Afghanistan, the Carter Administration took steps in January 1980 to demonstrate that such conduct would have severely adverse effects on all forms of cooperative activity including science and technology cooperation. In the area of government-to-government exchanges, all high-level meetings have been indefinitely postponed, including a March 1980 meeting of the U.S.-U.S.S.R. Joint Science and Technology Commission. Additionally, all specific activities have been individually reviewed. Only low-level, substantive activities of specific scientific interest to the U.S. or of humanitarian interest (e.g., health and environment projects) have been permitted. These steps were taken in order to maintain the framework of the cooperative program so that it could be selectively increased if the international situation improves--or further reduced if the climate worsens. As a result of these actions, the United States has reduced by approximately 75 percent its cooperative science and technology activity with the U.S.S.R.

Efforts continued during fiscal year 1980 to expand cooperative programs in science and technology with both the middle tier countries and the poorer nations of the developing world. The Director of the Office of Science and Technology Policy led a delegation of high-level representatives of several Federal science and technology agencies on an official visit to Nigeria, Zimbabwe, Kenya, and Senegal in September 1980. Cooperative agreements executed in each of these countries focus on specific areas in which U.S. capabilities can be of assistance in helping to meet economic needs. A similar scientific delegation visited Latin America in October 1979 to strengthen cooperative science and technology programs with Venezuela, Brazil, Peru, the Andean Pact nations, and the nations in the Caribbean region. Program development with these countries is continuing.

Scientific and technical cooperation with Mexico was enhanced during President Carter's February 1979 visit to that country when the two sides agreed that existing mechanisms for such cooperation should be strengthened. Accordingly, a Memorandum of Understanding on Science and Technology Cooperation was signed. This memorandum augmented the earlier 1972 bilateral agreement and a host of other agreements and arrangements. As a result, programs in agriculture, energy, housing, railroad transportation, industrial technology, and basic sciences have been developed and are being implemented. The United States-Mexico Mixed Commission provides central planning and coordination for all bilateral science and technology activities. One of the most successful areas of cooperation with Mexico has been in the field of arid lands and new crops. Excellent headway has been made in reaching agreement on specific steps. In particular, development of guayule—a substitute for natural rubber—could lead to significant production and employment opportunities in both countries.

During fiscal year 1980, Australia, Argentina, and South Africa joined Canada, Brazil, Italy, Sweden, Japan, and India in having in operation ground stations capable of direct reception of remote sensing data from Landsat satellites. A Memorandum of Understanding signed in 1980 with the People's Republic of China will allow that country to purchase a Landsat ground station. Discussions are either planned or in progress with the European Space Agency, France, Canada, Japan, and India to promote the development of complementary land remote sensing satellites to be operated by those nations.

Several international agreements concerned with environmental policy were signed or were being negotiated during fiscal year 1980:

- A contingency agreement regarding pollution of the marine environment by hydrocarbons and other hazardous substances was signed with Mexico in July 1980. The United States is also participating, under the auspices of the Intergovernmental Maritime Consultative Organization, in the preparation of a draft treaty text for a Convention on Liability and Compensation in Connection with the Carriage of Noxious Substances by Sea, to be considered in 1982.

- The United States played a major role in developing the Convention on Long-Range Transboundary Air Pollution, signed at the Economic Commission for Europe in November 1979, and also signed a Memorandum of Intent with Canada in August 1980 to develop an air quality agreement, with emphasis on reducing acid rain.

- Since most countries do not have environmentally sound disposal and recycling capabilities, the export of hazardous wastes has become a sensitive international policy issue. The United States is attempting to develop an internationally acceptable program of hazardous waste disposal that would be consistent with U.S. domestic requirements. An Interagency Working Group on Hazardous Substances Export Policy submitted its report and recommendations to President Carter in January 1981.

Mechanisms are also being established to coordinate U.S. energy planning with that of other industrialized nations through the International Energy Agency in Paris and economic summit meetings. The United States and six other industrialized countries have established a High Level Group on Energy Technology Commercialization as an outgrowth of the 1979 Tokyo Summit. In fiscal year 1981 that group will take specific steps to promote development of new energy technologies, including an exchange of detailed information on plans through the year 2000 to expand production of plants employing such new technologies, and an examination of prospects for international collaboration on commercialization of advanced energy technologies in six specific areas. The group will also consider financial incentives and other feasible measures to reduce risks and accelerate development. During fiscal year 1980, the United States also joined with Japan and West Germany to initiate planning for a major solvent-refined coal liquefaction demonstration project at Morgantown, West Virginia.

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CHAPTER II

FEDERAL RESEARCH AND DEVELOPMENT PROGRAMS

A. INTRODUCTION

This chapter describes a variety of Federal research and development programs directed at national problems. Discussions are organized around broad substantive topics to highlight recent major accomplishments and important new initiatives in federally supported science and technology programs at the agency and interagency levels.

Representatives of 23 Federal agencies worked together in task groups to prepare the 11 reports that follow, each group corresponding to one of 11 substantive areas. Each agency with a science- and technology-related mission within a given functional area provided source materials to the corresponding group, and these contributions were integrated by a designated lead agency into a single narrative appropriate to that substantive area. Agencies were encouraged to contribute to reports corresponding to the functional area in which they have activities or programs, and many provided inputs to functions in which their budgets are normally not reported. This procedure was followed in order to provide as comprehensive a view as possible of the interactions among Federal science and technology supporting agencies, even though it precluded the possibility of a one-to-one correspondence between the components of each functional narrative and the components of each Office of Management and Budget functional budget category.

In making their contributions, the Federal agencies were asked to provide information about recent major programmatic thrusts and accomplishments relating to science and technology, confining these accomplishments to fiscal year 1980 if possible. They were also asked for information on important new programmatic initiatives for fiscal year 1981. This chapter, therefore, does not cover all science and technology programs of the Federal Government. Nor does it discuss recent accomplishments of the non-Federal sectors of the science and technology enterprise. Rather, it is designed to highlight major changes that occurred in federally supported science and technology programs at the agency level and point to probable significant developments likely to occur within approximately one year.

B. NATIONAL SECURITY*

Science and technology have long been important components of U.S. national security and foreign policy. The Nation's technological superiority has been a major source of its military strength. The future security of the United States will continue to depend on its ability to meet technological challenges. For these reasons, the declining support for defense research and technology that characterized the first half of the 1970s was reversed, starting with fiscal year 1976, in order to provide for significant real growth in these areas.

This increased support is reflected in the expanding science and technology programs of the Department of Defense (DOD) and related programs of such other Federal agencies as the Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA). These programs should provide the foundation for the continued technological superiority of U.S. military weapons systems and capabilities vis-a-vis those of potential adversaries. The descriptions that follow illustrate selected elements of a broad technology program, the principal objectives of which are (1) to function as a source of concepts and innovation leading to new and advanced weapons systems, such as cruise missiles, the MX intercontinental ballistic missile, and high energy lasers; (2) to effect substantial improvements in existing systems, particularly in

*Participants in the task group developing this section included representatives of the following components of the Department of Defense: the Office of the Deputy Under Secretary of Defense for Research and Advanced Technology, the Defense Advanced Research Projects Agency, and the Departments of the Army, Navy, and Air Force. The Nuclear Regulatory Commission and the National Aeronautics and Space Administration also provided information on their defense-related activities.

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areas such as command, communications, and control; (3) to demonstrate equipment and subsystems for integration into coherent new systems; and (4) to provide understanding of new technologies in order to avoid technological surprise by potential enemies. The descriptions cover electronics; human resources; space defense and surveillance; aircraft technology; arms control; command, control, and communication; materials; and manufacturing technology.

ELECTRONICS

The defense mission requires highly sophisticated electronic systems capable of high-speed information processing, operation in hostile environments, resistance to jamming and interception, applicability across the total electromagnetic spectrum, and high reliability and maintainability. Diverse research and development programs in DOD and supporting agencies range from basic studies of electronic materials, through the way such materials behave in devices, to the design and construction of components, the combining of components into circuits, and, finally, the building of systems based on those circuits.

Physical Electronics

Research in physical electronics concerns development of a basic understanding of such phenomena as the generation, transport, and control of charge carriers in semiconductors and the magnetic properties of materials. A typical program is the growth of a gallium arsenide silicon (GaAsSi) bipolar heterojunction by molecular beam epitaxy.

Very High Speed Integrated Circuits (VHSIC)

The very high speed integrated circuit (VHSIC) program aims to maintain and extend U.S. leadership in military electronics technology, a factor that can play a pivotal role in the defense of the Nation. For example, precision guided munitions offer a means to defeat Soviet armor without competing tank for tank. Similarly, the air-launched cruise missile will provide enormous leverage in negating massive Soviet investments in air defense. Those and other systems that depend heavily upon microelectronics are in various stages of development, and their eventual deployment depends on the development and production of large, complex, fast integrated circuits. The VHSIC program, now in the developmental stage, is aimed specifically at a new generation of integrated circuits which will make possible revolutionary improvements in signal processing for advanced weapons systems.

Ultrasmall Electronics Research (USER)

Closely related to the VHSIC program is a new effort on ultrasmall electronics research (USER), which will be a tri-service DOD program. The advent of high-resolution electron, X-ray, molecular, and ion beam lithographic techniques is pushing toward an era of ultrasmall devices with individual features of molecular scale. USER has been called one of the last remaining frontiers of solid-state electronics, where the new fundamental unit is an aggregate or array of molecules or atoms. The USER program is due to begin during fiscal year 1981 and promises to be one of DOD's most exciting research efforts.

Antennas and Electromagnetic Detection

The transmission and reception of electromagnetic radiation are becoming increasingly necessary for the performance of military missions. Navigation, radar, electronic warfare, communication, direction, direction finding, and electronic countermeasures depend on the full understanding and efficient use of antennas, atmospheric and ground propagation, and sensitive, optimized detection schemes. Examples of current emphasis are electrically small and conformal antennas, effects of proximity to complex structures, radar-resolution enhancement, research in the near-millimeter wave region dealing with low-cost, high-performance antennas, and an improved data base in atmospheric propagation and target/background characterization.

HUMAN RESOURCES

The arena in which the armed forces must be prepared to function is becoming increasingly complex. Weapons systems are more sophisticated, the speed of battle has increased, and the demands on the individual are mounting. Even the pressures of change in our social system during peacetime are being felt by the military. Therefore, DOD supports research in the behavioral sciences that aims at a fuller understanding of the individual in the context of the defense mission.

SPACE DEFENSE AND SURVEILLANCE

The rapid exploitation of space as a medium for important military functions raises the potential for hostile acts against U.S. space assets and the commensurate need for effective space defense and surveillance.

Lasers

Recent DOD advances in space laser technology create opportunities for high-energy laser weapons. While very long lethal ranges and propagation at the speed of light make lasers uniquely capable for space applications, order of magnitude improvements in critical performance factors are required. The current DOD effort is intended to develop the basic technology for applying those improvements in critical laser design parameters as well as advances in system performance.

In the past year, there has been substantial progress toward establishing the technology base for chemical laser weapons. Scale system testing has verified that the high fuel efficiency obtained previously with subscale systems also applies to high-power laser devices. In addition, researchers have developed unconventional concepts that permit the performance of existing devices to be equalled, and in some cases exceeded. The high fuel efficiency and decreased weight attainable when the new concepts are applied will permit space laser weapons systems of lighter weight or more fuel storage capacity.

To support long-term space laser applications, DOD has initiated a ground-based laser radar program that utilizes a high-power laser to track U.S. space objects. The system has successfully tracked high-altitude targets with exceptional accuracy.

Charged Particle Beams

The objective of the current charged particle beam program is to explore the feasibility of stable, predictable propagation of high-power, relativistic electron beams in the atmosphere over distances of military interest. The essential tool for investigation of atmospheric electron beam propagation is an Advanced Test Accelerator (ATA), now under construction at Lawrence Livermore Laboratory. The Experimental Test Accelerator (ETA), which will serve as the front end for the ATA, was completed recently, and experiments will be performed in order to extend previous low-energy propagation data. Two independent theoretical teams at Lawrence Livermore Laboratory and the Naval Research Laboratory are presently refining theoretical beam propagation models, which will be updated on the basis of ETA data.

Space Surveillance

The principal emphasis in the space surveillance program has been on advanced visible and infrared detector arrays. The enhanced capabilities of such devices permit a variety of surveillance and battle management missions not possible previously. HI-CAMP (high resolution calibrated airborne measurement program), an advanced high-resolution infrared sensor, has been installed in a NASA U-2 aircraft to collect measurements of Earth background and tactical targets. The program is the first field demonstration of mosaic focal plane technology with large numbers of detectors. Target data have been principally of aircraft; future measurement data will include other selected targets.

Advanced detector array production for the Defense Advanced Research Projects Agency (DARPA) TEAL RUBY experiment, the first on-orbit demonstration of advanced detector technology, will provide a target/background signature data base to support the design of future operational systems. The sensor is scheduled for delivery to the U.S. Air Force for integration with the P80-1 spacecraft for a planned Shuttle launch in 1982.

The DARPA HALO (high altitude, large optics) program is developing an advanced technology base in large focal plane arrays, spectral filters, substantial signal processing, optics, and detector cooling. A space experiment, Mini-HALO, will demonstrate HALO technology using the sensor to evaluate the feasibility of performing various strategic surveillance missions from space.

Space Telescope

DOD and NASA will collaborate on the Space Telescope Program. As part of the technology transfer, DOD will design, develop, and construct booms for the high-gain antenna, a critical component of the space telescope.

AIRCRAFT TECHNOLOGY

The military expects future air warfare to be characterized by a heavy concentration of air defense weapons and numerical air superiority by the enemy. DOD is continuing to exploit forward swept-wing (FSW) and X-wing technologies in an attempt to combine affordability with substantial improvements in aerodynamic performance. While DOD has not specifically emphasized technology development for rapid deployment forces, the FSW technology can apply to a wide range of future systems, and the X-wing could offer rapid intratheater deployment. Additionally, capabilities provided by the air vehicle technology programs will contribute substantially to effective lower-cost force projections.

X-Wing Technology

The X-wing V/STOL program is based on a technique that combines the vertical lift efficiency of a helicopter with the high-speed performance of a fixed-wing aircraft. A full-scale rotor hub, blade, and flight control assembly have been successfully tested in a wind tunnel. Results indicate that an operational X-wing vehicle will have approximately three times the range and speed of a conventional helicopter with equivalent lifting capability.

Forward Swept-Wing Technology

The objective of the forward swept-wing program is to produce an integrated flight vehicle to demonstrate advanced technologies ranging from composite wing structures to a digital fly-by-wire flight control system. Free-flight scaled model testing is continuing at NASA Langley to expand the existing data base. A joint DARPA/NASA/Air Force program is anticipated during fiscal year 1981 to focus on the detailed design and fabrication of two flight vehicles to be flown in mid-1982.

Near-Term Aeronautical Technology

Significant advances in various technical domains of aeronautics will have considerable impact on the design and operation of both military and civilian flight vehicles in the near future.

With the increasing sophistication and complexity of modern military aircraft and the increasing physical and mental demands on the pilot, there is an emphasis on integration of flight control, navigation, propulsion control, fire control, and weapons control. That integration, made possible by advances in digital electronics, should relieve the pilot's workload and improve mission performance. Fly-by-wire flight control soon will be complemented by power-by-wire, in which electromechanical control surface actuators will replace vulnerable hydraulic actuators, and by fly-by-light, where the flight control signals will be transmitted by optical fibers, immune from electromagnetic interference.

Improvements in vehicle equipment include new lightweight, long-life cryogenic coolers for use in missile and space applications to aid the performance of infrared sensors. Radial tires, now accepted as advantageous for automobiles, are being developed for aircraft use.

Applied computational research, coupled with increased computer capacity, has provided aerodynamic prediction methods and associated computer programs that analysts and designers can use in the development of optimized aircraft configurations and novel design concepts. A "mission adaptive wing" is scheduled for flight testing in 1982. The wing has deflecting leading and trailing edges to vary the camber, thus permitting the optimization of the airfoil section for different flight conditions and maximization of the lift/drag ratio for better economy or range.

ARMS CONTROL

As a result of increasing concern about possible further proliferation of nuclear weapons and the current efforts to negotiate a comprehensive test ban treaty, DOD and the Nuclear Regulatory Commission (NRC) have increased their efforts to develop nuclear test detection and verification methods and to improve safeguards on civil and military nuclear facilities and materials.

Nuclear Test Verification

DOD research in nuclear arms test verification has two goals: to provide direct analytical support to U.S. comprehensive test ban negotiations, and to provide greater assurance of detection and a wider range of sensor options to the United States in development of verification systems.

DOD is supporting research to develop advanced sensor systems and associated data analysis procedures, with emphasis on methods to receive data from seismic stations inside the U.S.S.R. as part of a comprehensive test ban treaty. With recent advances in characterization of seismic sources and wave propagation modeling, and the completion of a worldwide network of high-quality digital monitoring stations, it is possible to develop source identification procedures based on physical and geometric properties. Such techniques could be applied to areas for which prior signal records are not available for calibration purposes. The current effort includes synthesizing existing models into a processing technique for application to recorded digital data and designing an experiment to validate the technique.

Domestic Safeguards

Several forms of commercial nuclear material are also useful for military and terrorist purposes. Enriched uranium and plutonium (both of which can be manufactured into nuclear explosives) and used fuel assemblies (which can be sabotaged, spreading highly toxic nuclear fission products into the surrounding area) present the most difficult problems.

To deter attempts at theft, NRC sponsors research to account for and to control the processing of nuclear material. The technical aspects of the research focus on developing devices for measuring the volume of nuclear material at any plant, and on developing statistical methods for reducing measurement error. To deter attempts at sabotage and to minimize the dangers in the event of such an attempt, NRC carries out research on the physical protection of nuclear facilities. A major objective is to supplement guards with such equipment as lasers. The results of the research are used as part of the technical data base for establishing regulations. NRC frames its safeguards regulations around performance criteria, which allow a licensee to develop his own methods for achieving required levels of protection.

COMMAND, CONTROL, AND COMMUNICATION

The DOD program in command, control, and communication (C^3) is attempting to develop advanced technology and system architectures to improve the Nation's ability to control its fighting forces around the world. Strategic and theater C^3 effectiveness will depend upon recent advances in information processing that allow reliable and rapid manipulation and movement of information across long distances. Strategic C^3 systems must be able to survive in combat and be highly dependable as the link between the command structure, strategic reserve forces, and troops in the field. Communications response time is also a critical factor.

DARPA is pursuing the development and demonstration of C^3 technology in a broad strategic and tactical systems context. Experts are exploring computer communications technologies for application to both individual C^3 networks and internetwork systems. Emphasis on distributed computer network research should result in improved combat survivability and reliability and should help meet geographic distribution requirements. Where appropriate, DARPA is using testbeds to evaluate the impact of new digital processing techniques in military operations in realistic settings.

Computer Communications

DOD is developing advanced packet communications techniques and a powerful experimental internetwork that provides local, regional, and longband computer communications via ground radio transmission, terrestrial circuits, and satellites. A multi-station packet radio network with distributed control functions was successfully installed at Fort Bragg and connected to ARPANET. It is supporting a joint DARPA and U.S. Army data distribution testbed, and substantial improvement in network communications survivability is expected. During fiscal year 1981, DARPA will continue the application of low-cost technologies to packet radio development and to the testing and evaluation of methods for increasing packet radio network survivability.

Secure Distributed Information Systems

DARPA, in cooperation with other DOD agencies, is developing the technology for securing classified information processed or stored in computer and communication networks. Basic research in distributed computer systems that addresses the military need for geographically dispersed multicomputer command and control systems is being conducted. An end-to-end network encryption system was recently demonstrated, and DOD is using the concepts in securing the experimental testbeds described below. In fiscal year 1981, new initiatives will begin on the design of secure distributed transaction systems in which several security levels must be handled concurrently.

Experimental Testbeds

DARPA is conducting experiments jointly with the armed services to evaluate new information-processing technologies in realistic military environments. The Advanced Command and Control Architecture Testbed (ACCAT) is a DARPA/U.S. Navy effort to develop, demonstrate, and evaluate innovative command and control architectures. A mobile access terminal to support ACCAT access from Navy ships is under development. In fiscal year 1981, experimentation will expand to include surveillance and combat direction functions. The DARPA/U.S. Army Data Distribution Testbed is a series of "hands-on" C^3 experiments conducted by the XVIII Airborne Corps at Fort Bragg, North Carolina, using packet radio technology.

MATERIALS

Over the years, pioneering developments in advanced materials emerging from the DOD materials and structures science and technology programs have led to vastly improved military capabilities as well as the creation of new U.S. industries. Virtually every U.S. and free world military aircraft, spacecraft, and ballistic missile uses fiber-reinforced plastic composite materials in its construction. Moreover, aircraft now in development will use increasing amounts of such materials to improve efficiency and reduce fuel consumption. In effect, DOD, through early developments in the program, has created the rapidly growing, new worldwide industry of fiber-reinforced plastic composite materials.

Carbon/Carbon Composites

The development of carbon fiber-reinforced carbon (C/C) composite materials has led an increasing number of missile developers to consider those materials for significant performance gains. A growing number of military and commercial aircraft use C/C composite materials, and C/C composites are being further exploited by the gas turbine community. Use of lighter C/C composites in the gas turbine of a typical fighter aircraft carrying a 1,000-pound payload could lead to overall reductions in fuel consumption of about 14 percent.

In addition to the performance gains possible with C/C composites, their domestic availability and potential low cost could make them attractive alternatives to the high-cost gas turbine superalloys that contain substantial amounts of imported cobalt and chromium.

Metal-Matrix Composites

Over the past few years, DOD has been emphasizing the development of fiber-reinforced metallic materials referred to as metal-matrix composites (MMCs). The tri-service/DARPA program in MMCs is proceeding on schedule toward development and application of the materials for a variety of military purposes. Contractual and in-house efforts in helicopter transmission housings, portable bridging components, strategic missiles, mines and torpedoes, tactical missiles, airframe and gas turbine components, and satellite components are under way.

MMC materials show promise for an ever-widening range of uses, including laser mirrors, lightweight gun mounts, submarine propellers, and radar antennas. One of the early results of the program is a fiber-reinforced lead grid material for submarine batteries that can lengthen the submarine battery-replacement cycle from 5 to 10 years, thereby aligning it with the nuclear core replacement schedule and reducing maintenance costs appreciably.

In addition, trade-off studies indicate that extensive use of MMCs as structural components of a typical supersonic cruise missile could lead to a weight reduction of about one-third. The development of C/C composites for gas turbine application could alone lead to an overall weight reduction in the same missile of about 50 percent. When both technologies are synergistically applied, the missile's weight could be reduced to about a third of that presently attainable. Such weight reductions would make range extension and/or an increased number of missiles per aircraft possible.

Another significant consequence is the potential substitution of MMCs for such critical materials as chromium, cobalt, titanium, and beryllium. For example, high-modulus graphite fiber-reinforced magnesium alloy composites exhibit stiffness, strength, and dimensional stability equivalent or superior to those of beryllium at the same weight. Thus, a new industry may emerge that will some day rival that of fiber-reinforced plastic composite materials.

Rapid Solidification Technology

In fiscal year 1982, DOD will move vigorously into the area of rapid solidification technology (RST). The objective is to produce very high-quality starting materials for new families of aluminum and titanium alloys as well as superalloys. The current modest investments have shown sufficient promise and maturity of the technology to justify DOD's initiating a major, long-term financial commitment. Moreover, RST has demonstrated the potential for producing superior superalloys with only minor amounts of critical or scarce materials.

Recent trade-off studies have indicated that RST can lead to dramatic aircraft performance increases by the following routes:

- Aluminum, molybdenum, and tungsten were alloyed with nickel to obtain a 200°F improvement in heat resistance over that of current jet engine superalloys. The payoff is an engine that can produce higher thrust or greater fuel efficiency than any of today's turbomachines.
- Lithium was alloyed with aluminum to obtain a 30 percent increase in specific modulus of elasticity and a 100-time improvement in life-under-cyclic-stress conditions over presently available aluminum materials. The payoff is an airframe that weighs 30 percent less.
- Iron was alloyed with aluminum, titanium, and boron to obtain a 20 percent weight reduction and a 200°F improvement in heat resistance over current ferritic stainless steels. The payoff is a chromium-free stainless steel for use in critical jet engine components.

Because of the high payoffs expected in military systems, DOD is launching a new thrust to exploit RST in improved ferrous, aluminum, and nickel-based alloys. The program will involve basic research, exploratory development, specific technology demonstrations, and manufacturing technology efforts conducted at university, industrial, and government laboratories. The emerging technology will provide major economic benefits to transportation, space, and energy systems and the U.S. commercial manufacturing base in general.

MANUFACTURING TECHNOLOGY

The function of DOD's manufacturing technology program (MTP) is to insure the most efficient use of the Department's materials acquisition resources. By providing new or improved production processes, equipment, and methods, the MTP reduces production costs, shortens production lead-time, improves product quality and reliability, and provides alternate production sources. Substantial benefits will be derived from improved production safety, reduced pollution, and conservation of critical materials.

Recent accomplishments of the MTP include:

- Automation technology developed for a detonator loading process quadrupled the output per shift, reduced hazardous exposures, decreased the number of facilities required, and reduced costs by $37 million; and

- Implementation of a computer-aided ultrasonic inspection system for turbine components cut inspection time by 50 percent, minimized operator errors, and improved the utilization of forgings.

In fiscal year 1982, MTP projects will address a wide range of issues, including:

- Recycling 105-mm gun tubes by advanced remelting techniques that will reduce gun tube costs and conserve critical materials;

- Developing automated, computer-controlled assembly and testing techniques to reduce fabrication costs of a family of sonobuoys; and

- Reducing the cost of solid propellant missile fuel through a process to extract and recover high-cost additives from rejected, scrap, or waste solid fuel.

C. SPACE*

The Nation's civilian space program was initiated with the National Aeronautics and Space Act of 1958. The thrust of the program was continued when President Carter, in his October 1978 statement, announced his space policy. An underlying principle of that policy is that the space program should follow an evolutionary path. The policy calls for a program that reflects a balanced strategy of application, science, and technology. An important component is the continuation of the application of space technology to the solution of problems on Earth. Currently, the primary focus is on the Space Transportation System—the combination of Space Shuttle, Spacelab, and inertial upper stage. The system will replace this country's expendable launch vehicle fleet.

The Space Act created the National Aeronautics and Space Administration (NASA), which continues to be the primary agency for conducting space science, applications, and technology development. However, as NASA's activities resulted in new knowledge about our physical surroundings and new technology for sensors and systems, this knowledge and technology have been increasingly focused on problems facing mankind, and other agencies have become involved. In recognition of this fact, the Policy Review Committee (Space) created by President Carter provided a forum for all Federal agencies to offer advice and propose changes in national space policy. This committee, chaired by the Director of the Office of Science and Technology Policy, had representation from the following: the Departments of Agriculture, Commerce, Defense (DOD), Energy, the Interior, and State; NASA; the Environmental Protection Agency; the National Science Foundation; the Office of the Director of the Central Intelligence Agency; the Joint Chiefs of Staff of DOD; and the Arms Control and Disarmament Agency. NASA's space science and technology activities are considerably more extensive than those of any of the other agencies. DOD's total space program, however, has grown to be comparable to NASA's in size.

A growing feature of the U.S. civil space program is international cooperation. Cooperation is arranged with individual nations or consortia such as the European Space Agency (ESA). One broad cooperative activity is the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, UNISPACE '82, which will be held

*Participants in the task group developing this section included representatives of the National Aeronautics and Space Administration, the Department of State, and the National Oceanic and Atmospheric Administration in the Department of Commerce.

in Vienna, August 9 through 21, 1982. As the first such conference sponsored by the U.N. since 1968, UNISPACE '82 will provide the world community an opportunity to discuss the practical benefits that mankind, particularly the populations of the less-developed countries, can derive from space activities. U.S. preparations, already under way, will be a broad interagency process under the direction of the Department of State in close cooperation with NASA.

For discussion purposes, space science and technology can be subdivided into four broad categories: origin, nature, and evolution of the universe; remote sensing; space transportation systems; and space communication and navigation systems.

ORIGIN, NATURE, AND EVOLUTION OF THE UNIVERSE

Access to space has provided a significant increase in the rate of acquisition of knowledge about the universe. Space science research during the past year has yielded spectacular increases in information on bodies in the solar system and objects outside it, and such research has also supplied information that will help us understand processes on Earth.

Astrophysics investigations are providing new knowledge about the origin, nature, and evolution of the bodies in the universe and of the interstellar gas and dust. Solar studies are yielding new insights into the basic physics of solar-terrestrial relations and may shed light on relationships such as a possible causal link between disturbances on the Sun and Earth's weather and climate. Knowledge of such natural effects on Earth's environment is necessary to an understanding of and an ability to control possible human-caused influences. Comparative planetology can increase understanding of terrestrial geologic and atmospheric processes, thereby aiding in discovery of Earth's natural resources and prediction of human impacts on Earth's environment. Also, the unique environment of space can make possible the performance of research in fundamental plasma physics and biological processes that cannot be performed in Earth-based laboratories.

Planetary Studies

During the past year, the Pioneer Venus Orbiter (PVO) spacecraft completed altimetry mapping of about 83 percent of the surface of cloud-enshrouded Venus. The results disclosed three continents with mountains as high as Everest and deep rift valleys. Although the range from lowest to highest elevations on Venus is similar to that on Earth, Venus is much more nearly spherical than the Earth. The Venus Orbiting Imaging Radar, planned for initiation in 1982, will use advanced radar techniques to map the entire surface of Venus.

Pioneer 11 continues to work well after successfully flying past Saturn, the most distant planet examined at close range. It is heading out of the solar system after returning the first close-up images of Saturn, which disclosed two additional outer rings and possibly a new moon.

The two Voyager spacecraft have flown by Jupiter. Voyager 1 has also flown by Saturn and is proceeding out of the solar system. Voyager 2 will encounter Saturn in August 1981 and will then continue on to Uranus and possibly Neptune in the late 1980s. Spectacular images of Jupiter and Saturn and their satellites are disclosing previously unobserved phenomena. They have revealed a ring around Jupiter consisting of small particles; a much more complex ring structure for Saturn than had previously been identified; the complexity of the motion of Jupiter's and Saturn's atmospheres; details of the geologic nature and diversity of Jupiter's and Saturn's satellites, including extensive volcanic activity on Jupiter's Io; three additional satellites of Jupiter; superbolts of lightning in Jupiter's atmosphere; and details of the atmosphere of Saturn's satellite Titan.

Astrophysics

Launch of the third High Energy Astronomy Observatory (HEAO-3) was included in the astrophysics activities of fiscal year 1980. Its cosmic ray telescopes are finding that cosmic rays do not originate from a single process of element building—contrary to the theory that cosmic rays come from supernova explosions. The gamma ray telescope on HEAO-3 has observed gamma rays from the annihilation of antielectrons in the center of our galaxy, and a cosmic ray telescope carried by a balloon has discovered antiprotons among the cosmic rays that reach Earth. Other discoveries this year include a super-bubble of million-degree gas behind the constellation Cygnus, quasars two-thirds of the way to the edge of the universe, a white dwarf star that gets eclipsed by its red giant companion, a corona of 100,000-degree gas surrounding our galaxy like a halo, and coronas around two more galaxies.

The Infrared Astronomy Satellite, which is being developed jointly by this country, the Netherlands, and the United Kingdom, is scheduled for launch in 1982. It will make a comprehensive all-sky survey that is expected to detect as many as 10 million infrared sources and identify the most interesting of them for intensive study with later instruments.

The Gamma Ray Observatory, which has been approved for initiation in fiscal year 1981, will observe extremely high-energy electromagnetic radiation emanating from nuclear processes within objects such as pulsars and from the interactions of cosmic rays with the interstellar medium. Because of their extremely high energy and great ability to penetrate dense matter, gamma rays are a very important source of information about processes in the depths of optically opaque regions. The detection of gamma rays emanating from extremely distant celestial objects should also provide information about processes that occurred very early in the history of the universe.

Solar-Terrestrial Investigations

The Solar Maximum Mission (SMM), launched in February 1980, will significantly advance understanding of the Sun and, consequently, contribute to knowledge of Sun-Earth relationships. Its primary objective is to study solar flares and other types of solar activity during the current peak of the 11-year sunspot cycle. It is observing flares at wavelengths ranging from those of visible light to those of the highest energy gamma rays. SMM also is making the most accurate measurements of the total output of heat and light from the Sun. It already has shown fluctuations of up to 0.2 percent in the Sun's output over periods of several days. One important understanding being sought is whether those fluctuations alter Earth's weather or climate.

NASA and ESA have reached agreement on the restructured International Solar Polar Mission, which they will launch in 1985 to explore solar and interplanetary phenomena from trajectories out of the plane of Earth's orbit around the Sun and passing through largely unknown regions of space. It will be the first space system to observe the polar regions of the Sun. NASA and ESA will each provide a spacecraft, and scientists from the Federal Republic of Germany, the United Kingdom, France, and Switzerland will have experiments on the U.S. spacecraft.

An important step toward integrating and understanding solar-terrestrial relationships was the initiation of a solar-terrestrial theory program. Several groups of solar and plasma physicists throughout the country are launching a coordinated attack on theoretical modeling of various aspects of solar-terrestrial processes and relationships. The work will make use of the most recent observational results.

Life Sciences Research

Cooperation is continuing in life sciences research between the United States and the U.S.S.R. The complement of experiments on the Soviet Cosmos 1129 biological satellite included 14 U.S. experiments, and joint planning is in process for the flight of U.S. experiments on a Soviet primate mission in 1981. Cosmos 1129 experiments showed a 20 percent loss of body calcium in rodents during the 18-1/2-day mission, affecting both mature bone and new growth. In contrast, early stages of plant growth and development were unaffected.

Laboratory studies to understand and characterize motion sickness resulted in the development of a model for Ménière's disease. Laboratory experiments demonstrated the nonbiological synthesis of macromolecules (proteins and nucleic acids) similar to those essential for life. The simplicity of that synthesis lends confidence that important biomolecules can form in environments that generally arise as a result of planetary formation.

REMOTE SENSING

National policy decisions on the environment require a broad understanding of many factors. These factors include weather and severe storms and possible human impacts on the environment, such as stratospheric ozone depletion, tropospheric air pollution, and climatic changes related to carbon dioxide emissions. Decisions on many matters affecting people also depend on (1) an understanding of the oceans and the role they play in our daily activities, (2) the intelligent management and judicious use of agricultural and other renewable resources, (3) methods for assessing, exploring for, and developing mineral and hydrocarbon resources on a global scale, and (4) knowledge of geodynamic mechanisms that cause earthquakes. Space remote sensing has already demonstrated strong potential value in all the above areas and is one of the principal components of the Nation's space program for the future. It can provide synoptic, repetitive data on a global and national basis.

Remote sensing experiments and research facilities in the Space Shuttle and Spacelab will gradually replace current, free-flying, experimental remote sensing systems. Those experiments and facilities will then provide a basis for development of future free-flying and platform-mounted systems, some of which are currently under study.

During 1980, work progressed on the National Oceanic Satellite System (NOSS), the ocean-monitoring satellite system, with the goal of demonstrating a limited operational capability for observing ocean conditions and describing ocean processes, ice dynamics, and coastal processes. The program is jointly funded by the Navy, the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce, and NASA. NOSS will continuously measure ocean surface winds, sea state, surface-water temperature, wave height, ice, and other geophysical characteristics in near real time and under various weather conditions. An important feature of NOSS will be its full-scale operational data processing and distribution system. The resulting data will be of value to ocean transportation and shipping, oil exploration, and pollution monitoring.

Since 1972, the United States has conducted civil remote sensing for resources management and environmental monitoring through Landsat satellites. NASA's experimental Landsat program has developed many successful applications and attracted many users. Recognizing this fact, President Carter issued a directive on civil operational remote sensing in November 1979. This directive provided the framework within which an operational satellite remote sensing system for land areas could be implemented; it assigned the operational management responsibility for civil remote sensing activities to NOAA. NASA will continue to provide assistance, perform the research and development for the required advanced sensors and data processing techniques, and carry development through the prototype stage.

The Landsat series has been the basis for many experimental remote sensing programs to evaluate and manage both renewable and nonrenewable resources. The principal program has been the joint NASA, Department of Agriculture, Department of Commerce, Department of the Interior, and Agency for International Development program called AgRISTARS (Agriculture and Resources Inventory Surveys through Aerospace Remote Sensing).

Remote sensing of nonrenewable resources is concerned with geological applications of space technology. The principal purpose is to provide data for geologic mapping and research related to Earth's crust. Such data have major implications in the search for additional sources of scarce mineral and energy resources. Another purpose is to monitor the geodynamics of Earth's crust to continue improving knowledge about such natural hazards as earthquakes.

The United States continues its policy of wide dissemination of remotely sensed land data by supporting direct reception of the data by foreign ground stations and by providing such data to foreign users under suitable conditions. In 1980, Australia, Argentina, and South Africa joined Canada, Brazil, Italy, Sweden, Japan, and India in having Landsat stations in operation. Agreements signed last year with Thailand and the People's Republic of China cover their acquisition of Landsat ground stations, and a number of other stations are in the planning stage.

The United States is promoting, by discussions with prospective satellite-operating nations, the development of complementary land remote sensing satellites to be operated by those nations. Discussions are either under way or planned with France, the European Space Agency, Canada, Japan, and India. In 1980, the United States participated in multilateral meetings hosted by Canada and France concerning complementarity and compatibility of remote sensing systems.

SPACE TRANSPORTATION SYSTEMS

Both the civil and the military sectors of the United States need capabilities that will provide more efficiency, flexibility, and effectiveness than past and current expendable launch vehicles have been able to provide. The Space Shuttle will provide those capabilities in the next decades.

Space Shuttle

Development of the Space Shuttle is progressing. Roll-out of the first Orbiter from the Orbiter Processing Facility took place on November 24, 1980, and roll-out from the Vertical Assembly Building to the launch pad took place on December 29, 1980. The first launch is scheduled for early April 1981. During the past year, the Shuttle program successfully passed several major milestones. Structural testing of the Orbiter is complete. Test firings of main engines have exceeded the 80,000-second criterion for initiation of orbital flight tests, and the entire propulsion system of three engines completed four successful full-duration firings. Development and qualification firings of the solid rocket motor have occurred, and all elements for the first orbital test flight are at Kennedy Space Center (KSC).

The orbital flight test program will consist of four flights of the Orbiter Columbia currently being processed at KSC. Three additional orbiters are in various stages of production, and procurement of long lead-time items for a fifth orbiter has been authorized. The Shuttle's operational era will be initiated by NASA in 1982. Current and planned developments in materials and components and in reducing the weight of the Shuttle's engines, external tank, and solid rocket motor will improve the Shuttle's ability to satisfy the requirements of its users. A number of those requirements will call for upper stages; some are currently in development and others are being studied.

During 1980, NASA prepared a new projection for Shuttle operational flights. That projection shows that the demand for Shuttle services will be heavy and will continue to come from three basic communities of users: civil agencies of the government, DOD, and commercial and foreign organizations. The interest of the commercial community is increasing: an example is the Joint Endeavor Agreement that McDonnell Douglas Astronautics Corporation signed with NASA in January 1980 that will lead to commercial production of pharmaceuticals in space in the late 1980s.

In January 1980, NASA signed a contract to purchase a second Spacelab flight unit from ESA as a follow-on to ESA's development of Spacelab and contribution of the first flight unit. Spacelab is the reusable spaceborne laboratory that is a major element of the Space Transportation System. Mounted in the Shuttle's cargo bay, it will provide a pressurized environment for human-tended experimentation in the near-zero gravity environment of space. ERNO, in West Germany, is the prime contractor for Spacelab, and at least 26 subcontractors in ESA-member nations and the United States are involved. The engineering model of Spacelab was delivered to Kennedy Space Center on December 13, 1980, for use in facility check-out and integration operations.

SPACE COMMUNICATION AND NAVIGATION SYSTEMS

Global demands for satellite communications will exert more and more pressure for efficient use of the frequency spectrum and the geostationary orbit arc positions. Advanced technologies for frequency reuse and for moving up to higher frequency bands to ease the congestion will require development of high-risk, long lead-time technology that industry has not initiated. In order for the United States to maintain its leadership in civil sector communications, President Carter approved NASA's re-entry into selected areas of satellite communications. NASA plans to seek industry collaboration and to encourage industry to participate in joint ventures. Development and test efforts will emphasize three areas: the 20- to 30-GHz band for fixed services, the 900-MHz band for mobile services, and means for handling the large volume of data from applications systems, especially remote sensing systems. The 20- to 30-GHz region will have message capacities of 50 to 100 times those of the currently overcrowded 4- to 6-GHz region. The focus for the spaceborne elements will be high-technology satellites employing multibeam antennas, onboard signal processing and switching, high-power transmitters using both solid-state and traveling-wave tube amplifiers, and solid-state low-noise amplifiers.

DOD has extensive programs to operate and improve communications and navigation systems to satisfy its needs. In addition, NASA's advances of the state of the art will benefit military as well as civil systems. A major example is the Tracking and Data Relay Satellite System (TDRSS). TDRSS will consist of two synchronous-orbit relay satellites, one on-orbit spare, and a ground-terminal facility at White Sands, New Mexico. Launch of the satellites is scheduled to start in September 1982. They will be able to view all spacecraft in orbits with altitudes less than 10,000 kilometers, maintaining contact with them for about six times as long as is possible with NASA's entire current network of ground stations.

TDRSS will furnish launch, landing, and almost continuous orbital support to the Space Shuttle. It will increase space-to-ground communications capabilities by providing the high data-transmission rates (up to 300 million bits per second) that such sensors as the high-resolution sensors of Landsat-D will require. It will practically eliminate the coverage limitations of Earth-based tracking stations, particularly for satellites in low Earth orbit.

In 1981, NASA plans to begin studies to characterize a tracking and data acquisition system for use in the 1990s and beyond. The studies will define future needs and technology, systems approaches, and trade-offs. They will consider such factors as needs for increased bandwidths, relay-to-relay communications, and the potential of optical communications technology.

Another highlight in satellite communications is an agreement by the United States, Canada, and France to demonstrate and evaluate a satellite-aided search and rescue system called SARSAT. Several other countries, including Japan and Norway, are considering participation. The U.S.S.R. recently signed an understanding with the SARSAT parties regarding cooperation with a similar Soviet system designed to be interoperable with SARSAT. The experiment will begin in 1982.

D. HEALTH*

The health research supported and conducted by the Federal Government provides the foundation for improved medical care and for better and more effective health promotion and disease prevention measures. The National Institutes of Health (NIH) contributes the largest share of Federal support for medical research; significant amounts are also provided by the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA), the Department of Defense (DOD), and the Veterans Administration (VA). Altogether, 16 Federal agencies currently fund health-related research and development activities.

Singularly important in recent years has been the need to stabilize the basic science component of this national research effort, a concern reflected in presidential and congressional actions on the NIH budget. Those actions establish a firm level for the number of competing, investigator-initiated research project grants to be awarded each year. Thus, the ability of NIH to fund annually about 5,000 competing grants will contribute substantially to ensuring that the Nation's biomedical science base will not deteriorate; it also underscores the Nation's determination to maintain fundamental research as an indispensable long-term societal investment. Demonstration of support for this principle is necessary so that young Americans will choose to devote their careers to the health sciences.

Research project grants, however, represent only one element—although a crucial one—in the multifaceted approach that provides a balanced program of support for health research. The science base is the primary source of fundamental new knowledge. That knowledge, however, must be translated into practical applications; clinical trials must be conducted; technology must be moved into community settings and evaluated; new scientists must be trained; research resources must be maintained; and centers of excellence must be preserved.

All of these imperatives are being carefully considered in Federal health research planning. Over the past two years, the health agencies of the Department of Health and Human Services (HHS) have joined in a formal planning effort designed to introduce greater cohesiveness in their diverse health research programs. A number of high-priority interagency research initiatives, representing unique experiments in cooperative research planning and management, have resulted from this effort.

Highlighted below are a few examples of important developments in the health sciences. They include advances in the rapidly moving fields of immunology and the neurosciences, efforts to address urgent environmental health problems posed by toxic chemicals and radiation, initiatives in behavioral research, and improvements in our capacity to assess new health care technologies. Also briefly considered are recent efforts to explore systematically the broad range of research-related problems besetting academic institutions and to shape actions to sustain the research environment.

IMMUNOLOGY

The emergence of powerful recombinant DNA and hybridoma (cell fusion) technologies coupled with an increased understanding of the immune system now permits radically different approaches to the many still unresolved problems of immunization. Through a concerted Department-wide effort, HHS will seek to exploit these opportunities to bring new and improved vaccines rapidly into use. Emphasis will be placed on development of vaccines against:

- Gonorrhea and other sexually transmitted diseases;
- Bacterial meningitis;
- Pseudomonas aeruginosa (a source of pulmonary infection and a major cause of death in individuals with cystic fibrosis);
- Dental caries;
- Hepatitis virus infections;
- Certain respiratory diseases, such as infantile bronchiolitis;
- Infantile diarrhea; and
- Herpes simplex infections.

Industry is currently making large investments in recombinant DNA and hybridoma technologies, some of which are directed at vaccines. In contrast, the HHS initiative is limited to those vaccines that appear to be promising, but which are unlikely to

*Participants in the task group developing this section included representatives of the following components of the Department of Health and Human Services: the Office of the Assistant Secretary for Health, the National Institutes of Health, the Alcohol, Drug Abuse, and Mental Health Administration, the Food and Drug Administration, the Centers for Disease Control, and the National Center for Health Care Technology. In addition the Veterans Administration and the Nuclear Regulatory Commission provided information on their health-related activities.

be developed by industry without governmental leadership. It is probable, however, that the program will encourage greater private participation—considered essential, as industry will have responsibility for the eventual preparation and distribution of the newly developed vaccines.

The National Institute of Allergy and Infectious Diseases will lead the program, with active involvement of the Centers for Disease Control (CDC) and the Food and Drug Administration (FDA). DOD will continue its related programs to develop vaccines of special military relevance.

NEUROSCIENCES

Recent investigations have led to a virtual explosion of information about the nervous system and its disorders, and new research techniques promise to extend our knowledge significantly. Perhaps the most exciting of the new developments in neurobiology is the discovery of the body's natural painkillers—the endorphins and other opiate-like substances—which may provide a vital key to fuller understanding of the mechanisms of brain function, the causes of substance abuse and drug addiction, and the treatment of pain. This important discovery has opened a whole new area of research—the investigation of psychoactive substances and their specific receptors in the body—which is being vigorously pursued by ADAMHA and NIH.

Also significant is a potentially powerful new research technique called positron emission transaxial tomography (PETT). Detection (by means of a scanner) of positrons emitted from injected radioisotopes permits scientists to view the movement and deposition of substances involved in metabolic processes within the human brain. Thus, it is possible to learn what happens functionally, in the living human brain, when a person speaks, hears, sees, and thinks. Nine research centers employing the new technique are being funded by the National Institute of Neurological and Communicative Disorders and Stroke.

Research on nervous system regeneration is another promising area of inquiry that has received special program emphasis in the past few years, within both NIH and the VA. That emphasis appears justified by rapidly expanding technical and theoretical advances. The fact that individual nervous system components can be grown in test tubes holds promise for selective implantation in humans. Moreover, recent research suggests greater potential for regeneration in mammals than was previously thought possible.

Researchers have also made considerable progress in elucidating fundamental mechanisms involved in such diseases as multiple sclerosis, myasthenia gravis, and Parkinsonism, and they have developed important new information on actions of neurotransmitters, neuropeptides, and neurohormones. Discoveries relating to the role of neuropeptides in modulating the activity of brain and spinal cord neurons have profound implications for regulating pain and behavior.

In the extraordinarily active area of neuropharmacology, the testing of chemical compounds that act as agonists (mimickers) or antagonists of certain neurotransmitters has given scientists new insight into many movement disorders. The development of new drugs is a vigorous enterprise, and NIH and other laboratories throughout the country and the world are testing a large variety of compounds. These compounds promise to transform the pharmacological treatment of neurological disorders.

HEALTH AND THE ENVIRONMENT

Greater cognizance of environmental factors as causes of disease has inspired two important initiatives, the impact of which should be felt increasingly in the next few years. These initiatives address important health problems posed by chemical toxicology and radiation.

Chemical Toxicology

In some cases, a relationship can be established between a medical disorder and exposure to a specific chemical. Examples include: lung cancer and asbestos, liver sarcomas and vinyl chloride, male sterility and DBCP (a pesticide), and neurological conditions and mercury and lead. Identifying chemicals that should be controlled is an enormous task, considering that there are at least 48,000 chemicals in commerce today in the United States.

The National Toxicology Program (NTP) is designed to strengthen the Federal Government's activities in testing those chemicals of public health concern and to accelerate the development of new test methods and validation techniques. The program comprises the relevant activities of the National Institute of Environmental Health Sciences, FDA, the National Institute for Occupational Safety and Health, and the National Cancer Institute. Also participating are the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration, and the Consumer Product Safety Commission. Thus, NTP brings together a unique mix of resources to support its toxicology research and testing functions. Its components provide essential scientific expertise in general toxicology, mutagenesis, and carcinogenesis; extensive laboratory facilities and animal testing skills; and broad experience in conducting carcinogen bioassays and human epidemiological studies. The National Library of Medicine's TOXLINE and CHEMLINE computerized information systems support the program.

NTP has attracted widespread attention outside the Federal Government, and a number of organizations in this country and abroad have expressed an interest in participating in the program. Another area of international activity is toxicology data evaluation, where NTP is linking its activities with those of the World Health Organization.

Radiation

Widespread use of radiation in medicine and industry, growing dependence on nuclear energy, and an increase in available radioactivity resulting from the mining of uranium have heightened public concern regarding the health hazards posed by radiation. The perception has also grown that the weapons testing programs of the 1950s and 1960s may have had detrimental health effects. Further, the Three Mile Island accident at Harrisburg, Pennsylvania, on March 28, 1979, has raised fears of similar occurrences in the future.

To coordinate the formulation and implementation of Federal policy relating to radiation protection, President Carter established, in February 1980, the Federal Radiation Policy Council and appointed the Administrator of EPA as its first chairman. An Interagency Radiation Research Committee was also created at the President's request to coordinate the Federal Government's conduct of research into the effects of radiation. That committee, chaired by the Director of NIH, includes representatives from 14 agencies; it constitutes an important innovation in interagency science planning, with responsibility for formulating a comprehensive Federal strategy for research into the biological effects of radiation.

Basic and confirmatory radiation effects studies further define the fundamental mechanisms, including genetic and carcinogenic effects of low-level radiation exposure; characterize the environmental sources of ionizing radiation; and establish the individual, occupational, and societal risks and benefits associated with the uses of radiation or radioactive materials. The Nuclear Regulatory Commission conducts epidemiological studies of effects from low-level accumulations of radioiodine and thorium in humans, the hazards from respirable radioactive materials to which workers or the public could be exposed, the effectiveness of personnel neutron dosimetry programs at nuclear power plants, the reliability of respiratory equipment when used to protect against radioactive materials, and development of methods to assess dose from internally deposited radionuclides.

Paralleling research on the effects of radiation on humans is research on how best to isolate humans from radiation hazards. The Three Mile Island accident and the growing volume of nuclear wastes have made such investigations increasingly urgent. When Three Mile Island made it clear that nuclear accidents could occur, efforts to improve radiation monitoring technology received added impetus. As the volume of nuclear wastes of all types has grown and the nature of their hazards becomes better known, research on ways to isolate those wastes from society has increased.

HEALTH AND HUMAN BEHAVIOR

Advances in brain research—particularly on brain hormones—have opened entirely new conceptual approaches to the study of both normal and abnormal patterns of human behavior. Hormones in the brain are now thought to influence sexual development; responses to stress, hunger, and thirst; pleasure and pain; and, possibly, learning and memory. Current investigations, largely supported by ADAMHA and NIH, are applying new technologies to exploring the normal development and function of the human brain and to investigating the causes of such deviant behavior as drug abuse, juvenile maladaption and delinquency, depression, and mental disorders. New and expanded initiatives will address such behavioral problems as alcohol abuse and smoking.

Prevention of illness through control of individual lifestyles must continue to be a high priority. Greater understanding is needed of the biological and social bases of human behavior, and better methods are needed to increase awareness of the importance to well-being of environmental and behavioral factors that are under individual control. To illuminate further the impact of lifestyles on health, the Public Health Service recently initiated a national survey to link mortality over a 10-year period with specific combinations of health habits.

Alcohol Abuse

The National Institute on Alcohol Abuse and Alcoholism is rigorously pursuing research on genetic predisposition and individual biochemical characteristics as the best prospect for advancing knowledge on the causes and pathogenesis of alcoholism. Investigations are also proceeding to identify basic principles of learning and motivation in alcohol-related problems (for example, accidents and violence) and to explore how economic and regulatory techniques or family and peer relationships might be used in prevention programs. The reported increase in the incidence of newborns with anomalies associated with alcohol abuse by the mother during pregnancy, the fetal alcohol syndrome, underscores the need for more research to elucidate the mechanisms of impairment and related risk factors and to increase public awareness of this health problem. Because alcoholism and alcohol-related medical and psychiatric disorders are responsible for about 40 percent of hospital discharge diagnoses in the VA, the agency conducts a high-priority research program in this area.

Drug Abuse

Available evidence indicates that two thirds of all young adults have tried marijuana. Indeed, 10 percent of the high-school class of 1979 used it daily. Because of potential social and health consequences that this and other drug-abuse problems pose, the National Institute on Drug Abuse (NIDA) is attempting to determine the factors that lead to experimentation with drugs, the reasons for progression from one drug to another, the basic mechanisms of drug addiction and tolerance, and the best methods for prevention and treatment. An important research effort is NIDA's long-term prospective study of the characteristics of clients in drug-treatment programs. By correlating client characteristics (age, race, sex, type of drug used, and circumstances surrounding drug use) with type of treatment and long-term results, it will be possible to improve treatment regimens as well as to learn about the correlates of drug use.

Smoking

The Surgeon General's report on smoking cites evidence that 325,000 premature deaths each year are associated with cigarette smoking; annual costs of resulting death and disability are estimated at $27 billion. Dealing with these problems requires intensive research on such questions as why people smoke, what maintains this behavior, why it is difficult to stop smoking, and why such a large number of people relapse. A new cooperative initiative involving ADAMHA, NIH, and CDC will address this persistent health problem. An interagency committee, co-chaired by ADAMHA and NIH, will serve as a forum to share basic information on health and smoking and to coordinate individual agency research efforts. One consequence of these coordinated efforts should be more effective prevention programs.

OTHER RESEARCH PRIORITIES

Promising research accomplishments in the immensely important areas of cancer and heart disease were highlighted in the first *Five-Year Outlook* on science and technology (May 1980). The hybridoma technology, for example, which may facilitate early detection of cancer and enable scientists to label cancer cells more easily, has opened new avenues in cancer research. Efforts to combat heart disease are proceeding apace with the aid of new noninvasive techniques, and the recent completion of a five-year clinical trial of means for controlling mild hypertension offers hope for a significant reduction of mortality through vigorous treatment of that condition. Other high-priority health research efforts include initiatives to:

- Address Alzheimer's disease, the dementias of aging, and other health problems of the aged;
- Develop a coherent program of nutrition research and research training involving participation of all relevant Federal agencies;
- Apply science and technology to the special problems of veterans (e.g., delayed-stress disorders of Vietnam-era veterans) and handicapped individuals; and
- Develop better, more cost-effective, health care delivery systems and encourage wiser use of these systems by individual consumers.

TECHNOLOGY ASSESSMENT

The National Center for Health Care Technology (NCHCT) conducts, sponsors, and coordinates assessments of high-priority health care technologies. Such assessments take into account the safety, efficacy, cost, cost effectiveness, and the actual or potential social, economic, and ethical implications of particular health care technologies. They provide important information to the practicing and academic medical and scientific communities, health systems agencies, professional standards review organizations, and others, and can help achieve desired national objectives in health planning, cost containment, and improved health care.

NCHCT has developed a tentative plan setting forth the health care technologies that it will address during the next few years. Among them are PETT, coronary artery bypass surgery, ultrasound for cardiac diagnosis, dental X-rays, cesarean delivery and electronic fetal monitoring, and cardiac nuclear imaging—to name but a few. The Center has also developed and begun to implement the methodology and format that will be followed in performing technology assessments.

SUSTAINING THE RESEARCH ENVIRONMENT

Over the past two years, Federal health agencies, in cooperation with scientists and administrators from research institutions, have begun systematically to explore the broad range of problems that beset health research programs at educational institutions. Universities have expressed particular concern about (1) the failure of Federal support to keep pace with steadily increasing costs at research institutions, (2) standards for indirect costs, (3) institutional needs for more flexible funding arrangements, (4) the impact of regulatory requirements on the costs of doing research, and (5) Federal auditing procedures. On May 13-14, 1980, at a meeting of the Advisory Committee to the Director of NIH, the major groups concerned—Federal program managers and auditors and university administrators and faculty—came together to consider these issues. Crucially important is the need to find levels of fiscal accountability that will be mutually acceptable to universities, granting agencies, the Office of Management and Budget, the Congress, and the public. Alternative approaches are being explored, including changes in traditional funding mechanisms (such as use of fixed-price grants in lieu of cost-reimbursement agreements, and greater use of organizational grants). A public forum, such as the one supported by the National Commission on Research in its 1980 report, is a possible mechanism for consideration of a host of issues that characterize government-university relationships.

E. ENERGY*

Energy research and development activities provide substantial support for the national goal of reducing dependence upon liquid petroleum fuels. The conflict between increasing global demand for oil and limited supply will encourage alternative supply technologies, more efficient energy utilization, and investments in a range of selected long-term future options. The transition away from the primarily oil-based approach will require a careful and cooperative effort on the part of the Nation's scientific and technical community—academic, industrial, and governmental. A vigorous effort is being made by this community to accomplish the required research, development, demonstration, and commercialization that will bring new energy sources into use.

Major U.S. Government organizations involved in the effort include the Departments of State, Energy, Agriculture, Transportation, Health and Human Services, Defense, the Interior, and Commerce; the National Science Foundation; the Environmental Protection Agency; the National Aeronautics and Space Administration; and the Nuclear Regulatory Commission. A new, quasi-public organization, the Synthetic Fuels Corporation, has as its goal the enhanced development of the Nation's synthetic fuel production capacity. Not authorized to fund research and development, it is chartered by Congress mainly to help the private sector make investments in liquid and gas synthetic fuels from coal, biomass, peat, and oil shale.

This section highlights a number of important Federal energy research and development initiatives and accomplishments. Activities will implement President Carter's comprehensive program for reducing U.S. dependence on petroleum products by (1) permitting expanded use of coal in environmentally acceptable ways, (2) accelerating the development of oil shale, (3) improving energy efficiency, (4) improving the safety of nuclear power systems, (5) developing future energy systems through a range of programs (solar photovoltaic, fusion, and diverse basic research), and (6) improving the technology base in energy.

EXPANSION OF COAL USAGE

Extensive U.S. coal reserves offer significant potential as an energy source. However, numerous critical problems with coal energy techniques must be resolved.

Coal environmental control technology must be developed to minimize the adverse effects of coal combustion. The Department of Energy (DOE) is developing new approaches to remove pollutants after coal combustion (flue gas cleanup), during the combustion process (fluidized bed combustion), and prior to coal combustion (coal cleaning). In addition, investigators are looking for new means to treat fossil energy wastes.

Recent cooperative efforts between DOE and the Environmental Protection Agency (EPA) have concentrated on improving the performance and reliability of conventional lime/limestone scrub-

*Participants in the task group developing this section included representatives of the Department of Energy, the Nuclear Regulatory Commission, the Environmental Protection Agency, and the Department of State.

bers; developing new generations of scrubbers that solve the wet sludge disposal problem of conventional devices; and limiting emissions of nitrous oxides, sulfur oxides, particulates, and heavy metals from advanced coal systems. The National Science Foundation (NSF) is supporting research in atmospheric chemistry and funding a variety of materials investigations that will contribute new knowledge and support to coal environmental control technology. Engineering of commercial coal control systems continues to be carried out primarily in the private industrial sector, although both Federal and private activities are fostering it.

Combustion of fossil fuels is increasing the concentration of carbon dioxide in the atmosphere; resulting changes in the global climate might lead to terrestrial biosphere dislocations and other disruptions in the oceans and ice-covered regions of Earth. Research continues to improve understanding of how carbon dioxide is absorbed by the atmosphere, the level of future concentrations that could evolve, and how the climate could change in response to higher concentrations in the biosphere. A national effort in this area is being led by DOE. NSF, EPA, the National Oceanic and Atmospheric Administration (NOAA), and the Departments of Agriculture and the Interior are also cooperating in this research.

Acid rain, regional haze, and particulate sulfates are all related to sulfur and nitrogen oxide emissions; however, further research is necessary to resolve uncertainties about the emissions-transport-transformation-deposition adverse effects mechanisms. Because sulfur and nitrogen oxide emissions are associated with fossil combustion products, extensive future research efforts will focus on this emission-effects relationship. EPA, DOE, NOAA, and other agencies are performing applied research on this topic, including studies of costs, effectiveness, and energy impacts of alternative emission controls and other developments. NSF has also initiated basic research in the area. Because precipitation has become more acidic on a global scale, particularly in Western Europe and the northeastern parts of the United States and Canada, research collaboration has become international.

The development of such alternative energy technologies as coal gasification and liquefaction raises attendant concerns regarding potential health effects. DOE is conducting research to define the health impacts that may result from exposure to products or emissions from a variety of coal conversion activities.

ACCELERATED DEVELOPMENT OF OIL SHALE

Oil shale deposits may be one of the largest energy potentials of the United States. Research has been initiated to reduce the costs and hazards of processing shale on the surface and in place (in situ) to extract oil, and DOE is providing technical assistance to private companies that are developing commercial oil shale technologies.

Several major surface shale processing techniques have reached the demonstration stage with encouraging results, and in situ processing using retorts also shows promise. At locations where large shale processing operations may eventually evolve, DOE is supporting investigations into environmental and socioeconomic factors. The Department is also planning extensive involvement with State authorities, including community assistance grants to alleviate local stresses caused by large-scale shale development. In addition, other agencies are taking actions to facilitate the development of oil shale resources.

IMPROVED ENERGY EFFICIENCIES

Conservation of energy will contribute substantially to the national long-term transition to energy forms that replace or supplant oil. Federal actions directed toward improving energy efficiency include the use of energy pricing; information, education, training, and demonstrations; financial incentives; regulation; and research and development action.

Because the industrial sector uses large amounts of energy, the need to make major improvements in efficiency in that sector has become a crucial part of the conservation effort. DOE is sponsoring cost-shared research, development, and demonstration of a range of more energy-efficient industrial processes and less energy-intensive industrial technologies. DOE is also involved in implementing and deploying advanced and existing but underutilized energy-efficient technologies and is working to gain industry acceptance of them. Substantial work is in progress on cogeneration; using both bottoming and topping cycles for the extraction of shaft horsepower in conjunction with the production of process steam often doubles the available useful energy when generating electricity. The private sector is taking many low-cost initiatives to install first-generation fuel-saving equipment to obtain high payback potentials.

Many U.S. buildings—residential, industrial, commercial, and public—were not designed to incorporate existing or emerging technologies to improve their energy efficiency. Researchers are seeking ways to redesign, rebuild, or replace such buildings to obtain satisfactory energy efficiency levels. Conservation techniques for schools and hospitals have priority attention, as do ways to expand the use of urban wastes as an energy source. Energy-efficient heating equipment, heat pumps, lighting, windows, appliances, diagnostics, and controls are examples of accelerated conservation-related development programs in progress.

In the transportation sector, the Nation's overall success rate in conservation will be linked with efforts to improve automobile and truck efficiencies. The government has set increasingly stringent automotive fuel economy standards, and numerous scientific, technological, and production achievements are delivering significant on-road fuel efficiency improvements. Basic research in materials and combustion has been especially important in this effort.

NUCLEAR POWER SYSTEMS

Following the Three Mile Island accident in March 1979, reactor safety research began to focus on "small loss of coolant" accidents and other accidents that could result in a degraded or melted core as well as on the relationship between system operators and their plants. Accident management procedure research includes expanded use of risk assessment methodologies in accident sequence studies. Investigators are studying the evolution of hydrogen gas, developing new methods for removing decay heat from reactor cores, and conducting human factor research to refine system diagnostic and control instrumentation. Research is also being done in areas where nuclear energy interacts with the environment, including earthquake risk assessments, tests of atmospheric dispersion models, studies of the effects of water effluents on aquatic systems, and ecological investigations to help determine the pathway of radionuclides through various ecosystems and food chains. In addition, research is under way to examine the socioeconomic effects on nearby communities of constructing and operating nuclear power plants. Studies on the health effects of very low-level, long-term exposures of power plant workers will continue.

Researchers are developing alternative ways to dispose of both high-level wastes, such as spent nuclear fuel assemblies, and low-level wastes. Investigations are also continuing on means to manage effectively uranium mill tailings and effluent radon. Approaches to improve radioactive waste management include probabilistic risk assessments of the use of different geologic storage media, development of new waste containment forms, and studies of alternative site designs.

In addition, the Nuclear Regulatory Commission is implementing a research and regulatory program to improve the nuclear industry's margin of safety, including the expansion of industry's ability to respond to a wide array of contingencies. Likewise, industry has organized the Nuclear Safety Analysis Center and the Institute of Nuclear Power Operations to conduct a strengthened safety and operability research and training program, with the view of making rapid and effective use of new safety-oriented technologies and processes. A Nuclear Safety Oversight Committee was established by President Carter to monitor the efforts of Federal agencies and the private sector in improving the safety of nuclear power plants and to report periodically on the progress being made.

DEVELOPMENT OF FUTURE ENERGY SYSTEMS

Commitment to a vigorous research and development program, including the needed basic research, is expected to contribute significantly to the Nation's goals of increasing and diversifying the energy supply and achieving conservation objectives. Selected program examples follow.

Solar Photovoltaic Research

Photovoltaic (PV) devices that produce electricity from sunlight can now reach conversion efficiencies of about 10 percent. The Federal PV research program has recently placed considerable emphasis on efforts to lower PV costs to levels that are more competitive with costs of present and projected energy sources. Development of advanced materials and large automated production facilities should continue to reduce PV system costs. In addition, research on crystalline silicon cells and selected film-cell candidates may bring about basic advances in PV system effectiveness. Recent accomplishments include installation of a photovoltaic power source for an Indian village in Arizona, an irrigation system in Nebraska, and power for a national monument in Utah, as well as extensions of previous applications, including power for forestry towers, ocean buoys, highway signs, and mobile communications equipment. Currently under construction at Georgetown University is one of the largest solar-based buildings in the world; it will serve as a prototype solar structure designed especially for educational institutions.

Fusion Research

Controlled nuclear fusion may, in the long term, provide a cheap and essentially inexhaustible source of electrical power. DOE is conducting an intensive endeavor to overcome the obstacles that remain before commercial reactor systems can be built and operated.

The magnetic fusion program is now emphasizing the completion at Princeton University of the Tokomak Fusion Test Reactor, which is scheduled to be in operation in 1982. The program should demonstrate the scientific feasibility of fusion power by about 1984 and move into its engineering development phase as soon as practicable, with the operation of a large-scale fusion energy device by about 1990. Work on that device could lead to a prototype reactor soon after the year 2000. Likewise, the Particle Beam Fusion Facility at Sandia National Laboratory was recently dedicated, and experiments over the next few years should demonstrate energy break even.

NSF-funded research in plasma physics, and in the interactions between high density fluxes and materials, is contributing important new knowledge to the fusion energy program. International cooperation in fusion research, particularly with Japan, is also providing valuable information.

Basic Research

Programs supported by the Federal Government address a wide range of energy-related research areas. The DOE basic research program, in particular, should help provide the fundamental information and knowledge required for the production, conversion, and prudent use of energy in the future.

DOE supports a broadly based, discipline-oriented body of research projects. Basic research in energy has emphasized both science for specific technologies and science with cross-cutting and overlapping applications. Of the latter, materials science is one of the most important, since all major new energy technologies are limited technically or economically by materials problems. DOE basic research includes over 1,000 projects, mostly in the physical sciences, although biological energy projects are also much in evidence. Topics cover fossil fuels, solar energy, nuclear fission and fusion, and conservation. Projects often involve the operation of large research laboratories, among them the Nation's principal neutron research facilities and major high-energy physics accelerators for fundamental investigations into the composition of matter.

IMPROVING THE TECHNOLOGY BASE

The rate of introduction of new energy technologies into the marketplace and, in a few areas, the viability of the technology itself will depend upon improvements in the performance of critical materials and better sensors, control systems, and other measures to increase efficiency and effectiveness. Among the needed control systems and materials are: (1) solar collector panels that are less costly to manufacture and install and that resist the detrimental effects of prolonged exposure to sunlight, temperature extremes, and other weathering; (2) containment vessels for fusion reactors that resist deterioration from plasma-wall interaction; (3) retorts for oil shale processing that survive under high-temperature and high-pressure corrosive regimes; and (4) wind generator blades made of new, lightweight, and fatigue-resistant materials. In particular, coal gasification systems need reliable sensors for measuring process parameters under hostile conditions, for example, bed levels within pressurized process vessels, instantaneous chemical and physical compositions of flowing streams, temperatures in areas with difficult access, and weightflow of coal, both dry and in a slurry. Automated and remote-controlled mining, in situ resource assessment, and diagnostic procedures also require new sensors and control systems. Similar needs and opportunities exist in essentially every area of energy technology development, and researchers are addressing them with the aim of improving efficiency, reliability, safety, and economics.

Control technique and materials research projects directed toward selected critical systems are seeking to use workshops and other means to transfer technological information from other fields and are trying to obtain early industrial instrumentation production and supply capabilities. To rapidly advance alternative fuels (such as synfuels) to commercial viability, federally sponsored programs in high-risk areas are developing advanced process controls and safety devices. Industry is also endeavoring to resolve a variety of process improvement questions that involve improved instrumentation. Advanced technologies developed in the Department of Defense (DOD) and the National Aeronautics and Space Administration—such as the work on man-machine interfaces in space applications, robotic systems for DOD reconnaissance programs, and advanced aircraft fly-by-wire—have potential for use in improving the control processes and operational safety levels of new energy systems.

The Technology Base Council, newly formed in

DOE, is addressing concern over the adequacy of the available technology base for emerging or future energy systems. The Council consists of DOE's research and development outlay assistant secretaries, who are required annually to review foreseeable technology base needs as an integral part of the DOE budget process. Also, DOE's Energy Research Advisory Board is independently studying the adequacy of the technology base.

F. GENERAL SCIENCE AND TECHNOLOGY*

Federal support for long-term fundamental and applied research in science and engineering and for developing and maintaining the infrastructure that underlies the Nation's science and technology enterprise has been a cornerstone of U.S. science policy since World War II. A good deal of the Federal funding of fundamental research in industry, universities, and other nonprofit institutions is provided by the mission-oriented agencies. That support is complemented by funds from the National Science Foundation (NSF), which has a broad mandate to support the advance of basic sciences and engineering across all disciplines. NSF, the Departments of Commerce (USDC), Defense (DOD), and Energy (DOE), the National Institutes of Health, and the National Aeronautics and Space Administration contribute significantly to supporting the U.S. science and technology infrastructure.

Selected research areas where recent progress has implications across the entire range of scientific investigation and technological development are described in the first part of this section. The second part describes elements of the infrastructure that support science and technology research.

EXPANDING THE SCIENCE AND ENGINEERING KNOWLEDGE BASE

Much of the research that falls into the scope of general science and technology serves to expand our view of the universe and the human role in it. During the past years there have been some dramatic advances in our knowledge that deserve mention.

*Participants in the task group developing this section included representatives of the National Science Foundation, the Department of Energy, the Consumer Product Safety Commission, the Department of Agriculture, the Department of Commerce (National Bureau of Standards and National Oceanic and Atmospheric Administration), the Department of Defense, the Department of the Interior, the National Aeronautics and Space Administration, the Environmental Protection Agency, the National Institutes of Health, and the Veterans Administration.

Life Sciences

Of the many recent advances in the life sciences, the manipulation of DNA, the genetic material of living cells, is perhaps the most spectacular. The field of biotechnology is very young and is yielding results frequently. The pharmaceutical industry is an early beneficiary of the research. Recent accomplishments include development of processes to synthesize human hormones, enzymes, and vaccines based on recombinant DNA; tests of human insulin; and synthesis of interferon, important in treating viral infections and possibly cancer. Other industries will benefit from the production of bacteria or enzymes designed to transform grain biomass into various petrochemicals or to convert oil and other materials into forms less harmful to the environment. Placing highly active nitrogen-fixing organisms in the soil could be of immense value, as could genetically modifying plants so that they are able to use atmospheric nitrogen and thus produce without nitrogen fertilizers.

Earth Sciences

The continual tasks of monitoring, protecting, and improving the environment have necessitated research on the chemical cycles of the atmosphere, oceans, and land masses and their interactions. Understanding the increase of carbon dioxide in the atmosphere has involved study of the carbon cycle of vegetation and various chemical reactions and transport processes in the atmosphere and oceans. The causes and effects of acid rain, particularly related to the emission of sulfur oxides from industrial activity, are under study at a number of institutions. The need to understand the various roles of trace chemicals in the environment is encouraging the development of sophisticated measuring instruments that will also find application to other technical problems.

Investigation of the Earth's crust beneath the oceans has provided answers to fundamental questions regarding the origin and evolution of the oceans and continents. Such research also holds promise for indicating potential sources of hydrocarbons and other minerals. A major cooperative effort, the Ocean Margin Drilling Program, involving several U.S. Government agencies and industry and university scientists, will continue to expand research into the properties and structure of the ocean margins. Similarly, plans for increased research on the evolution and structure of the deep continental crust involve domestic and international efforts. Early results of deep seismic profiling of the continents are promising.

The importance of the earth sciences to many matters of international concern has led to extensive and generally effective international cooperation. Under the Global Atmospheric Research Program (GARP), involving about 140 nations and coordinated through both the U.N. World Meteorological Organization and the International Council of Scientific Unions (ICSU), several major international meteorological experiments have been conducted. The International Decade of Ocean Exploration, begun under President Johnson, has now ended. Its program produced major scientific returns and led to improvements in our ability to perform ocean research.

Physical Sciences and Mathematics

Newly developed polymeric materials have special strength, electrical, thermal, and optical properties. In addition to activities supported by DOD, DOE, the National Bureau of Standards, and NSF, there is a great deal of private sector activity in materials development. Such activity is expected to continue in response to specialized needs in the energy, transportation, defense, and other industries. Metal cluster compounds may offer a key to the design of new energy-efficient catalysts, particularly homogeneous catalysts. Recent advances in amorphous or "glassy" metals promise the development of materials of exceptional strength, corrosion resistance, and ease of magnetization. If such materials were used as transformer cores in residential power distribution systems, power losses of about $500 million per year might be avoided. Amorphous semiconductors for electronic and energy conversion devices are nearly at the point where exploitation may be possible. It has recently become feasible to combine surface characterization techniques and knowledge of molecular architecture to tailor-make the electrical and chemical properties of surfaces. This may be the key to solving problems of corrosion and the design of catalysts and electrodes.

A rapidly expanding arsenal of lasers is now available for probing details of molecular structure and reactivity at high sensitivity and resolution. The free-electron laser is essentially an electron beam interacting with an optical beam. It has high intensity and is tunable across a very wide spectrum, from microwave frequencies into the ultraviolet. As a tunable laser, it holds promise for improved laboratory investigations and is a prime candidate for a high-energy laser. Laser-driven or laser-controlled processes are yielding ever more applications to industrially useful ends.

Significant advances have been made in the last several years in solving nonlinear, partial differential equations modeling liquid-liquid and liquid-gas systems, which occur frequently in the piping of natural gas and petroleum, in environmental pollution, and in other industrial processes. Efforts are under way to develop algorithms for the computer solution of other complex problems. A polynomial algorithm in linear programming was recently developed in the U.S.S.R., and it may prove to be an important advance with significant applications in many areas, including cryptography. In a number of practical problems, however, the better-known Simplex method for solving linear programming problems is still far superior.

Engineering

Automated manufacture may be a key to solving industrial productivity problems. Robots, computer-controlled machines, have successfully replaced human workers for such unpleasant or dangerous jobs as painting and spot welding. Recent progress in the development of visual and other sensors and improvements in control language promise much wider use of robots in ever more complex functions. Today's robots are slow and limited, but the field is moving rapidly, and the time when the robot may successfully compete with human workers in such complex activities as assembly may not be far off.

Ultrasmall electronic devices have been generated using ultrafine resolution X-ray masks, features of which are as small as 50 atoms across, and successive replication by X-ray lithography can produce even finer gratings. New techniques for producing crystalline material from an amorphous melt will do away with the need for special substrates and allow electronic devices to be fabricated with increasing ease. The work may eventually lead to fabrication of systems on the macromolecule scale and, combined with bioengineering, could open up new and useful technologies on the molecular level.

Interest and activity in structural mechanics have intensified recently because of the field's fundamental role in the space program and in the design of tall buildings and bridges of moderate and long span which are particularly subject to environmental stresses. Analogous situations exist in the design of offshore structures and in nuclear power plants, which present serious problems for the design of containment structures, cooling towers, and piping. Advances are being made in the analysis of such structures and in the prediction of their responses to seismic disturbances, extreme and turbulent winds, and wave action. Significant advances are being made in the development of active and passive control technologies for structures having stringent orientation or vibration requirements, particularly under environmental loading. Understanding of the microbehavior of concrete, reinforced concrete, and composites is progressing.

INFRASTRUCTURE

The strength of U.S. science and engineering and the Nation's traditional competitiveness in technology result from a well-trained, skilled, and creative professional work force and an extensive set of supporting elements that includes instruments, technology transfer networks, and information handling techniques. Those elements constitute the science and technology infrastructure.

Education in Science and Engineering

An important consideration in the health of the science and technology infrastructure is the development and maintenance of a pool of trained and able individuals. Scientists and engineers are not the only components of this pool; there is a hierarchy of support in which administrators and technicians, among others, manage the efforts of scientists; prepare documentation; and operate, maintain, and repair equipment, etc. Rapid advances in such fields as computer science and certain types of engineering have led to the development of new products and have spawned increased competition in the development of novel applications; a concomitant shortage of scientists and engineers trained in those fields has arisen.

At the same time, many university faculty members are forsaking educational institutions for more highly paid positions in industry where they can do exciting work, frequently with better instruments and facilities. Also of great concern is the shortage of teachers of mathematics and natural sciences who are able to teach and stimulate students in secondary schools.

In response to a directive from President Carter in February 1980, the National Science Foundation and the Department of Education carried out a study to determine whether the Nation's science and engineering education was adequate, both in quality and in number of graduates. The study recommended: (1) a new, long-term national commitment to excellence in science and engineering education for all Americans to prepare them for the technological age in which they live and work, and (2) immediate action to alleviate shortages of personnel and obsolescence of equipment in critical technical and scientific fields.

Instrumentation

As science and engineering knowledge and techniques advance, the demand for increasingly sophisticated and costly instrumentation grows. Because there is a reluctance or inability to purchase the instruments needed, much scientific research is performed with obsolescing equipment. The use of such equipment tends to slow the advance of science in general. In those few fields where prospects for commercial gain increase the supply of the most advanced instruments, a larger share of talented professionals may be expected to appear, and more rapid progress may be made.

Technology Transfer— Within the United States

To obtain the most from scientific and technological developments, it is necessary to have the means to communicate those developments to other scientists and engineers working in the same subject area and to transfer the developments to other fields or for other applications. This technology transfer occurs domestically and, within certain political considerations, internationally.

Federal laboratories and federally funded research and development (R&D) centers, while responsive to the needs of their sponsoring agencies and related industries, generally are poorly linked to other industry sectors. To address this situation, a new Center for the Utilization of Federal Technology has been established within the National Technical Information Service (NTIS) as a focal point for aggregating federally sponsored technical information, assessing its usefulness to other industry sectors, and actively seeking out potential users in private industry.

The Federal Government has initiated a variety of efforts aimed at improving the use of science and technology by State and local governments through the development of new institutional mechanisms. The National Science Foundation has sponsored innovation groups involving local governments in each of the 10 Federal regions. The groups constitute a National Innovation Network. Officials from cities and counties meet together to define common problems and encourage private businesses, universities, Federal laboratories, and not-for-profit institutions to invent, develop, or adapt advanced products to meet the needs of the localities. A National Innovation Council acts as the official policymaking body of the network.

The Patent and Trademark Office files contain a wealth of technical information; however, those files are virtually inaccessible to anyone but patent examiners. NTIS, in cooperation with the Patent and Trademark Office, will work to provide greater public access to the information. The NTIS Government Inventions Program will seek to increase private sector use of government-held technology that is in the public domain.

Recently the Federal Government has expanded efforts to promote cooperation between industry and universities in science and technology. NSF has established a program to encourage cooperative research efforts across the range of sciences and engineering, and other agencies are mounting similar efforts. The Technology Innovation Projects program at NSF provides support to demonstrate how research results from previously supported projects could be used by industry. Those technologies selected have the potential to advance the state of the art or provide a breakthrough that will result in substantial public benefit. The projects provide the basic data necessary for companies to anticipate their risk and return on investment in the new technologies.

Technology Transfer—Internationally

Only a small portion of the extensive foreign technical literature is routinely available to scientific and technical personnel in the United States. To enable that community to monitor foreign developments of potentially great impact on U.S. technology, NTIS has begun a program to locate, acquire, abstract, index, publicize, and make available selected foreign technical literature and translations.

Most of the world's new scientific knowledge is generated in the United States, the industrialized countries of Western Europe, and the U.S.S.R. Encouraging U.S. scientists to confer with scientists from other countries where work of high quality is taking place can speed the absorption of new approaches and techniques into U.S. science. Cooperation with Western Europe will continue to expand, and cooperation with the U.S.S.R. will resume when the political climate permits.

The transfer of technological information can have implications for the military capability of potential adversaries. In such cases, the benefits to science and technology must be weighed against the possible detriments to U.S. national security, particularly in view of the Nation's long-range needs and concerns. Development of a list of technologies critical from this standpoint is under way at DOD. A preliminary listing appeared in the *Federal Register* of October 1, 1980.

Productivity

Significant advances in a number of technological areas have created opportunities for increasing productivity in manufacturing. They include computer-aided design, manufacture, and testing (CAD/CAM/CAT) as well as new and improved processing operations. However, there is concern that U.S. industry may not be investing in such critical, productivity-enhancing technologies at levels sufficient to reestablish a competitive position.

In order to provide a foundation for productivity improvement, both the Department of Commerce and the National Science Foundation, among other agencies, are implementing activities to provide information that will facilitate enhanced productivity by the private sector. To focus Federal resources more directly on productivity and innovation problems and opportunities, the USDC Office of the Assistant Secretary for Productivity, Technology, and Innovation projects the establishment of a special Office of Technology Strategy and Evaluation (OTSE), to be built upon the knowledge base generated by its forerunner, the Experimental Technology Incentives Program of the National Bureau of Standards (NBS). OTSE will develop investigative methodologies and conduct strategic analyses; as a result, future policymaking will reflect an enhanced understanding of Federal program impacts and industrial trends.

To make Federal support available for private sector productivity improvements, USDC is establishing the Productivity Reference Service. In addition to performing a clearinghouse function for productivity-related data, the Service will actively cooperate with the private sector to develop and disseminate new technical, managerial, and other information contributing to productivity enhancement.

Technology development is a major contributing factor to increased productivity, but "underlying" or generic technology development often suffers from inadequate private investment, due to long payback periods, problems of maintaining proprietary or exclusive interests, and competition from alternative investments with higher immediate returns or lower risk levels. To foster increased innovation in selected generic technologies (including manufacturing processes and materials development), USDC will fund start-up costs for at least five pilot Cooperative Technology Centers in fiscal year 1981. In addition, the NSF University/Industry Cooperative Research Centers program provides "seed money" to initiate generic research centers at universities. Centers are initially cofunded with industry; however, research programs are to be responsive to industrial research requirements so that industry will increase its support over a five-year period to replace decreasing Federal support.

A direct contribution to the science and technology base that underlies industrial productivity will result from the expansion in fiscal year 1981 of the traditional programs of the NBS in providing measurement methods, standards, and technical data needed by the microelectronics, computer-assisted manufacturing, and materials industries.

Support for Small Business

Small firms, especially those organized to develop and market high-risk innovations, often lack the capital resources necessary to succeed. As a result, promising technological advances are delayed or lost. To make it easier for small firms to obtain start-up capital before conventional sources are willing to provide financing, USDC will establish four Corporations for Innovation Development in fiscal year 1981. They will provide financial packages for venture capital from various Federal, State, and private sources.

In addition, NSF has developed a program to stimulate R&D in small research firms; this program serves as a model for Federal agencies to encourage small business participation in their programs. The Small Business Innovation Program at NSF provides early funding for creative small science- or technology-based firms. It supports the small business in converting research into technological innovation and increased productivity.

Information and Telecommunications

Improvements in ways to process and transmit information have a profound effect on the entire scientific establishment. Since 1959, when integrated circuits were first introduced, microcomputer component densities have doubled yearly, reliability every 2 years, and operating performance every 3 years. The costs of processing and storing information have fallen at a similar pace. In telecommunications, the channel capacity of a single communications satellite has doubled every 2-1/2 years since the first such satellite was launched in 1965, while the required investment per circuit-year has declined at roughly the same rate. Fiber optic cables that can carry thousands of voice circuits are now possible, and the raw materials come from a very prevalent source—a vital development in this era of diminishing access to raw materials. In addition, fiber optic cables cost substantially less than copper cables. Computer-based communication systems are also exploiting recent advances in processing and storage. With such systems, costs are virtually independent of distance, and users need not use the same circuit at the same time. NSF has sponsored operational trials to explore numerous other features of computer-based communication.

Recent research results have applications in information science. Advances in knowledge of the structure of natural language have been applied to speech synthesis and recognition and to information retrieval. Progress in the theory of relational data bases and other advances in data base technology are improving information management techniques. Information resources tend to expand exponentially, with doubling times of 35 years for the general archival holdings of libraries, 15 years for scientific and technical journals, and 6 years for the paper-based holdings of the National Archives and Records Service. Numerical and image data bases are growing even more rapidly.

Current research includes investigation of knowledge representation, natural language structure, visual pattern recognition and classification, decisionmaking under uncertainty, and information retrieval. The question of how knowledge is represented in thought and language has drawn increasing attention in the cognitive sciences and in connection with artificial intelligence; it plays a central role in both basic and applied information science. The relationship between linguistic and nonlinguistic (e.g., image) representations and perception of categories plays a central role in knowledge and fact retrieval.

In telecommunications technology, satellite services offer a significant potential for stimulating technical and economic advances. For example, in fiscal year 1980, the National Telecommunications and Information Administration supported programs to implement inexpensive satellite technologies and services appropriate to the low-volume public service user. Applications currently funded include a satellite/cable network for instructional and community service programming for public service users, a network of teleconferencing and training centers, a market aggregation consortium for public service access to advanced telecommunications technology, and a distribution network for continuing education courses at the professional level.

G. NATURAL RESOURCES*

In recent years, the Nation has begun to view its natural resources not merely as sources of useful commodities, but as one part of a total system that must be managed properly with minimal environmental damage. Land management, water resources, natural hazards, remote sensing applications, nonfuel minerals, national parks, living marine resources, forests, and weather are aspects of natural resources discussed in the following paragraphs.

LAND MANAGEMENT

Federally administered lands (public domain) make up nearly 30 percent of the total 3.5 million square miles in the United States, and Federal control of those lands is shared by the Department of the Interior and the Department of Agriculture (USDA).

The Department of the Interior's Bureau of Land Management (BLM) has management responsibility for over 60 percent of the public land, plus all the outer continental shelf (OCS) land and public land subsurface minerals management. The U.S. Geological Survey (USGS) in the Department of the Interior provides scientific and management support towards this public land responsibility.

Leasing of the offshore oil and gas resources of the OCS is the responsibility of the Department of the Interior. In 1980 the Department started a five-year accelerated OCS leasing program with many scientific studies supporting its schedule. The studies are examining geologic and oceanographic hazards, biological reconnaissance, and endangered species. Some specific research efforts conducted during 1980 are an extensive geophysical survey of the Bering Sea, regional environmental investigations of the Alaskan shelf, and the mapping of geological hazards.

During the last decade, the country's agricultural lands have been converted to nonagricultural uses at a rate of 3 million acres per year. To address this problem, USDA, the Council on Environmental Quality, and 10 other Federal agencies began an 18-month National Agricultural Lands Study (NALS) in mid-1979. The study's objective is to determine the nature, rate, extent, and cause of reductions in the Nation's agricultural land base and to recommend appropriate action. A 20-person staff is conducting the study, which is scheduled to be finished in January 1981. Public involvement has been considerable through 19 workshops held throughout the United States.

Another major natural resources concern is desertification where human impacts on arid and semi-arid lands cause them to decline in usefulness and revert to desert conditions. To determine the extent of the problem in the United States, the BLM is coordinating a major study of desertification. Executive agencies, congressional offices, State and local governments, and professional groups are all participating in the study, which had initial public hearings in the Western States in August 1980. The United States and Mexico also began scientific and technological cooperation to combat desertification in early 1979, when an agreement was signed to conduct research on the development of salt- and drought-tolerant plants, commercial development of various arid-lands plants, new technologies for watershed and rangeland management, and improved techniques for water harvesting.

WATER RESOURCES

Water availability is, and will increasingly be, a major determinant of the direction and pace of economic and social development in the United States and abroad. U.S. water interests also involve bilateral relationships with Mexico and Canada. One major research thrust in the Federal Government has been to develop new processes and systems for converting seawater and brackish water to useful quality. That research has now reached the stage where demonstration plants will be built. Three sites have now been chosen after a nationwide review that considered 37 possible locations. The sites are at Alamogordo, New Mexico; Virginia Beach, Virginia; and Grand Isle, Louisiana. Each plant will demonstrate a different technology for producing 2 million gallons per day at an estimated cost of $1-1.50 per 1,000 gallons, and each plant will cost about $10-11 million.

NATURAL HAZARDS

Natural hazards that can result in disasters (earthquakes, floods, landslides, volcanic eruptions, etc.) are a major concern of government at all levels. The Disaster Relief Act of 1974 gave USGS the responsibility for warning State and local officials of potentially hazardous geologic events.

A dramatic natural disaster was the May 18, 1980, eruption of Mount St. Helens in

* Participants in the task group developing this section included representatives of the Department of the Interior, the National Oceanic and Atmospheric Administration in the Department of Commerce, the Department of Agriculture, and the Department of State.

Washington's Cascade Range. It resulted in an estimated $1 billion in damages and caused 31 deaths, with 32 persons still missing. On March 27, 1980, prior to the eruption, USGS issued a formal hazard alert resulting in the evacuation of some families and restricted entry to the Mount St. Helens area. On April 30, USGS issued a hazard warning after which Governor Ray of Washington closed the area to all but authorized personnel.

In the preblast monitoring stage, scientific teams averaging 10 persons maintained watch over the volcano. Following the blast, 25-30 scientists were on hand performing a wide variety of studies. Despite the havoc caused by the blast, Mount St. Helens' activity presented the first real opportunity for trained volcanologists to make systematic observations using modern techniques.

After the eruption on May 18, Federal, State, and local authorities immediately mounted a cooperative, intensive public information effort to respond to the concerned public, the media, and a general desire for up-to-date information. USGS, USDA's Forest Service, the Environmental Protection Agency (EPA), the Centers for Disease Control, the National Institute for Occupational Safety and Health, and the Food and Drug Administration teamed with Washington State scientists and officials to provide most of the data. A Federal Disaster Field Office was established at Vancouver, Washington, under the overall direction of the Federal Emergency Management Agency. During a 5- to 6-week period after the eruption, a small staff of technical experts at Vancouver prepared and distributed 32 technical bulletins providing guidance to the public on such topics as the nature of Mount St. Helens ash; driving and vehicle maintenance in the ash; health guidance, including face mask recommendations; farm equipment maintenance; advice to fruit and livestock farmers; health surveillance; insurance concerns; dust control; flood hazards; and air quality monitoring.

REMOTE SENSING OF NATURAL RESOURCES

Two Landsat satellites (Landsat 2 and Landsat 3) are providing a wide variety of earth resource data, as shown in Table 2. Because of the success of the experimental Landsat program, the Carter Administration decided in November 1979 to make it a permanent operational satellite system under the management of the National Oceanic and Atmospheric Administration (NOAA), which also operates the weather satellites. Despite that Federal commitment, the actual operational Landsat system will probably not come into being until the late 1980s, and possibly not until the early 1990s. Management decisions, such as satellite design characteristics, agency responsibilities, pricing policies, and Federal/private sector relationships, are under intensive study.

In its eight years of experimental existence, remote sensing with Landsat data has had a wide variety of applications. Among the highlights in the past year are (1) the monitoring of the movement of crude oil from the Mexican IXTOC I oil spill (the largest spill in history) to the Texas coast; (2) a cooperative program with the People's Republic of China in which satellite imagery over two sedimentary basins showed promise of oil and gas reserves; and (3) the USGS evaluation of an Australian land systems approach that uses Landsat images to assess and monitor the land as a resource. USGS has concluded that the Australian technique could be a useful first step in evaluating arid-region terrain and could assist BLM in its management of U.S. public lands in the 11 Western States.

CRITICAL NONFUEL MINERALS

A major nonfuel minerals policy review was initiated in 1977 at the direction of President Carter. Phase I of the study concluded, "Future supplies of several imported minerals critical to the United States and its allies are becoming less secure. Chromium, manganese, cobalt, and the platinum group metals are the commodities of the greatest concern." South Africa, Zimbabwe, and Zambia are important sources for these critical minerals, and they are all areas of increasing political instability. The review also found that several domestic mineral industry segments will probably experience declining production by the year 2000, and those, plus a number of other mineral industries, may also lose shares in both the U.S. and world markets over the same time period. Additional research and development investments by both the private and public sectors in exploration, mining, and processing are required, with Federal research carried out and supported primarily by USGS and the Bureau of Mines. Presently, USGS efforts provide an assessment of the distribution, quantity, and quality of U.S. mineral resources. They have completed mineral analyses on 3.5 million acres of public land being investigated by the Forest Service for wilderness potential and on 1.7 million acres of BLM wilderness study areas. Major mineral resource appraisals are underway in Alaska and the coterminous United States. Remote sensing (Landsat) is providing regional structural information and helping to identify rock types.

TABLE 2. Summary of Operational Landsat Applications in the States*

A. *Water Resources Management*

- Surface water inventory (7)
- Flood control mapping and damage assessment (7)
- Snow cover mapping (3)
- Water resources planning and management (2)
- Irrigation demand estimation (2)
- Cropland runoff determination (2)
- Watershed or basin studies
- Water circulation
- Lake eutrophication surveys
- Irrigation/saline soil
- Geothermal potential analysis
- Groundwater location
- Offshore ice studies

B. *Forestry and Rangeland Management*

- Forest inventory (6)
- Forest productivity assessment (3)
- Clear cut assessment (2)
- Forest habitat assessment (2)
- Wildlife range assessment (2)
- Fire fuel potential
- Fire damage assessment and recovery

C. *Fish and Wildlife Management*

- Wildlife habitat inventory (9)
- Wetlands location and analysis (3)
- Vegetation classification
- Snow pack mapping
- Salt exposure

D. *Land Resources Management*

- Land cover inventory (18)
- Comprehensive planning (4)
- Corridor analysis (2)
- Facility siting (2)
- Flood plain delineation
- Solid waste management
- Lake shore management

E. *Environmental Management*

- Water quality assessment and planning (16)
- Environmental analysis or impact assessment (4)
- Coastal zone management (3)
- Surface mine inventory and monitoring (2)
- Wetlands mapping
- Lake water quality
- Shoreline delineation
- Oil and gas lease sales
- Resource inventory
- Dredge and fill permits
- Marsh salinization

F. *Agriculture*

- Crop inventory (7)
- Irrigated crop inventory (5)
- Noxious weeds assessment
- Crop yield prediction
- Grove surveys
- Flood damage assessment
- Disease monitoring

G. *Geological Mapping*

- Lineament mapping (9)
- Geological mapping (6)
- Mineral surveys (4)
- Power plant siting
- Radioactive waste storage

*The numbers in ( ) indicate the number of States for each application, where greater than one.

NATIONAL PARKS

The National Park Service in the Department of the Interior is launching new initiatives to manage the vast portions of Alaskan lands in the National Park System. Contractors will undertake a priority group of research projects in fiscal year 1981. Among the projected topics are large mammal studies, cultural resources overviews for specific park sites, glacial history and dynamics of Kenai fjords, brown bear population surveys, and vegetation mapping.

LIVING MARINE RESOURCES

The mission of managing and protecting the living resources of the seas lies primarily with the National Marine Fisheries Service of NOAA, which operates a network of laboratories with extensive research programs to assess ocean resources, to study habitats, and to conduct aquaculture investigations into ways of supplementing selected fish and shellfish species. Under the Fishery Conservation and Management Act of 1976 (FCMA), the Department of Commerce has management responsibility for most of the marine resources within a 200-mile-wide exclusive economic zone bordering the U.S. coasts. FCMA established U.S. authority over the 200-mile economic zone; however, it allows foreign fishing within the zone when domestic fishermen will not take the entire optimum yield. Fishery research efforts have been stimulated by the demand for better information with which to make fishery resource management decisions. Management plans, based on specific objectives such as maximum sustainable yield or optimum yield, must now be developed for each of the most important fish species.

NOAA is currently using nine of its ships to support surveys conducted under its marine resources monitoring, assessment, and prediction program (MARMAP). NOAA is also conducting some surveys cooperatively in the Atlantic with the U.S.S.R., Poland, Canada, and the Democratic Republic of Germany, and in the Pacific with the U.S.S.R., Mexico, and Japan. MARMAP results provide comprehensive resource assessments and ecological and environmental information for formulating national and international fishery conservation and management regimes.

FORESTS

Federal responsibility for forestry lies in the Forest Service. Among special research initiatives for fiscal year 1981 are programs to develop more efficient reforestation practices for Eastern hardwood and softwood timbers, new systems for producing high-quality products from small trees and residues, engineering designs to permit the substitution of hardwoods for softwoods, and use of biomass for energy. Other initiatives include Western range and desertification programs to improve rangeland productivity and research to rehabilitate land damaged by surface mining. A major recent accomplishment is the development of a truss-frame design for homes that can reduce construction costs by an estimated $10/square foot; builders in six States are reportedly already using the method.

The reason for the research initiative on Eastern hardwoods is that surpluses of softwoods in the West have been reduced, and Eastern hardwoods now form an important large resource with increasing value for multiple uses. New science and technology capabilities can permit the substitution of hardwood for existing softwood uses. Forest Service scientists have developed several research products that are of great interest to industry. Among them are a pulping method (called press drying) for hardwoods, such as oak, and a technique for making shipping boxes from red oak, which has short fibers and previously was not considered strong enough for container materials.

WEATHER PROGRAMS

The principal meteorological agency in the Federal Government is NOAA, which contains the National Weather Service and related groups that provide weather satellite observation services and conduct supporting research on weather. An important new effort of NOAA in fiscal year 1981 is the initiation of the National Oceanic Satellite System's (NOSS) 5-year prototype operational program to operate and maintain polar-orbiting satellites to provide global measurements of the ocean surface. The data will be provided in a timely and useful form to all operational users. NOAA, the National Aeronautics and Space Administration, and the Department of Defense will jointly conduct the project.

To provide maximum warning of weather-related natural hazards (floods, hurricanes, and tornados), NOAA maintains extensive operational and research centers, including the National Hurricane Center in Miami, Florida, and the National Severe Storms Forecast Center in Kansas City, Missouri. An important new predictive capability on which major efforts are under way is Next Generation Radar using Doppler technology, which potentially can greatly improve thunderstorm and tornado warnings.

Nine Federal agencies are conducting major weather programs, and Federal meteorological services and supporting research efforts are being coordinated through an Interdepartmental Committee for Meteorological Services and Supporting Research. The most important recent advances in science and technology for improving the weather program have come in remote sensing and the automation of surface weather observations (using such advanced computer technology as "talking computers" to provide additional user services at lower staff costs).

H. ENVIRONMENT*

Attainment, protection, and enhancement of an environment that is healthful, safe, and sustaining to the Earth's natural ecosystems remain the major objectives of environmental programs. Environmental research and development provide the scientific and technological information necessary for the programs to choose among alternative regulations and policies that may help the Nation meet its major environmental goals in a cost-effective manner. Government agencies performing or sponsoring environmental research include the Environmental Protection Agency (EPA), Department of Energy (DOE), Nuclear Regulatory Commission (NRC), Department of the Interior, National Oceanic and Atmospheric Administration (NOAA), Department of Agriculture (USDA), Agency for International Development (AID), and National Aeronautics and Space Administration (NASA). Some topics of current concern are the disposal of nuclear and other hazardous wastes, spills of hazardous materials, groundwater supplies, the atmosphere, acid precipitation, and climate.

NUCLEAR WASTES DISPOSAL

Researchers are developing improved ways to dispose of different types of nuclear wastes—high-level wastes (HLW), low-level wastes

*Participants in the task group developing this section included representatives of the Environmental Protection Agency, the Department of Energy, the National Oceanic and Atmospheric Administration in the Department of Commerce, the Nuclear Regulatory Commission, the Department of the Interior, and the Department of State.

(LLW), and uranium mill tailings. DOE undertakes the majority of research relating to disposal of nuclear wastes, with support from the U.S. Geological Survey (USGS) and EPA. NRC confirms the research of others (both public and private) to assist in making its regulatory decisions.

High-level wastes are the concentrated fission products arising from the reprocessing of spent reactor fuel; they require thermal cooling and shielding. As a result of President Carter's decision in 1977 to postpone indefinitely the processing of spent fuel, NRC also includes unreprocessed spent fuel as a high-level waste. The HLW research program develops data on the stability and integrity of waste forms, packaging materials, and the capability of engineering designs to ensure the long-term containment of these wastes in geologic formations. Results of this research will help determine the form that waste will be required to take before disposal and the types of sites and repositories that might be acceptable for licensing as disposal areas. Research methods include in situ testing in geologic media and probabilistic approaches to assessing risks of storage. NRC intends to publish regulations specifying technical criteria for disposal site and waste form by the end of fiscal year 1981.

Low-level wastes include a wide variety of radioactive materials generated in reactors and from medical, industrial, and academic uses. These materials do not normally require cooling but generally do require special handling. DOE and NRC have accelerated and strengthened their LLW research programs in response to President Carter's February 12, 1980, policy statement, which stressed that for nuclear power to continue as a source of electricity, acceptable solutions must be found for disposing of the wastes nuclear power generates. Researchers are placing strong emphasis on identifying waste characteristics, determining site suitability, designing improved facilities, evaluating alternatives to shallow land burial, and developing a methodology for assessing the health risks associated with LLW.

Uranium mill tailings are the voluminous piles left after uranium has been extracted from the ore. These piles have very low levels of radioactivity but contain uncovered uranium and other radioactive components such as radium and thorium. The mill tailings release radon-222 and radioactive particulates. The problem is acute because it was not until recent years that the health hazards represented by uranium mill tailings (resulting from operations stretching back to the 1950s) were recognized as serious. In addition, uranium mining and milling have been expanded significantly since 1977. In responding to the problem, researchers have examined facility sites and transport processes to help find ways to attenuate emanation of radon gas and control erosion of the tailings.

OTHER HAZARDOUS WASTES DISPOSAL

Of the approximately 4 billion tons of industrial, municipal, and agricultural wastes produced annually in the United States, about 30 to 40 million tons are considered hazardous. Not only must the Nation manage these and future waste products in an environmentally sound fashion, but it must clean up existing disposal sites that can present threats to public health. The problem was dramatized at Love Canal, New York, where the Carter Administration took steps to relocate citizens threatened by exposure to hazardous chemicals deposited there over 20 years ago.

To help evaluate acceptable disposal plans, researchers at EPA and USGS have developed mechanisms for assessing the health and environmental damages caused by hazardous wastes. They have developed guidance manuals that outline best engineering practices for land disposal and for measuring the destruction efficiency of hazardous waste incinerators. Regulators need such manuals to review waste disposal permit applications filed by manufacturers.

In fiscal year 1981, new federally funded programs will focus on the problems of existing disposal sites. Researchers will attempt to find better ways to identify and monitor hazardous waste sites; to develop analytical procedures to estimate the composition, size, and potential risk of the sites; and to determine appropriate on-site remedial actions for areas where disposal of hazardous wastes had not been adequately controlled. EPA plans to locate existing waste sites and take steps to clean them up, reducing the risk to public health.

OIL AND HAZARDOUS MATERIALS SPILLS

Unauthorized or accidental spills of oil and hazardous materials are of major concern in the United States and around the world. To respond to the more than 15,000 reported incidents, research at EPA and NOAA has focused on ways to prevent spills, minimize damage to the environment, and control, remove, and dispose of the spilled material.

In fiscal year 1980, EPA incorporated the results of spill control research into a manual on preparing contingency plans for responding to accidental spills. The manual lays out the best state-of-the-art techniques for cleaning up hazardous substances released into the environment. Also, guidelines for prevention and control of pesticide spills have been published, and effective ways to treat contaminated soils have been demonstrated.

During fiscal year 1981, the research program will prepare statistical analyses of spills (frequency, cause, volume, cleanup, cost) and will test such personal safety devices as protective clothing and breathing apparatus. The program will also produce a kit for detecting, identifying, and reporting spills. Plans call for the design of mathematical models that can predict the movement of pollutants from spills through air, land, and water and the development of methods to separate hazardous substances from water.

GROUNDWATER SUPPLIES

The Nation's groundwater constitutes one of its most valuable natural resources, exceeding its surface counterpart in quantity and, generally, quality. Groundwater supplies the domestic water needs of 20 of our largest 100 cities and 96 percent of rural America. Prevention of groundwater contamination is vital but complex due to the number and variety of sources of pollution, geological differences from place to place, difficulty in determining acceptable quality of water below the Earth's surface, and limited knowledge of groundwater transport processes.

Research at EPA and USGS has attempted to increase knowledge of the Nation's groundwater resources. In fiscal year 1980, a user's manual was prepared that summarized fundamental procedures for collecting samples of groundwater and subsurface materials. Selection of a particular procedure depends on (1) the objective of the sampling program, (2) the characteristics of the pollutant and the analytical procedures to be used, (3) the nature of the possible pollution source, and (4) hydrogeologic considerations. Research to determine under what conditions viruses enter groundwater, how long they survive, how far they move, and how they can be detected has shown that virus survival depends on three factors: climate, soil characteristics, and the type of virus. A result has been the derivation of an equation that correlates roughly with virus survival in soil.

Groundwater research during fiscal year 1981 will pursue an improved capability for predicting the movement and transformation of contaminants in the subsurface environment. In addition, scientists will evaluate available methods for detecting subsurface contamination from surface indicators (e.g., seismic and electromagnetic). EPA plans to publish a manual for determining allowable septic tank densities as related to groundwater pollution potential. The program's resources are also increased in fiscal year 1981 to address specific research needs related to the disposal of hazardous wastes. The agency plans to publish a report describing a method for quickly and roughly determining the mobility of a hazardous waste in the subsurface. In fiscal year 1981 and beyond, the groundwater research program will apply the knowledge gained about processes in and characteristics of the subsurface to developing and improving methods for predicting the movement and transformation of contaminants in groundwater. Transferring that knowledge and those methods to the user community will continue to receive high priority.

ATMOSPHERIC POLLUTION

EPA, DOE, NOAA, the National Science Foundation (NSF), and NASA are paying serious attention to improving understanding of atmospheric processes and their role in determining air pollution levels. Scientists have begun to realize that atmospheric transport processes convert local air pollution problems into regional and even international ones. Research efforts have focused on tracking and measuring (from the ground, aircraft, and satellites) actual pollution plumes and on developing models that can predict near and distant transport patterns associated with pollution sources and the attendant health effects. The models have taken on added complexity as scientists learn more about the chemical transformation processes that affect pollution in the atmosphere.

In fiscal year 1980, a first-generation air quality simulation model for predicting concentrations of photochemical oxidants on a regional scale was completed. The States need such models to determine optimum strategies for controlling the emissions of oxidants and their precursors. Environmental planners are now better able to determine the effects of existing and proposed new sources of pollution. Future modeling efforts will attempt to describe accurately the dispersion of plumes over complex (e.g., mountainous) terrain—important in light of future development of energy sources in the West.

The presence of carcinogenic substances in the atmosphere is of growing concern. In response, EPA recently established a systematic approach for regulating such substances. In fiscal year 1980, EPA screened a large number of organic compounds found in ambient air for toxic potency.

Researchers determined the level of human exposures to those compounds and their rates of atmospheric transformation. Additional projects will subject more compounds to detailed evaluation over the next several years to determine which pose the greatest health risk and which should be subject to more stringent regulation.

There is concern that the wider use of diesel-powered vehicles may result in the emission of additional carcinogenic substances into the atmosphere. EPA and DOE have been conducting studies to determine the health risks associated with greater dieselization of the U.S. automotive fleet. During fiscal year 1980, methods were developed that will enable regulators to test engine emissions for their mutagenic or carcinogenic potency. Public health standards for diesel particle emissions that, as judged by EPA, are attainable by auto manufacturers were set in fiscal year 1980. Further studies of the effects of diesel exhaust will continue into fiscal years 1981 and 1982 to improve the data base and determine whether any changes in the emission standards are warranted.

On a global scale, there is concern about the threat that chlorofluorocarbon (CFC) emissions pose to the stratospheric ozone layer that protects the Earth from ultraviolet light. Depletion of the ozone layer could result in serious human health effects and damage to food crops and other vegetation. NASA has assumed a leading role in responding to the CFC problem by sponsoring research to identify the extent and implications of stratospheric ozone depletion, and EPA banned nearly all use of CFC as an aerosol propellant. Through the United Nations Environment Program, the United States has urged other nations to reduce use and production of CFC. These efforts have shown some success as the European Economic Community decided to cut CFC production by 30 percent in 1981.

ACID PRECIPITATION

The emission of pollutants, particularly sulfur dioxide and nitrogen oxides, to the atmosphere results in increased acidity of precipitation, often many miles from the source of pollution. Environmental effects include damage to lakes and streams, forests and rangelands, crops, soils, materials, and drinking water. Acid precipitation research attempts to identify sources of acidifying precursors, their transport and transformation into acids, the forms and extent of acid precipitation, environmental effects, and possible control technologies or mitigating strategies.

A principal Federal accomplishment in fiscal year 1980, in which EPA has taken a leading role with USDA and the Council on Environmental Quality (CEQ), has been the drafting of the Federal Acid Rain Assessment Plan (FARAP) under the auspices of the Acid Rain Coordination Committee. With the passage of the Energy Security Act of 1980, this committee was replaced by the Interagency Task Force on Acid Precipitation, which is cochaired by NOAA, USDA, and EPA. The final draft of FARAP will provide guidance for the rest of the decade. Federal research initiatives for fiscal years 1981 and 1982 will address the principal recommendations of the draft plan: establishment of a nationwide acid deposition monitoring network, research on critical topics, and use of existing information for control and mitigation of the effects of acid precipitation.

During the past year, activities relating to acid precipitation have provided significant results. A national data system for all acid rain monitoring information has been created. Field surveys and samplings have characterized susceptibilities of soils, lakes, and streams to acid rain. Results have shown that in Minnesota and Wisconsin, for example, lakes are low in buffering capability and thus subject to adverse acidification effects if atmospheric acid loadings increase. Cost-effective retrofit controls for nitrogen oxide emissions are being developed; these controls will be needed if regulations to reduce acid rain are adopted.

On the international front, the United States has signed a Memorandum of Intent with Canada to develop an air quality agreement with emphasis on reducing acid rain. Through agreements reached at the Convention on Long-Range Transboundary Air Pollution in 1979, the United States has been encouraging European nations to take similar action.

CLIMATE

The National Climate Program, initiated in 1978, and coordinating efforts of NOAA, DOE, USDA, NASA, and NSF have provided the framework for planning activities to enhance understanding of climate and climate fluctuations. The program was established recognizing that climate has a major influence on such matters of national concern as energy consumption, agricultural production, and water resources management.

A five-year plan was issued under the program with the objective of producing useful climate data based on existing information while simultaneously expanding knowledge of climate and its effects on society and the economy. High-priority research areas include: dissemination of climate information, climate prediction, effects of carbon dioxide, world food production as a function of climate, and ocean heat transport and storage.

In concert with the plan, activities in 1980 produced some notable achievements. Improved measurement standards for carbon dioxide were established, allowing for increased monitoring of this gas in the atmosphere. New models for cloud cover, based on measurements taken by satellites synchronized with the Earth's movement, were developed. Relationships between climate variability and the Nation's economy were quantified. Also, continued advances were made in our ability to analyze and predict severe weather conditions, and those improvements are being incorporated into automated warning systems.

USDA, in cooperation with the Department of the Interior, NOAA, NASA, and AID, has instituted an environmental data survey system to determine the usefulness, cost, and extent to which meteorological data can be correlated with domestic and foreign crop production. Ultimately, the system will be used to develop statistical crop/climate yield models to assess better the social and economic effects of climate.

In fiscal years 1981 and 1982, NOAA will complete a system for providing worldwide data on climatic fluctuations and will issue monthly temperature outlooks. Those data will help DOE and energy producers forecast worldwide energy needs.

I. TRANSPORTATION*

The decade of the 1980s marks a new era for transportation. As the availability of relatively cheap and abundant natural resources declines, many assumptions about transportation priorities, the Nation's place in world markets, and government/industry relationships must change. Transportation Secretary Neil Goldschmidt, in announcing his Transportation Agenda for the 1980s, stressed the importance of conservation and the modernization, repair, and more effective use of the existing transportation infrastructure. To meet the challenge of changing priorities and relationships, the government's focus must be on (1) making improvements in the Nation's transportation systems, (2) assuring that the outstanding safety record of those systems is not compromised, and (3) capitalizing on new technology to enhance the systems' efficiency and productivity as well as to manage better the information so vital to the accomplishment of these goals.

*Participants in the task group developing this section included representatives of the Department of Transportation, the Department of Energy, and the National Aeronautics and Space Administration.

Science and technology efforts will take place not only in the Department of Transportation (DOT) but elsewhere throughout the Federal establishment. Such agencies as the National Aeronautics and Space Administration (NASA), Department of Energy (DOE), Environmental Protection Agency (EPA), National Science Foundation (NSF), and others will continue to contribute to the research that will guide and shape transportation decisions in the future.

TRANSPORTATION SYSTEM IMPROVEMENTS

Excessive dependence on foreign sources of oil threatens the Nation's future. In addition, exorbitant price increases in oil and a reduction in transportation investments have led to a serious decline in transportation productivity. Energy conservation and capital investment strategies aimed at improving and protecting the Nation's investments in transportation can be used to combat inflation, waste, and inefficiency. During fiscal year 1980, research and technology efforts in various Federal agencies played a major role in identifying conservation strategies and areas where capital investments have a high potential for reducing waste and inefficiency in transportation.

Automobiles

The Department of Transportation has undertaken a major new initiative that will use Federal and automotive industry resources to sponsor and conduct long-term basic research in the sciences that support the automobile industry. The long-range goal is to promote major advances and technology breakthroughs from which the industry can develop a new generation of fuel-efficient and cost-competitive automobiles that can compete in the international automobile market in the 1990s. The program coincides with President Carter's Economic Program for the 1980s, announced in August 1980, which sets forth proposals and programs to revitalize American industry and to forge a new partnership between government and the private sector.

The National Highway Traffic Safety Administration (NHTSA) has made great strides in developing highly fuel-efficient vehicles that stand up to rigorous safety standards. During fiscal year 1980, NHTSA demonstrated that its Research Safety Vehicles can withstand 40 mile per hour front and side impacts while automatically protecting the safety of the vehicles' occupants. Advanced structural concepts, including innovative foam-filled designs, are used to absorb the crash energy. Fuel economy exceeds 30 miles per gallon while meeting all 1981 Federal emission requirements.

DOE has sponsored a program to produce improved electric and hybrid vehicles and to demonstrate their commercial feasibility. A recent accomplishment is the development of a rechargeable lithium battery whose performance far exceeds that of the conventional lead-acid battery. When fully developed, the lithium battery will be capable of increasing the range of a vehicle by five to ten times over what is now possible, thus making the electric automobile more acceptable to the public. NHTSA, in cooperation with DOE, has evaluated the safety of the vehicle. Over the past year, the agencies have demonstrated that current DOE electric vehicles meet most but not all of the numerous Federal motor vehicle safety standards. Those components that do not meet the standards will be modified and tested in the future. A full-scale introduction of the electric automobile being developed would lead to substantial savings of expensive imported oil without having an adverse impact on the environment or on vehicle safety standards.

Aircraft

NASA, in cooperation with the aircraft industry, has been involved in extensive research to improve the efficiency of transport aircraft. NASA research flight tests have verified advanced guidance, navigation, and flight control systems and displays, which will help give the industry sufficient confidence to incorporate digital electronics technology into such new generation aircraft as the Boeing 757 and 767. Researchers are also experimenting with various materials, for example, titanium, as the leading edge section for the wings of transport aircraft. The cleaner those edges can be maintained during flight, the less drag there is on the aircraft and the more fuel efficient the aircraft becomes. Another area of NASA research that shows promise in increasing fuel efficiency is the use of composite light-weight materials. An interagency team, headed by NASA researchers, completed a study in fiscal year 1980 which determined that the risk to humans and their environment from the accidental release of carbon fibers contained in composite materials is insignificantly small. Given that assessment, research into the use of composite materials in aircraft seats and even structural components can proceed. Such materials may also have important, weight-saving applications in the automobile industry.

The Federal Aviation Administration (FAA) has reached a major milestone in advancing its Discrete Address Beacon System. FAA has completed the technical data package necessary for the development of a production specification and a national standard for the industry. This is a major step toward enhancing FAA's air traffic control and capacity abilities.

Ships

The Maritime Administration, in cooperation with the shipbuilding industry, has established a technology program to improve domestic shipbuilding productivity through the development of tooling, procedures, management, and advanced manufacturing methods. The program has also been instrumental in creating a more vigorous technical infrastructure to improve technology transfer, establish national industrial standards, and improve the content of professional education.

Road and Highway Maintenance

The Federal Highway Administration (FHWA) has been experimenting with the use of substitute materials in highways. At present, asphalt and portland cement are the only competitive paving materials, and they are both energy-intensive. Of considerable promise is the use of domestic industrial and mineral wastes as substitute highway materials. Already, several builders of trial pavements have used sulfur binders to replace asphalt and portland cement.

Railroads

The Federal Railroad Administration (FRA) has several research and development programs to improve railroad operations. These programs are dedicated to the development of innovations to improve the reliability and operational efficiency of freight service, improve intermodal freight transportation technologies, provide environmental protection and improve energy conservation of rail operations, and advance the state of the art of railroad electrification technology. A major bottleneck in railroad freight operations has traditionally been in the classification yards. FRA, however, has recently developed a new methodology for classification yard design that is already being adopted by the industry and will result in a significant increase in the number of freight cars processed by the newer yards.

TRANSPORTATION SAFETY

For many years, Federal transportation programs have given major attention to the safety of passengers, drivers, pedestrians, and others exposed to the transportation system. Improvements in highway and vehicle design, air traffic control, transportation regulations, and other areas have resulted in an outstanding safety record. Nevertheless, given the high mobility of American society and its extensive use of the transportation network, the absolute number of accidents and fatalities in transportation remains high. Only the combined efforts of government and the private sector can bring about improvements in the safety record. Federal research and development efforts have endeavored to promote transportation safety through preventing accidents and increasing accident survival.

Highway and Motor Vehicle Safety

FHWA, in its continuing effort to reduce highway accidents and fatalities, has identified highway reconstruction and maintenance zones as increasingly more dangerous environments for both motorists and road workers. Newly initiated research into channelizing, warning, and other devices and techniques will lead to the development of proven methods and guidelines for use by States to reduce accidents and injuries in highway work zones.

NHTSA has recently completed some efforts for improving the safety of light trucks and vans, which have not received the same attention as passenger cars concerning the protection provided to occupants. Requirements for the use of current technology to reduce steering wheel intrusion and provide padding will be in effect for model year 1982 light trucks and vans. Research into the application of automatic restraint and other protection for vehicle occupants should result in standards that will reduce the number of people killed and injured in light truck and van accidents. NHTSA has also recently completed requirements for performance improvements in: child restraint systems, hydraulic brakes for light trucks, comfort and convenience of occupant restraint systems, and fields of visibility for passenger car drivers.

Aviation Safety

Recent improvements in transportation navigation systems will substantially enhance aviation safety. A joint NASA and FAA concept for an automated pilot advisory system at a noncontrolled general aviation airport was successfully demonstrated this past year. The system, which combines radar and communication technology, automatically tracks and transmits aircraft location information, which can then be used by aircraft to monitor other aircraft operating in the same area.

NASA and FAA recently completed work with the Loran-C navigation system, testing it in Vermont in the spring of 1980 for its mountainous terrain navigation capabilities. Tests have shown that the system can be used to aid aircraft operating under adverse weather conditions. Such use of the system could greatly improve access to airports in mountainous areas under poor weather conditions.

FAA and NASA have also made strides in developing the technical basis for updating FAA standards to improve occupant survivability in the event of postcrash fires. Laboratory testing this year of an antimisting kerosene additive to jet fuel has demonstrated a strong potential for minimizing the fire hazard. Sometimes fuel released from ruptured tanks in impact-survivable aircraft crashes can result in a fine mist. Random ignition sources present in such cases can cause a "fireball" that may envelop the aircraft as it comes to rest. Development of a jet fuel with antimisting characteristics will greatly reduce that probability.

Marine Transportation Safety

The Coast Guard has just demonstrated the all-weather capabilities of the Loran-C navigation system in harbors and harbor entrances and has tested a vessel-tracking system that uses radar and other surveillance techniques to assure separation of vessels in heavily traveled ports. The navigation aid those systems provide has become very important in today's maritime environment as ports have become increasingly crowded and the maritime transport of hazardous materials has become prevalent.

Pipeline Safety

Recent efforts by DOT's Research and Special Programs Administration (RSPA) should lead to enhancements in the safety and productivity of the Nation's movement of both natural and liquefied gas through its pipeline transportation system. At present, Federal standards for such small gas operators as municipalities, universities, and even trailer parks are no different than those for major gas distributors. RSPA has just initiated an effort to determine the applicability of the standards to small gas operators. RSPA will strive to simplify and streamline the standards so that they may ultimately serve as a model that can be incorporated by communities into local building codes.

Railroad Safety

FRA research activities continue to emphasize railroad safety. FRA has recently formulated candidate statements for developing performance standards for track cross-level (height of rails relative to one another), rail fatigue, and requirements for fastening of rails to ties. Additionally, FRA has done work this past year to improve the safety of hazardous material tank cars. Such improvements through rail research should lead to a reduction in derailments and other railroad accidents.

HAZARDOUS MATERIALS

Of growing concern is the continuing increase in hazardous materials—required by industry, agriculture, and medicine—and their safe movement. Because of the possibility of a catastrophic occurrence, States and local communities have begun to generate laws designed to protect themselves, often imperiling their neighbors and impeding the flow of goods. The Federal Government must establish that it is capable of developing realistic mechanisms to prevent such catastrophes, ensuring effective emergency response, and achieving compliance with sound regulatory controls.

Liquefied Natural Gas

As an offshoot of its pipeline regulations, early in 1980 RSPA issued proposed regulations on the design, siting, construction, operation, and maintenance of liquefied natural gas (LNG) pipelines and facilities. The regulations are the culmination of lengthy investigation into the new technology needed to transport that super cold, highly flammable material. DOE has also been involved in research to assure that liquefied gaseous fuels can be processed, transported, stored, and used in a safe manner. Its efforts have been aimed at understanding the effects of accidents and identifying effective accident prevention and control measures. The findings have helped RSPA in its promulgation of final rules on LNG pipelines and facilities.

Radioactive Materials

Another area of controversy in which RSPA and FHWA have recently been heavily involved is the highway routing of radioactive materials. State and local laws designed to protect communities have resulted in a labyrinth of restrictions and regulations on the transport of radioactive materials across the country and even across a State. RSPA has published a notice of proposed rulemaking that suggests that interstate highways are the most appropriate routes for the transport of such materials. Although the regulation would preempt certain State and local laws, it would allow States to designate alternate routes within specified guidelines. To assist, FHWA has developed a procedure, based on accident risk, for designating routes to transport hazardous materials and has pilot-tested the procedure in three cities. DOE is also conducting research and development related to transportation of radioactive materials.

Oil Spills

The Coast Guard is integrating the AIREYE aerial surveillance system, which can detect oil and possibly other hazardous material spills, into its new medium-range surveillance aircraft. The system, which uses a group of airborne electronic sensors, has day or night, all-weather capability. Evidence documented by the system is of high quality and can be used in a court of law.

TRANSPORTATION INFORMATION MANAGEMENT

An area of growing importance to the transportation sector is the management of information and data, including the use of data processing. A substantial amount of information about the national transportation system and its effects on people and business is required for Federal planning and program development purposes. Such information supports technological initiatives and transportation investment decisions. In addition, the high-speed processing capabilities of today's computers have many applications in the transportation field. However, the American public has perceived the government's quest for more information and data as a growing burden. Efforts must be made to consolidate information requirements, eliminate unnecessary reporting, and focus data needs on present Federal transportation missions and functions.

RSPA has recently completed a major information management tool—the transportation statistical reference file. It includes over 1,000 transportation data bases and sources and is available to all Federal agencies and the public. The availability of this reference tool will greatly reduce uncoordinated, redundant reporting requirements for the public. It will also be extremely valuable to those agencies, universities, and individuals conducting research in the transportation sector.

Applications of computer technology have been demonstrated by several public transportation systems. The Urban Mass Transportation Administration (UMTA) has actively sponsored the innovative use of computers in transit operations by taking advantage of the computer's ability to handle large quantities of data with lightning speed. Perhaps the most innovative and beneficial applications of computers that UMTA has developed are the control of automated guideway transit systems, routing and dispatching of paratransit vehicles, automatic monitoring of fixed and random route roadway vehicles, and provision of quick, accurate information about routes, schedules, and fares to riders.

The U.S. Coast Guard has also used computer technology to develop chemical hazard response information and hazard assessment computer systems. Although the systems are not fully operational, recent efforts have shown that the computer models and information they can provide to response personnel will allow fast assessment and appropriate reaction to potentially hazardous spill situations.

J. AGRICULTURE*

Agricultural science and technology help support efforts to meet the Nation's needs in food and agriculture. Those needs include agricultural production sufficient to meet domestic and export demands, adequate returns to farmers, reduced fluctuations in food prices, improved health through nutrition and food safety, and improved efficiency and reliability in domestic and export agricultural marketing systems.

The Department of Agriculture (USDA) addresses those needs by supporting many types of agricultural science and technology. Cooperative, coordinated, and independent efforts in other Federal agencies and non-Federal institutions, especially the land-grant universities, constitute a major share of the total effort. Among the major topics of concern are agricultural productivity, the quantity and quality of agricultural land and water, human nutritional needs, the need for information about world crop and natural resource conditions, and energy usage.

*Participants in the task group developing this section included representatives of the Department of Agriculture, the National Aeronautics and Space Administration, and the Department of State.

AGRICULTURAL PRODUCTIVITY

To help provide an ample food and fiber supply for domestic needs and export markets at reasonable market prices, the U.S. agricultural system needs efficiently produced plant and animal products. The agricultural research and extension system contributes to improved agricultural productivity and product quality, using improvements in biological and genetic resources and in the management of microenvironments.

Crop Production

Specific accomplishments in crop production include the development of tomato varieties that are adapted to the intermountain Western States and that are highly resistant to curly top disease, and the opening of an Appalachian Fruit Research Center in West Virginia to help expand the fruit industry in the Eastern Central States. Two new semi-dwarf lines of soybeans have been introduced in Illinois and Ohio. They yield an average 10 to 20 percent more than the taller soybean varieties in the same region.

Current basic research initiatives related to crop production include: (1) efforts to determine fundamental plant biophysical and metabolic responses to environmental stresses, including stresses induced by variations in temperature, or water and mineral availability; (2) accelerated membrane research related to water and nutrient transport, energy conversion, bioregulation, and translocation; and (3) determination of heritable linkages of plant metabolism and biophysical mechanisms in crop germ plasms.

The development of genetic engineering methodologies for the control of gene transfer and gene expression in organisms of agricultural importance will be emphasized. This will include an attempt to fill current knowledge deficiencies in plant molecular biology that seem to be barriers to the use of certain plant recombinant DNA technologies.

Animal Production

A major initiative in animal production is the use of genetic engineering, cell-mediated immunity, monoclonal antibodies, and subunit vaccines in efforts to achieve major improvements in livestock health. Other initiatives include multidisciplinary team research by Federal and State scientists on the interactive effects of disease and suboptimal conditions of nutrition and management on reproductive efficiency. Researchers will also try to increase the efficiency of protein synthesis in food animals and control the amount of fat deposition.

The discovery of viroid-like agents is a major scientific advance in understanding the causes of infectious diseases in animals and may have wide implications for the control of certain degenerative and inflammatory diseases and scrapie, a serious disorder of sheep. Also, scientists have recently adapted the sensitive, simple, rapid, and relatively inexpensive Enzyme-Linked Immunosorbent Assay (ELISA) diagnostic test for detection of several animal diseases. That test may now help in eliminating dangerous carriers of infectious anemia of horses and progressive pneumonia of sheep, in preventing introduction of African Swine Fever into the United States, and in controlling costly liver flukes in cattle and sheep and hemorrhagic pneumonia in mink.

Foot-and-mouth disease is a highly contagious foreign animal disease that causes enormous losses of cattle, swine, and sheep in other countries and periodically threatens to enter the United States. Scientists are using recombinant DNA to produce a fraction of the foot-and-mouth disease virus coat that is noninfectious and can produce immunity in livestock.

Pest Management

In pest management, a tiny wasp that is a parasite to the citrus blackfly is so effectively protecting citrus crops worth several billions of dollars in Florida and Texas that a $5 million-a-year chemical spray schedule in Florida was cancelled. Increased spread of parasites of the alfalfa weevil in the Northeastern States reduced insecticide use by 75 percent in 1979, saving approximately eight times the total cost of the project over a 20-year period. The screwworm is a serious and costly parasite of mammals in warmer regions. A recently developed bait/toxicant system is now being used by the USDA Animal and Plant Health Inspection Service in conjunction with the Mexican Government to try to eradicate it from the northern part of Mexico.

About 250 government and university scientists are cooperating in consortium projects to develop economically and environmentally sound systems of integrated pest management (IPM) for major crops on a regional basis. Their efforts are complemented by extension projects in IPM systems. The regional emphasis on crop pests is to be furthered in fiscal year 1982.

Aquaculture

In 1980, the USDA completed development of an aquaculture plan that outlines research, extension, technical assistance, marketing, data collection, economic assessment, and crop reporting activities. The Joint Subcommittee on Aquaculture of the Federal Coordinating Council for Science, Engineering, and Technology, involving the Departments of Agriculture, Commerce, and the Interior, plus several other Federal agencies, completed Phase I of the National Aquaculture Plan. The joint subcommittee initiated comprehensive studies of the extent to which the growth and development of commercial aquaculture are being impeded by the lack of sufficient venture capital, disaster loans, and insurance and by Federal, State, and local rules, regulations, and procedures. Cooperative efforts between the Carter Administration and the Congress resulted in the passage and signing of the National Aquaculture Act of 1980, which mandates Federal activities designed to encourage the development of the U.S. aquaculture enterprise.

AGRICULTURAL LAND AND WATER

With projected U.S. and world population increases, there is growing concern over the future quantity and quality of land and water for agricultural production. It has recently been estimated that 2 billion tons of farm soil are lost annually through erosion. Also, agriculture now draws more than 80 percent of the water used in the Nation. About 40 percent of irrigation water is groundwater that is being seriously depleted in some regions, particularly the Great Plains and the Southwest. Increases in population and energy production mean growing competitive demands for the available water.

Research has shown that plants stressed by water shortage have higher leaf temperatures than nonstressed plants. A hand-held infrared thermometer and an aircraft equipped with a thermal scanner have been developed for field monitoring to improve the ability to schedule irrigation for efficient use of water.

Models have proved extremely useful in studying land and water resources. Using data made available by applications of space technology, a model has been developed to predict the effect of conservation practices on nonpoint source pollution of the environment for use by planning and regulatory agencies. Scientists have also developed and tested a new sediment yield model which relates cropland erosion to storm events. Thus critical erosion areas can be quickly and realistically identified and assessed, providing guidance for concentration of treatment needs.

A major current initiative is the provision of research and extension in support of the Soil and

Water Conservation Act. Science and technology activities include the determination of relationships between soil erosion and productivity, development of data and economic models, development of conservative tillage systems, and improvement of erosion prediction equations. Additional initiatives are planned for 1982 to assess changes in water quality, develop approaches to improve water quality, and elucidate basic processes that determine the fate of chemicals.

As the Nation moves to greater dependence on coal as an energy source, the acidity of precipitation is expected to increase, potentially inhibiting gains in agricultural productivity and affecting production costs and prices for agricultural products. A National Atmospheric Deposition Project has been initiated to monitor trends in acid rain and develop research projects. Cooperators in this project include 25 State agricultural experiment stations, 8 Federal departments and agencies, 3 State agencies, and industry. The substance of the current initiative on acid rain consists of the collection and analysis of weekly rain samples to establish trends and spatial occurrence and determine the biological effects of acid rain on agricultural and forest productivity. For fiscal year 1982, the national monitoring program will be expanded and strengthened, and substantive research on the effects of acid rain on plant stress will be initiated.

HUMAN NUTRITION

Consumers, health professionals, action program officials, and legislative bodies are becoming increasingly aware of the relationship between diet and health and the importance of good nutrition throughout life. Consequently, the Congress has mandated development of national nutrition information and education programs. In support of these goals, specific laboratories have been established to identify better ways of assessing food intake and nutrition status, study human nutrient requirements, and evaluate nutritional needs during pregnancy, lactation, infancy, and aging.

Recent accomplishments in human nutrition are diverse. New analytical tests include a more reliable and sensitive method for measuring vitamin D in milk and a very sensitive method for measuring chromium in foods and human tissues; the latter permits better information on human requirements for the dietary trace mineral chromium. Research programs have found that blood cholesterol levels are lowered most when humans consume bran from hard red spring wheat as compared to other food fibers and that carbohydrate-sensitive individuals, at least 20 million Americans, may be able to reduce their risks of heart disease and diabetes by cutting intake of sucrose, including table sugar.

Accomplishments in nutrition education include the issuance of dietary guidelines in collaboration with the Department of Health and Human Services. USDA's food guidance programs are being reoriented in keeping with those guidelines. Also, 600,000 community leaders, 3,800 county home economists, and 135 State extension specialists have been trained in nutrition education. Families with young children, low-income families, elderly people, and youth have been involved in programs focused on food selection, handling, and preservation; weight control; understanding nutrition labeling; and such controversial food issues as the use of nitrates and saccharin.

Current and planned initiatives in human nutrition emphasize: monitoring and assessment of the nutritional status of our population; the establishment of standards and analytic methodologies for the nutrient composition of foods; understanding nutrient bioavailability and nutrition needs of such large subgroups of the population as the aging, and pregnant and lactating women; and the general requirements and relationships between nutrition and the maintenance of health. USDA is making and will continue to make special efforts to increase participation of food stamp users in the Expanded Food and Nutrition Education Program, through which paraprofessionals provide in-home instruction to 1.6 million low-income families throughout the United States.

WORLD CROP AND NATURAL RESOURCE CONDITIONS

A major national concern is the provision of timely and accurate information about world crop and natural resource conditions to help ensure adequate supplies of food and materials and promote conservation of the Nation's natural resources. USDA's cooperation with other concerned agencies in AgRISTARS (Agricultural and Resources Inventory Surveys through Aerospace Remote Sensing) offers an opportunity to develop a coordinated program designed to meet priority operational and research program information needs.

Data collected through aerospace technology are being used to monitor weather, inventory forests, map fires, monitor crop acreage for economic intelligence, map soil, and determine land use. These data also contribute to modeling of crop growth and yield, providing early warning alarms for winter kill, determining wind and water damage, detecting insect and disease infestations, and measuring soil moisture.

In fiscal year 1981 principal initiatives are associated with knowledge and better use of land and water resources for agricultural production; they include early warning systems, crop yield modeling, conservation, and pollution detection. These initiatives will be accelerated by USDA in fiscal year 1982, with increased emphasis on early warning and crop yield modeling.

ENERGY CONCERNS

High productivity in our national food economy relies heavily on an energy-intensive agricultural system. Agriculture can contribute to lessening the critical energy problems facing the Nation through: the production and conversion of biomass for fuels and petrochemical substitutes; more efficient use of energy during agricultural production, processing, and distribution, and in rural homes and communities; and use of alternative energy sources where they are economically feasible.

Innovative energy-saving processes include the following:

(1) A new ammonia treatment process that permits corn to be stored safely without artificial drying has potential for saving huge amounts of propane gas. In a test during the 1978 harvest season, this treatment resulted in less than one-half the cost per bushel as that for drying with propane gas.

(2) Electrical stimulation of beef carcasses has a tenderizing effect on the lower grades of beef and permits the packer to cut up larger portions of the carcasses much sooner. The savings of energy can amount to as much as 35 percent of the carcass chilling costs and 20 to 30 percent of the labor costs as compared with traditional methods.

Two agricultural energy centers have been established to serve as focal points for research, development, and technology transfer in alternative energy sources. The Southern Agricultural Energy Center is concentrating on the development of on-farm energy systems, and the Northern Agricultural Energy Center is concerned primarily with the production and conversion of biomass as an energy source.

Current emphasis has been on research on alternative sources of energy and research and extension in energy conservation. Those activities will accelerate, especially those to (1) increase biomass production as an alternative source of energy, and (2) encourage conservation in crop production and food processing and distribution. Other initiatives will focus on the use of energy for production of byproducts and the development of technical information systems related to energy. Increased resources for energy research will be provided to USDA by passing through funds appropriated to the Department of Energy (DOE). DOE has the lead to oversee, manage, and fund energy-related activities financed by the Federal Government.

K. EDUCATION*

Two distinct aspects of education are covered in this section: (1) educational research and development and (2) education in science and technology. Efforts in the first area are concentrated principally in the Department of Education, which came into being on May 4, 1980. The National Institute of Education (NIE) in the Department's Office of Educational Research and Improvement (OERI) is charged with providing leadership in scientific inquiry into the educational process. Research initiated at NIE is focused on promoting equality of educational opportunities and improving educational practice. The Science Education Directorate of the National Science Foundation (NSF) also supports research and development on learning processes to improve science education at all levels. The efforts of the two agencies draw upon the relevant research supported by other programs of NSF, the Department of Agriculture (USDA), and the Department of Health and Human Services (HHS).

Activities in the second area—education in science and technology—are concentrated in NSF's Science Education Directorate. However, the Department of Education supports three programs (minority science improvement, pre-college science teacher training, and biomedical sciences) that are designed to assist institutions in improving their programs and to assist individuals in increasing their access to fields of science and technology. NSF's major goals for science and technology education are twofold: to assure a stable flow of the most talented students into careers in the sciences, with particular reference to increasing the participation of minorities and women, and to help all citizens increase their basic understanding of science and its contributions to the quality of life. In addition to funding research on how science and mathematics are learned and the development of more effective instructional techniques, NSF supports individuals and institutions in strengthening their capabilities in science. Such other Federal

*Participants in the task group developing this section included representatives of the Department of Education and the National Science Foundation.

agencies as the Department of Defense, HHS, and USDA also support education in science and technology to further their own, more specialized missions.

EDUCATIONAL RESEARCH AND DEVELOPMENT

The objective of educational research and development is to generate knowledge and techniques that will aid the learning process and serve as a base for improving educational practice.

Cognitive Science

Researchers are applying knowledge from the new discipline of cognitive science to delineate the mental processes that take place in learning and to identify how sex, culture, and intellectual experience influence those processes. For example, research has found that reading comprehension involves fitting what is being read to what the reader already knows rather than being a simple assimilation of new information. Facts of this sort will form the basis for better classroom practice and are incorporated into NIE research programs in literacy and mathematics learning. A joint NSF-NIE program requires that researchers in human cognition work with scientists and mathematicians to improve the teaching of science and mathematics. Also being explored is the often striking difference between the student's and the teacher's conception of subject matter and of problem-solving strategies. A new NIE research program focuses on the development of learning, study, and problem-solving skills applicable in a wide range of subject areas.

Equity for Minority Groups

All the education research programs mentioned give emphasis to the problems of minority group members. In addition, there is research devoted exclusively to exploring means of increasing educational equity for those persons. Over 5 million school-age children in this country come from homes where a language other than English is spoken and thus face special difficulties in school. Current research suggests that students who have attained a level of oral proficiency in their native language are better able to learn a second language. NIE has established a National Center for Bilingual Research and is also soliciting proposals for research by individual investigators.

Minority performance in mathematics and science is the focus of a number of projects supported by NIE and NSF. Minority students take fewer mathematics and science courses, and their scores tend to be below national averages. However, recent research suggests that, at the elementary level, the difference in scores is narrowing.

Youth

President Carter's youth initiative provides funds for attacking the problem of youth unemployment in part through special supplementary education programs in districts with high concentrations of poor and unemployed youth. These programs have cooperative activities involving schools, employers, and the employment training system in research, development, and dissemination. The types of activities funded include development and demonstration of exemplary programs, studies of factors bearing on youth employability, program evaluation studies, and programs for higher education institutions to set up nonprofit organizations to provide technical assistance to local projects.

Organization Science

Organization science is being applied to the processes that take place in the educational system, with the aim of finding ways of facilitating constructive change in schools and colleges through better flow of useful innovations and reduction of dysfunctional practices. For example, NIE projects are clarifying the processes by which new educational policies and regulations imposed from above affect schools in both intended and unintended ways. Other projects are identifying factors that favor the initiation and persistence of innovations.

Information Technology

Low-cost information technology that combines computer graphic displays and videodisc systems is being applied to the teaching of mathematics and science. The videodisc system, in conjunction with an ordinary TV set, provides 54,000 separate color images on one side of a disc similar in size and cost to an LP record. The images can be displayed one at a time in any desired order or as a motion picture at 30 frames per second. Those technologies make possible individualized, interactive instruction, ranging from drill and practice to simulation of complex problem situations, and inexpensive diagnostic testing to detect and help correct the student's errors of knowledge, procedure, and problem-solving strategy. NSF and NIE are instituting joint programs that support the development of prototypes for the instructional use of information technology in school mathematics.

The Office of Special Education and Rehabilitation in the Department of Education is developing numerous applications of technology to education of the handicapped. Closed captioning for the deaf is now available on commercial television. Computer systems designed to help deaf children learn the structure of English and learning-disabled children decode words and phrases are being developed. Similarly, there are systems that can replace bulky Braille books by converting almost any printed page into tactile signals or into synthesized speech.

School Finance

The Department of Education is beginning a congressionally mandated study of school finance designed to inform the Congress of issues that may affect the future Federal role in that area. The study will: (1) provide data on status and trends in school finance, (2) conduct analyses of problems in financing public and private schools and prospects for adequate funding over the next 10 years, and (3) recommend Federal policies to improve the equity and efficiency of school finance systems.

EDUCATION IN SCIENCE AND TECHNOLOGY

Historically, education in science and technology has focused on insuring that adequate numbers of suitably educated professional and technical workers needed by the scientific and technical enterprises are provided. The ability of science and technology to contribute to the economy and the national welfare depends not only on the inventiveness and technical competence of its practitioners but also on the degree to which citizens understand its results and can assimilate them into the Nation's social structures and institutions. Therefore, education in science and technology also addresses the level of scientific and technical understanding of all citizens.

Science and Engineering Education Report

In response to a directive from President Carter in February 1980, the National Science Foundation and the Department of Education prepared a report, entitled *Science and Engineering Education for the 1980s and Beyond*, to assess whether the Nation's science and engineering education is adequate, both in quality and in number of graduates, for long-term needs. The report, whose preparation involved a wide range of persons and organizations, focused on two sets of issues: (1) science and engineering education for those who plan careers in those fields, and (2) scientific and technical literacy requirements for those who do not plan to pursue such careers but who require some level of understanding and competence in their work and in their roles as citizens. The report's principal conclusions are discussed in chapter I, section B. Existing Federal programs that focus on specific problems identified in the report include those associated with teaching modern engineering design techniques, improving education for early adolescents, and involving larger numbers of women and minorities in science- and technology-related causes.

Engineering Design

One of the difficulties in educating future scientists and engineers is ensuring that educational programs keep up with changes in technology. Even if all students cannot be taught on state-of-the-art equipment, students should be taught on equipment that at least performs the same function as the more advanced models. In some cases, technology has outpaced the educational programs. For example, in engineering design procedures the application of computer-aided design speeds the creation of complex engineering structures such as energy-efficient cars, computers on a chip, and the wings of supersonic planes. NSF is sponsoring research into the best current practices in teaching the new engineering design procedures and is identifying ways to develop curriculum materials in engineering design.

S&T Education for the Early Adolescent

It is rare for a student to neglect science in high school and then go on to earn a science degree during higher education. Therefore, the overall decline in the number of science and mathematics courses taken by precollege students does not bode well for the supply of scientists and engineers. In response, NSF is developing programs for the early adolescent that address skill development and motivation in those grades where children are still required to study science.

Involvement of Women and Minorities

A dominant concern of the National Science Foundation and the Department of Education is that of increasing the involvement of minorities and women in the scientific and technological enterprise. The underrepresentation of those groups is a serious liability to the country for it wastes human resources and indicates inequalities in educational and occupational opportunities. In addition to programs in NSF and the Department of Education, such other agencies as the National Institutes of Health, Department of Energy, and National Aeronautics and Space Administration have programs to improve the capabilities of minority educational institutions and increase the involvement of minorities and women in science and engineering.

A major barrier to participation in many careers by women is their tendency to avoid advanced mathematics courses in school. Recent research from NIE and NSF projects has shown that parental encouragement and the student's perception of the usefulness of mathematics for future academic and career goals are strong factors in her course decisions. The degree to which a female student believes that mathematics is a "masculine" subject has little effect on her choice. Other studies have focused on women's career decisions, as well as on the relationship of sex differences in spatial reasoning to science problem-solving abilities.

Out-of-Classroom Learning

Informal, out-of-classroom learning activities in science and technology center on television, print media, museums, and libraries. Such activities emphasize reaching audiences that do not ordinarily have access to scientific and technical information, including minority groups, rural populations, senior citizens, urban populations, and the disadvantaged. NSF is proposing an increase in projects that support science and technology museums in fiscal year 1982.

A significant recent achievement is the planning and development of "3-2-1 Contact," a major new children's television series about science. The series began daily half-hour broadcasts over public television stations in January 1980 and should reach a significant portion of 8- to 12-year-old U.S. children. It seeks to help children experience the excitement of scientific exploration and motivate them to pursue an interest in science.

Undergraduate Faculty Development

The growth of scientific knowledge and information requires special efforts and opportunities to help faculty members in science and technology keep pace. That requirement combined with a more diverse and heterogeneous student body and changing patterns in the job market presents a challenge to colleges and universities to continually update their offerings in undergraduate science instruction. Therefore, NSF has placed greater priority on faculty development with particular emphasis on subject-matter updating for undergraduate science faculty. That effort began in fiscal year 1981, and the plan is for it to continue over the next five years.

L. INTERNATIONAL AFFAIRS*

Science and technology can be used to serve the Nation's interests in both domestic and foreign policy. Bilateral and multilateral science and technology (S&T) agreements with developed countries contribute to the goals of domestic S&T programs and at the same time permit cooperative approaches to large-scale and global problems that might be impossible for any single nation to address because of personnel or financial resource limitations. S&T assistance to developing nations can also be expected to play a role in various development programs. U.S. policy encourages developing countries to strengthen their science and technology infrastructures, enabling them to bring S&T solutions to bear on their problems.

Much international collaboration today concerns energy, resources, and environmental issues, and selected bilateral and multilateral agreements in those areas are described in the following paragraphs. A review is then presented of bilateral S&T ventures between the United States and China, the U.S.S.R., and Mexico and other Latin American countries. The final section discusses the application of science and technology to Third World development, including a description of U.S.-African programs.

ENERGY, RESOURCES, AND THE ENVIRONMENT

Energy

The Department of State, the Department of Energy (DOE), and other agencies are working toward increased cooperation in energy research and development (R&D) with other industrialized democracies through the International Energy Agency (IEA) in Paris. The IEA Committee on Research and Development reviews member nations' energy research and development policies and oversees a joint energy R&D program that includes over 50 projects. The International Energy

*Participants in the task group developing this section included representatives of the Department of State and the Agency for International Development.

Technology Group, growing out of the 1979 Tokyo Summit, prepared a report identifying six promising technology areas for international collaboration in the construction of commercial-scale demonstration facilities. Follow-on activities are being carried out by the High Level Group on Energy Technology Commercialization.

The United States also cooperates bilaterally with a number of countries and encourages regional initiatives in energy development. During fiscal year 1980, the United States joined with Japan and West Germany in a major solvent-refined coal liquefaction demonstration project to be built at Morgantown, West Virginia. U.S. Government officials also signed an energy R&D cooperation agreement with Venezuela to assist in the development of Venezuela's petroleum resources. Negotiations have begun with Canada on cooperation in coal R&D, and a Memorandum of Intent to reach agreement on R&D cooperation with Nigeria in the energy field has also been signed.

Energy consumption in developing countries is projected to grow faster than in developed countries. For those developing nations that do not export oil, the principal areas for increased attention are exploration and expansion of domestic commercial resources, more efficient use of commercial and traditional energy supplies, development of nonconventional and renewable sources, and the need to adjust to higher energy prices. The energy assistance program of the Agency for International Development (AID) focuses on renewable energy and institution building for improved management of all resources. AID's emphasis on renewable energy reflects its concern for the needs of the poor, who will be increasingly unable to meet the rising cost of conventional fuels. Many alternate technologies using indigenous resources to solve local energy problems are not proven; AID will finance testing and adaptation of those technologies to determine their cost and effectiveness in specific applications in developing countries.

The Administration is actively involved in preparations for the U.N. Conference on New and Renewable Sources of Energy to be held in Nairobi, Kenya, in 1981. For the conference, DOE is drawing on industry and the scientific community to prepare a report detailing U.S. experiences with 14 kinds of new and renewable energy sources. The United States seeks to use the conference and its preparatory period to accelerate the development, acceptance, and use of new energy technologies and help educate all countries about the real opportunities offered by alternative sources for meeting future energy demands.

Global 2000 Report

In May 1977, President Carter directed the Department of State and the Council on Environmental Quality to work with other Federal agencies to study "probable changes in the world's population, natural resources, and environment through the end of the Century," as a foundation for longer term planning. The *Global 2000 Report*, which took three years to complete, was transmitted to President Carter in June 1980. The Secretary of State made the report the centerpiece of his August 29 speech to the Special Session of the United Nations on Economic Development. The report was discussed in the context of the Venice Economic Summit and was referred to in the communique of that meeting, reflecting agreement among the participating heads of state that the issues the study addressed will be critical factors affecting economic growth in the years ahead. A Department of State task force is implementing a broad-based strategy to expand the international dialogue on Global 2000 issues and to increase the Department's ability to integrate those issues into U.S. foreign policy planning. Several specific activities in population control, tropical forest management, ocean management, and environmental pollution control are summarized in the following paragraphs.

Population

The Venice Economic Summit recognized the control of population growth as a matter of high priority, and population growth has become an important issue in negotiations of the U.N. International Development Strategy. The U.S. International Development Cooperation Agency has identified population, along with food, energy, and health, as a priority area for U.S. development assistance. Population was also singled out in the Brandt Commission Report and in World Bank studies as one of the strongest forces shaping human society—and as an obstacle to world development. In addition, the Secretary of State recently expressed the desirability of increasing assistance to developing countries for population programs in the 1980s.

The United States is also seeking to expand international collaboration and funding to improve the safety, convenience, acceptability, and effectiveness of contraceptives; develop new methods of fertility control; and adapt existing methods of family planning to the particular needs of developing countries. Joint scientific workshops under bilateral science and technology agreements are planned. A workshop on contraceptive research and development is under way in India, and similar possibilities are being explored with Nigeria and Kenya. Both the National Institutes of Health and AID support biomedical research in family planning. In addition, the United States recently agreed with China to undertake joint research on population, and the Department of State sponsored a National Academy of Sciences seminar on population research in China in October 1980.

Tropical Forests

Over the past year, in part as a result of U.S. efforts in the United Nations, international awareness of the need to prevent the further loss of tropical forests has heightened, and first steps toward an international program have been taken. Fifteen U.S. Government departments and agencies constituted an Interagency Task Force on Tropical Forests, cochaired by the Department of State and the U.S. Forest Service. The National Science Foundation (NSF) and the Smithsonian Institution played a role in research, AID and the Peace Corps in development assistance, the Department of Commerce in economic analysis, the National Oceanic and Atmospheric Administration (NOAA) in monitoring, and the Departments of the Interior and Agriculture in ecological management. President Carter has asked appropriate Federal agencies to identify ways in which the United States might best respond to the program recommendations included in the report of the Task Force.

Oceans, the Seabed, and Polar Regions

At the third U.N. Conference on the Law of the Sea, agreement is near on a treaty for an international regulatory regime to govern the mining of the deep seabed, as well as the conduct of marine scientific research. An interim framework to regulate deep seabed mining until a law of the sea treaty enters into force has been established by Congress' passage in fiscal year 1980 of the Deep Seabed Hard Minerals Resources Act.

An important new agreement, the Convention on the Conservation of Antarctic Marine Living Resources, which was concluded in Canberra, Australia, on July 20, 1980, will apply an ecosystems approach to the management of shared resources. Its effective operation will require a sustained program of scientific research in Antarctic waters. Five Intergovernmental Maritime Consultative Organization (IMCO) instruments dealing with pollution, safety, and other shipping matters have been ratified. On July 24, 1980, the United States and Mexico signed a contingency agreement regarding pollution of the marine environment by hydrocarbons and other hazardous substances. That agreement parallels an existing joint contingency plan between the United States and Canada. The United States is also participating, under IMCO auspices, in the preparation of a draft treaty for a Convention on Liability and Compensation in Connection with the Carriage of Noxious and Hazardous Substances by Sea—to be considered at a conference in 1982. The Nation also continues to take the lead in the International Whaling Commission and elsewhere to protect whales and other marine mammals and is supporting a worldwide ban on commercial whaling.

Pollution and Waste Management

A number of atmospheric pollution problems transcend national borders, requiring international cooperative efforts in research and control measures. Acid rain, carbon dioxide (CO_2) accumulation, and ozone depletion are major issues, and the United States has taken an active part in dealing with each of them. The United States played a key role in developing the Convention on Long-Range Transboundary Air Pollution, which was signed by members of the Economic Commission for Europe in November 1979, and signed a Memorandum of Intent with Canada to develop an air quality agreement. In response to a U.S. initiative, the United Nations Environment Program (UNEP), World Health Organization, and International Conference of Scientific Unions met in Nairobi in February 1980 to recommend a three-step approach to handling the CO_2 build-up problem. Experts from those organizations will meet early in 1981 to develop a research plan, and a technical conference in 1981 will prepare an action plan and recommendations for international cooperation.

To reduce ozone depletion in the atmosphere, the United States has cut its chlorofluorocarbon (CFC) use in half and has proposed that worldwide CFC production be limited to 1977 levels. Prompted in part by those actions, the European Economic Community decided to cut CFC production by 30 percent in 1981. U.S. Government representatives will urge the UNEP to complete an assessment of the global CFC problem and will take the lead in the Organization for Economic Cooperation and Development (OECD) to encourage other nations to act individually and collectively to develop and implement CFC control strategies.

Hazardous Substances and Wastes

U.S. export of hazardous substances and waste materials raises difficult issues because the risks and benefits to the importing nations may be different from those in the United States due to diverse economic, social, and cultural conditions. The Carter Administration has considered a policy under which the potential recipient country would be provided with information about substances that are banned or strictly limited in the United States. The information could be used as the basis for each country to make an informed judgment on whether or not to accept the substance. U.S. foreign policy interests and whether disposal or recycling of hazardous wastes will be done in an environmentally acceptable manner by the importing country will also be given consideration.

COOPERATIVE SCIENCE AND TECHNOLOGY PROGRAMS

China

The Science and Technology Agreement signed on January 31, 1979, by Vice Premier Deng Xiaoping and President Jimmy Carter opened the way for formal cooperation between the two countries. Such cooperation already involves large numbers of scholars and scientists and has become a pillar of our new bilateral relationship. Fiscal year 1980 has witnessed a rapid expansion of protocols pursuant to that agreement. Cooperation has been launched in 14 fields: agriculture, high-energy physics, space technology, metrology and standards, atmospheric science, environmental protection, marine science and fisheries, medicine and public health, hydropower and water resource management, earthquake studies, earth sciences, academic exchanges, science and technology management, and basic sciences. Agreements in construction and urban planning, transportation, nuclear physics, and fusion research are under negotiation.

While negotiations and planning between counterpart agencies have taken up most of the first 18 months of the program, some joint work has begun. A NOAA research ship, the first U.S. ship to enter a Chinese port in 30 years, joined Chinese scientists studying Yangtze River sedimentation. DOE is participating with the Chinese in construction of a proton synchroton, and Chinese scientists are at U.S. installations learning to operate a modern accelerator. The U.S./People's Republic of China Understanding on Cooperation in Space Technology will allow the Chinese to purchase a satellite broadcasting and communications system and a Landsat ground station, and the National Aeronautics and Space Administration is studying proposals for future cooperation in both space technology and aeronautics R&D.

U.S.S.R.

As a result of the Soviet invasion of Afghanistan, the United States reduced scientific and technical exchanges under 11 joint technical agreements with the U.S.S.R. by about 75 percent during the first half of 1980. Several joint working groups and high-level, long-term planning meetings were postponed. The United States has gone ahead with some working-level cooperation in areas of direct substantive benefit to the Nation and in humanitarian fields. The Soviets have refused to renew exchanges under the Agricultural Agreement until a formal meeting of the Joint Committee on Agricultural Cooperation is convened.

Mexico

Cooperation with Mexico is provided for under a 1972 bilateral S&T agreement, agency-to-agency agreements, programs of international organizations, and informal arrangements. A railway transportation research and development project was completed in 1980. Progress has continued in commercialization of guayule, a substitute for natural rubber. Work is proceeding under the agreement on arid lands management to combat desertification in the border zone. Other activities cover energy, agricultural productivity, basic and applied sciences, industrial research, housing and urban development, wildlife conservation, and meteorological observation. The central planning and coordinating body—the Mixed Commission—meets approximately every two years to formulate, orient, and review all programs.

Latin America

The President's Science Adviser traveled to Latin America in October 1979 to discuss expanded scientific cooperation. He visited Venezuela, Brazil, Peru, and Barbados for bilateral and multilateral meetings.

In Brazil, working groups met and explored the possibilities for cooperation in industrial technology, energy, health, intergovernmental S&T, and university linkages. The key topics in Peru were basic science, agriculture, energy, industrial development, health, the environment, resource administration, geoscience, and the role of universities in infrastructure development. In meetings with Andean Pact representatives in Lima, agreement was reached to promote and assist technical contacts in agriculture, health, industrial development, forestry, energy, and food production. At the meeting in Venezuela, the two delegations devoted special attention to Venezuelan proposals for basic and applied scientific research in the fields of marine biology, neurobiology, electronics, and hydrology. The United States has agreements with Venezuela in energy, health, and agriculture, and an umbrella science and technology agreement was signed in January 1980.

The visit to Barbados was an occasion for discussions with representatives of 10 Caribbean governments and regional organizations. The United States expressed its readiness to organize NSF workshops in priority science fields, establish industrial information exchanges, assist in the development of agricultural research capabilities, and examine possibilities for providing information and expertise in health. Working groups met on science and technology policy, agriculture, basic science research, industrial technology, energy, natural resources, and health.

SCIENCE AND TECHNOLOGY FOR DEVELOPMENT

The task of applying science and technology to Third World development has two major thrusts. First, there is the immediate need to increase the amount of scientific research and technological adaptation devoted to solving critical problems in the areas of food production, nutrition, health, energy, industrialization, and other priority development areas. Second, there is the ongoing effort to strengthen the capacity of these countries to solve many of their localized problems and to generate their own supply of knowledge, skills, and manpower necessary for self-sustained social, economic, and technological growth. Because the needs and capabilities of developing countries differ substantially, particularly between middle-income and lower tier countries, different modes of assistance and collaboration are required. The United States has sought to respond to priority areas by actively supporting programs of science and technology cooperation in multilateral and bilateral arrangements.

In the multilateral program area, the U.N. Conference on Science and Technology for Development held in Vienna in August 1979 focused world attention on the need for a coordinated international effort to better use science and technology in support of development. The conference dealt with the choice of technologies and their transfer, methods for integrating science and technology into economic and social development, and the development of new science and technology to overcome obstacles to social and economic growth. One recommendation of the conference was to establish a special fund for science and technology to be administered by the United Nations Development Program. The United States initiated this proposal, and a U.S. contribution to the fund was included in the fiscal year 1981 budget request to the Congress, contingent on complementary funding being made available from the Organization of Petroleum Exporting Countries and other donors.

The United States and other donor countries also support the work of 13 international research centers under the aegis of the Consultative Group for International Agricultural Research (CGIAR). CGIAR's research and training programs are designed to produce information, materials, and scientists with the objective of increasing agricultural productivity. A similar international effort to study tropical diseases is under way. The U.N. Fund for Population Activities coordinates demographic and social research by Third World nations. Other multilateral organizations, such as the World Bank, OECD, and the United Nations Educational, Scientific, and Cultural Organization, have programs that address the full context in which economic priorities are developed, research is stimulated, and technology choices are made.

Bilateral programs are of great importance in promoting science and technology cooperation with developing countries and have become a significant component of our foreign relations. Several major presidential initiatives with Mexico, other Latin American states, and Black Africa have been particularly beneficial in this regard. Visits and negotiation of bilateral agreements have stimulated an intensification of specific cooperative S&T activities, demonstrated high-level U.S. interest in durable S&T relations, and served to deepen the understanding of the types of cooperative relationships most appropriate for the selected countries.

A good example of U.S. attention to such concerns occurred in October 1980 when the President's Science Adviser, accompanied by representatives of technical agencies, visited Nigeria, Zimbabwe, Kenya, and Senegal. The visit was intended to demonstrate U.S. commitment to cooperate with those key countries in sub-Saharan Africa.

As a result of the Science Adviser's trip, the United States and Nigeria signed an S&T agreement that will serve as the overall framework for cooperation. Activities will include scientific exchanges and fellowships, management and training in applied research, and projects in marine science, remote sensing, and environmental protection. In Kenya, a new agreement network and project initiatives funded by AID should help to meet priority needs. Under a Renewable Energy Agreement, for example, the United States will provide technical assistance to the newly formed Kenyan Ministry of Energy in an effort to develop a national energy policy for that country.

The principal result of the visit to Zimbabwe is also a scientific and technological cooperation agreement, providing for technical visits, workshops, publications procurement, and short-term training. Specific projects on agriculture, photovoltaics, regional remote sensing, and trade and development of ammonia-based synthetic fuels are planned. Expanded scientific and technical cooperation with Senegal will focus on rural satellite communications, marine fisheries research, and management of scientific research and technical information to aid in that country's development process.

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CHAPTER III

SCIENCE AND TECHNOLOGY POLICY COORDINATION

A recurring theme in this review of the Carter Administration science and technology actions and decisions is the importance of cooperation at all levels of government and between governmental agencies and the private sector. The Carter Administration has strived to strengthen the partnerships that are vital to the science and technology enterprise by encouraging all aspects of government-industry-university cooperation. Many examples of such cooperation have been described earlier in this *Report*.

There are a number of informal and formal mechanisms that facilitate coordination and cooperation between the Federal Government and the academic and industrial sectors with which it deals. For example, in developing and analyzing national science and technology policy alternatives, the Office of Science and Technology Policy (OSTP) draws on expertise from the Federal Government, State and local governments, industry, and universities throughout the country. The policy analysis process OSTP applies to major issues depends to a considerable degree on a continuing dialogue with representatives of the university and business communities and of the many scientific and technical disciplines and fields. Acting as individuals, or as ad hoc panels focused on specific, high priority issues, these individuals have proved to be an effective and flexible means of fostering cooperation and coordination among a broad spectrum of individuals and institutions.

In addition to such informal mechanisms, there are two major, formal coordinating mechanisms that have been established within OSTP. One has the mission of coordinating Federal science and technology programs, the other of interrelating Federal science and technology concerns with those of States and localities.

A. FEDERAL GOVERNMENT SCIENCE AND TECHNOLOGY COORDINATION

The Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) constitutes a flexible, ready mechanism for anticipating and defining science and technology issues confronting the government, mobilizing Federal agency reactions to these issues, and coordinating the activities and programs of the many agencies with research and development responsibilities. FCCSET is the highest level, formal, government-wide coordinating mechanism for science and technology. Its members are the chief officials for research and development (R&D) in the various agencies, with the Director of OSTP as Chairman.

The Council itself meets as appropriate to consider major policy matters of concern to all R&D agencies. Over the past year, the Council has dealt with several broad science, engineering, and technology policy issues, including:

- Federal research and development budgets;
- Industrial innovation;
- Three Mile Island;
- Radiation research policy;
- Minorities in science and engineering;
- Scientific exchanges with China, Japan, Latin America, and Africa;
- Scientific and technological assistance to developing countries; and
- Initiatives related to economic revitalization.

Interagency coordination on specific policy and program issues is achieved through topical committees made up of policy-level officials from the agencies. Special problems are handled by ad hoc groups. At present, the Council has six major standing committees, two ad hoc committees with highly focused missions and definite time schedules, and two joint subcommittees of two standing committees.

During 1980, FCCSET committees, ad hoc committees, and joint subcommittees increased and improved interagency coordination and cooperation in a number of areas. Examples include:

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1. *Atmosphere and Oceans*

During 1980, the FCCSET Committee on Atmosphere and Oceans (CAO) established subcommittees on atmospheric research, marine research, and weather modification and set up the Federal Oceanic Fleet Coordination Council to facilitate interagency attention to topics of priority interest to CAO member agencies. Substantive accomplishments during the year include: formulation of a Federal plan for weather modification research; preparation of a comprehensive 4-year report on Federal marine sciences; development of a nationally coordinated program of solar-terrestrial research; strengthening of coordination of Federal ocean engineering programs; initiation of an interagency review of plans for oceanographic research vessel construction and acquisition; compilation of a data base on the needed size and mix of the Federal oceanographic fleet; and establishment of a mechanism to provide convenient information to agencies about unused oceanographic research vessel time.

2. *Health and Medicine*

Over the past year, the Committee on Health and Medicine has provided a forum for member agencies to consider such issues as Federal guidelines for recombinant DNA research; Federal support and conduct of health services research; the conduct and coordination of Federal radiation research; and coordination of Federal support for germ plasm resources. Specifically, the committee critiqued the Department of Health and Human Services health research plan; organized interagency attention to policies governing disclosure of research information under the Freedom of Information Act; developed a position on continuation of overseas medical research laboratories funded by the Department of Defense; coordinated an interagency review of research cost and accountability issues; and organized agency contributions to the health research sections of this *Report* and the second *Five-Year Outlook* on science and technology (to be published).

3. *Food and Renewable Resources*

During 1980, the Committee on Food and Renewable Resources considered a wide range of policy issues related to the food and agricultural sciences and to research on renewable resources, including: Federal budgets for research and development on food, agriculture, and renewable resources; research and regulatory issues related to radiation preservation of food; Federal research programs on acid rain; food loss; methods of recovering food waste from food service installations; and biomass conversion as a source of energy.

4. *International Science, Engineering, and Technology*

During 1980, the Committee on International Science, Engineering, and Technology organized its activities primarily around implementation of Title V of Public Law 95-426 ("Science, Technology, and American Diplomacy"), which mandates increased and improved coordination of Federal international scientific and technological activities. Through three working groups established to look, in particular, at the reporting, informational, budgetary, and personnel aspects of Title V, the committee played a major role in the preparation of the 1980 report to the Congress on Science, Technology, and U.S. Foreign Policy. In addition, the committee initiated a major effort to upgrade U.S. participation in the Committee for Scientific and Technological Policy of the Organization for Economic Cooperation and Development (OECD).

5. *Ocean Pollution*

During the past year, the Committee on Ocean Pollution Research, Development, and Monitoring prepared a detailed inventory of existing Federal and non-Federal ocean pollution programs, assessed and ordered regional and national needs and priorities, analyzed the extent to which existing programs assist in meeting those priorities, and made recommendations for changes in the overall Federal ocean pollution effort where necessary. Specifically, the committee undertook several activities to develop the second Federal ocean pollution plan, including: the second interagency workshop on in situ water quality sensing, five regional conferences on marine pollution, and four conferences on petroleum pollution problems. The second Federal plan is scheduled to be submitted to the President and the Congress in September of 1981.

6. *Materials*

The FCCSET Committee on Materials was established during 1980 to identify key points of emphasis for Federal materials research, resource development, and utilization within the context of the total materials system in the U.S. economy. The Committee's purposes are to: review national needs for materials research, development, transfer, and assistance; assess the effectiveness and adequacy of Federal efforts to meet those needs; and plan, coordinate, and initiate communication among Federal agencies engaged in materials research.

7. *Automotive Research and Development*

The FCCSET Ad Hoc Committee on Automotive Research and Development completed its planned one year of intensive work in July 1980. The purpose of the ad hoc committee was to provide policy review for the program plan of the Cooperative Automotive Research Program. By reviewing the plan from its interagency perspective, the ad hoc committee contributed to the development of the program's administrative and technical frameworks, assisted in the definition of appropriate Federal agency roles and interagency relationships, and provided fiscal information on which the overall program budget is based.

8. *Science and Technical Information Policy*

During 1980, the work of the FCCSET Ad Hoc Committee on Science and Technical Information Policy focused on strengthening government-private sector cooperation in providing information services. Specifically, a working group of the committee guided contractor assessment of: (1) agency arrangements with the private sector; (2) the comparative costs of Federal-private sector services; and (3) Federal-private arrangements for information products compared with those for other goods and services. In addition, the ad hoc committee helped effect the transfer of the functions of the Smithsonian Science Information Exchange to the Department of Commerce, critiqued a draft Office of Management and Budget (OMB) circular on information policy, and worked with OMB to help shape legislation that strengthens OMB information policy activities.

9. *Nutrition*

During 1980, the FCCSET Joint Subcommittee on Human Nutrition Research strengthened Federal human nutrition research programs by publishing a major comprehensive report entitled "Federally Supported Human Nutrition Research, Training, and Education; Update for the 1980s (I. Human Nutrition Research Training)." This report begins by presenting, for the first time, a definition of human nutrition research accepted by Federal nutrition research agencies. Based on this definition, the report then presents an overview of the Federal human nutrition research effort, reviews the legislative authorities of departments and agencies in this area, reviews interagency coordinating mechanisms, identifies critical issues in human nutrition research, and presents specific conclusions and recommendations. Work began on future sections of this major report dealing with nutrition education and international research efforts.

10. *Aquaculture*

During 1980, the FCCSET Joint Subcommittee on Aquaculture continued its efforts to strengthen the overall Federal effort related to aquaculture. Specifically, the joint subcommittee completed preparation of Phase I of a National Aquaculture Plan, initiated contracts for studies on the financial and regulatory constraints on the development of commercial aquaculture in this country; helped to establish an interagency cooperative effort that collects statistical information on U.S. freshwater and marine private aquaculture; supported a scientific article translation service; and cooperated with House and Senate congressional staff on the development, passage, and eventual signing by President Carter of the National Aquaculture Act of 1980.

B. INTERGOVERNMENTAL COORDINATION OF SCIENCE AND TECHNOLOGY

An important science and technology coordinating mechanism linking State and local governments to the Federal science and technology policy structure is the Intergovernmental Science, Engineering, and Technology Advisory Panel (ISETAP), currently co-chaired by Dr. Frank Press, Director of OSTP, and Governor James Hunt of North Carolina. The Panel is composed of State and local government officials as well as the Directors of OSTP and the National Science Foundation (NSF). ISETAP assists the Director of OSTP in: (1) identifying and defining civilian problems at State, regional, and local levels which science, engineering, and technology may help solve; (2) recommending priority approaches for solving such problems; and (3) identifying policies to facilitate the transfer and use of R&D results to maximize their application to civilian needs.

The most important part of ISETAP's work in recent years has been the identification and definition of priority State and local problems that are amenable to solution by federally sponsored research. ISETAP task forces selected 3 or 4 priority problems in each of 10 functional areas to focus on initially; these are listed in Table 3. The American

TABLE 3. ISETAP Functional Areas and Priority Problems

Energy

1. Energy and Resource Recovery from Solid Waste
2. Alternative Energy Sources

Community and Economic Development

1. Neighborhood Preservation, Including Residential Abandonment and Role of Local Business in Neighborhood Stability
2. Policy Analysis Tools for Evaluating Alternative Growth Patterns
3. Retention of Central City Business
4. Urban Recreation Area Standards

Health

1. Alternatives to Institutionalization for Care of the Aged and Other Chronically Disabled Persons
2. Comprehensive Health Screening Services
3. Health Care Cost Control
4. Restructuring of Efforts to Foster a Healthy Lifestyle

Environment

1. Non-nuclear Toxic and Hazardous Materials
2. Water Management/Land Applications of Wastewater

Management, Finance, and Personnel

1. Fiscal Forecasting and Policy Analysis
2. Information Processing
3. Effectiveness and Productivity Measurement
4. Financial Accounting and Reporting

Human Services

1. Evaluation Methodology and Criteria
2. Integrated Social Services Delivery System
3. Research on Services to the Elderly, Including Transportation, Housing, and Alternatives to Retirement

Public Works and Public Utilities

1. Sewer System Rehabilitation
2. Project Control
3. Extending Life of Fleet Vehicles
4. Noncorrosive Methods of Ice Control

Fire Safety and Disaster Preparedness

1. Evaluation of Fire Prevention and Suppression Management
2. Causes and Prevention of Injuries and Disability Among Firefighters
3. Public Awareness of Fire Hazards
4. Disaster Preparation Planning

Transportation

1. Transit System Productivity
2. Transportation Planning and Impact Forecasting Tools
3. Small Community Mass Transit Systems
4. Integration of Paratransit with Conventional Transit
5. Road/Bridge Construction and Maintenance (including permanent winter repair materials)
6. Transportation Financing

Police and Criminal Justice

1. Better Use of Police Personnel
2. Police Effectiveness and Efficiency
3. Improvement of Court Systems
4. Police Vehicles
5. Comprehensive Crime Prevention Program

Association for the Advancement of Science (AAAS), under an NSF contract, has conducted a series of workshops devoted to the ISETAP priority problems. The workshops examined these problems to identify knowledge gaps, to determine existing knowledge that should be disseminated, to suggest technology transfer mechanisms suitable to these problems, and to recommend areas in which new R&D or technology transfer efforts are needed. So far, 9 of the 10 functional areas have been covered in workshops. (The workshop on Police and Criminal Justice has not yet been held.) Dr. Press formally transmitted the AAAS workshop reports and recommendations to agency policy officials in April 1980.

With substantial completion of the first phase of the ISETAP problem identification process, greater emphasis is being placed on actively disseminating the findings to Federal agencies and State and local governments. Even at this early stage, some positive responses can be identified. Several agencies (including the Administration on Aging in the Department of Health and Human Services, the Federal Highway Administration in the Department of Transportation, the Economic Development Administration in the Department of Commerce, and the U.S. Fire Administration in the Federal Emergency Management Agency) have already used the workshop results to shape their current and future research agendas and to focus new dissemination activities. ISETAP task forces continue to meet with Federal agency officials to discuss the findings, recommendations, and other agency responses.

Steps are under way in OSTP and OMB to coordinate the ISETAP findings and recommendations with the overall Federal R&D planning and budgeting cycle. In May 1980, a joint White House/OSTP/OMB memorandum was issued to the heads of all agencies and departments in the executive branch. Each agency and department was asked to respond: (1) by listing those R&D programs that are expected to substantially affect State and local governments, (2) by identifying new or high-priority continuing programs of that nature, and (3) by describing the processes by which State and local governments were consulted in the formulation of those R&D programs. The new program identification and consultation process is being evaluated concurrently with the fiscal year 1982 budget cycle.

In January 1980, ISETAP recommended that an assessment of the present status of Federal activities in intergovernmental science and technology be undertaken. That broad assessment has been initiated in a cooperative effort by NSF and AAAS.

ISETAP has already found that regional technology exhibitions and expositions are effective means for building awareness of potential benefits of technological innovations. Based on this finding, ISETAP is encouraging Federal, State, and local officials to conduct, participate in, and support regional technology expositions. Another tangible result of ISETAP activities came from a task force study of the potential uses and benefits to State and local governments of the Landsat satellite systems. The recommendations of that study were instrumental in President Carter's decision to guarantee the continuity and availability of remotely sensed Earth resource data through the 1980s.

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SUPPLEMENT TO ANNUAL SCIENCE AND TECHNOLOGY REPORT TO THE CONGRESS—1980

SCIENCE AND TECHNOLOGY POLICY ISSUES AND DEVELOPMENTS*

*The opinions expressed by the authors named as contributors to this supplement are their own and do not necessarily reflect the views of the National Science Foundation or the U.S. Government.

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CHAPTER I

ISSUE DEFINITION BRIEFS: EMERGING POLICY ISSUES IN SCIENCE AND TECHNOLOGY

A. INTRODUCTION

Chapter I consists of a set of six issue definition briefs written by individual specialists who explore policy problems associated with emerging developments in science and technology. None of the six issue briefs provides a detailed analysis of policy issues, nor do they weigh the advantages and disadvantages of possible policy options. Rather, each is intended to identify significant national issues that are likely to emerge in the near future, and to stimulate discussion about them among policymakers and the general public. While these briefs have been reviewed for technical accuracy, the views and perspectives they express are those of their authors and do not necessarily reflect the policy of the National Science Foundation or of the U.S. Government.

The topics for the six issue definition briefs were selected by the National Science Foundation, in consultation with the Office of Science and Technology Policy. The briefs illuminate selected policy problems in three of the categories that the Director of the National Science Foundation identified as particularly significant in his overview for the first *Five-Year Outlook* on science and technology: (1) ensuring the continued vitality of the Nation's scientific and technological base; (2) ensuring adequate supplies of energy and nonrenewable resources; and (3) contributing to improvements in health.

ENSURING THE CONTINUED VITALITY OF THE NATION'S SCIENCE AND TECHNOLOGY BASE

The first two issue definition briefs are concerned with the ability of U.S. universities to continue to serve as centers for quality scientific research activity and to provide adequate education for sufficient numbers of scientists and engineers to meet the Nation's long-term needs.[1]

"The Consequences of Limited University Growth" reviews some of the problems that American universities are facing, as scientific research institutions, in adjusting to the era of limited growth that began in the 1970s and is likely to persist into the 1990s. These problems have resulted from the leveling off or decline of undergraduate and postgraduate enrollments in most scientific (although not in engineering) fields, low retirement rates among tenured faculty, and steadily rising costs of maintaining and replacing obsolete research apparatus. The authors suggest that a continuation of these trends could lead to a further centralization of quality research facilities in a relatively small number of premier universities, thus creating particular problems for second- and third-tier institutions. They call for better long-range science policy planning, involving government, industry, and universities, to ensure the continued viability of universities as a necessary component of the Nation's scientific base.

University engineering and computer departments, unlike most departments of science, have been experiencing increases in undergraduate enrollments and, simultaneously, increases in the number of faculty vacancies. In addition, many of these departments suffer from obsolete facilities for both research and teaching purposes. These problems are discussed in an issue definition brief entitled "Recent Trends in the Education of Scientists and Engineers," which summarizes the principal findings of a 1980 report prepared by the Secretary of Education and the Director of the National Science Foundation.[2] The best available personnel projections indicate sufficient numbers of scientists and engineers in most fields and at all degree levels to satisfy demands for their services by 1990. Those projections are based, however, on the assumption that engineering colleges will maintain their capacity to offer adequate education to all qualified applicants, an assumption that may not be valid if current faculty shortages and facilities restrictions persist. The paper reviews policy issues associated with various modes of

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direct and indirect Federal support for the education of scientists and engineers. It argues that whereas direct Federal support is probably justified and required to solve immediate, urgent problems, the most appropriate long-term Federal role would be to catalyze more effective university-industry cooperation.

ENSURING ADEQUATE SUPPLIES OF ENERGY AND NONRENEWABLE RESOURCES

Biomass conversion could be one of the first forms of solar energy to provide a commercially viable alternative to oil, natural gas, and coal as an energy source.[3] Extensive use of biomass would, however, have significant implications for agricultural policy, since it could lead to land degradation and competition between food and fuel crops. An issue definition brief entitled "The Use of Biomass as an Energy Source" reviews the present scientific and technological base underlying efforts to increase the commercial use of biomass, and it identifies and discusses some associated policy issues, particularly those related to agriculture. The author argues that despite passage of the Energy Security Act of 1980, a clear Federal role in the commercial development of biomass as an energy source has yet to emerge.

During the past decade, experimental remote sensing satellites and their associated ground stations have proved to be invaluable tools for obtaining detailed information about Earth's renewable and mineral resources, atmosphere, and oceans. As a result, the United States is now committed to developing a fully operational remote sensing system, with involvement of private industry as a firm goal.[4] A paper entitled "Public Policy Implications of Satellite Remote Sensing Applications" reviews recent policy decisions in this area and points to a number of unresolved issues. The issues include the nature of private sector involvement, the role of users in determining system operations and policies, and problems associated with international aspects of remote sensing systems. The author notes that the resolution of many of the policy problems will depend on still uncertain institutional and technological developments that are likely to occur during the 1980s.

CONTRIBUTING TO IMPROVEMENTS IN HEALTH

Recent investigations in neurobiology have led to an enormous increase in information about the human nervous system and its disorders.[5] One of the most significant of the new developments is the discovery of a variety of psychotropic drugs, the effectiveness of which in the treatment of major mental disorders has now been established beyond reasonable doubt. Their use has transformed the structure of service delivery, altered treatment expectations and strategies, and led to new programs in both basic and applied research. The issue definition brief entitled "Mental Health Policy Implications of Scientific Research on Drugs" identifies several policy issues associated with the further development and use of psychotropic drugs. It recommends support for a wide spectrum of research strategies (ranging from genetic to epidemiological), a more active Federal role in new drug development, and a reconsideration of the thrust of community service programs for the chronically ill. The authors consider the organization of Federal funding for psychiatric research, questioning whether both research and patient care in the field of mental health should remain the responsibility of the same agency.

The importance to health of environmental and behavioral factors, controlled by individuals, is receiving increased attention in Federal health care planning[6] and is also the province of the new interdisciplinary field of behavioral medicine. "The Role of Stress in Physical and Mental Health and Disease" reviews the current state of scientific knowledge about the relationships between stress and both mental and physical illness. It suggests steps that could be taken by the Federal Government and by private industries, such as insurance companies, to encourage more people to take greater responsibility for their own health.

References

[1] Recent Federal decisions, actions, and program initiatives associated with this topic are described in the body of this *Report* in sections I-A, B, and C, and II-F and K.

[2] *Science and Engineering Education for the 1980s and Beyond.* Washington, D.C.: National Science Foundation, October 1980. NSF 80-78.

[3] Recent Federal decisions, actions, and program initiatives are discussed in sections I-D and II-E in the body of this *Report.*

[4] Recent Federal decisions, actions, and program initiatives associated with remote sensing are described in sections II-C and G in the body of this *Report* and in *Science and Technology: Annual Report to the Congress* (June 1980), pp. 9, 21.

[5] Recent related Federal program initiatives are described in section II-D in the body of this *Report.*

[6] See section II-D in the body of this *Report.*

B. THE CONSEQUENCES OF LIMITED UNIVERSITY GROWTH

by

Albert H. Teich*
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ABSTRACT

American universities have entered into an era of limited growth, with student enrollments likely to level off or decline during the mid-1980s and Federal research funding unlikely to show much real growth for the next several years. Public resistance to ever higher taxes is causing problems for State universities, while private universities are suffering from a decline in the value of their endowments. The need to adjust to these difficult situations will be a dominant fact of university life during the 1980s. It will impact on all parts of the university, but on some fields more than others. Basic science areas, more than those associated with engineering and medical research, will be more strongly affected owing to their greater distance from tangible outputs. Several consequences will be particularly important.

Declining enrollments and low retirement rates among existing tenured faculty will create a shortage of new faculty positions in many fields. Aside from posing an employment problem for new Ph.D.'s, this situation threatens the vitality of the academic research enterprise, since young faculty play a key role in the diffusion of new approaches and methodologies and in challenging the accepted doctrines of their fields.

This problem, and others resulting from limited university growth, will not affect all universities in the same way. The existing concentration of research resources among a relatively small number of institutions is likely to be reinforced, and efforts to distribute research funds and graduate student support more equitably will be harder to implement. The result may be a "shaking out" of weaker second- and third-tier universities, which some observers feel might be useful for the system as a whole, but which also is bound to be difficult and wasteful for those in the less favored institutions.

Academic research and graduate science education, long considered as two sides of the same coin in U.S. universities, may find their paths increasingly divergent. Universities that desire to maintain vigorous research efforts but find their enrollments dwindling may choose to develop a larger role for organized research units outside of academic departments and a step removed from the teaching function. Hard-pressed second-tier universities may find faculty research efforts conflict with demands for greater productivity in undergraduate teaching.

The costly technological revolution that has been taking place in scientific instrumentation will put additional pressures on universities in a limited growth environment. Approaches involving sharing of instrumentation among several universities are already being tried out as a remedy. Industrial firms may also play a role in such arrangements.

The problems posed by limited growth are embedded in a larger matrix of problems facing universities today. Several commissions and other bodies representing the needs and interests of the university community have studied the situation and made recommendations for dealing with such aspects as the new faculty problem and the need for upgrading instrumentation. It is hoped that an increased emphasis on long-range planning in national science policy will provide a framework for dealing with the situation.

INTRODUCTION

Following a prolonged period of expansion in student enrollments and Federal research funding, American universities have entered an era of limited growth. Demographic data suggest that enrollments will level off or even decline somewhat during the mid-1980s (1). In the face of overall budgetary stringency and a generally unfavorable economic outlook, Federal funding of university research is unlikely to show much real growth during the next several years. The "taxpayer revolt" threatens some publicly supported State universities, and the decline in endowment values further diminishes the base of support for some universities. The need to adjust to such difficult situations will be a dominant fact of college and university life during the 1980s. While all parts of a university will be affected, the basic science departments, rather than the professional schools, are likely to be affected most severely. This paper examines a number of the key issues that are likely to arise as consequences of limited university growth for basic science fields and assesses the policy outlook with respect to those issues.

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"THE NEW FACULTY PROBLEM"

University requirements for teaching faculty are strongly dependent on student enrollment levels. If enrollments decline, as seems likely, universities will seek to limit the growth of their faculties and, in some cases, cut them back. That, of course, will tend to reduce the number of academic positions available to recent Ph.D.'s. What makes the situation even more problematical is that the cessation of growth follows the rapid expansion of faculties during the 1950s and 1960s. As a number of observers have pointed out, the rapid expansion has produced a "bulge" in the middle of the age distribution of tenured faculties in many universities. Thus many faculties have a relatively large proportion of members in their late 30s and 40s and a relatively small proportion nearing retirement. In some fields (e.g., mathematics) the problem appears worse than in others (e.g., agriculture). The young or new faculty problem may not apply so strongly in engineering, where industry is providing strong competition for recent graduates. In general, however, in the affected fields, low retirement rates will persist through the 1980s, exacerbating the shortage of positions for new faculty caused by declining enrollments (2).

This "new faculty problem" has two sets of consequences. On one side, it will create a sharply reduced demand for new science Ph.D.'s in what has traditionally been their most important sector of employment. This means that graduate programs in many scientific fields either will have to cut back their enrollments even further as students become more aware of the limited job prospects in those fields, or they will have to adapt themselves to training a larger share of their students for non-academic positions.

On the other side, the lack of academic opportunities for new scientists can pose a serious threat to the overall vitality of the research enterprise in American universities. A recent National Academy of Sciences report points out the far-reachinig contribution of such investigators:

> ...young researchers are indeed of great importance to the effective functioning of university science, not because of higher productivity associated with youth per se, but because there are certain roles and tasks in the university research process which young scientists are especially likely to perform. The special relations of young faculty to innovation in research topics and to the spread and implantation of new ideas and techniques are crucial to the academic research effort.... (2; p. 55)

It is the new faculty members who are expected to initiate research in novel areas in which they can make their reputations, who bring with them original approaches and methodologies and, in many cases, introduce them to their more senior colleagues, and who, through their risk-taking and competitiveness, push forward the frontiers of their fields. Thus, the new faculty problem leads to a diminution of the pool of creative new scientific investigators, most of whom would ordinarily look to universities for employment. Unless the number of alternative jobs, not faculty based, can be expanded, there will be no place for potential new investigators to go, and there will be fewer and fewer new investigators coming into the system as a result.

STRATIFICATION AMONG UNIVERSITIES

The pressures resulting from growth limitations are not going to be distributed uniformly among American universities. Indeed, the concentration of Federal research support among a relatively small number of institutions and the stratification by quality, prestige, and resources among graduate departments—both of which have been characteristics of the academic research system over the past several decades—are likely to be reinforced, and efforts to make the system more equitable will be increasingly difficult to implement.

Approximately 40 percent of all Federal research and development (R&D) funds to universities goes to the 20 largest recipients. Roughly 85 percent goes to the top 100 institutions (3). These figures have remained more or less constant over the past two decades, not as a result of a conscious policy, but primarily as "an after-the-fact consequence of thousands of independent decisions on the merits of individual research proposals" (4; p. 86). While the system might be considered elitist in character, most observers of science policy feel that concentration of resources serves an important purpose for scientific progress. In the words of the recent report of the Sloan Commission on Government and Higher Education:

> A relatively small number of highly talented individuals can make important contributions and, in each discipline, tend to assemble in a few departments so that they can work together. The distribution of funds thus reflects the distribution of scientific and scholarly talent and is in turn a consequence of the way research is naturally carried on. (5; p. 28)

Nonetheless, considerations of geographical and institutional equity are important to those Federal agencies that fund university research and that are concerned with the overall welfare of graduate education. Equity considerations are also important to those institutions that would like to upgrade their status and to the various regions of the country that would benefit from such upgrading. During the period of expansion in the 1960s, a variety of initiatives, such as the National Aeronautics and Space Administration's Sustaining University Program, the Department of Defense's Project Themis, and the National Science Foundation's (NSF) Science Development Program, were undertaken by the Federal Government to foster development of new "centers of excellence" among universities, and a considerable number of second- and third-tier campuses asserted ambitions of entering the first tier.

The constraints on university growth in coming years are likely to fall particularly hard on the second-tier universities. The "age bulge" among tenured faculty seems likely to be especially severe among those universities that expanded rapidly during the 1950s and 1960s. More intense competition for research funding will likely favor established first rank universities at the expense of others. A declining job market for Ph.D.'s may make it more difficult for second-tier universities to attract quality graduate students, which, in turn, may reduce the research productivity of faculty members in those universities and further depress the vitality of their research environments. Financial pressures resulting from rising costs and declining enrollments will be severe in second-tier universities and increase pressures on faculty members to increase their teaching loads, leaving less time and energy for research. This kind of process is already producing increased stratification among universities (6). Second-tier private universities seem to be under particularly intense pressure. However, publicly supported State universities—in an era of taxpayer revolt and "Proposition 13" attitudes—are also subject to financial stresses.

There are those who feel that a "shaking out" of weaker second- and third-tier universities is not necessarily bad for our national research system as a whole. Rather, it is a form of institutional "survival of the fittest" which will lead to overall strengthening of the system. As Dael Wolfe has pointed out:

> The country does not need as many universities emphasizing research and graduate education as aspired to that status a decade ago, or perhaps as it has now. . . . If we can be confident that the right universities will survive the competition so that readjustment leads to an appropriately sized and nationally distributed system of strong research universities, that will be a desirable outcome. (7; p. 56)

Still, the process is certainly painful and wasteful of the significant talent contained in the less favored institutions. And, as Wolfe notes, there are questions as to whether the "right" universities will survive, or whether the survivors will simply be those universities that are publicly supported by relatively affluent States or have significant private endowments.

CHANGING RELATIONS BETWEEN RESEARCH AND EDUCATION

One consequence of limited university growth may be a schism, or at least a divergence, between education and research. Traditionally, academic research and graduate science education have been viewed as two sides of the same coin. The professor who taught also did research; the graduate student not only learned in the classroom, but also served an apprenticeship in science as an assistant on a professor's research project. The research and education functions of the university worked hand in hand, one strengthening the other.

In an era of declining student enrollments, some universities may choose to expand their research efforts or deal with the new faculty problem by fostering the growth of organized research units (ORUs) rather than traditional academic departments. The Massachusetts Institute of Technology, the University of California at Berkeley, and other universities have large entities of this kind. Research in ORUs staffed with nonfaculty doctoral researchers is not limited by constraints on faculty growth. One result, however, may be that the synergism between research and education is weakened. The ambiguous status of nonfaculty researchers, who hold qualifications similar to those of faculty members but do not receive faculty rank or perquisites and are not eligible for tenure, may also pose problems for universities (8,9). In any case, such an approach might produce a divergence between academic research and graduate education.

At the same time, one can see instances where educational demands become so great that the professor finds it difficult to carry out his or her research plans. As financially pressed university administrators seek evidence of faculty productivity, they look to ever larger numbers in hours, courses, and students taught. They create a situation in which there is little time for anything other than teaching. There is thus, in some institutions, teaching without research.

A potential divergence between graduate education and research would be a regrettable consequence of limited university growth. The cases in which it results from educational pressures are more likely to occur at second-tier institutions. The cases where it results from growth of research in ORUs may occur in some of the more prestigious universities.

SHARING FRONTIER INSTRUMENTATION

Another problem that universities are having to face is the cost of the sophisticated instrumentation in such areas as nuclear magnetic resonance spectroscopy and laser spectroscopy. This would be a problem under any circumstances, but conditions of limited growth will make it especially difficult.

Science is undergoing a technological revolution in instrumentation. New technologies are permitting scientists to perform traditional measurements with ever greater precision. They are also allowing scientists to carry out experiments that were not possible before the new instruments became available. Chemistry, biology, and engineering research, in particular, are taking on characteristics of "big science." Problems of resource allocation formerly seen only in physics and astronomy are now arising in other sciences. There is some question whether researchers without the latest equipment can do research on the frontiers of their disciplines (10).

How much money should go to instrumentation rather than personnel? How should instrumentation be allocated? Since much instrumentation is very costly, not every university can afford such tools; nor can government afford to supply every university with needed instrumentation. Regional sharing of instrumentation in specific centers is one answer, and NSF is experimenting with such a solution. Is regular sharing the best answer to the problem? What are some alternatives? How does the government assure equitable access to instrumentation on the part of many universities when the instrumentation is placed on one campus? Also, given Federal interest in encouraging university-industry interaction for industrial innovation, it can be argued that industry should be involved in instrument-sharing arrangements, along with universities. But the proprietary interests of industry may conflict with traditional academic values. Doing optimal science in an era of limited growth is going to propel to the forefront issues of joint arrangements among universities, industry, and government. These issues may surface most immediately and concretely around the question of frontier instrumentation—who should use such instruments and under what conditions.

POLICY PERSPECTIVES

Concern about the consequences of limited university growth has been voiced by various science policy observers since the mid-1970s. A number of initiatives have been proposed, primarily by spokesmen for the academic science community. The Carter Administration has offered several proposals, but Congress has yet to display much interest in the subject.

Overall, the problems posed by limited growth are embedded in a larger matrix of problems facing universities today. The problems are multifaceted and have a variety of causes and possible remedies. Some relate to demographic trends, variations in regional growth, and basic attitudes in our culture about the value of pure research and graduate education. Others can be traced, at least in part, to Federal relations and thus can be amenable to Federal policy solutions. These include: accountability for the expenditure of public funds, tension between short- and long-range objectives in support of research, questions about the project system of supporting research, disagreements over indirect costs, conflicts over social controls and government regulation, and public participation in decisionmaking on university research (4; pp. 93-97). Dealing with these issues is difficult since, in practice, discussions of limited university growth and proposals for coping with its consequences are not readily separable from discussions and proposals devoted to other university problems. The policy perspectives noted here, therefore, are but one slice through a larger complex of issues.

Ideally, issues might be classified in terms of scale and responsibility. Some issues are of such a scale that they are best handled within the university per se. They are fundamentally matters of academic policy, such as tenure versus nontenure academic slots. Others fall at an intermediate scale and reflect problems of particular States or regions. The "service" role of universities in aiding regional development, for example, might be dealt with best as a State or regional problem. Policy issues, thus, are not necessarily Federal policy issues. Those that should be so classified appear to fall in a category of those that are national in scope and of longest range significance. Certainly, those pertaining to the overall supply of new scientists, stratification among universities, and the appropriate allocation and sharing of very expensive, and very limited, state-of-the-art equipment can be considered national problems. They all relate to an overarching public interest in preserving the health of the scientific enterprise. They include a concern for the institutional base of that enterprise, namely the university, and the consequent ties between research and teaching.

With respect to the new faculty problem, a number of proposals have been advanced. A favored approach is the establishment of fellowship or awards programs for young scientists. The so-called "Seven Springs Report" from the presidents of 15 major research universities called for a program of unrestricted, portable 5- to 7-year awards to "unusually promising younger scientists," as well as an analogous program for established researchers (11; p. 50). The Sloan Commission recommended a Federal expenditure of $100 million per year for a program of 1,000 competitive post-doctoral fellowships and 300 5-year "national research fellowships" (5; p. 30). The National Academy of Sciences Committee on Continuity in Academic Research Performance proposed a more modest "research excellence awards program" for promising younger scientists "to help academic science adapt with maximum effectiveness to the conditions of reduced growth of the 80's and 90's" (2; p. 134).

None of the fellowship proposals has been adopted by either the Carter Administration or the Congress, and there have been few indications of serious interest in them within the government or of broad-based support for them in the scientific community. The somewhat elitist cast the proposals share may be one factor inhibiting interest in them. Another difficulty is the fact that the amount of discretion for the researcher implied in such fellowship programs—however meritorious it may be in itself—runs counter to the prevailing pressures to enhance accountability in research. NSF, however, has indicated that it is reserving a certain share of funds in several basic research programs for young investigators.

Possibly there will be a need to be more attentive to marrying an old idea with the new need. We refer here to the notion of "block" grants to selected universities which would then select new Ph.D.'s for awards. Grants could be awarded on a competitive basis among universities within the various regions of the country. Such a mode of distribution would get away from the "elitism" problem facing most of the suggestions for dealing with the new faculty problem. It would also convey the possibility of strengthening universities as institutions—another important aspect of the overall concerns with which we are dealing. The danger of such a course, as is obvious, is that an effort to combine institutional support with solutions to the new faculty problem can lead to a scattering of funds in such a way as to dilute any measurable effect on either front.

Other proposals for maintaining the vitality of academic science in a limited growth environment have focused on the possible establishment of new national research centers within or adjacent to universities (12,13). Such centers would facilitate the kind of mobility for scientists that is said to be so essential for academic science. However, no concrete programs for the establishment of such centers have been developed yet.

Calls for Federal assistance to universities in upgrading scientific instrumentation and laboratory facilities have been somewhat more fruitful. The Sloan Commission and the Seven Springs Report recommended allocation of Federal funds to these purposes, and Smith and Karlesky's study also stressed the problem (5,11,6). A recent study by the Association of American Universities has examined the problem in depth (10). R&D budgets of key Federal agencies, especially NSF, have included increased allocations for instrumentation in universities. A major new program in regional instrumentation has been established by NSF. A $14 million NSF initiative for university research facility improvement in the original fiscal year 1981 budget was eliminated in the March 1980 budget revisions, however.

Relatively little has been said about the delicate matter of stratification among universities. Smith and Karlesky's study (6) pointed it out as an emerging trend and recommended that concerned agencies monitor it carefully. The Seven Springs Report took note of political pressures toward equity and countered with its authors' belief that "the highest-quality programs in all fields of graduate study should be strengthened and maintained, without reference to their geographical distribution, . . . or any such factors that influenced policy during the decades of growth." (11; p. 70) The impact of that perspective was probably diminished by the fact that it was voiced by the presidents of 15 highly prestigious research universities. In any case, no significant programmatic initiatives aimed at either encouraging or inhibiting stratification among universities appear to have emerged.

Issues related to limited university growth have appeared on other policy agendas and some actions have been taken. When, for example, several years ago Congress was considering legislation to raise the mandatory retirement age for employees from 65 to 70 years, university officials became concerned about the impact of extended faculty service on the young faculty situation. While it was unable to obtain an exemption for faculty, the university community did succeed in delaying for several years the effective date of the law's application to faculty. Thus, the effects of increasing faculty retirement age are uncertain at this time.

In a somewhat different vein, the notion of a Federal role in enhancing university-industry cooperation is receiving considerable attention in Washington—for example, in connection with S. 1250, the Industrial Innovation Bill, and in relation to Carter Administration programs recommended in the President's Industrial Innovation Initiatives and contained in the fiscal year 1981 budget request. While these plans were motivated primarily by a desire to increase the rate of industrial innovation, they will have the effect of providing universities with additional research resources.

Probably the major reason that the consequences of limited university growth have not received more direct attention in the policy process is that few decisionmakers outside the university community seem willing to concede that there is a problem that is worthy of national (i.e., Federal) attention. There is some disagreement about enrollment projections and budget expectations, but even among those who share a pessimistic view of enrollments and budgets, the notion that a critical situation with potentially important national implications deserving of priority Federal Government attention exists is not generally accepted. The real dangers appear to be in the future, and today's situation is not palpably urgent to those outside the system.

The cries of alarm about the issue have come not from the second-tier universities that are likely to suffer most, but from the first-tier institutions, who may suffer less, but who view their own continued well-being as essential to the Nation's welfare. That identity of interests between the elite universities and the future well-being of the country may well exist—but with direct evidence of the situation ambiguous at best, and so many competing claims on the national purse, it is a difficult case to make.

At a minimum, there appears to be a requirement for more long-range planning with respect to academic science. All the issues raised here—new faculty, stratification, the relation between education and research, and instrumentation—are real and will likely become more pressing in the 1980s. Whether or not they constitute a present crisis, they certainly can be said to represent problems that are going to become more serious in the future. They are problems whose solutions will necessitate careful attention to matters of excellence and equity. In the long run, these two values may be made compatible. In the short run, there are bound to be conflicts. Resolving such conflicts can be left to chance and the interplay of power within and between universities, or their outcome can be affected by long-range planning in the framework of national science policy. The need to decide how much planning and Federal involvement is enough may well be the most important implication of limited university growth.

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C. RECENT TRENDS IN THE EDUCATION OF SCIENTISTS AND ENGINEERS

by

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ABSTRACT

There are four critical problems associated with science and engineering education and future personnel needs: (1) inadequate numbers of new graduates at all degree levels in the computer professions, most engineering specialties, and a few subspecialties in the physical and biological sciences; (2) the likely persistence of shortages of computer professionals and engineers with advanced degrees in several critical specialties; (3) severe shortages of qualified faculty in university engineering and computer departments; and (4) obsolete university research facilities in several science and engineering specialties, as well as obsolete teaching equipment in university engineering and computer departments. The success of technology-related enterprise also depends on the quality of available technicians. However, the data base to assess the adequacy of technician training for technology-intensive industry is presently inadequate.

The Federal Government could help resolve some of the problems associated with science and engineering education by means of fellowship and traineeship programs in fields where the persistence of personnel shortages will hamper the achievement of critical national goals, and by providing equipment purchase grants. It could also use existing grant and contract mechanisms to enhance research support for faculty and graduate students, thus strengthening, indirectly, the instructional capabilities of the U.S. science and engineering education system. The most effective long-term Federal role, however, would be to provide incentives for more active industry-university cooperation. In addition, the Federal Government should continue to improve methods for predicting future needs for scientists, engineers, and technicians, and to disseminate its assessments to interested parties.

INTRODUCTION

The ability of the scientific and technological enterprise in the United States to maintain its high levels of achievement will depend substantially on the adequacy of its science and engineering work force, in both numbers and quality. These factors depend, in turn, on the ability of American colleges and universities to attract sufficient numbers of good students to the study of a broad range of science and engineering specialties at both the undergraduate and postgraduate levels, and on the capacity of those institutions to provide science and engineering students with an education adequate to meet the demands of prospective employers in industry, government, and academia. The adequacy of the country's science and engineering work force is also determined, in part, by the effectiveness with which employers use available personnel.

Since World War II, the Federal Government has regarded support for science and engineering education as an integral component of its overall science and technology policy, although both the visibility of that component and the strength of its coupling to other science and technology policy components have changed over the years with changing perceptions of the significance of science and technology to national needs and goals. In his classic report, *Science—The Endless Frontier* (1), Vannevar Bush recommended that: (1) the Federal Government support basic scientific research in American universities and thus, indirectly, support science faculty and graduate students; and (2) that the government establish graduate fellowships and undergraduate scholarships for science students. Although the undergraduate scholarships were never instituted, the acceptance and implementation of the other recommendations firmly established the principle of Federal assistance to further the advanced education of talented students in areas related to national needs.

Federal support of university research and advanced graduate education in science and engineering expanded considerably following the launch of Sputnik I in October 1957. The rationale for the expansion, as stated in two reports (2,3) issued by the President's Science Advisory Committee (PSAC) in 1960 and 1962, was that the capacity of American colleges and universities to provide quality education to sufficient numbers of scientists and engineers at the undergraduate level would automatically be enhanced if basic research and graduate education were strengthened.

Implementation of the recommendations contained in the second of these reports (the Gilleland Report (3)) accelerated an already rapid expansion in university science and engineering departments.

*National Science Foundation.

Beginning in the early 1970s, however, the size of these faculties began to stabilize and, in some cases, to decrease: first, because the growth rates in undergraduate enrollments began to slow down markedly as the World War II "baby boom" generation moved through and out of college; second, because real-dollar total national investments in university research decreased sharply from 1968 through 1975. Since 1975, the number of Ph.D.'s awarded in the mathematical and physical sciences has decreased sharply, in partial response to the continuing weak demand in the academic sector. Ph.D. degrees awarded in the life and social sciences have, however, remained approximately constant. The number of Ph.D.'s awarded in engineering fields has also declined, but apparently as a result of a strong demand by industry for bachelor's level engineers rather than weak demand for Ph.D.'s (4,5).

The stability in the size of university science departments and the leveling off and decrease in Ph.D. production have led some observers to worry about whether the quantity and quality of university basic scientific research are being adversely affected (6). No doubt this was one of the concerns that led to President Carter's February 8, 1980, request to the Secretary of Education and the Director of the National Science Foundation (NSF) to assess the adequacy of science and engineering education at both the secondary school and university levels "to preserve our national strength." (7) Unlike the PSAC reports of the early 1960s, the Carter memorandum was based on concerns about the quantitative and qualitative adequacy of science and engineering education as they affect the industrial as opposed to the academic sector. These concerns derived, in part, from decreasing U.S. industrial productivity relative to Japan and West Germany, for example, and increasing military competition with the Soviet Union. They also derived from a recognition that implementation of the Carter Administration's National Energy Plan (8), particularly the synthetic fuel component as envisioned by the Energy Security Act of 1980, would require a good deal of advanced research and development.

The four most significant problems associated with the education of scientists and engineers (9) are:

(1) Current personnel shortages at all degree levels in most specialties of engineering, in the computer professions, and in some subspecialties of the physical and biological sciences;

(2) The likelihood that at least some of these shortages will persist for as long as a decade, particularly at the advanced degree levels;

(3) Severe faculty shortages in university engineering and computer departments, and the likelihood that these shortages will persist; and

(4) Obsolescence of university research apparatus and facilities and, in the engineering and computer fields, of instructional apparatus as well.

University departments in several science fields, most notably physics and mathematics, are also experiencing a serious problem due to the virtual disappearance of tenure positions for young investigators, with the possible consequence that the ability of such departments to benefit from innovative approaches to instruction and research could be reduced. This problem and its implications are discussed elsewhere in this chapter (10).

The success of any technologically related enterprise depends to a large degree on the number and quality of skilled technicians who provide support for the work of professional scientists and engineers, as well as on the quantitative and qualitative adequacy of the science and engineering work force itself. Other industrialized countries, including West Germany, Japan, and the Soviet Union, place heavy emphasis on training technicians in special vocational schools. Technician training in the United States, however, has largely been a haphazard enterprise, accomplished through a combination of on-the-job training, a few technical institutes, and vocational training in secondary schools. In addition, a substantial fraction of the technicians in this country is trained in the Armed Forces in high-grade, high-cost educational programs. Recently, two-year community colleges have also begun to play an important role in technical training. However, such institutions are not well integrated into the U.S. science and engineering education system. Nor is there sufficient information available for a systematic assessment of the present and future needs of technology-based industry for skilled technicians or the adequacy of existing educational programs to train them.

Any complete assessment of the state of science and engineering education must also deal with the adequacy of science and mathematics education in secondary schools. Such an assessment should deal with precollege education both as it affects the quality of students who later become scientists and engineers and as it determines the general technical competence of those who do not intend to pursue careers in those areas but require some understanding and competence in science and mathematics in nonscience and nonengineering occupations and professions. The report of the Secretary of Education and the Director of the National Science Foundation concluded that whereas the preparation of secondary school graduates who intend to pursue careers related to science and technology has remained high and constant for over a decade, achievement levels for most other graduates have declined appreciably over the same period of time. Issues associated with general science requirements and technological literacy are discussed in detail in the second *Annual Science and Technology Report* (11).

TRENDS AND DEVELOPMENTS

Quantitative Adequacy of the U.S. Science and Engineering Work Force

Current Supply/Demand for Scientists and Engineers

There are, at present, shortages of computer professionals and engineers in most specialties and at all degree levels. Statistical measures, such as salary data and surveys of job earnings, and anecdotal information from industry and from Federal agencies indicate difficulties experienced in hiring new engineers, most notably in chemical, electrical, and industrial engineering specialties. There is also considerable competition for engineers and computer professionals among different economic sectors, particularly between industry and universities. In addition, the Department of Defense has reported difficulties in recruiting and retaining both civilian and military engineers because of a general perception of superior career opportunities in nonmilitary employment.

In contrast with the engineering and computer personnel situation, the current supply of scientists is adequate to satisfy existing demand. There are shortages, however, in a few critical subfields of the physical and biological sciences, including solid-state and plasma physics, optics, analytical and polymer chemistry, and toxicology.

Projected Supply/Demand for Scientists and Engineers

Based on the best current surveys carried out by the Bureau of Labor Statistics, the National Center for Education Statistics, and the National Science Foundation, these aspects of the situation anticipated in 1990 are noteworthy (12):

(1) The number of computer professionals at all degree levels is likely to be insufficient to fill available positions.

(2) There should be an ample supply of new bachelor's level engineers in most specialties, reflecting anticipated strong increases in undergraduate engineering enrollments, provided it is assumed that U.S. engineering schools will be able to admit and retain all the qualified secondary school graduates who aspire to become engineers. Several observers question the validity of this assumption, however.

(3) A rapid expansion in defense expenditures is likely to have only a small effect on projected personnel demands, except in aeronautical engineering. Likewise, the assumption that a significant synthetic fuels program will be in operation in 1990 has virtually no effect on projected employment, particularly at the bachelor's level, since the requisite engineers could be drawn from other sectors of the economy. The latter conclusion appears to be in essential agreement with more limited sectoral projections commissioned by the Department of Energy (DOE), which are based on different energy scenarios (13; 9, pp. 28-30).

(4) There is some question about whether the supply of Ph.D. engineers, particularly in energy-intensive areas, will be adequate. NSF projections indicate that the supply of Ph.D. engineers will be more than sufficient to fill anticipated job openings. DOE, however, is less optimistic, noting that the synthetic fuels program will place an early peak load on engineering capacity and will have to be established by advanced degree engineers who are now active. Some of these engineers will have to be enticed away from other sectors of the economy which, in the opinion of DOE, could cause major dislocations in those sectors (9, pp. 30-31).

(5) The aggregate number of new science graduates in all broad fields and at all degree levels should exceed the number able to find jobs in the fields in which they are trained. Spot shortages may develop in some subspecialties due to scientific or technological advances that present personnel projection techniques are unable to anticipate.

Quality Considerations

While statistical indicators that could predict the future quality of American scientists and engineers are not available, the quality of U.S. science has been exceptional. Evidence of U.S. scientific and technological leadership is found, to cite a few examples, in the record of the space-flight program, the continuing dramatic improvement in computer engineering, breakthroughs in our understanding of genetic processes, and new insights into the fundamental structure of matter. In recognition of such pioneering work, American scientists and engineers have won over 50 percent of the Nobel Prizes awarded in the post-World War II period, excluding the prizes for peace and economics. Publication activity and citation analyses provide additional evidence of the past high level of productivity of U.S. scientists and engineers.

On the negative side, several indicators point to a relative decline in the technological advantage of U.S. industry compared with its foreign competitors (14). These include relative changes in labor productivity and relative numbers of U.S. patents granted to U.S. and foreign applicants. No proven relationships exist between the quality of the science and engineering labor force and industrial productivity, though there are correlations, at least, between productivity and rates of R&D investment (15). It is at least plausible, however, that the level of technical competence of all workers in an industry, including scientists and engineers, bears directly on the problem of improving industrial productivity. If so, then the qualifications of students who intend to enter science and engineering occupations are germane to the broad issue of the adequacy of science and engineering education for long-term national needs. The academic ability of those who plan to study science and engineering at both the undergraduate and postgraduate levels remains high. In particular, in each year from 1966 to 1979, at least 41 percent of the high school students who won National Merit Scholarships indicated plans to major in science, engineering or mathematics (16). At the post-graduate level, Graduate Record Examination (GRE) test scores of prospective science and engineering graduate students remained high and unchanged throughout the 1970s, both in absolute terms and relative to the average scores of graduate students in nonscience and nonengineering fields (14, pp. 125-129).

Research and Instructional Capacity of University Science and Engineering Departments

Indicators of the academic ability of students who enter college or graduate school intending to pursue science or engineering specialties provide no information about the quality of the education they receive at those institutions. A full assessment of the adequacy of professional science and engineering education would of necessity require reference to present and future expectations of prospective employers. However, even in the absence of such information, there are indications that the U.S. higher education system is under considerable strain and is not able to provide education of as high a quality in science and, more particularly, in engineering as many specialists believe it should.

Postgraduate Research and Instruction

The high and rising cost of maintaining existing laboratory equipment and replacing obsolete research apparatus and facilities is a severe problem for university faculty in almost all fields, particularly in such equipment-intensive fields as electrical engineering, computer science, physics, chemistry, and the life sciences. Over the past decade, the development, purchase, and maintenance costs of instrumentation have escalated rapidly, while the apparatus needed to conduct research at the cutting edge of science has become increasingly sophisticated and expensive. Federal funds for research equipment declined, however, during the same period. Industrial laboratories, in contrast, have continued to equip themselves with needed scientific apparatus. Comparison of university instrumentation inventories with those of two leading commercial laboratories reveals that the median age of university equipment is twice that of commercial laboratory instrumentation (17).

Equipment obsolescence has a direct effect on the quality of university research. Advanced instrumentation is, to an increasing degree, a prerequisite to maintaining a position at the forefront of a field. In addition, since advanced postgraduate education and research are intimately connected, the lack of accessibility to the newest and best apparatus has adverse effects on the quality of education at that level. Finally, the existence of superior research facilities in industry, coupled with difficulties in obtaining research support and the lack of stability in Federal research funding, is an important contributor to the decreasing attractiveness of academic careers, particularly in engineering and the computer professions.

Engineering and Computer Faculty Shortages

The most pressing and immediate problem in engineering schools and computer science departments is the acquisition, retention, and maintenance of high-quality faculty. At the beginning of the academic year 1979-80, there were as many as 2,000 unfilled faculty positions in engineering departments and approximately 200 vacancies in departments that specialize in the computer professions. Moreover, up to one-third of the faculty positions in these departments are filled by foreign nationals (18, 19).

The faculty shortage problem in engineering and the computer professions has resulted from several factors. First, Ph.D. production in engineering and the computer professions has been declining since 1972 so that the available pool of graduate students from which new faculty will have to be drawn is relatively small. The available pool is even smaller than the raw numbers suggest, since it includes large numbers of foreign nationals who intend to return to their own countries after receiving their Ph.D.'s. Second, salaries offered by universities to new Ph.D.'s (as well as to senior faculty members) are simply not competitive with industrial salaries. University faculty members, however, have traditionally been willing to forego higher salaries in exchange for opportunities to work with good graduate students and conduct research in a university setting. Thus, the noncompetitiveness of academic salaries, while important, may not be the overriding contributor to the faculty shortage problem. Academic careers have become less desirable for other reasons as well. The previously cited research facilities obsolescence problem is certainly an important factor. Increasing undergraduate enrollments in engineering and computer specialties have led to class sizes that many regard as too large for effective instruction. Finally, the decreasing availability of graduate students to serve as teaching assistants has placed an additional burden on faculty members, leaving them with less time for contact with individual students and for research.

Obsolescence of Instructional Equipment

Engineering schools, in general, lack sufficient resources to modernize teaching facilities and equipment. This deficiency is particularly serious because industrial design and engineering practices have changed rapidly under the impact of modern electronic technology. As a result, many new engineers and computer professionals are not adequately trained in the newest techniques.

The obsolescence of instructional equipment has a direct bearing on the quality of engineering education. During the 1970s, computer-assisted methods in manufacturing began to provide important gains in productivity for some large U.S. industrial companies. Because the apparatus required to teach these methods to students is generally unavailable to engineering schools and many computer science departments, a good deal of the instruction now being offered is obsolete simply because it must rely on obsolete equipment (18, 19, 20). While this situation may not pose significant problems for the large employers that can afford on-the-job training for newly hired engineering personnel, it could have appreciable adverse effects on smaller companies and industries that traditionally have relied on new graduates to keep them abreast of the latest developments.

POLICY PERSPECTIVES*

Two related questions need to be raised about Federal policy for science and engineering education:

First, under what conditions is the Federal Government justified in taking steps to resolve problems associated with science and engineering education?

Second, in those instances where there is such justification, what actions will be most effective?

The Federal Government has assumed responsibility for the support of science and technology:

- To serve its own direct needs and responsibilities—in such areas as defense, space, and air traffic control, for example;
- To accelerate the rate of development of new technologies in the private sector, particularly when the risks are great or the costs inordinately high, as in the fields of health, energy, and transportation, for example; and
- To support basic research to maintain and replenish the knowledge base required to meet broad economic and social needs in the future.

Using these three categories as guidelines, and assuming that Federal education policy should be an integral component of science and technology policy, the Federal Government is justified in supporting science and engineering education to ensure that the numbers and quality of professional scientists and engineers are adequate to:

- Carry out direct Federal responsibilities—most notably, for national security;
- Meet long-term national goals (in energy, for example), the detailed implementation of which is primarily the responsibility of the private sector; and

*While the discussion that follows is based on the analysis and recommendations in *Science and Engineering Education for the 1980s and Beyond* (9), specific interpretations and opinions are those of the author and do not necessarily reflect policies of the National Science Foundation or the U.S. Government.

- Maintain the capabilities of universities, industry, and other institutions to conduct basic research, particularly in areas that show promise of yielding knowledge that can be applied to realize long-term goals.

Application of the second of these guidelines argues in favor of the Federal Government's playing a catalyzing rather than a direct role whenever possible and, in particular, providing incentives to encourage closer university-industry cooperation to resolve problems associated with science and engineering education. Application of the third guideline argues in favor of providing adequate and stable research support to qualified university science and engineering faculty members in order to strengthen the research and instructional capability of their institutions. However, it argues *against providing* institutional support to colleges and universities except for special purposes.

The most feasible modes for Federal assistance differ somewhat with respect to the three critical problems discussed earlier:

Short-Term Personnel Shortages

While market forces are likely to relieve most shortages that currently exist in industry in most specific science and engineering specialties, spot shortages in other subfields that cannot presently be identified are almost certain to occur in the future even if the aggregate supply of scientists and engineers is sufficient. This supposition argues in favor of university curricula that provide students with a grasp of broad conceptual foundations in addition to training in specific techniques, thus equipping new graduates with the ability to retrain themselves in fields that may be somewhat different from those of their original specialties. If the resources of universities are inadequate to permit this, then the role of the Federal Government in strengthening the academic base is an issue that needs to be faced.

In view of the long training cycle that characterizes the formal educational process, particularly at the Ph.D. level, colleges and universities can never hope to respond without an appreciable time lag to changing demands for personnel with specific types of scientific and engineering training. Thus, Federal intervention to help relieve specific short-term spot shortages can only be effective if it can help the educational system to respond rapidly to changing market demands, and this circumstance places severe limits on what the government can do effectively. Federal agencies that anticipate personnel shortages in fields in which they have specific concerns could, for example, provide support to colleges and universities to develop special 1- and 2-year programs. These would allow qualified undergraduates to transfer from their original courses of study in a scientific or engineering field to a related course of study in a field in which significant personnel shortages exist or are projected. Likewise, Federal mission agencies could, in cooperation with industry, offer postgraduate industrial traineeships in fields where there are existing or projected shortages at advanced degree levels.

The effectiveness of Federal programs to help relieve existing and anticipated shortages in the science and engineering labor market will depend in large measure on the appropriateness and reliability of personnel supply and demand projections. Considerable advances in personnel projection techniques have been made during the past few years, particularly for demand projections. These techniques, however, appear inadequate to forecast demand reliably in rapidly developing subspecialties, for example, those associated with advanced energy R&D (9). In addition, the data base is inadequate to assess future needs for skilled technicians in technology-based industries. Analytical tools and data are needed to predict likely spot shortages at the technical, bachelor's degree, and advanced degree levels as early as possible. Results of such projections need to be disseminated in a form that will be useful both to employers of scientists, engineers, and technicians and to schools, universities, and students as career guidance information.

Faculty Shortages

Since most engineers are employed by the private sector, increases in the quality of engineering education will primarily benefit that sector. Universities and industry should thus assume primary responsibility both for relieving present faculty shortages and for maintaining the teaching and research capacities of university science and engineering departments. The Federal Government can play a decisive role by catalyzing and providing indirect incentives for enhanced university-industry cooperation.

Since the faculty shortage in university engineering and computer departments is immediate and critical, some level of direct Federal assistance may be essential. The government could encourage outstanding undergraduate engineering students to pursue graduate studies in fields associated with critical national needs by offering assistantships, traineeships, and fellowships. Particular incentives should be offered to students who are attracted to academic careers.

Research and Teaching Equipment

Direct Federal support for the purchase of research equipment can be justified either to facilitate research related to areas of national need or to maintain basic research capabilities. Such support is presently provided through existing Federal grant and contract mechanisms, though at levels that most specialists agree are inadequate (17). These levels should be increased. Additionally, the government should provide incentives to encourage greater use of centralized research facilities and pooling of apparatus among institutions.

The problem of obsolescence in engineering instructional apparatus needs to be viewed from a somewhat different perspective, since Federal support for the purchase of such equipment is justified only if it can be demonstrated that the rate of industrial innovation and productivity is being severely hampered by the obsolescence of undergraduate engineering instruction. If such a case can be made, then Federal grants for the purchase of instructional apparatus would be justified. In addition, since any improvement in the quality of undergraduate engineering instruction will be of direct benefit to industry, work-study programs at both the undergraduate and postgraduate levels to provide students with access to the most advanced equipment should be encouraged. Because industrial practices will probably continue to advance, university teaching equipment will always exhibit some degree of obsolescence. If so, then any long-term solution to the problem can best be addressed through closer cooperation between industry and engineering schools.

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   > I am increasingly concerned whether our science and engineering education is adequate, both in quality and in numbers of graduates, for our long-term needs. Accordingly, I would like you to carry out a review of our science and engineering education policies at the secondary and university levels to ensure that we are taking measures which will preserve our national strength. Please submit a report to me, with your recommendations, by July 1, 1980.

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    Supply projections for new scientists and engineers at the bachelor's and master's levels were estimated by the National Center for Education Statistics on the basis of projections of college and university enrollments. These projections are based, in turn, on the percentage of the population enrolled in higher education in each of several recent years and on general demographic data. Projections for both supply and demand for Ph.D. scientists and engineers were developed by National Science Foundation. The supply data were based on past trends, the demand data on econometric modeling, and trend extrapolation.
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D. THE USE OF BIOMASS AS AN ENERGY SOURCE

by

Ruxton Villet*

ABSTRACT

Increased petroleum prices have made alternative energy sources more attractive. Biomass, a form of solar energy stored in agricultural crops, wood, municipal solid wastes, etc., is such an alternative.

Key issues with regard to using biomass as an energy source are: food versus fuel, environmental considerations, net energy balance, and Federal encouragement of its use. Another concern is to obtain fuel in liquid form. At present, fermentation of such grains as corn into ethanol for use as a vehicle fuel is available. The greatest potential, however, lies with the conversion of lignocellulosic materials (wood) to fuel, using a range of technologies serving multiple uses and users. Other processes, somewhat analogous to coal conversion, can be used to produce fuel gas and methanol.

Although there are Federal incentives for the use of biomass energy sources, a clear Federal role remains to be developed.

INTRODUCTION

The worldwide energy crisis, which has jolted the United States through rapid increases in petroleum prices, has produced increased interest in alternative energy sources. One alternate is biomass, a source of solar energy stored through photosynthesis, which occurs as agricultural crops and residues, forests and wood byproducts, grasses and forage crops, food processing wastes, municipal solid wastes, aquatic plants, and such other materials as human and animal wastes.

Biomass can be used as a fuel source in a number of ways. It can be directly burned; the burning of wood and agricultural waste to produce heat and electricity is now the principal use of biomass for fuel in the United States and, primarily used in developing countries, accounts for roughly one-seventh of the world's total energy use. Biomass can also be fermented to produce a liquid fuel (ethanol), digested anaerobically to produce methane gas, or converted thermally (as can be done with coal) to produce methane or methanol.

FOOD VERSUS FUEL

Perhaps the most politically volatile use of biomass is the production of ethanol as a vehicle fuel. Since ethanol can be manufactured from such readily fermentable substances as starches and sugars (just as drinking alcohol is), its greatest source is likely to be the American agricultural system. This quite naturally raises the issue whether using crops on a large scale to produce fuel will jeopardize the food security of the United States. The issue hinges on two points: what are the alternative uses of the land and what are the alternative uses of the crops being grown?

The principal grain considered for ethanol production is corn. About 90 percent of the corn grown in the United States is used as feed for beef and dairy cattle; it is supplemented mainly by soybean meal. When the corn is used directly as feed, it primarily provides calories and nutrients, while the soya contributes most of the protein. In the production of ethanol from corn, however, the byproduct is relatively protein-rich and commands a premium price on the cattle feed market—a major consideration for farmers in deciding to use corn for this purpose. (Another consideration is the four cents per gallon Federal subsidy for gasohol production.) The byproduct can be supplemented by more corn or forage crops for their caloric value. One result of converting corn to fuel alcohol on a large scale would likely be a decrease in the demand for soybeans as feed, since they would be less needed for their protein contribution.

Any significant change in the use of arable land for existing crop production raises the spectre of reducing the acreage available for food crops, as well as narrowing the reserve against unforeseen crop losses—whether domestic or overseas (e.g., in the Soviet Union). It also presents the possibility of shifts in the delicate balance of crop prices on the open market and price supports provided by the government, although a study by Hertzmark et al. of the Solar Energy Research Institute has projected that such shifts would not be a major problem—rather a matter of adjustment. In addition, a change to large-scale production of a single crop may increase the possibility of devastation from a single disease or insect.

Other food crops now grown on a smaller scale than corn (e.g., beets, pineapples, and sugar cane) can be used for fermentation and have been proposed for use as fuel crops by advocates from those parts of the United States where they are being or can be grown.

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When nonfood crops are proposed as fuel crops, there is less opposition to using the land for this purpose from those concerned with food supply. (The chairman of the Tennessee Valley Authority, for example, has strongly opposed using food crops for fuel while supporting the use of cellulose.) Even less opposition occurs when use of previously untilled land—e.g., semi-arid regions—is proposed.

The most massive biomass energy source in the United States is in the form of wood. The total standing forest covers 750 million acres; more than half is in private hands—much of it in small lots in Eastern States where there is a ready market. A recent Office of Technology Assessment (OTA) study, *Energy from Biological Processes,* concluded that biomass could supply as much as 12 to 17 quads per year by the year 2000 (or up to 15 to 20 percent of current U.S. energy consumption), of which up to 10 quads per year could come from wood. The Energy Task Force of the Society of American Foresters reported that the capacity for growth of U.S. forests in 1980 is equivalent to 11.5 quads per year, and, if intense management were started now, capacity could be increased to the maximum practical limit of 24 quads per year by 2050.

It should be noted that it is possible to produce chemical feedstocks, as well as vehicle fuels, from biomass. U.S. industry now uses almost three quads of petroleum and natural gas as feedstocks. Until 30 years ago, there was a commodity chemicals industry based on such readily fermentable carbohydrates as molasses. It declined, however, in the face of competition from cheap petroleum and the development of effective cracking technology. Ethylene is an example of a chemical feedstock now produced from petroleum that might be derived competitively from fermentation ethanol if suitable technology were developed and the price of petroleum were high enough. A study by Hannon and Blanco has found this to be the case already. In addition, while the production of domestic natural gas has the national security advantage over imported petroleum of being an assured energy source, decontrol and the subsequent increase of its price could cause a tilt toward production of grain-based fuels.

ENVIRONMENTAL CONSIDERATIONS

The large-scale use of biomass for fuel can pose environmental problems. Land degradation is one such concern. Indiscriminate cutting of forests and harvesting of crops can lead to serious erosion. Both forests and farmlands may be degraded through the removal of groundcover, created by dead and unused parts of trees and crops, which protects the soil from erosion and adds nutrients to it. Intensive one-crop farming of corn can also degrade the soil. In addition, building of processing plants and transportation routes can have adverse effects on the land.

On the other hand, positive steps can be taken. All forests (especially those in Eastern States that have been cut over) benefit from improved management. Planting exotic species on semi-arid lands could avoid some problems, and the use of leguminous plants as energy sources would in fact add nitrogen to the soil. Research is needed in these areas.

Another environmental consideration may be the availability of water. While water requirements for fermentation and distillation are not excessive, the amount required to grow increased biomass fuel sources could drain existing water supplies and, in such areas as the High Plains region of the United States, not only compete with food crops for diminishing water reserves but also add to the projected demand for water by coal and oil shale conversion processes.

Biomass fuel sources can also produce air pollution. A consideration here is the trade-off between nonpoint pollution caused by residential wood heating and the greater ease of control if central station heating sources are used.

NET ENERGY BALANCE

A key issue raised about the production of fuel from biomass sources other than wood, especially ethanol as a vehicle fuel, is whether the potential energy produced is greater than the energy required for its production. Among the factors that can be considered are the system itself and the alternatives to the sources and uses of the substances involved.

For example, if corn is used to produce ethanol for gasohol (a mixture of 10 percent ethanol by volume with 90 percent gasoline), the energy inputs could be calculated for the fuel to run the tractor for planting and harvesting, for producing the fertilizer used, for pumping water for irrigation, for drying the corn, and for transporting it to a fermentation plant. The outputs could include the energy in both the ethanol and the byproducts.

A review article by Chambers, et. al., found that the results of such calculations are determined by a number of assumptions about the factors to be included (some are required by legislation—e.g., the Food and Agriculture Act of 1977) and especially the miles per gallon for gasohol versus gasoline. The conclusion was that, using conventional agricultural production and distillation technology, the net energy balance for gasohol production is negative; if energy-conserving production and distillation techniques are used, the balance is modestly positive; while, if a petroleum-only energy balance is used, then gasohol can produce a clear net positive energy balance since the energy for distillation can be supplied by coal.

The Gasohol Study Group of the Department of Energy's Energy Research Advisory Board, in a controversial report, also found that, using technology available before 1985, the net energy balance from corn and other crops is about zero. However, if the processing plants were fueled by coal, each gallon of ethanol produced could save roughly half a gallon of petroleum. They also concluded that in this time period ethanol production could reach 800 million gallons per year, but this would displace less than 1 percent of U.S. gasoline consumption. They found as well that converting coal directly to methanol could cost about one-half to one-third as much as producing ethanol from grain, although the technology involved has potential environmental problems for land, air, and water.

The OTA study indicated, too, that a net displacement of petroleum and natural gas can be achieved if ethanol distilleries are not fueled by petroleum or natural gas. According to the OTA study, it appears that the most significant way at present for biomass to displace petroleum is in direct combustion and gasification of wood for process heat and steam and home heat.

CONVERSION TECHNOLOGIES

As already indicated, the production of ethanol from grain is a technically and commercially viable process, with the net energy balance and cost dependent in part on the fuels and techniques used for distillation.

Wood and other lignocellulosic materials can be used directly as fuel through burning. Approximately 7.5 million Americans now burn wood for heat, and about 2.5 million wood-burning stoves were purchased in the past 2 years. The same materials can also be used through commercial conversion to fermentable sugars by acid hydrolysis. Forage crops and grasses are easier to convert than wood, since they require less pretreatment to reduce the shielding by which lignin protects cellulose from such conversion. Three areas of research are now being pursued: (1) chemomechanically treating woody material with acid and extrusion, (2) converting cellulose to fermentable sugars through the use of cellulose-degrading enzymes produced by fungal cells, and (3) direct conversion of cellulose and hemicellulose to ethanol and other chemicals using thermophilic anaerobic bacteria. Although the technical feasibility of the second process has been demonstrated, the cost of enzyme production is high. That fact could tend to favor the development of direct microbial conversion.

Biomass biotechnology requires intensive research and development, including an integration of modern molecular genetic technology, microbiology and biochemical engineering. It could, however, have considerable commercial potential. One advantage is that large-scale operation is not necessary for the process to be economically sound. Another is that it can be carried out at room temperature and pressure. In Europe and Japan there are rapid developments taking place in biotechnology. U.S. participation has been less vigorous and should be increased.

Aquatic sources of biomass could provide high energy yields. Microalgae have modest nutritional requirements. They are adaptable to such biochemical engineering techniques as continuous processing. Certain species produce as much as 70 percent of their dry cell mass as hydrocarbons. Aquatic plants such as weeds, hyacinth, and giant kelp might be used as energy sources, once the appropriate farming techniques are developed.

Methane fuel gas can also be produced by anaerobic digestion of organic waste material. There is interest in the industrial production of methane by this method using manure from large feedlots or landfill sites. However, the present state of technology is primitive and the processes are unstable (partly because of the mixed cultures of bacteria involved). It could be feasible to extend the raw material base to include marine algal biomass.

A biomass technology of some importance is thermal conversion. As with coal, biomass can be heated to form (with air) a gaseous fuel containing carbon monoxide and hydrogen, which can be converted to methanol. It can also be used as a fuel gas for existing steam boilers; using it that way is likely to be considerably cheaper than installing new wood-burning systems. Gas of much higher energy content can be generated using oxygen; such gas is suitable for use in local industrial areas rather than for transmission over long distances through pipelines.

Another thermal technique is pyrolysis. Temperature, pressure and heating time can be varied to influence the products formed—e.g., char, tars, alcohols, acetic acid, and ethylene. Tars contain polyaromatic compounds that can be carcinogenic, so gloves and face masks must be worn when handling them. Fast-pyrolysis and rapid-quench technology is being developed; hydrocarbon compounds, similar to those that result from cracking naphtha in the petroleum industry, can be obtained.

The conversion of biomass to methanol via gasification appears technically sound but remains to be demonstrated on a commercial scale. Methanol derived from biomass (and from coal) could play an important role as a vehicle fuel and in driving turbines and other stationary equipment. For the economics to be attractive, however, methanol plants generally must be large and capital intensive. Because biomass, though abundant, is not densely concentrated (like coal), gathering and transporting the feedstock could prove costly. Yet in policy discussions, methanol is increasingly replacing ethanol as the biomass-based fuel of the future.

FEDERAL ENCOURAGEMENT OF BIOMASS USE

The Federal position on encouraging the use of biomass as a fuel source is affected by the full range of political, institutional, economic, and technical factors that are part of the worldwide energy crisis. No single position has been taken, and no "correct" answer seems evident.

The National Energy Plan II, for example, issued in May 1979, reported on a Domestic Policy Review of solar (including biomass) energy. The review outlined a four-part strategy: (1) accelerating commercial use in the near term of technologies, such as direct burning of biomass (e.g., wood-burning stoves), that are economically competitive or nearly so; (2) pushing development of technologies, such as systems for conversion of biomass and agricultural products to liquid fuels and gases, that have commercial potential in the intermediate term but are not yet fully competitive in the marketplace; (3) developing technologies, such as biomass plantations, that have great potential in the long term but are farther from economic application than the technologies described above; and (4) identifying and evaluating long-range options (e.g., photochemical conversion) that require extensive basic and applied research. This review, however, was only one input into possible Carter Administration decisions.

In January 1980, following the embargo on grain sales to the Soviet Union, President Carter announced a program to quadruple ethanol production by the end of 1980 and to produce six times as much (500 million gallons per year) by 1982. The program was to use such means as a permanent exemption for gasohol from the Federal gasoline excise tax, a production tax credit for ethanol, and $3 billion of Federal credit for small- to medium-scale plants producing ethanol from biomass.

The role of various Federal agencies is still evolving. After passage of the Energy Security Act, the Department of Energy (DOE) created an office to coordinate the synthetic fuels commercialization program until its transfer to the Synthetic Fuels Corporation in mid-1981. In response to that legislation, DOE is also studying alcohol fuels and other biomass programs as well as working with the Department of Housing and Urban Development on a mandated solar and conservation bank. The Department of Agriculture continues to be an actor in the financing of projects to use grains for fuel.

The DOE funding competition for feasibility studies in alcohol fuels and other biomass areas was met with more proposals than anticipated and far more than could be funded. In the private sector, major food and fuel companies have taken such steps as considering the formation of joint ventures to produce and market fuel alcohol from grain, although at least one major oil company has come out strongly favoring coal conversion to methanol.

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E. PUBLIC POLICY IMPLICATIONS OF SATELLITE REMOTE SENSING APPLICATIONS

by

Bernard R. Stein*

ABSTRACT

The maturation of satellite remote sensing systems technology is reflected in numerous practical accomplishments in areas as diverse as the assessment of land and ocean resources, the determination of environmental forecasts, and the enhancement of scientific understanding. During 1979, the Executive Office of the President assigned operational responsibility for civil remote sensing to the National Oceanic and Atmospheric Administration in the Department of Commerce. That action brought into sharp focus a number of policy issues that relate to national security, economic, privacy, and technology concerns. Indirectly, the resolution of these concerns can be expected to influence the scope and quality of public and private services, international relations, demographic development, and even cultural change.

The particular policy issues that dominate the present public/private dialogue include the following: the participation of the private sector in the provision of both space and ground services; the involvement of users of satellite remote sensing operations in determining services to be offered, management procedures, and research and development options; the appropriateness of communication satellite systems for use as models in pricing civil remote sensing services; international regulation of sensing, data transmissions, and natural disaster monitoring; national and international competitive practices; data pricing structures; governmental purchasing policies; sensing resolution limits; equipment and services compatability; and public involvement in, and the unintended consequences of, the use of remote sensors.

The above-mentioned issues are illustrative of the more important present policy concerns for dealing with satellite remote sensing. The issues are not independent of each other. Their overlapping nature tends to make individual resolution more difficult, as jurisdictional authority and institutional boundaries cannot be clearly fixed. The involvement of multiple interests, especially those of a foreign nature, indicates that the resolution of complex and vital concerns will take considerable time. Meanwhile it is possible that further advances in technology may create new issues, as well as modify (if not eliminate) certain existing issues.

*National Science Foundation.

INTRODUCTION

Satellite remote sensing is the technology used to observe Earth and its environment with instruments placed on artificial space satellites. These instruments record energy patterns emitted or reflected from Earth in various portions of the electromagnetic spectrum. The data, in turn, are either transmitted electronically directly to ground stations or are collected on photographic film, magnetic tape, or other media and later returned to Earth. Remote sensing systems comprise both space and ground elements. The space element consists of the satellite platform, sensors, data collectors, and transmitters. The ground element comprises data reception stations, data processing facilities, and data storage and dissemination services.

The importance of and interest in satellite remote sensing stems from the large number and varieties of uses that have been and probably will continue to be found. Examples of uses include crop acreage and yield forecasting; soil surveys; rangeland, forest, and water resources management; geologic surveys; mineral and petroleum exploration; cartography; urban and regional planning; demography; environmental protection; marine resources; oceanography and coastal engineering; disaster warning and assessment; and human and animal health. Comprehensive research and development programs that focus on producing knowledge of Earth and its environment have also benefited from the implementation—experimental to date—of remote sensing technology.

The Landsat series of satellites has been specifically designed to observe land areas of Earth. Landsat data are available either from the Earth Resources Observation Systems (EROS) Data Center of the Department of the Interior or by means of direct readout by an Earth station. The most complex policy issues have arisen concerning land remote sensing. For example, present U.S. capability in civil remote sensing of land areas has been limited by a series of equipment problems, raising major questions about the operational and policy significance of serious interruptions in data continuity. In the case of Landsat 2, only direct readout operations are possible, limiting use of data to those countries with such facilities. For Landsat

3, the principal sensing device is malfunctioning; however, some data are obtained from another, more spectrally limited, instrument. Landsat 1 is no longer in operation. In 1982, the National Aeronautics and Space Administration (NASA) plans to launch a fourth satellite (Landsat D) and later another (Landsat D′).

The United States has financed both the research and development and the operation of the space and the domestic ground elements of the present system. The experience and knowledge gained with Landsat operations have confirmed the utility and potential of the technology. Recognition of the practical benefits to be obtained by a variety of users—public and private—has prompted the U.S. Government to move toward the implementation of regular system operations and, in so doing, encourage greater private sector participation. In December 1979 President Carter assigned governmental responsibility for an operational civil remote sensing satellite system to the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce. NOAA now manages the limited operations of Landsats 2 and 3 and is in the process of developing a space policy which is to place civil remote sensing operations in the private sector. (Current agency thinking regarding such operations is discussed in detail in a June 1980 report entitled *Planning for a Civil Operational Remote Sensing Satellite System.*)

PRIVATE SECTOR INVOLVEMENT

The private sector has been routinely involved in the design and construction of both space and ground elements of the Landsat system and in the processing and analysis of resulting data. The U.S. Government has underscored this feature (in its decision to vest operational aspects of civil remote sensing in NOAA) by pointing out that private sector operation is a firm goal of government activities in this area. The same sentiments have been voiced in congressional hearings, among which were those held by the House Subcommittee on Space Science and Applications of the Committee on Science and Technology on May 2 and 3, 1979.

Private involvement in the operation of a remote sensing satellite system will depend on a large number of factors. From the private sector perspective, financial risk looms as the principal consideration. At present the lack of a well-defined, reliable market is a major barrier to private sector assumption of risks inherent in remote sensing operations. The financial risk issue is further influenced by such concerns as the nature of government commitments to purchase data or services, data pricing, data rights (to protect the economic integrity of the product), international competition, and even possible government subsidies. However, while resolution of the financial considerations is of prime importance, there is also the issue of governmental (national and international) regulation, which can be expected to influence the manner of private sector participation. Within the national framework, such concerns as national security, copyrights, technical standards, and equipment compatibility will affect the nature and schedule of private involvement. On the international scene, in the U.N. Outer Space Committee some nations continue to urge that major constraints be placed on operational remote sensing. The constraints are designed to protect national sovereignty and security and could, as proposed, lead to significantly reduced data dissemination and use.

USER PARTICIPATION

A major issue in the operation and development of satellite remote sensing systems is the participation of those who require the products of such systems. The financing, design, construction, and operation of civil remote sensing systems until now has been performed by the U.S. Government through NASA. While several U.S. Government agencies, among them the Department of the Interior, NOAA, the Agency for International Development, and the Department of Agriculture, have participated in various experiments on data acquisition and interpretation and have made routine use of Landsat data, the user community in general has not had a strong influence on the decisions which determine the types and quality of data to be produced by this experimental system. In assigning the operational authority for remote sensing to NOAA, the U.S. Government made an explicit commitment to establish a system clearly responsive to user needs. This initiative can be expected to be accompanied by more vigorous efforts to achieve greater private involvement in the operation of remote sensing satellites and the provision of image data. Such a shift in policy perspective also can be expected to strengthen both government and private sector efforts to involve the user community—public, private, national, international—in discussions regarding types, quality, frequency, and costs of data. Specific procedures for such involvement will be proposed by the Department of Commerce. Since many users have individually and collectively often stated their positions—witness the congressional testimony by the Geosat Committee, representing a number of interested industrial organizations, and the Report on State and Local Government Perspectives on the Landsat Information System (1978)—governmental efforts to achieve some consensus should be facilitated. Within the Federal Government, the Department of Commerce (NOAA) has been designated to preside over a new interagency Civil Remote Sensing Program Board that will continue Federal coordination and regulation of civil remote sensing activities.

It is important to note that the user community cannot be completely identified at this time since many of the practical possibilities for remote sensing technology have not yet been adequately explored and new uses and users may appear. However, a greater involvement by the private sector is expected to provide the impetus for enlarging the importance of user considerations just as operational considerations require that greater attention be paid to economic factors.

COMMUNICATIONS SATELLITES AS A MODEL FOR PRIVATE SECTOR OPERATION

The achievement of private sector involvement and user participation in both the research and development (R&D) and operations of remote sensing satellites may be served by examining the operations and products of communications satellites. In both the communications and remote sensing satellite systems there are numerous similarities. The most obvious are those of the system launch and command and control. Both satellite systems provide information to a distant receiver. Yet the similarities cannot hide some rather fundamental differences. For example, when space communications systems became operational, there already existed a long-standing framework for the determination of prices for commercial services and products. The space communications technology replaced existing technology, and prices were determined to a great extent on the basis of the pre-existing rate schedules. At the moment, significant changes are indeed occurring in space communications, and these in turn are likely to have dramatic impacts on prices, user practices, and competition.

The remote sensing satellite technology does not yet have an extensive and sophisticated pattern of products and services. While a portfolio of services might be assembled without too much difficulty, the conclusion of agreements—especially in the international area—may yield constraints on data collection and transmission that make for major differences between communications and remote sensing operations. A further difficulty in the use of the communications satellite system as an example for remote sensing operations is the current absence of any commercial pricing policies. At present the price for remotely sensed data products is limited to the cost of reproduction of materials and not the true cost of their acquisition. Thus while commercialization may be achieved in any one of several ways (quasi-government corporation, government contract leasing, private nonprofit or profit corporations, among others), the issue of which and how costs are to be borne by the consumer must be dealt with. Should such costs include the design, development, and implementation of both space and land technology elements? Should prices reflect only marginal costs following installation of the system? There are many other questions that require study. The resultant answers can, of course, be expected to determine the nature of private sector involvement, the degree of user participation, the extent and character of government involvement (financial, regulatory, and R&D), and the framework of international cooperative activity. This last can be expected to play a dominant role in the eventual formulation of a viable international civil remote sensing system.

INTERNATIONAL PARTICIPATION

The implementation of civil satellite remote sensing systems cannot but help raise issues of an international nature. Concern has been expressed by certain nations on such matters as sovereignty and privacy; economic and security factors; dependence and accountability; and assurance of reliability and reasonable cost in the provision of data. In one major locus of international discussion, the U.N. Committee on Peaceful Uses of Outer Space, efforts have been made over many years to prepare a statement of principles governing remote sensing satellites. Among the conditions considered are (1) a requirement of consent by a sensed nation prior to dissemination to third parties of data pertaining to the sensed nation; (2) a requirement that system operators monitor sensed data to determine the existence of information on national disasters and communicate that information to affected nations; (3) restrictions on the dissemination of fine resolution data; and (4) advance notification by sensing operators to nations whose territory will be sensed. Closely related to these principles are foreign national attitudes to U.S. practices that deal with rights in data to preclude circumvention of pricing policies and the nature of foreign participation in the management of an international system.

The manner in which the above-noted issues are resolved will be critical to the development and expansion of a remote sensing system and the concomitant benefits a system can yield to the international community. The construction of institutional barriers to collection and dissemination of data is likely not only to reduce the utility of information and increase costs but also to affect the R&D programs undertaken to yield more effective and less costly systems. To convince nations concerned about national resources, sovereignty, and security that widespread dissemination of physical information on the nature of their territories will lead to benefits that outweigh potential costs is a continuing challenge.

INTERNATIONAL COMPETITION

Of equal significance to the issues of international regulation and participation is that of national and international competition in the design, construction, and provision of satellite remote sensing systems. The latter arises from the same concerns that dominate regulation and participation, viz., sovereignty, economic factors, security, and dependence. The competition, now increasingly probable, may take place in ground and space element services as well as in the design and construction of equipment. At the forefront of non-U.S. activities are the efforts of France and the European Space Agency (ESA) in the European remote sensing space program EARTHNET. The program of the latter is expected to yield a European operational remote sensing service which would acquire, preprocess, store, and distribute remote sensed satellite data obtained from U.S. satellites of the Landsat and Nimbus kinds. The service would focus on marketing promotion and training and could conceivably make data available to selected users on a more timely basis than that obtained from EROS Data Center of the Department of the Interior. In addition, the ESA Council has given approval for the design and construction of land applications and coastal ocean monitoring satellite systems. The ESA systems will be designed with special consideration for European and developing country needs.

A strong commitment to establish and operate a European earth resources satellite has also been made by France. In direct response to user interests, France (through its National Space Studies Center) has invited suggestions from potential users, among which are U.S. firms, for design modifications. The Soviet Union already has a satellite remote sensing system and has made a public offer to provide its services to any country on negotiated terms. Other possible competitors include Japan, India, and China.

Apart from the direct economic and technological challenges posed by these systems, there are the questions, already raised, of their significance within a possible international framework. Here the issue would be the maintenance of a constructive competitive environment while reducing redundancy and disruptive practices. Technologically, competition within such an international system would require consideration of technological compatibilities and complementary techniques. It might also indicate new competitive areas such as the management of an international operating system.

CONCLUSION

The policy issues touched upon here are specific to remote sensing technologies and, because of their immediacy, have dominated a number of longer range issues that are common to the implementation of other new technologies (for example, modern computer communications networks and advanced energy systems). Such longer range, generic issues include the level and degree of public participation in decisions associated with the design and use of new technologies, the nature of public control over the technologies, and methods for assessing and dealing with secondary consequences of their implementation.

Previous experience with operational technologies, such as nuclear power, and changes in public perceptions and sensitivities have combined to create a strong awareness of the significance of political and economic structures in determining the kinds and distribution of benefits and disadvantages that may result from new technologies. In the case of remote sensing satellites, such generic issues have not been given great prominence, in part because other concerns, discussed above, have dominated. However, as resolution of the more immediate issues is achieved, public demands to address these generic issues may well be voiced.

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F. MENTAL HEALTH POLICY IMPLICATIONS OF SCIENTIFIC RESEARCH ON DRUGS

by

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ABSTRACT

The effectiveness of psychotropic drugs in treatment of the major mental disorders has been established beyond reasonable doubt. Since their introduction in the mid-1950s, their use has helped to transform the structure of service delivery, has altered treatment strategies and expectations, and has led to new programs of both basic and applied research.

Further improvement of patient care rests on the extent of resources provided both for treatment delivery and for research programs. Recommendations are made for support of a wide spectrum of research strategies, ranging from genetic to epidemiological, for a more active government role in new drug development, and for a reconsideration of the thrust of community service programs for the chronically ill.

The Food and Drug Administration's (FDA) review process is considered in terms of the safety of approved drugs and effects on incentives for pharmaceutical companies to invest in research and new drug development. The idea of a two-tiered approach to treatment delivery is noted; with that approach, patients who do not respond to usual care offered in standard facilities are referred to secondary, specialized centers with a concentration of specialists and innovative programs for extended evaluation and treatment.

The organization of government funding for psychiatric research is considered. At present, both research and patient care in the field of mental health are combined under the auspices of the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA). Some questions have arisen about whether it would be best to assign responsibility for these two functions to different agencies of the Federal Government.

BENEFITS OF PSYCHOTROPIC MEDICATION

Scientists have demonstrated convincingly that psychiatric patients with a wide range of disorders benefit from the psychotropic drugs introduced to general clinical practice since 1955 (1-3). Outcome measures as varied as number of mental hospital beds occupied (4), reduction in clinical distress and improved social adjustment (2), and economic costs (5) consistently show that psychotropic medications are clinically effective and cost efficient in the treatment of the major psychiatric disorders. Their use has helped to transform the practice of institutional psychiatry and has fostered the development of new treatment delivery systems, methods, and policies. In this brief review, we first note the current impact of drug development on treatment of the most prevalent psychiatric disorders, then discuss needs and paths of future developments in basic and clinical research, drug development, and patient care.

SCHIZOPHRENIA

Schizophrenia is a severe and disabling illness characterized by delusions, hallucinations, and impairment in thinking and in the ability to communicate. The illness tends to be chronic, and about two-thirds of schizophrenic patients are likely to remain impaired even with psychotherapy and support services. One American hospital bed in two is occupied by a mental patient, and about half of these are diagnosed as schizophrenic (6). Since the introduction of psychotropic drugs in the mid-1950s, the number of mental patients hospitalized on any given occasion has declined precipitously, but the majority of hospitalized patients continue to be schizophrenic, and the majority of schizophrenics continue to be hospitalized (albeit more briefly than formerly). The proportion of people in the general population who become schizophrenic has not changed, but the use of medication has rendered feasible community-based treatment and maintenance (7).

The drugs used in the treatment of schizophrenia are not simply a means of keeping the patient quiet. Sedation with hypnotics (barbiturates, benzodiazepines) does not benefit patients with schizophrenia so that the term "major tranquilizer" is a misnomer and has been replaced by "neuroleptics" or, more simply, "antipsychotic" medication. While short-term use of antipsychotic drugs

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reduces quite effectively such acute symptoms of schizophrenia as delusions and hallucinations, it does not prevent future episodes.

The long-term use of antipsychotic medication is indicated by the high probability of recurrence and relapse in this illness. Such prophylactic use is effective in preventing or postponing recurrence of acute illness episodes. It incurs the occasional risk, however, of the development of tardive dyskinesia, a neurological syndrome consisting primarily of abnormal, involuntary, persistent movements of the tongue, lips, and face, which is often not reversible (8) and can be serious and socially disabling. Since antipsychotic medication entails both considerable benefits and considerable risks, the clinician is placed in a difficult position. Research to develop drugs with equal efficacy and less serious side effects would contribute toward resolution of this dilemma.

AFFECTIVE DISORDERS

The term "affective disorders" includes both depressive (unipolar) illness and manic-depressive (bipolar) illness. The latter is characterized by alternating cycles of depression and mood swings to states of elation, belligerence, and excitement accompanied by poor judgment and impulsive behavior. While schizophrenia is the most common diagnosis among hospitalized patients, affective illness is the most common both among psychiatric outpatients and the general population, and as such it constitutes a major public health problem. Patients with either depression (unipolar illness) or bipolar illness are among those most likely to be helped by psychotropic medications including lithium and the antidepressant medications (tricyclic antidepressants and monoamine oxidase inhibitors).

The severity of symptoms and degree of disability among patients with affective disorders vary greatly. Some patients are frankly suicidal (about 15 in 100 depressed people eventually kill themselves), while others go about their usual activities but without interest or pleasure. The majority of patients with major depressive and manic-depressive illness clearly benefit from antidepressant medication and lithium. Repeated studies have shown that about 70 percent of those with major depressions respond within a matter of weeks to antidepressant medications and are restored to their former level of functioning (9). The effectiveness of lithium for treatment and prevention of manic and depressive episodes has been decisively established; a recent conservative estimate (5) is that lithium treatment of manic-depressive illness has saved the United States over $4 billion in the past 10 years—a sum that dwarfs the research investment.

The situation is less clear-cut for patients with milder forms of depression. Such patients show variable degrees of sleep and eating disturbances, loss of ability to enjoy social activities and biological pleasures, and a general decline in level of accomplishment. Not infrequently these states are accompanied by drug abuse and alcoholism. Furthermore, depression often is found among patients with other psychiatric and medical conditions. It seems likely that mild depression actually is an umbrella term for several different illnesses with varying causes and confusingly similar symptoms, some of which may respond better than others to a particular class of antidepressant medication. More research is needed to work out the precise indications for the different types of antidepressant medications in relation to subtypes of affective disorder.

While antidepressant medication and lithium are usually dramatically effective in the treatment of acute episodes of illness, such treatment does not forestall the later reappearance of symptoms after a period of well-being. There is clear evidence that for patients with affective disorders, the chronic prophylactic use of medication may prevent relapse. No detrimental long-term effects have been observed in the use of antidepressant medications, although there are unresolved questions about the effects on the kidney of prolonged lithium medication.

ANXIETY DISORDERS

Antidepressants are strikingly effective in blocking sudden attacks of panic that often lead to multiple phobias, but patients suffering from other anxiety disorders do not benefit from the use of these drugs. Such symptoms of anxiety as feelings of tension, apprehension, dry mouth, sweating, and cardiac palpitations are alleviated by both barbiturates and by the benzodiazepines of which Librium and Valium are the best known and most often prescribed. The benzodiazepines are far safer than the barbiturates, which are more addictive and more dangerous in accidental or deliberate overdoses. While some antianxiety drugs, such as methaqualone, also have addictive properties, this has not been shown for most others.

In general, antianxiety drugs do not seem to be symptom-specific but offer relief for a wide range of anxiety symptoms. Numerous controlled studies have demonstrated that the benzodiazepines and related compounds are effective short-term antianxiety agents (2). There is no clear evidence that any one is superior to another in magnitude of effect or spectrum of applicability.

TREATMENT OF CHILDREN

Less is known about the diagnosis and drug treatment of childhood disorders than about those of adulthood. That fact reflects a striking paucity of research in child psychiatry and child psychopharmacology. However, drugs have been found useful in the treatment of several childhood conditions, including attention deficit disorder and separation anxiety disorder.

The syndrome of attention deficit disorder with hyperactivity used to be referred to as hyperkinetic reaction or minimal brain dysfunction (MBD). Children with this disorder are not simply "overactive," but display marked impulsivity, attentional difficulties, and excessive motor activity which together characteristically disrupt classroom behavior. Such stimulants as amphetamine and methylphenidate have the well-established, if apparently paradoxical, effect of alleviating these symptoms (2). Since the disorder persists at least to adolescence and sometimes to adulthood, long-term drug treatment is often indicated. There is some controversy about the use of such medication; the debate often centers around unwarranted concerns about social controls and pressures for conformity.

Separation anxiety disorder has as its central feature the child's inability to leave the mother's presence, to the point where going to school or camp can cause acute distress. This disorder has been known somewhat imprecisely as "school phobia." About 75 percent of such children respond to psychological treatment that includes the parents. Antidepressant medication has been shown in one study to be highly effective for children who do not respond to psychological treatment.

CONTROVERSY ABOUT MEDICATION

The use of psychotropic drugs to treat mental disorders in children and adults is a subject of controversy among both health professionals and the general public. Some criticisms focus on the medical risks of drug interactions and the unknown consequences of chronic therapy. Other critics contend that reliance on drugs may lead to the "sedated society" and that alternative methods—psychological counseling and support services—could accomplish the same purpose in many cases, although attempts to demonstrate this have regularly failed.

Only the accumulation of experimental evidence will ever provide answers to such questions.

For example, the statements that Americans are over-medicated with such psychotropic drugs as Librium and Valium rest largely on testimony before congressional committees, often by people with alcohol problems antedating their drug use. Studies sponsored by the National Institute of Mental Health (NIMH) indicate that most people use prescribed antianxiety drugs appropriately for short periods during unusual stress (10). Furthermore, public consumption of antianxiety drugs has been declining since 1973. The major problem with public abuse of a sedative drug involves alcohol, and research on the relationship of alcohol and the abuse of sedatives and tranquilizers would be helpful. (Many of the statements to congressional committees mentioned this.) Further studies may isolate a subgroup of alcoholics with covert psychiatric disorders who can be expected to respond well to the new antidepressant medications (11).

No amount of research may satisfy those critics who are opposed philosophically to any "messing with people's minds." This is not the place to deal with the various manifestations of this school of thought, but they do seep into many areas of discussion of all aspects of mental health.

OUTLOOK

Experience with using psychotropic agents in animals and humans has promoted interest in brain physiology and chemistry. Scientists have devised a research method—the randomized double blind trial—to determine the efficacy of therapeutic techniques. It should prove useful in determining the comparative effectiveness of medication, behavior modification, counseling and social supports, and combined treatment. In such cross-modality studies, "blindness" can be maintained by using independent evaluators and "active" and "placebo" pills and psychotherapies simultaneously. The development of this and other sound research strategies has implications in three areas: research, drug development, and patient care.

Research

Millions of people suffering from mental disorders can benefit from greater understanding by health professionals of the psychobiological basis of their illness. Much of the basic research on central nervous system functioning must be carried out on animals for ethical reasons. Since there are major species differences, studies of higher primates will be necessary. They entail establishment of expensive primate centers and the development of animal models of human psychiatric disorders.

In the past decade, cumulative evidence has shown convincingly the importance of hereditary components in many of the major mental disorders and in the individual's response to medication (12). The unequivocal role of heredity for schizophrenia was demonstrated in studies of Danish children with schizophrenic mothers who were adopted by healthy families (13). Since then, genetic factors have been observed in a range of disorders including major depressions (14), bipolar illness (15), and alcoholism (16). These findings clearly justify increased investment in genetic studies using effective new strategies and models that distinguish between the effects of heredity and of family upbringing.

The recognition that mental disorders constitute a major public health problem combined with the development of new methods for diagnosing illness in untreated people as well as identified patients points to the need for expanded commitment to community studies. Such epidemiological studies can promote identification of people at particular risk for developing different kinds of disorders, can measure the magnitude of untreated illness in the community, and can provide guidance for the placement and organization of service delivery organizations.

Improved methods of psychiatric diagnosis are essential for effective treatment, since psychotropic drugs do not work in a nonspecific way but are related to particular disorders in their effects. In recent years there has been marked improvement in the scientific basis for psychiatric diagnosis and in the reliable application of diagnostic techniques. The new *Diagnostic and Statistical Manual* of the American Psychiatric Association (DSM-III), published in 1980, for the first time attempts to provide specific inclusion and exclusion criteria for each psychiatric disorder. While the manual provides a firm basis for classification of patients according to their current illness behavior, extensive work remains to be done in identifying precursors of illness, clarifying patterns of illness course, and establishing long-term outcomes related to different treatment strategies.

Evaluation studies of combined psychiatric treatments are sorely needed. Drugs are regularly given at the same time that patients receive psychotherapy, yet little is known about the relative impact of such combined treatment compared to other alternatives. It is even possible that certain combinations, such as intensive psychotherapy together with pharmacotherapy for schizophrenics, are counterproductive (17-20). The issue can be resolved through the study of many patients at several centers under a unified program. Such studies would be facilitated by the development of large clinical research facilities, since the usual project grant mechanism is inadequate for the purpose (21).

Finally, research is needed to determine the relative costs and effectiveness of various treatment programs. It is not yet clear what combinations of treatment method, provider, delivery site, duration of contact, and provision of auxiliary support services are maximally effective for patients with different types of psychiatric disorders, despite the millions of dollars spent annually by patients, insurance companies, and government agencies on patient care. It is quite certainly the case that the costs of such research would be regained many times over in the impact of increased knowledge on more efficient use of available personnel, treatment techniques, and planning for current and future needs.

One need that is immediately apparent is an increase in investigators who are skilled in both psychosocial and biological techniques. Such investigators are few and far between. The number of medically trained scientists entering the field is actually declining, in part due to the uncertainties of research funding and in part due to the complex and proliferating regulations regarding human experimentation. There are also conflicting philosophies on how best to protect individuals with impaired capacity to consent in a research setting. To modify the negative consequences on motivation to conduct research, closer consultation between those who establish the regulations and clinicians and researchers might be helpful.

There is a growing feeling in the scientific community that both research and patient care would benefit from being placed under different governmental agencies. Many researchers believe that as long as both endeavors are subject to the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA), research funds will be allocated to community service programs for maintenance of current service delivery methods rather than for efforts to develop more effective treatments. Divorce of research from clinical support and the return of psychiatric research funding programs to the research-oriented National Institutes of Health is one possible strategy for resolving this problem.

Drug Development and Pace of Government Approval

The current regulatory policies of the Food and Drug Administration (FDA) require the establishment of both the safety and efficacy of a drug before it is approved for general prescription use.

Medications in general use in Europe cannot be used here without retesting, which can take years to complete. These policies have led to statements that the United States is suffering from a drug lag (22).

The testing of drugs—particularly assessment of their comparative efficacy—is a costly and time-consuming process. Clinical testing takes place after a drug is patented which leads to a reduction in the number of years during which the developer can expect to sell the product at a profit. One consequence has been increased reluctance by American companies to invest in research—as shown by the shifting of the research (particularly of psychotropic agents) to other countries (23).

Another example of the limits on drug development imposed by the profit orientation of private industry is the history of the so-called "orphan drug." Such drugs are medications that benefit only small groups of patients, e.g., long-acting methadone, or that cannot be protected by patent, e.g., lithium, so that the potential return on the investment is necessarily small. At present, the National Institute of Neurological and Communicative Disorders and Stroke is sponsoring a pilot program to develop antiepileptic drugs (24). However, the institute lacks the scope, authority, and mandate to carry out new drug development on a broad basis.

The delay in development of effective new medications has not been restricted to psychiatry. Indeed, the problem is even more visible with respect to potentially life-saving drugs available in Europe and not yet approved for the American market, as in the case of isoprinosine, used to combat the degenerative effects of subacute sclerosing panencephalitis (25).

In view of these considerations, it seems that a direct government role in new drug development might be useful. Currently, the National Institutes of Health are organized largely in terms of a disease or organ-oriented model. An institute devoted to the development of new clinical pharmacological techniques applicable to all forms of illness would compensate both for the structural deficiencies of the pharmaceutical industry stemming from its profit orientation and the present lack in academic and public research settings of experts trained in clinical pharmacology.

Patient Care

The use of antipsychotic and antidepressant medications has led to a rapid decrease in the number of inpatients in State mental hospitals. That decrease, however, has not resulted in an appropriate increase in the support of community mental health programs and other outpatient facilities. Antipsychotic medications enable schizophrenic patients to live outside the hospital but rarely transform them into self-supporting members of society (26). Discharged but chronically disabled patients often end up living in squalid boarding homes without basic amenities, much less competent psychiatric aftercare (27).* The burden of their care has been shifted to the community, but State mental health dollars continue to go to institutional services (28). The political process has been slow to respond to the change in patient locus, and declining funds will exacerbate the problem in a period of economic downturn.

During the 1960s, when community psychiatry flourished, it was widely believed that much of the behavioral deviance displayed by chronic patients was caused by prolonged hospitalization rather than by the illness itself. It was thought that the return of patients to community life together with psychotherapy offered by local community mental health centers would alleviate their psychiatric distress and foster improved functioning. That hope led to widespread adoption of "deinstitutionalization" policies, under which large numbers of hospitalized patients were discharged to communities. Unfortunately, the approach has not been very successful; the chronically ill do not as a rule recover even in community settings (29). Nevertheless, hospitalization continues to be regarded as a negative alternative, a choice of last resórt, and community mental health centers (CMHCs) still emphasize individual and group psychotherapy in the relatively few programs they provide for chronic patients, despite lack of demonstrable efficacy. Even more of a problem is the fact that most CMHCs provide few services of any kind to chronic patients, preferring to work with more tractable and responsive patient groups. Re-examination of both the quantity and content of services offered by the community mental health center program seems warranted (30).

Another major problem in community services concerns staffing and professional roles. Differential diagnosis of mental disorders and the prescription of proper medication in suitable doses with effective management of side effects are highly skilled arts that require well-trained practitioners. There are too few psychiatrists now working in outpatient community settings to render these services to a significant proportion of the patient population. Since most such facilities do not provide ei-

*Horror stories about ex-patients living in squalor or being preyed on by criminals and unscrupulous boarding house operators can be found in any daily newspaper.

ther adequate economic or academic incentives, they are thinly staffed, staff turnover is marked, and the role of the psychiatrist in either clinical or administrative capacities continues to decline. As Pardes (31) noted, "more than 50% of the community mental health centers have fewer than 2.3 full time equivalent psychiatrists, not enough to assure quality of care." Lack of systematic evaluation of community centers and the services delivered to the chronically ill has contributed to general lack of awareness of their limitations, detracting from the quality of services provided.

Fewer medical students are choosing psychiatry as a career (32), but that is only part of the problem. Until a generation ago, mental health professionals had no effective medications. The discipline was dominated by theories emphasizing psychosocial and psychodynamic causes and treatments of mental illness, with little documentation of efficacy. Adjustment to the new developments in biological and psychopharmacological research is still under way, both in the medical schools and in patient care.

Medical, psychology, social work, and nursing students do not learn enough about the new methods of diagnosis and treatment. Particularly for nonmedical health professionals, formal training in psychopharmacology and biological psychiatry is meager if available at all. Too many psychiatrists make mistakes in diagnosis and prescription. They prescribe the wrong drugs or the wrong amount of the right drug for insufficient periods of time. This problem can be solved through improved professional education and the development of more effective methods of peer review of the quality of patient care. Both remedies are especially difficult to apply to private practice.

CONCLUSION

Philip May (33) has long recommended a "two-tier approach" to treatment facilities. His idea is really quite simple: the type of care that is ordinarily provided is beneficial to many patients and is all that they need. Those who do not show appropriate improvement within three months should be referred to secondary, "expert" centers for extended evaluation and treatment. Studies of the reorganization of the care of mental health patients along these lines—and the development of centers of advanced expertise—would demonstrate whether this is the best way of dealing with the shortage of clinicians who are skilled in the use of psychotropic agents. The centers would also serve a valuable role in the continued education of health care professionals.

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G. THE ROLE OF STRESS IN PHYSICAL AND MENTAL HEALTH AND DISEASE: IMPLICATIONS FOR PREVENTIVE HEALTH STRATEGIES

by

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ABSTRACT

Everyone may recognize that stress, tension, and worry contribute to physical and emotional illness, but this "common sense" knowledge has been rather neglected in modern medicine with its emphasis on the "cure" rather than the prevention of illness. The small amount of research on stress that has been done suggests: (1) some forms of stress are healthy; (2) bodily mechanisms for dealing with stress are implicated in both reversible and irreversible illness; (3) excessive stress either causes or aggravates 70 to 90 percent of all illnesses; and (4) techniques to prevent illness by reducing stress could lower the incidence of such illnesses by a factor of up to five. The various techniques devised to help reduce stress fall into the new field of behavioral medicine, which emphasizes the importance of individual responsibility.

Various incentives could be devised both by government and by private interests, such as the insurance companies, to encourage more people to take responsibility for their own health. These efforts should include teaching individuals how to prevent illness.

ISSUES

Virtually everyone recognizes that stress, tension, and worry contribute to physical and emotional illnesses. But regardless of this "common sense" knowledge, health professionals have tended to ignore the crucial role of stress in the treatment and, particularly, in the prevention of illness.

The situation is changing. After the so-called scientific revolutions in medicine that have led to increasingly effective drug therapy and surgery, we are witnessing the rise of "behavioral medicine" or "health psychology" (15). The change is due to increasing longevity, with its associated rise in the incidence of chronic disease, and the escalating cost of a health care system that is focused on treating illness. The new emphasis is on prevention of illness, in large part through self-modification of the stress mechanisms and changes of lifestyle designed to reduce exposure to illness-causing agents.

The importance of this shift is difficult to overstate. "Health insurance" has in the past meant a system to compensate people who are sick; now there is serious talk of extending it to keeping people well. (Reduced premiums for nonsmokers are one example.)

BACKGROUND

Distress has been identified as a significant contributing factor in many animal and human diseases, including cardiovascular disease, cancer, and mental depression in elderly and retired people (16). Both retrospective and prospective studies have shown that reducing stress is associated with a lower incidence of disease—sometimes by a factor of five (8,9). Not all stress can be eliminated, however, and some studies indicate that a certain amount of stress (termed "eustress" by Selye) is healthy and can increase productivity in workers (16). Holmes and Rahe have redefined adverse stress as that leading to "significant life change or social readjustment" and have devised scales for its assessment (7).

Physicians who work in behavioral medicine believe that stress either causes or aggravates 70 to 90 percent of all cases of illness (13,16). Current research has identified at least four phases in the mechanism of stress:

(1) The alarm phase, also known as the acute fight-or-flight response. This phase, first described by Cannon, involves release of adrenalin and can lead to such reversible psychosomatic symptoms as headache, labile essential hypertension, bruxism, irritable colon, palpitation of the heart, and general anxiety (13).

(2) The general adaptation syndrome. This phase tends to protect the body against overreaction to stress stimuli but can leave it vulnerable to other disease-causing factors (16). Overactivation of the adrenal steroid system can in time lead to kidney impairment, malignant hypertension, ac-

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celerated development of atherosclerosis (with potential sequelae of heart attack or stroke), and duodenal ulcers. The body's defense against such overactivation also produces the suppression of the immunological defense system against viruses, bacteria, and the results of errors in cell division (these faulty cells can become cancerous). Such environmental stressors as cigarette smoke and certain pollutants lead to more errors in cell division.

(3) Dysponesis, or faulty or erroneous muscle bracing against pain or discomfort. Such muscle bracing can be a source of further stress, aggravating the effects of the first two phases (23, 25). It is involved in many cases of chronic pain, and the President's Commission for Employment of the Handicapped has estimated the cost of this growing contributor to disability (and compensation) as more than $50 billion a year (11).

(4) A sense of helplessness and hopelessness, often called the failure-to-learn syndrome. In this phase persons are overwhelmed by the consequences of stress and become depressed, losing confidence in therapy and in their own ability to recover. This depression is an underlying cause of many disorders; it is often "masked," and treatment with tranquilizers only makes the condition worse (19).

Each individual apparently differs in the way his or her various vulnerable body systems respond to stress by developing symptoms of illness. Some people get ulcers; others develop hypertension—this is known as the principle of psychophysiologic response specificity. Popular classification of Type A and Type B personalities deals with the same principle (2). Selye argues that a Type A "racehorse" (driven, high achieving, coronary prone) finds as much stress in being put to pasture as a Type B individual finds in being forced to race (16).

The theoretical issues underlying the role of stress in physical and mental health are clear and are summed up by the worn, but often ignored, dictum that "an ounce of prevention is worth a pound of cure." The cost and complexity of "cures" by means of drugs or surgery are increasing; an effort in preventive medicine, persuading people to learn to cope adaptively with stress, would pay off by reducing the costs of health care in the future.

Many of the strategies and techniques for dealing with stress have been known for a long time (17). Unfortunately, the rates of compliance are low; it is estimated that only 11 percent of persons with hypertension take their prescribed medication regularly. (This is often due to the side effects of drugs; many people do not find high blood pressure troublesome—until the first heart attack or stroke.) Statistics in other areas are equally discouraging: people do not exercise, lose weight, or stop drinking, smoking, and abusing drugs. The American populace has developed a "transplant technology" attitude that it is not important to pay attention to preventive maintenance when you can get repaired later—at enormous personal and social cost.

SCIENCE AND TECHNOLOGY TRENDS

The health care community gives modest support to stress reduction and other preventive measures, but due to low compliance by patients most physicians have come to rely on chemotherapy. Most patients accept drugs more readily. For potentially reversible stress disorders, the most common treatment is the prescription of a minor tranquilizer of the benzodiazepine category. These drugs—Valium is the most widely used—interrupt the neural stress pathways and are extremely effective in acute alarm phase situations. The trouble is that chronic use of tranquilizers permits individuals to subject themselves to more and more stress, without awareness of the continuing function of the stress mechanism of the body—until one day they develop symptoms of some possibly irreversible disease. Selye has dealt with this problem at some length (16).

Several alternatives to the use of tranquilizers were introduced during the 1970s. These include biofeedback instrumentation used with or without autogenic, progressive relaxation and other supportive procedures that of themselves require little or no equipment (3,4,12). Biofeedback is a self-regulation technique that appeals to many Americans because of the instrumentation and its dramatic ability to demonstrate the presence of unconscious tension states in different organ systems. Because it involves self-discovery without the threat of "head shrinking" by a therapist, as in psychotherapy, the technique is more acceptable to many persons with stress disorders.

Autogenic and progressive relaxation procedures also involve self-discovery, although individuals may be introduced to their use in group situations. Some of them are based on meditation techniques (which may use religious terminology); others involve passive concentration on certain bodily functions (22).

Both approaches to stress reduction are based on the fact that conscious awareness of smooth muscle and glandular activity is meager, except when something is wrong. At such times, we are likely to feel pain (a relatively crude sensation) that may seem to be in a different part of the body. The basic scientific principle of biological feedback is providing parallel information through a simple external signal—a sound or light, for instance—so that a normally unconscious bodily function becomes observable at the conscious level. The instruments are used on a temporary basis, much like the training wheels on a bicycle, while the conscious mind uses its capacity for learning to acquire voluntary control over an organ system. Professor Neal Miller, a pioneer in the studies, has speculated that, "Biofeedback should be well worth trying on any symptom, functional or organic, that is under neural control, that can be continuously monitored by modern instrumentation, and for which a given direction of change is clearly indicated medically.... for example, cardiac arrhythmias, spastic colitis, asthma, and those cases of high blood pressure that are not [essentially compensating] for kidney damage)" (10).

The autogenic relaxation techniques try to achieve the same result without the use of instrumentation, though some of them emphasize the importance of overall relaxation of all the body systems. That, too, implies conscious control, however.

Exaggerated claims in the mass media (and by some unscrupulous practitioners and outright charlatans) have led to a generally cautious attitude to both biofeedback and the autogenic relaxation techniques on the part of most health care professionals. Their caution applies to both preventive and curative use of the techniques. Studies undertaken under auspices of the Biofeedback Society of America (24) have shown that the instrumentation, without adjunctive techniques, can alleviate symptoms in the clinic but that there is little carryover into stressful real life situations.

The adjunctive techniques include progressive relaxation, autogenic training, relaxation response (1), and a relatively new technique called the quieting response (5,20). All of them foster a relatively passive learning setting, which is emerging as an important factor in preventive health strategies. The rationale lies in the Western work ethic that encourages high achievement through goal-directed effort: a patient with tension headache, when told to "just relax," tries to relax with the same intense effort that led to the original symptom. The resulting headache, or other symptom, can actually be even worse than the original! Persons being treated for headache by biofeedback are told to passively attend to a tone that reflects muscle tension and "simply let the tone decrease through whatever mental images are effective."

Persons differ in their response to stressful situations; some regain a relaxed state relatively soon after "emergency response" episodes, while the process takes a long time in others. Individuals who are predisposed to stress illnesses tend to maintain excessively high levels of activity in both muscular and hormonal systems. This may be due to biological causes (disease, injury, or hostile environment), but evidence is accumulating that most stress-prone individuals gradually learn to override their inherent "quieting mechanisms" (5,20). Children with tension headaches return to the relaxed state more quickly than adults; indeed, some adults reach a state where the arousal response becomes almost automatic. Such persons often say that periods of calmness and relaxation are elusive and should even be avoided if "one is to make the most of life." Some of them claim to be relaxed when body sensors indicate otherwise. They may also experience discomfort when they do achieve genuine physiological quieting—an indication of how deeply ingrained stress expectancy can become (13).

Concerns about automatic compliance with biofeedback techniques in real life situations and observations that children learn the techniques easily and quickly have led to the development of compliance strategies for preventive health care in this area. The basic technique is six-second reversal of the initial phases of the stress response known as the "quieting response" (5,9,20). A modified technique has been developed for use in the classroom, without the use of instruments and at relatively little cost, to prepare youngsters for coping with the stresses of life (18).

POLICY PERSPECTIVES

Improvement in the Nation's economy will reduce stress among the population, and environmental protection will reduce the impact of other stress factors, but it is unlikely that health directives per se will change the increasingly stressful pace of our lives (9). Stress is a health problem that must ultimately be dealt with on an individual basis.

In 1979, at least 10 million individual Americans swallowed a total of more than 5 billion tranquilizer pills (14,6). Biofeedback and the various autogenic relaxation techniques potentially promise a noninvasive and cheaper alternative to chronic medication. Economic incentives could be devised to encourage the use of techniques to prevent illness, including lower taxes and lower "health insurance" premiums. Of course compliance would have to be—and can be—monitored; many medium-sized communities already have clinics and stress management training centers with the necessary instrumentation. Screening programs for the early detection of serious health problems, such as cancer and heart disease, also underline the importance of preventing illness—and of such modifications in behavior as weight control and giving up smoking or drinking. The same centers used for determining compliance could also be used to conduct screening (14).

While the National Institutes of Health has been steadily increasing its support of research and clinical application of behavioral medicine, the total dollar amounts are still small: while $3 billion is allocated for illness research, the prevention-oriented program under National Heart, Lung, and Blood Institute auspices has received only $8 million in the current fiscal year. That means an awful lot of money, time, and effort is being spent to put out the fire and very little to keep the fire from starting. A policy underlining the importance of prevention (and in our society importance is all too often expressed in dollars) would also help to change the present treatment-of-illness orientation of the health care professions. Finally, any economic inducements to change the behavior of people will cost money, and public education efforts alone have not had very impressive results in the general population.

It would be logical to direct many of these efforts at children—and it would not be overly expensive to expand the elementary school curriculum to four R's: Reading, 'Riting, 'Rithmetic, and Relaxation. The National Education Association, in fact, is recommending precisely that in the "Stress Management" chapter of its definitive report on *Health Education in the 1980's* (18).

It is possible to change things. Senator Kennedy's subcommittee hearings in 1979 on overprescription of minor tranquilizers led to a Food and Drug Administration recommendation, and the voluntary acceptance by the pharmaceutical manufacturers, that such medications should carry a label warning against their use "for the stress and strain of daily living." This warning has been criticized as too weak, but it is an important step in the right direction because it will cause physicians to think about behavioral medicine alternatives. The warning serves as a reminder that minor tranquilizers are not, and that no drug ever will be, the "soma" that formed a basis of Aldous Huxley's *Brave New World.* It will also foster a shift from the costly medical model of responsibility for "illness care" and increased awareness of the crucial role of individual responsibility in health.

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CHAPTER II

NOTES ON EMERGING ISSUES IDENTIFIED BY THE SECOND ANNUAL SCIENCE AND TECHNOLOGY REPORT

A. INTRODUCTION

Chapter IX of the second *Annual Science and Technology Report* (June 1980) includes a set of issue definition briefs that identifies emerging policy problems in science and technology.* The briefs are similar in scope and purpose to the papers that constitute chapter I of this supplement. This chapter consists of short, updating notes on recent scientific, technical, and policy developments in five of the issue areas highlighted in the second annual report. The five areas discussed are risk assessment and management, earthquake prediction, coal consumption, information and communications, and privacy and computer data bases. Significant Federal decisions, actions, and programs initiated during 1980 that relate to four other sets of emerging issues considered in the second annual report—nuclear waste management; weather and climate; technology, energy, and agriculture; and technology and health care costs—are described in the body of this *Report* (sections I-D and II-E, I-E and II-G, I-D and II-J, and II-C).

B. RISK ASSESSMENT AND MANAGEMENT

On July 2, 1980, a sharply divided Supreme Court invalidated the Occupational Safety and Health Administration (OSHA) standard for worker exposure to benzene, a widely used industrial chemical that is known to cause cancer. In a 5 to 4 decision, the Court said that OSHA had not made a proper initial finding on which to base the benzene standards. Nor, it said, had OSHA proved that an older, less stringent benzene standard is inadequate.

Science and Technology: Annual Report to the Congress. Washington, D.C.: National Science Foundation, June 1980, pp. 61-79, NSF 80-21.

In handing down the decision, the Supreme Court did not address the deeper issue of whether an agency is required to weigh the benefits of safety standards against the costs of compliance. The U.S. Court of Appeals had ruled that such a benefit-cost analysis was required when it struck down the new benzene standard in 1978. OSHA had appealed this decision, arguing that the benefits and costs of a toxic substance often cannot be quantified.

Justice John Paul Stevens, writing for the majority, noted that OSHA, before issuing a new safety standard, must determine that "a significant risk of harm exists" from current exposure levels. He wrote, however, that "the requirement that a 'significant' risk be identified is not a mathematical strait jacket.... So long as they are supported by a body of reputable scientific thought, the Agency is free to use conservative assumptions in interpreting the data.... risking error on the side of overprotection." Justice Stevens pointed out that since OSHA had not presented evidence that benzene posed a significant risk, the Court of Appeals was correct in invalidating the new standard. As a result, the Supreme Court could affirm the decision of the lower court without addressing the benefit-cost question. Only Justice Lewis Powell, in a concurring opinion, supported the lower court's requirements that benefits and costs be reasonably related.

On the same day that the benzene decision was announced, the Supreme Court accepted for review a case that again would raise the benefit-cost question. That case, Republic Steel vs. OSHA, is a challenge by the steel industry to the agency's standard for emissions from coke ovens in steel mills.

C. EARTHQUAKE PREDICTION

Much of the initial enthusiasm for earthquake prediction in the United States centered on successes in identifying systematic changes in seis-

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mic velocities prior to earthquakes, together with the apparent success of the so-called "dilatancy model" in explaining those and other claimed precursory phenomena. Much of the enthusiasm still remains, but the initial euphoria has been somewhat tempered by recent detailed studies suggesting either that the phenomena are not as universal as had been hoped or that they are considerably less intense or in a smaller volume than had been expected. Successful prediction will continue to require both fundamental research on the earthquake process and the establishment of the technical means of monitoring precursory effects. Establishment, in 1980, of joint research projects on earthquake prediction between U.S. and Chinese scientists at the State Seismological Bureau in Beijing constitutes a significant step towards those ends.

There have been some successes in the United States in predicting small earthquakes, but the most difficult problems remain. For example, it is not clear whether the techniques that seem to have worked on small events are applicable in a practical way to large earthquakes—the only ones of real social significance. In fact, all earthquakes may not have the same types of precursors or, indeed, any recognizable precursors at all. If there are precursory signals for large earthquakes, they may not allow a sufficiently narrow predictive time window to permit practicable temporal social responses. Will the ultimate false alarm and failure rate be socially acceptable? Will the public be willing to accept the trial-and-error period during which the system is being developed and perfected?

There have been some significant developments concerning the earthquake potential in California since the second *Annual Science and Technology Report*. Detailed geologic studies of the San Andreas fault indicate that events similar to a large 1857 earthquake have occurred at intervals from 100 to 230 years and on the average of every 140 years. (In 1857 the San Andreas fault broke some 200 miles, from Cholame to just north of San Bernardino, giving rise to an earthquake of an estimated magnitude of 8.3 on the Richter Scale.) Since the last major breakage of the San Andreas fault in the region was in 1857, it is reasonable to assume that we are in a period, one spanning several decades, when another major earthquake is more likely than, for example, during the period 1860 to 1960.

For the past 8 years, the U.S. Geological Survey (USGS) has been making regular geodetic surveys in southern California to observe patterns of strain in the Earth's uppermost crust. Those surveys indicated initially that the uppermost crust in southern California was in a general state of increasing north-south compression. Given the geometry of the region, that strain pattern tended to push the sides of the fault together, which, in a simple model, might reduce the likelihood of slippage or breakage along the fault. Beginning in 1979, a dramatic change was observed in the crustal strain pattern, and the magnitude of the strain rate increased to about three or four times that previously observed. The magnitude of the recent strain changes, greater than any observed in the previous 8 years, is disconcerting.

The level of earthquake activity in the State has also recently increased. During the past year, there have been 11 earthquakes of magnitude exceeding 5.5 in the region. That is about twice the total of similar events in the previous 6 years. Although the previous 6 years seem to have been abnormally quiescent, the recent seismicity may indicate an increase in regional crustal stress.

Over the last year, increases have also been observed in the quantity of radon in the groundwater of certain wells in southern California. Similar increases have been observed prior to earthquakes in Japan and the Soviet Union. (Many rocks, particularly granites, contain trace amounts of radioactive elements. As these elements decay, they give off harmless quantities of radon, a radioactive gas with a short half-life. Because of its radioactive nature, the gas can be detected in minute quantities in groundwater.)

These developments prompted USGS to express its heightened concern over the earthquake potential in southern California in a letter to Governor Jerry Brown on July 3, 1980. On September 10, 1980, the USGS completed a review of available information and concluded that current observations do not constitute grounds for any concern greater than that expressed in that letter to Governor Brown.

The Federal Emergency Management Agency (FEMA) is the agency charged with providing the necessary management and coordination required to strengthen research, planning, and preparedness within the Federal Government, as authorized under the National Earthquake Hazards Reduction Program. A recent government review of the potential consequences of and the state of preparedness for the possibility of a major earthquake in California indicated that the Nation is not sufficiently prepared for a catastrophic earthquake in California, should such a disaster occur. The review involved FEMA, the Departments of Defense, Transportation, and the Interior (especially USGS), and several other appropriate Federal agencies.

Significant improvements in the Federal, State, and local capability for coordinating operational responses to a major earthquake seem to be needed. To help accomplish that objective, FEMA will establish a small staff in California to participate in jointly coordinated earthquake preparedness planning and implementation. A cooperative study is getting under way with State and local governments, other Federal departments, voluntary agencies, practicing professions, business and commercial interests, labor, educators, and researchers to develop an effective program for responding to an earthquake or a credible earthquake prediction in southern California. The emphasis is on public safety, reduction of property damage, self-help on the part of individuals, socioeconomic impacts, improved response and long-range recovery planning, mitigation activities, and public participation for both the postprediction and the immediate post-earthquake periods. This pilot effort is expected to be completed by late 1981 and to be usable in other earthquake-prone areas of California as well as in other States.

D. COAL CONSUMPTION

As discussed in the second *Annual Science and Technology Report*, coal is a large, assured energy source that the United States can exploit fairly quickly. But because of various problems associated with the use of coal (e.g., air pollution and coal's form and bulk), customers over the last 40 years have shifted to cleaner and more convenient energy sources such as oil and gas. Present heating systems are not now generally adapted to use of coal, so that coal currently appears to be most effectively used for electricity generation.

Recent evidence and projections show that overall demand for U.S. coal is growing and that coal is displacing other energy sources in electicity generation. Demand for U.S. coal in 1979 increased 5 percent over 1977 demand levels. This increase resulted from a 5.4 percent average increase in consumption by electric utilities and a 10 percent increase in total coal exports. The electric utilities' consumption occurred while the amount of electricity generated increased less than 3 percent, resulting in a net gain in the share of electricity generated by coal. With the increases, coal-generated electricity now accounts for slightly more than one-half of the electricity produced in the United States. Current demand projections by the National Coal Association anticipate that the consumption of coal by electric utilities will grow by more than 80 percent between 1979 and 1990, from 528 million tons to 959 million tons. The association also estimates that industrial use of coal will grow from 73 million tons to 125 million tons by 1990, and that the export market will grow from 46 million tons to 60-73 million tons in the same 11-year period. With the passage of the Energy Security Act of 1980, which establishes the U.S. Synthetic Fuels Corporation, it can be expected that coal will be a major contributor to the production of synthetic fuels and chemical feedstocks beyond 1990.

A recent report from the World Coal Study, entitled *Coal: Bridge to the Future*, by Carroll L. Wilson (Cambridge, Massachusetts: Ballinger, 1980) concludes that a 5 percent annual increase in coal production worldwide can provide two-thirds of the added energy needed to meet demands for the world's economic growth over the next 20 years.

E. INFORMATION AND COMMUNICATIONS

The Federal Paperwork Commission estimated, in 1977, the cost of Federal paperwork requirements at $100 billion a year. In December 1980, President Carter signed the Paperwork Reduction Act of 1980 (Public Law 96-511). The aim of the law is to reduce paperwork and enhance the economy and efficiency of the government and the private sector by improving Federal information policies. The authors of the bill estimate that its provisions could reduce the existing Federal paperwork burden by 25 percent in 3 years.

More specifically, the act is intended to:

- Minimize the Federal paperwork burden for individuals, businesses, and State and local governments;
- Minimize the cost to the Federal Government of collecting, maintaining, using, and disseminating information;
- Maximize the usefulness of information collected;
- Coordinate and integrate Federal information policies and practices;
- Insure that automatic data processing and telecommunications technologies are acquired and used by the Federal Government to improve service delivery and program management, increase productivity, and reduce the information processing burden for both the government and the public.

The act establishes an institutional framework to carry out recommendations of the Commission on Federal Paperwork, consolidates Federal information management policy functions in the Office of Management and Budget (OMB), and establishes, under the direction of OMB, a Federal Information Locator System (FILS).

Under the authority of Executive Order No. 12044, issued in early 1980, OMB began implementing some of the provisions of the Paperwork Reduction Act of 1980 in anticipation of its enactment. In particular, OMB established an Office of Regulatory and Information Policy and initiated work on FILS.

F. PRIVACY AND COMPUTER DATA BASES

Some progress has been made in legislation to protect personal data in automated information systems. Bills are under consideration in the areas of banking, credit, and insurance, although they have not yet moved through the Congress. However, the Paperwork Reduction Act of 1980 does give the Office of Management and Budget broad authority to set Federal information policy in a number of areas, including privacy. States have been active in passing medical privacy legislation, but no omnibus privacy bills have been passed.

At the international level, there has been a continuation in the proliferation of national privacy legislation, much of which aims to control the international transfer of personal data. The United States and Britain continue to oppose such a sweeping approach which, they maintain, could lead to a series of international problems associated with the so-called "transborder data flow" issue. The issues are likely to become complicated further as Third World nations inject their concerns about national sovereignty and economics into the debate. The ways in which the international issues are resolved could profoundly affect those areas of science, particularly the life and earth sciences, that depend on international collection and exchange of basic research data.

APPENDICES

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APPENDIX A

FEDERAL RESEARCH AND DEVELOPMENT FUNDS BY SELECTED FUNCTIONAL AREAS FOR FISCAL YEARS 1979, 1980, AND 1981

R&D Budget Authority for National Defense
(dollars in millions)

	1979 Actual	1980 Revised Estimate	1981 Revised Estimate
Total	$13,791	$14,959	$18,117
DEPARTMENT OF DEFENSE/MILITARY			
Research, development, test, and evaluation			
Technology base	2,010	2,259	2,712
Advanced technology	525	620	595
Strategic programs	2,139	2,187	3,365
Tactical programs	5,088	5,209	5,748
Intelligence and communications	759	1,164	1,577
Defensewide mission support	1,689	1,847	2,260
Subtotal	12,209	13,287	16,257
Other DOD military	441	508	532
Total, Department of Defense/Military	12,650	13,795	16,789
ATOMIC ENERGY DEFENSE ACTIVITIES (DOE)			
Inertial confinement fusion	105	115	160
Naval reactors development	273	241	250
Weapons R&D and testing activities	597	628	708
Verification and control technology	30	37	39
Materials production	10	13	16
Defense waste management	83	87	112
Nuclear materials security and safeguards	43	43	43
Total, Atomic Energy Defense Activities (DOE)	1,141	1,164	1,327

Source: Based on data contained in *Federal R&D Funding by Budget Function Fiscal Years 1979–81*, Division of Science Resources Studies, National Science Foundation, May 1980.

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R&D Budget Authority for Space Research and Technology
(dollars in millions)

	1979 Actual	1980 Revised Estimate	1981 Revised Estimate
Total	$3,969	$4,606	$4,918
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION			
Space transportation systems			
Space Shuttle	1,638	1,886[a]	1,873
Space flight operations	300	447	768
Expendable launch vehicles	74	71	56
Research and program management	390	416	429
	2,401	2,819[a]	3,126
Space science, applications, and technology			
Space science	626	717	680
Space and terrestrial applications	394	473	500
Space research and technology	175	190	188
Energy technology	29	31	34
	1,224	1,411	1,402
Supporting activities (tracking and data acquisition)			
Operations	250	265	270
Systems implementation	40	57	68
Advanced systems	10	11	11
Research and program management	43	43	41
	343	376	390
Total, National Aeronautics and Space Administration	3,969	4,606	4,918

[a]Includes a $300 million supplemental appropriation request.

Source: Based on data contained in *Federal R&D Funding by Budget Function Fiscal Years 1979–81*, Division of Science Resources Studies, National Science Foundation, May 1980.

R&D Budget Authority for Health
(dollars in millions)

	1979 Actual	1980 Revised Estimate	1981 Revised Estimate
Total	$3,401	$3,650	$3,792
HEALTH RESEARCH			
National Institutes of Health (HHS)			
Cancer	897	942	938
Heart, Lung, and Blood	488	488	503
Arthritis, Metabolism, and Digestive Diseases	287	317	345
General Medical Sciences	230	263	272
Neurological and Communicative Disorders and Stroke	204	231	239
Allergy and Infectious Diseases	183	204	218
Child Health and Human Development	187	198	206
Eye	100	105	112
Environmental Health	73	77	87
Aging	54	67	72
Dental	61	64	66
Research Resources	154	164	173
John E. Fogarty International Center	9	9	9
National Library of Medicine	10	11	10
Office of the Director	19	20	20
Subtotal	2,957	3,159	3,270
Alcohol, Drug Abuse, and Mental Health Administration (HHS)			
General Mental Health Research	144	161	179
Drug Abuse Research	47	50	55
Alcoholism Research	24	24	27
St. Elizabeths Hospital	2	2	2
Subtotal	216	237	262
Centers for Disease Control (HHS)			
Disease Control	23	25	26
Occupational Health	52	67	70
Subtotal	74	92	95
Assistant Secretary for Health (HHS)			
National Center for Health Services Research	NA	30	35
National Center for Health Care Technology	NA	3	5
Subtotal	34	33	39
Health Care Financing Administration (HHS)	17	31	29
Health Services Administration (HHS)	17	17	16
Health Resources Administration (HHS)	5	...	...
Special Foreign Currency Program (HHS)	11	7	...
Total, Health Research	3,330	3,575	3,711
CONSUMER AND OCCUPATIONAL HEALTH AND SAFETY			
Food and Drug Administration (HHS)			
Foods Research	22	22	22
Drugs and Devices Research	20	22	23
Radiological Products Research	10	10	10
National Center for Toxicological Research	9	11	12
Subtotal	61	64	67
Occupational Safety and Health Administration (Labor)	7	7	11
Consumer Product Safety Commission	4	4	4
Total, Consumer and Occupational Health and Safety	72	74	81

Source: Based on data contained in *Federal R&D Funding by Budget Function Fiscal Years 1979–81*, Division of Science Resources Studies, National Science Foundation, May 1980.

R&D Budget Authority for Energy
(dollars in millions)

	1979 Actual	1980 Revised Estimate	1981 Revised Estimate
Total	$3,461	$3,765	$3,675
DEPARTMENT OF ENERGY[a]			
Solar			
Solar technology	308	350	416
Solar applications	126	135	154
Solar	29	19	10
Subtotal	463	503	580
Geothermal	132	112	131
Hydropower	5	4	1
Nuclear fission			
Converter reactor system	68	63	51
Commercial nuclear waste	143	167	225
Spent nuclear fuel storage	6	11	20
Advanced nuclear systems	50	38	39
Breeder reactor systems	601	606	304
Light water reactor facilities	7	...	...
Uranium enrichment	131	129	147
Subtotal	1,006	1,014	786
Magnetic fusion	211	240	281
Fossil energy			
Coal	535	654	561
Petroleum	99	59	61
Gas	34	30	30
Subtotal	668	743	653
Electric energy systems and storage	95	100	109
Environmental R&D	195	216	219
Supporting research	192	220	259
Energy conservation			
Buildings and community systems	78	103	96
Industrial energy conservation	39	60	58
Transportation energy conservation	98	111	112
Multisector	10	17	29
Subtotal	226	291	294
Total, Department of Energy	3,192	3,444	3,313
NUCLEAR REGULATORY COMMISSION	157	204	228
ENVIRONMENTAL PROTECTION AGENCY	113	101	108
ENERGY SECURITY TRUST FUND	...	15	27

[a]The inclusion of revised estimates of budget authority for DOE R&D plant would add $571 million in 1979, $609 million in 1980, and $833 million in 1981.

Source: Based on data contained in *Federal R&D Funding by Budget Function Fiscal Years 1979–81*, Division of Science Resources Studies, National Science Foundation, May 1980.

R&D Budget Authority for General Science
(dollars in millions)

	1979 Actual	1980 Revised Estimate	1981 Revised Estimate
Total	$1,119	$1,246	$1,371
NATIONAL SCIENCE FOUNDATION			
Mathematical and physical sciences	201	225	258
Astronomical, atmospheric, earth, and ocean sciences	200	215	237
Biological, behavioral, and social sciences	157	171	183
Engineering and applied science	106	117	125
U.S. Antarctic research program	47	52	57
Scientific, technological, and international affairs	26	29	31
Cross-directorate programs	12	25	29
Ocean drilling programs	12	19	22
Science education	17	19	21
Special foreign currency program	4	6	6
Program development and management	26	26	28
Total, National Science Foundation	810	904	994
DEPARTMENT OF ENERGY			
High-energy physics	195	220	242
Nuclear physics	75	82	89
Life sciences and nuclear medicine applications	40	41	46
Total, Department of Energy	309	342	377

Source: Based on data contained in *Federal R&D Funding by Budget Function Fiscal Years 1979–81*, Division of Science Resources Studies, National Science Foundation, May 1980.

R&D Budget Authority for Natural Resources
(dollars in millions)

	1979 Actual	1980 Revised Estimate	1981 Revised Estimate
Total	$726	$753	$779
WATER RESOURCES			
Water and Power Resources Services (Interior)	12	13	15
Office of Water Research and Technology (Interior)	28	30	32
Corps of Engineers (DOD)	26	30	32
Total, Water Resources	65	73	79
CONSERVATION AND LAND MANAGEMENT			
Forest Service (USDA)	111	112	124
Bureau of Land Management (Interior)	1	2	2
Office of Surface Mining and Reclamation (Interior)	5	8	8
Total, Conservation and Land Management	117	122	134
RECREATIONAL RESOURCES			
Fish and Wildlife Service (Interior)	81	84	85
National Park Service (Interior)	8	7	8
Total, Recreational Resources	89	91	93
OTHER NATURAL RESOURCES			
National Oceanic and Atmospheric Administration (Commerce)	182	205	210
Geological Survey (Interior)	146	153	151
Bureau of Mines (Interior)	125	106	110
Office of the Secretary (Interior)	3	3	2
Total, Other Natural Resources	455	467	473

Source: Based on data contained in *Federal R&D Funding by Budget Function Fiscal Years 1979–81*, Division of Science Resources Studies, National Science Foundation, May 1980. The figures for Natural Resources were taken from the table for the budget function Natural Resources and Environment (pp. 65–72).

R&D Budget Authority for Environment
(dollars in millions)

	1979 Actual	1980 Revised Estimate	1981 Revised Estimate
Total (Environmental Protection Agency)[a]	$283	$337	$361
PROGRAMS FUNDED BY THE EPA R&D AND S&E APPROPRIATIONS[a]			
Air	50	67	71
Water quality	63	65	60
Solid waste: public sector activities	7	14[b]	26
Pesticides	12	13	9
Radiation	2	3	3
Interdisciplinary	19	23	23
Toxic substances	16	28	37
Management and support	24	28	29
Total, Programs Funded by the EPA R&D and S&E Appropriations	208	264	287
PROGRAMS FUNDED UNDER THE ABATEMENT, CONTROL, AND COMPLIANCE APPROPRIATION	73	73	73
SPECIAL FOREIGN CURRENCY PROGRAM	3	...	1

[a]Excludes energy-related R&D programs.
[b]Includes a $5.6 million supplemental request.

Source: Based on data contained in *Federal R&D Funding by Budget Function Fiscal Years 1979-81*, Division of Science Resources Studies, National Science Foundation, May 1980. The figures for Environment were taken from the table for the budget function Natural Resources and Environment (pp. 65–72).

R&D Budget Authority for Transportation
(dollars in millions)

	1979 Actual	1980 Revised Estimate	1981 Revised Estimate
Total	$798	$859	$875
GROUND TRANSPORTATION			
Federal Highway Administration (DOT)	50	44	48
National Highway Traffic Safety Administration (DOT)	52	55	63
Federal Railroad Administration (DOT)	41	43	44
Urban Mass Transportation Administration (DOT)	49	47	49
Energy Security Trust Fund (automotive basic research)	...	...	12
Total, Ground Transportation	192	188	215
AIR TRANSPORTATION			
Federal Aviation Administration (DOT)			
Research, engineering, and development appropriation (airport and airway trust fund)	75	75	85
Facilities, engineering, and development appropriation	11	13	15
Operations appropriation (development direction)	15	15	15
Subtotal	101	103	115
Aeronautical Research and Technology (NASA)			
Research and technology base	110	119	131
Systems technology	154	189	144
Research and program management	178	200	205
Subtotal	443	508	480
Total, Air Transportation	543	611	595
WATER TRANSPORTATION			
Maritime Administration (Commerce)	19	17	16
Coast Guard (DOT)	20	22	25
Total, Water Transportation	39	39	41
OTHER TRANSPORTATION			
Office of the Secretary (DOT)	12	9	12
Research and Special Programs Administration (DOT)	12	11	12
Total, Other Transportation	24	20	24

Source: Based on data contained in *Federal R&D Funding by Budget Function Fiscal Years 1979–81,* Division of Science Resources Studies, National Science Foundation, May 1980.

R&D Budget Authority for Agriculture
(dollars in millions)

	1979 Actual	1980 Revised Estimate	1981 Revised Estimate
Total	$552	$602	$634
SCIENCE AND EDUCATION ADMINISTRATION AGRICULTURAL RESEARCH (USDA)			
Animal production	66	69	72
Plant production	132	142	151
Use and improvement of soil, water, and air	43	48	51
Processing, storage, distribution, food safety, and consumer services research	72	76	75
Human nutrition research	22	30	35
Total, Science and Education Administration Agricultural Research (USDA)	334	365	384
SCIENCE AND EDUCATION ADMINISTRATION COOPERATIVE RESEARCH (USDA)	174	187	195
ECONOMICS, STATISTICS, AND COOPERATIVES SERVICE (USDA)	36	42	45
OFFICE OF INTERNATIONAL COOPERATION AND DEVELOPMENT (USDA)	6	6	8
AGRICULTURAL MARKETING SERVICE (USDA)	1	1	1
OFFICE OF TRANSPORTATION (USDA)	1	1	1

Source: Based on data contained in *Federal R&D Funding by Budget Function Fiscal Years 1979–81*, Division of Science Resources Studies, National Science Foundation, May 1980.

R&D Budget Authority for Education
(dollars in millions)

	1979 Actual	1980 Revised Estimate	1981 Revised Estimate
Total (research and general education aids)	$144	$146	$162
OFFICE OF ELEMENTARY AND SECONDARY EDUCATION (Education)	2	5	6
OFFICE OF POSTSECONDARY EDUCATION (Education)	1	1	1
OFFICE OF VOCATIONAL AND ADULT EDUCATION (Education)	7	7	14
OFFICE OF SPECIAL EDUCATION AND REHABILITATION SERVICES: HANDICAPPED RESEARCH (Education)	13	13	13
OFFICE OF EDUCATIONAL RESEARCH AND IMPROVEMENT (Education)			
National Institute of Education	81	77	79
National diffusion network	2	2	3
Total, Office of Educational Research and Improvement	83	79	82
GENERAL DEPARTMENT MANAGEMENT (Education)	1	2	2
SMITHSONIAN INSTITUTION	37	39	45

Source: Based on data contained in *Federal R&D Funding by Budget Function Fiscal Years 1979–81*, Division of Science Resources Studies, National Science Foundation, May 1980. The figures for Education were taken from the table for the budget function Education, Training, Employment, and Social Services (pp. 80–81).

R&D Budget Authority for International Affairs
(dollars in millions)

	1979 Actual	1980 Revised Estimate	1981 Revised Estimate
Total	$113	$124	$131
AGENCY FOR INTERNATIONAL DEVELOPMENT	107	59	70
INSTITUTE FOR SCIENTIFIC AND TECHNOLOGICAL COOPERATION	. . .	60	55
ARMS CONTROL AND DISARMAMENT AGENCY	4	4	4
DEPARTMENT OF STATE	2	2	2

Source: Based on data contained in *Federal R&D Funding by Budget Function Fiscal Years 1979–81*, Division of Science Resources Studies, National Science Foundation, May 1980.

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APPENDIX B

PROPOSED FUNDING OF FEDERAL RESEARCH AND DEVELOPMENT FOR FISCAL YEAR 1981 (JANUARY 15, 1981)[1]

The proposed 1982 budget reaffirms the Carter Administration's commitment to provide growth in basic research as an investment in the Nation's long-term scientific and economic health. In addition, it emphasizes other areas that are important to meeting national needs.

In fiscal year 1982 obligations for the conduct of basic research are estimated to be $5.9 billion. This represents an increase of $739 million, 14.4 percent over the 1981 dollar level, or 4.3 percent growth above projected inflation. In the period from fiscal year 1978 to 1982, the years for which budgets have been prepared by the Carter Administration, support for basic science increased from $3.7 billion to $5.9 billion. Thus, in this period, growth of 58 percent in current dollars is proposed, or 10.8 percent growth above inflation. This support is supplemented in fiscal year 1982 by a major new initiative to upgrade research instrumentation.

Proposed Federal obligations for the conduct of all research and development (R&D), including basic research and R&D facilities, are expected to total $44.2 billion in 1982, an increase of $7.1 billion, or 18.9 percent over 1981. Obligations for R&D facilities are estimated to be $2.4 billion in 1982. Exclusive of facilities, the 1982 budget includes $41.7 billion in obligations for the conduct of R&D, an increase of $6.5 billion, or 18.5 percent over 1981.

The increase in funding for the conduct of R&D is reflected in the 1982 budget of almost all agencies. Included within this increase are additional funds to cover cost increases due to inflation. However, in addition to those cost increases, the 1982 budget would provide a real growth on the order of 8 percent over 1981 in government-wide funding for R&D.

The dramatic growth over the period from fiscal year 1978 to 1982 reflects the Carter Administration's vigorous efforts to use R&D to deal more effectively with the economic, national security, energy, environmental, and health issues confronting the Nation.

Highlights of the programs of major R&D agencies are as follows:

Department of Defense (DOD): Obligations for total conduct of R&D will rise to $20 billion, an increase of $3.8 billion, or 23 percent over 1981. The total conduct of R&D by the DOD will account for almost half of total Federal funding for R&D. In addition to providing for anticipated increased costs due to inflation in 1982, the budget provides a real growth in defense R&D obligations over 1981. Growth in support for basic research will increase by 16 percent over 1981, consistent with the continuing effort to provide the scientific base for meeting future defense needs.

National Aeronautics and Space Administration (NASA): Obligations for conduct of R&D are estimated to total $6.6 billion in 1982, $1.167 billion, or 22 percent, over 1981. The budget provides for continued development of the Space Shuttle and procurement of a fleet to meet national needs in such areas as space science, communications, remote sensing of the Earth's environment, and natural resources and defense. The NASA budget also provides for future planetary probes, the space telescope, space applications projects, and new projects in aeronautical R&D.

Department of Energy (DOE): Obligations for the conduct of R&D are estimated to total $5.6 billion, an increase of $0.475 billion, over 1981. Obligations for the support of R&D facilities increase sharply from $1.4 billion to $1.8 billion in 1982. The budget provides for a broad mix of programs and the increase largely offsets cost increases due to inflation. In addition to providing for R&D facil-

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ities the budget provides increased support for longer term solar and fossil R&D; national defense programs of the DOE related to new technologies for monitoring nuclear weapons treaties and the safeguard, storage, and disposal of nuclear materials; nuclear physics research; nuclear fission R&D emphasizing safety, waste management, and breeder research; magnetic fusion research; and synthetic fuel research.

Department of Health and Human Services (HHS): Obligations for the conduct of R&D are estimated to total $4.3 billion in 1982, a $0.321 billion increase over 1981. The HHS R&D programs represent a broad-based effort in biomedical and life sciences. The largest component of the HHS budget for R&D is the National Institutes of Health (NIH). The 1982 budget proposal for NIH programs maintains a strong national effort in biomedical research, increasing from $3.4 billion in 1981 to $3.6 billion in 1982. In 1982 NIH plans to give special emphasis to basic and applied research in such areas as nutrition, genetics, diabetes, radiation and other environmental hazards, aging, and senile dementia.

National Science Foundation (NSF): Obligations for the conduct of R&D are estimated to total $1.157 billion in 1982, including $1.057 billion for the support of basic research. This total represents an increase of $0.142 billion, or 14 percent over 1981. Among other things, the 1982 budget provides for the initiation of a major program to upgrade research equipment and facilities at the Nation's most productive research universities to strengthen the conduct of R&D. Special emphasis is also given to research support in engineering and computer science as well as mathematical and physical sciences.

Interagency R&D Programs: Among the R&D programs proposed in the 1982 budget are a number of interagency efforts that illustrate the many areas in which agencies cooperate in research and development to ensure effective overall use of Federal funds. Such programs, including those in cooperative automotive research, experimental computer science, microelectronics and submicron science and technology, geological applications, agriculture and resources inventory surveys through aerospace remote sensing, and the National Oceanic Satellite System, are described in some detail in Part K of the Special Analysis of the Budget[2].

Funding of R&D at Colleges and Universities: Within the $41.7 billion proposed for R&D in 1982, $5.1 billion will be obligated by Federal agencies for the conduct of R&D in colleges and universities (including medical schools). More than two-thirds of the direct support of R&D (not including funds that flow to colleges and universities through national laboratories or other intermediaries) in these institutions is provided by the Federal Government.

References

[1] Office of Science and Technology Press Release. January 15, 1981. *Note added in proof*: A revised fiscal year 1982 budget was prepared by President Reagan in March 1981.

[2] Office of Management and Budget. *Special Analysis K. Budget of the United States Government, Fiscal Year 1982*. January 1981.

APPENDIX C

REVISIONS TO THE FISCAL YEARS 1981 AND 1982 RESEARCH AND DEVELOPMENT BUDGETS[1]

On March 10, 1981, President Reagan transmitted to the Congress a revised budget for fiscal year 1982 and proposed changes for fiscal year 1981. The revised budget has led to significant adjustments in the funding of research and development (R&D). This analysis summarizes the changes by the major R&D agency and separately identifies Federal expenditures by agency for:

- The conduct of research and development,
- The conduct of basic research,
- The support of research and development at universities, and
- Research and development facilities.

This analysis revises the data included in *Special Analysis K: Research and Development* which was published as part of the January budget for fiscal year 1982.

A. OVERVIEW

The March 10 revisions have been guided by budget and program priorities and criteria applied across all Federal programs. Those that particularly affected decisions on budgeting for R&D are:

- The Nation's defense capabilities must be rebuilt.
- Sound economic criteria must be applied to economic subsidy programs.
- Fiscal restraint must be imposed on programs that are in the national interest but are of lower priority than national defense and safety net programs. (Safety net programs provide income security measures to protect the elderly, unemployed, poor, and veterans.)

The application of these priorities and criteria to the funding of R&D has resulted in:

- A significant increase in the R&D programs of the Department of Defense.
- Significant decreases in "civilian" R&D programs of an economic subsidy nature, for example those in the Departments of Energy and Transportation, where the Federal Government should not fund R&D with near-term payoff but should limit its role to long-term, high-risk, high-potential programs in the national interest that the private sector is not likely to support.

  In addition, it should be noted that private investment in civilian R&D and in the application of innovative technologies in new processes and plants will be encouraged by the plans and proposals of the Reagan Administration to reduce inflation, lessen the burden of regulation, and provide tax incentives for investment—including provisions for accelerated depreciation.
- Reduction in the level of increases proposed in January for long-term R&D. Although such R&D is appropriate for Federal support, the large increases in the January budget for such agencies as the National Aeronautics and Space Administration and the National Science Foundation are inconsistent with the urgent need for fiscal restraint.

  One area of traditional Federal responsibility that has been protected from severe reductions in the revised 1982 budget is support of basic research. The Federal Government spends about $5 billion each year to fund about 70 percent of all basic research performed in the United States. Many believe that investment can be utilized most efficiently if it is accompanied by a measure of long-term stability in funding because basic research is a cumulative process, i.e., gaps created in a period of reduced support cannot be quickly overcome by even a sharp increase in basic research spending at a later date. The revised 1982 budget continues to provide

[1]Prepared by the Energy and Science Division, Office of Management and Budget, March 1981.

strong support for basic research, with obligations for such research expected to rise 1.3 percent in real terms, taking into account anticipated inflation.

The impacts of the revised budget on different categories of research and development support are described below.

Conduct of Research and Development

In fiscal year 1981 the budget revisions would *increase* obligations for the conduct of research and development by $229 million or about 0.7 percent over the appropriated level. That is due to increases in defense-related research and development (totaling $588 million) that more than offset reduction of $359 million in the programs of other agencies. The revised budget provides an increase for Federal obligations of $3.6 billion or 11.4 percent in 1981 over 1980 research and development, an increase of 1.2 percent above the anticipated inflation rate. Outlays for 1981 would decrease by $353 or 1 percent below earlier estimates. However, an increase of $3.2 billion or 10.7 percent over 1980 would be preserved.

In fiscal year 1982 the budget revisions would reduce obligations for the conduct of research and development by a net $795 million or 1.9 percent below the January budget but would preserve an increase of $5.3 billion or 15 percent over 1981. Included in those adjustments for fiscal year 1982 are *increases* in obligations for defense-related research and development of $1.4 billion that partially offset the reduction of $2.2 billion applied to the R&D programs of other agencies. Outlays in 1982 would decrease by $1.018 billion or 2.6 percent below January estimates but would still be $4.7 billion or 14 percent above the 1981 level.

Conduct of Basic Research

In 1981 the budget revisions would reduce Federal obligations for the conduct of basic research by $86 million or 1.7 percent below the appropriated level. The reduced level would be $356 million or 7.6 percent over 1980. The outlays for the conduct of basic research in 1981 would remain unchanged from the January estimates.

In 1982 the reduction in obligations for the conduct of basic research amounts to $319 million or 5.4 percent below the January budget. However, an increase of $507 million or 10.1 percent over 1981 would be preserved, providing a "real" growth of 1.3 percent above the anticipated inflation in 1982. Outlays in 1982 would decrease by $160 million or 2.9 percent below the January budget, but that reduced level would be $499 million or 10.4 percent above 1981.

Research and Development at Universities and Colleges

In 1981 the obligations for university and college R&D would be reduced by $104 million or 2.3 percent below the January estimates. The reduced level would be $256 million or 6.1 percent above 1980. In 1982, the obligations would be reduced by $342 million or 6.8 percent below the January budget. However, an increase of $271 million or 6.1 percent over 1981 would be preserved.

Research and Development Facilities

Significant savings would be achieved in both 1981 and 1982 primarily by reductions in Department of Energy funding for research and development facilities.

B. AGENCY R&D PROGRAMS

Department of Defense: The Department of Defense would increase obligations by $588 million in fiscal year 1981 and $1.436 billion in fiscal year 1982 relative to the January budget for research and development. Increases for the Navy will be applied to programs on high energy lasers, development of a new destroyer, upgrading of a missile fire control system, and development of long-distance submarine communications. The Army will receive increases for support of test ranges, work on ballistic missile defense, and development of equipment for use with chemical munitions. Additions to the Air Force R&D effort will be applied to the development of a manned bomber and work on air-to-ground capabilities for strike aircraft. Those increases will be offset, in part, by decreases elsewhere in the R&D account, including reductions in the use of consultants and in travel.

National Aeronautics and Space Administration: The revised budget for the National Aeronautics and Space Administration would reduce in obligations for R&D by $14 million in 1981 and $572 million in 1982 below the January budget. Despite the reductions, the commitment to the development of the Space Shuttle and its operation will continue. The savings have been achieved by deferring or eliminating 1981 and 1982 new program initiatives and by reducing selected ongoing programs. Specifically, in the area of space science, the launches of the Venus Orbiting Imaging Radar (VOIR) and Gamma Ray Observatory (GRO) missions would be delayed from 1986 and 1988, and spacelab experiment development and the International Solar

Polar Mission would be curtailed. However, the Galileo mission to Jupiter and the Space Telescope programs would continue as planned. In space applications, the proposed new initiatives in the Carter budget—the multiagency National Oceanic Satellite System (NOSS), the development of instruments for a proposed upper atmosphere research satellite, and a geological application program—would be delayed or cancelled. Such ongoing programs as materials processing in space, the agricultural application of remote sensing (AgRISTARS), and technology transfer and utilization would also be curtailed. However, programs related to operation of previously launched satellites and development of high priority projects would continue. In aeronautics, in addition to cancellation of new proposed initiatives (for example, the Numerical Aerodynamic Simulator), there will be a reduced level of effort primarily in the systems technology programs. However, long-term fundamental research and technology programs as well as defense-related programs would continue as planned.

Department of Energy: The overall R&D strategy for the Department of Energy, which is reflected in activities across a wide spectrum of energy-supply and demand-reduction technologies, has been significantly redefined by the Reagan Administration. Direct Federal intervention into technologies that are near the marketplace has been significantly restrained or eliminated. It is expected that research and development on technologies that have near-term payoff will be financed by corporations with a stake in the market. The Federal role as patron of truly long-term, high-payoff scientific inquiry and advanced technology development has been continued.

The long-term emphasis and short-term reduction strategy has resulted in only minor adjustments in the level of effort for the conduct of basic research within the 1982 request of $680 million, showing an increase of $86 million over the 1981 level of $594 million.

However, in the more applied research, development, and demonstration areas that compose the major portion of the DOE request, there have been significant decreases in and reorientation of activities. For example, funding for operation of major fossil energy pilot and demonstration plants and other near-term fossil research and development was reduced by more than $300 million from the Carter Administration request for 1982. The shift in the solar energy program from near-term development and demonstration toward long-term research and development would decrease that program more than $270 million. In addition, there have been significant decreases in conservation technology development. Proposed increases in the 1982 budget for the Clinch River Breeder Reactor, commercial waste management programs, and research at the Three Mile Island nuclear plant will partially offset the decreases.

On balance, the redefinition of the Federal role in R&D has resulted in decline in obligations of $245 million in fiscal year 1982 from 1981. Likewise, the obligations associated with R&D facilities have also declined by $325 million from 1981 to 1982. That also represents a reduction in facility construction of $916 million when compared to the Carter 1982 budget, primarily in construction funds for coal demonstration plants.

Health and Human Services: The budget revisions include reductions in obligations for research and development by the Department of Health and Human Services (HHS) amounting to $30 million in 1981 and $94 million in 1982 below the January budget. That amounts to about 1 percent in 1981 and 2 percent in 1982. The reductions in obligations for the conduct of basic research amount to only $16 million or 1 percent in 1981 and $44 million or 2 percent in 1982 below the January budget. Despite those reductions, basic research obligations by the department, which are the largest of any government agency, will increase by 6.4 percent in 1981 over 1980 and 7.4 percent in 1982 over 1981. The revisions would reduce the increases proposed in the January budget but still cover most of the cost increases due to inflation, particularly in 1982.

Obligations for research and development by the National Institutes of Health (NIH) would be reduced by about $25 million in 1981 and $28 million in 1982. That would primarily reduce the rate of increase in basic research funding through NIH. In addition, programs for drug abuse and mental health would be reduced, including phaseout of all but currently ongoing programs in social research. The Food and Drug Administration, the Centers for Disease Control, and other components of HHS would also absorb some reductions.

National Science Foundation: Obligations for research and development by the National Science Foundation (NSF) would be reduced by $74 million or 7 percent in 1981 and $149 million or 13 percent in 1982 below the January budget. Within those reductions the obligations for the conduct of basic research would be reduced by $53 million in 1981 and $113 million in 1982. However, the budget revisions would preserve an increase in NSF's support of basic research. In the natural sciences and engineering, the increase would amount to 9 percent in 1981 over 1980 and 12 percent in

1982 over 1981—about 3 percent above the cost increase due to anticipated inflation in 1982.

The budget revisions would reduce or eliminate all NSF R&D programs that are narrowly focused or relatively less critical to the Foundation's principal responsibilities for the support of research in the natural sciences and engineering that underlies the long-term economic health of the Nation. Support would be reduced or eliminated in the social, behavioral, and economic sciences; science education; and a number of miscellaneous intergovernmental, international, and industrial science and technology programs. The revised budget would largely protect the core programs of the Foundation for the support of research in the mathematical and physical sciences; biological and neural sciences; earth, ocean, atmospheric, and astronomical sciences; and engineering. In addition, the Antarctic research program and the ocean drilling programs would continue largely as planned. The NSF obligations for research and development facilities would be reduced by $85 million in 1982 below the January budget as a result of the deferral of new initiatives (for example, a university research instrumentation upgrading program and a 25-meter telescope) proposed in the Carter budget.

Other Departments and Agencies

The research and development programs of other departments and agencies account for only about 10 percent of the total Federal obligations for research and development and for the conduct of basic research. The changes proposed in the revised budgets of those departments and agencies would have a relatively smaller impact on overall Federal expenditures for R&D. Major reductions are in the programs of the Departments of Commerce and Labor.

Department of Commerce: Obligations by the Department of Commerce for research and development would be reduced by $28 million in 1981 and $123 million in 1982 below the January budget, largely through the termination of the Economic Development Administration and reductions of programs of the National Oceanic and Atmospheric Administration (NOAA). The termination of the Economic Development Administration is part of the decision to rely on the President's comprehensive economic plan to address the problems associated with deteriorating economic performance. The NOAA reductions include cancellation of the National Oceanic Satellite System (NOSS) and termination of the Sea Grant Colleges program. The reductions in NOAA were made largely due to the need to apply fiscal restraint even in some programs of national interest.

Department of Labor: In the programs of the Department of Labor, the proposed revisions would reduce obligations for research and development by $63 million in 1981 and $236 million in 1982 below the January budget primarily through phaseout of Welfare Demonstration Pilot Projects and elimination of 9 of the 10 Positive Adjustment Assistance Demonstration Projects proposed in the Carter budget. The welfare reform demonstrations, which include federally funded public jobs for welfare eligibles, were curtailed because they were designed to test concepts that the Reagan Administration will not renew. The Positive Adjustment Assistance Demonstration Projects would be curtailed because training and relocation programs for dislocated workers are being reviewed by the Administration, and the review does not require the expensive projects proposed in the Carter budget.

Other Reductions: Other significant reductions in obligations in 1982 from the January budget for research and development include reductions in the Department of Transportation, including termination of the Cooperative Automotive Research Program; reductions in the Agency for International Development for agricultural research targeted at the food production problem of Africa; and reductions in the Department of Interior, including the termination of the Office of Water Research and Technology.

APPENDIX D

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