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ABSTRACT
This document is the Reagan Administration's first "Annual Science and Technology Report." Chapter 1 presents overall guidelines of the Administration's national science and technology (S/T) policy. Major decisions and actions taken within those guidelines are described and highlights of the research and development (R&D) components of the President's fiscal year 1983 budget are noted. Chapter 2 discusses nine issues of particular interest to the Administration. The discussions illustrate some of the ways in which the Administration's new national science and technology policy guidelines (highlighted in chapter 1) are being brought to bear on a wide range of national problems. Issues include: science/engineering education; scientific instrumentation obsolescence; role of Federal laboratories; stimulating industrial R&D and innovation; military R&D; space science/technology; nuclear engineering; genetic engineering; and international cooperation in S/T. Federal R&D programs are discussed in chapter 3, focusing on major program thrusts/accomplishments. Programs include national security; space; health; energy; general science/technology; natural resources; environment; transportation; agriculture; education; and international affairs. An analysis summarizing R&D funding across all departments and agencies is provided in the appendix, highlighting R&D policies/trends in the 1983 budget and describing R&D programs of the 13 agencies whose 1983 obligations account for over 99 percent of total Federal funding for R&D. (JN)

Annual Science and Technology Report to the Congress: 1981

Office of Science and Technology Policy
in cooperation with the National Science Foundation

NSF 82-9

TO THE CONGRESS OF THE UNITED STATES:

I am pleased to submit to the Congress the fourth Annual Science and Technology Report as required under the National Science and Technology Policy, Organization, and Priorities Act of 1976. This is the first such report of my Administration.

Science and technology are essential to the accomplishment of the goals of this Administration and the needs of the American people for jobs, enhanced national security, increased international competitiveness, and better health and quality of life. The continued advancement of both theoretical and applied scientific knowledge is of vital importance to continued human progress and the resolution of the complex problems facing the world in the years ahead.

This Report emphasizes the important role of the Federal government in supporting our scientific enterprise. But it also emphasizes that some things can best be done by the private sector. I believe that together we will be able to harness science and technology to meet the needs and aspirations of all our people.

RONALD REAGAN

THE WHITE HOUSE,

April 21, 1982

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20500

April 12, 1982

The President
The White House
Washington, D.C.

Dear Mr. President:

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

The Report provides a comprehensive statement of our science and technology policy and priorities. As such it will serve as the basis for action in both the Executive Branch and the Congress.

Respectfully,

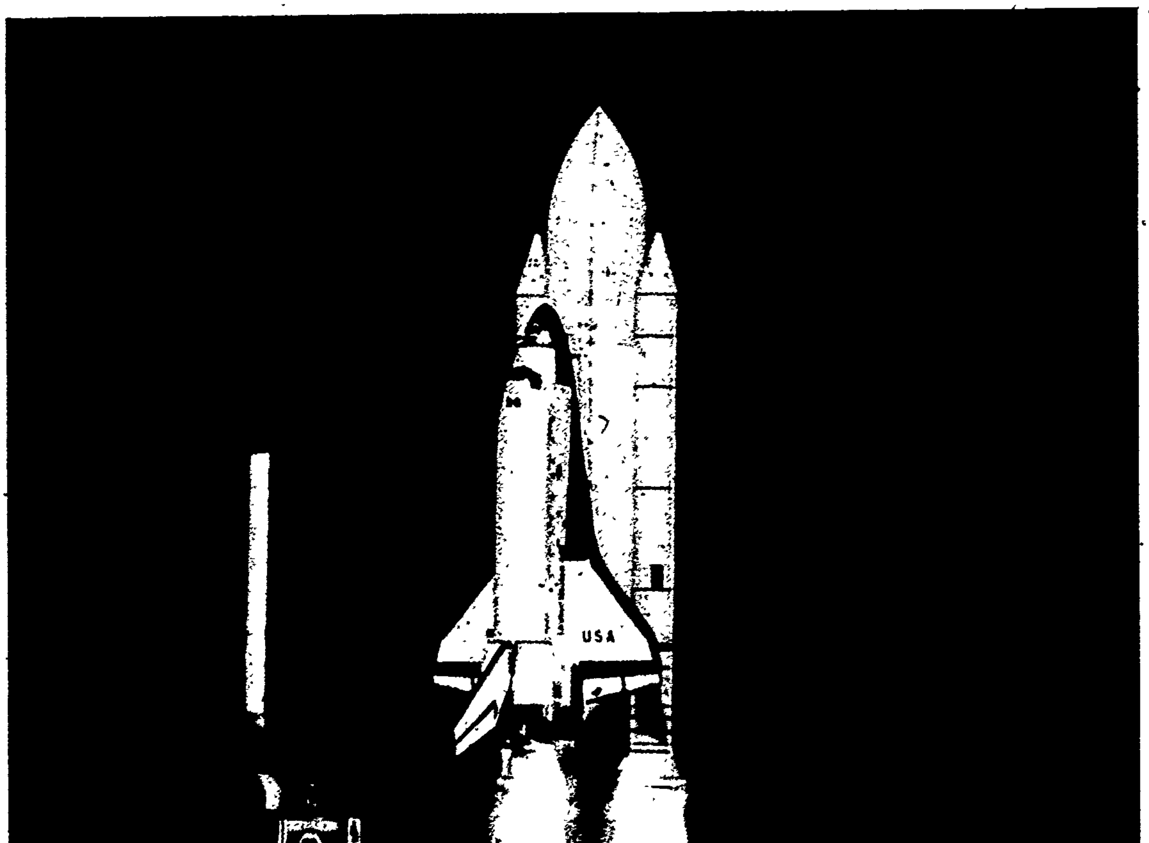
G A Keyworth

G. A. Keyworth, II
Director

Contents

Chapter I

Decisions and Actions in Science and Technology



National Aeronautics and Space Administration

This chapter presents the overall guidelines of the Administration's national science and technology policy. Major decisions and actions taken within those guidelines are described, and highlights of the research and development components of the President's fiscal year 1983 budget are noted. The chapter is divided into five parts:

- *Overview;*
- *Context for a New Science and Technology Policy;*
- *Criteria for Federal Support of Research;*
- *Industrial Research, Development, and Innovation; and*
- *Summary of Current National R&D Expenditures.*

The Shuttle, Columbia, is launched on its second space journey, realizing the first reuse of a manned spacecraft

Overview

Progress in science and technology has become an imperative for all modern industrial societies, and there are numerous indications that the United States continues both to strengthen its broad scientific and technological capabilities and to apply those capabilities to help define, illuminate, and resolve a wide range of issues that concern the Nation. In 1981, notable accomplishments in science and technology included:

- American citizens were awarded Nobel Prizes in chemistry, physics, physiology and medicine, and economics.
- Voyager 2's close encounter with Saturn in August provided a wealth of new scientific data, while successful test flights of the Space Shuttle in April and November ushered in a new era in commercial and military space applications.
- Pioneering developments in advanced materials science promised vastly more durable and efficient military and civilian aircraft and spacecraft.
- Clinical trials demonstrated the safety and efficacy of a new hepatitis vaccine developed by exploiting revolutionary cell fusion and recombinant DNA techniques.
- In another application of biotechnology, a new bioregulator was developed to increase the cold tolerance of plant seedlings and thus allow them to be planted farther north than the traditional zone.

As in previous years, the United States spent more money on research and development (R&D) during 1981 and had more scientists and engineers engaged in R&D activities than any other industrialized democracy. Total national expenditures for research and development during the year were estimated to be $70 billion, an all-time high in both current and constant dollars, with private industry's share of the total exceeding that of the Federal Government, as it has since 1980. Total Federal support for basic research in fiscal year 1983 will be $5.8 billion, also an all-time high. Industry moved rapidly during the year to build on the results of federally funded fundamental research in science and engineering by developing new technologies—in biotechnology and microelectronics, for example—that provide the basis for entirely new industries with enormous promise for enhanced social and economic well-being, and the Administration took steps to accelerate that trend. An Executive Order of the President, issued on February 17, 1981, was aimed at clarifying the regulatory environment, and the subsequent establishment of a Presidential Task Force on Regulatory Relief provided further evidence of the President's intention to remove a significant set of barriers to private sector investment in research, development, and innovation. The Economic Recovery Tax Act, enacted in August, included specific incentives to stimulate additional private sector investments. Those actions, together with decisions on Federal research and development investments incorporated into the President's fiscal year 1983 budget, are consistent with a new, emerging national science and technology policy that will provide guidelines for priority-setting and decisionmaking that reflect the realities of the 1980s.

Context for a New Science and Technology Policy

An effective science and technology policy must provide a consistent set of guidelines for addressing such questions as: What are the most effective investments that the Federal Government can make in science and technology? What are the respective roles and responsibilities of the Federal Government, State and local governments, and the private sector in those investments?

The Administration has recognized from the outset that maintaining and increasing the strength of the Nation's scientific and technological capabilities are critical to the realization of two of its cardinal goals: a revitalized domestic economy and a restored defense capability. Those goals define the primary context for a new national science and technology policy, a policy that also must be related more intimately than in the past to policies concerning such matters as international relations, energy, and social services. Above all, the new national science and technology policy must be consistent with the economic realities of the 1980s.

An unacceptable level of inflation, high interest rates, and a runaway Federal budget have plagued the United States for years, and those conditions limit the effective conduct of all activities, including science and technology. Complex and often unnecessary regulations, as well as inadequate incentives to encourage investment and growth in the private sector, have reduced U.S. productivity and competitive position in international markets. These problems are interrelated and can be overcome only by a coordinated effort. Clearly, there exists an urgent need to develop a better partnership between the public and the private sectors aimed at making the most effective use of all available U.S. scientific and technological resources—a partnership in which Government, universities, and industry carry out their appropriate, separate roles, while also focusing on overall national goals.

The Administration plans to bring the focus of the Nation's economy back to an emphasis on fiscal responsibility in the public sector and increased productivity in the private sector. Given this approach, the imperative to establish priorities and recognize limits on all components of the Federal budget, including research and development, becomes obvious. In particular, it is clear that automatic increases in Federal spending for these activities in the present period of fiscal austerity is not a goal to which a viable science and technology policy can aspire. Support for science and technology—especially basic research—is a long-term investment that is an essential element in the foundation of a healthy economy. But, to finance investments in science, both taxpayers and corporate executives must feel sufficiently secure economically to invest in the future.

A central goal of the Administration's science and technology policy is to make clearer distinctions than were made in the past between public and private sector roles and responsibilities for the support and conduct of research and development, while seeking to broaden the base of support for those activities. The Administration regards fundamental research in science and engineering as a vital investment likely to yield good returns for U.S. society. It believes that the primary responsibility of the Federal Government with respect to science and technology is to support long-term research. Since such research generally yields widely available information and knowledge, rather than specific products or processes, the incentives for strong support by private industry are lacking.

With respect to most technological development and demonstration projects, the Administration is committed to the view that the collective judgment of innovators, entrepreneurs, and consumers, made in a free market environment, is generally superior to any form of centralized programming. Federal investments in technological development and demonstration projects will, therefore, be restricted to those few areas where the Federal Government itself is the principal consumer and to a few potentially high-payoff areas in which the private sector is unable to invest because of the heavily regulated nature of the technology or because private firms cannot capture sufficient benefits from such investments.

The savings achieved by returning the responsibilities for many development and demonstration projects to the private sector will allow the Federal Government to focus more clearly on its primary responsibility to support long-term research. By contributing to overall reductions in the Federal budget, the savings achieved will also help to stimulate the economy and thus improve the overall climate in which all national activities, including scientific and technological activities, are conducted.

Criteria for Federal Support of Research

The Administration's budgets propose to maintain levels of support for fundamental research that are adequate to provide the knowledge, tasks, and skills on which the Nation's ability to meet unforeseeable future problems will depend. However, the Administration is also committed to ensuring that the value of the benefits to be derived from public investments in that research justify the cost to the Federal taxpayers

Past policies of Federal support for basic research have attempted to ensure some overall annual growth rate, and there have been serious proposals to tie basic research support to such external factors as Gross National Product (GNP). The Administration rejects such rigid approaches to resource allocations on the grounds that they have nothing to do with the quality of the research itself. Rather, it has adopted a set of general guidelines for making judgments about basic research support:

- First, because of the nature of basic research and the inherent uncertainty of its ultimate application, wide-ranging support across fields and subfields of science should be maintained, thus providing the country with a capability to take advantage of important scientific and technological breakthroughs quickly and to respond to unanticipated needs.
- Second, research supported by Federal mission agencies should include basic and applied research appropriate to the execution of the respective agency mission.
- Third, since Government support of research in universities influences the Nation's ability to meet its future scientific and technological personnel requirements, those requirements and research support policy are interdependent and should be coordinated.
- Finally, there is less justification for a dominant Federal Government role in near-term applied research and, especially, development, except in such areas of primary Federal responsibility as defense, space, and environmental regulation, and in heavily regulated technologies. Other areas in which the Government has a more limited role to play include those of shared responsibility—for instance, health and agriculture—where the broad societal benefits justify Federal involvement and those areas of development where the Government is the sole or dominant buyer.

Within these general guidelines, the Administration has adopted stringent criteria to discriminate between the scientific areas that are most promising and those that are less so. In addition, the Administration intends to work closely with the scientific and engineering communities to translate those criteria into levels of Federal budget support. The key criteria used to determine the degree to which a scientific discipline or a project within a discipline qualifies for Federal research support are excellence in the investigators, excellence in the subject matter, and excellence in the expected results. These decisions should be determined by the scientific and engineering communities themselves, working in cooperation with responsible Federal officials. An additional, important criterion for the public support of applied research aimed at providing the foundation for future technological advance must be pertinence—pertinence to the Nation's economic and social goals and needs.

These criteria—excellence and pertinence—are being applied both to projects carried out primarily by American scientists in American laboratories and to projects that involve substantial collaboration with foreign scientists or are carried out in non-U.S. facilities. Application of the pertinence criterion leads to a recognition that some areas of science and particularly of technology are more pertinent to the needs of other countries than to this country. U.S. science and technology is regarded as equal to or more advanced than any in the world in a wide range of fields, including high-energy physics, agriculture, astronomy, geophysics, laser chemistry, biotechnology, and microelectronics. The Administration regards the maintenance of American preeminence in selected fields as an essential national goal. However, an important reality of the 1980s is that many of the countries, the Western European nations and Japan in particular, have, with our help, reestablished the intellectual and productive capacities they lost during World War II. For that reason, undisputed world dominance in all fields of science and technology is not a goal to which U.S. national science and technology policy can aspire. American science can benefit from healthy competition among scientists of all nations as long as an appropriate level of international cooperation is also maintained as a means for expanding the scope of the U.S. research effort. With constrained research and development budgets facing all nations, collaborative projects in such areas of common interest as energy, space, and transportation will surely become more attractive.

While the Administration is committed to returning the responsibility for most development projects to the private sector, there are a few selected areas in which Federal support must necessarily continue throughout the research, development, demonstration, and implementation stages. The most essential of those areas are ones for which the Federal Government is itself the principal consumer of the results of research and development, or where R&D activities support essential Federal operating responsibilities. Included are national defense, some components of the civil space program, and some aspects associated with civil transportation. Additionally, Federal involvement beyond the research stage is appropriate in a few areas—for instance, in the nuclear industry—where the potential payoffs to the Nation are very large and regulation is so extensive that effective private sector investment is difficult.

Industrial Research, Development, and Innovation

The Administration is taking steps to stimulate greater industrial support for research, development, and innovation. In the past, however, uncertainties about future Federal policies with regard to taxes, patents, antitrust interpretations, and regulatory requirements, as well as the high cost of capital and the prevailing economic environment, have acted as barriers inhibiting more adequate industrial investments in long-term R&D. The Federal Government, by subsidizing certain development projects, has distorted the market and discouraged industrial investments. Termination of such economic subsidy programs will remove an important barrier to corporate investments in science and technology.

More specifically, the Economic Recovery Tax Act, signed by the President in August, includes R&D tax credits, accelerated depreciation schedules, and other incentives that, it is estimated, will stimulate an additional $3 billion in corporate R&D investments over the next 5 years. In addition, the Administration supports pending patent reform legislation that would extend to the entire private sector the right to retain patents developed under Federal R&D funding. That legislation would remove a major disincentive to industry participation in important national R&D efforts.

The Administration has also focused sharply on regulatory reform and has called for greater precision in assessing both the need for and the potential impacts of a broad class of Federal regulations as a means for encouraging greater industrial productivity. This reflects a widespread consensus that the Government overreacted during the 1970s—or reacted with inadequate information—in framing regulations designed to eliminate or minimize risks to health, safety, and the environment. The President's Task Force on Regulatory Relief, chaired by the Vice President, has initiated a comprehensive study of the entire set of regulatory laws and administrative procedures. One early result of the task force's work has been a 30 percent reduction in the number of pages of regulations published in the *Federal Register*. An important step in improving Federal regulations will be to increase the reliability of the scientific and technical information and the analytical methods on which estimates of environmental, health, and safety risks are based. Regulatory reform will reduce the overall burden to industry of compliance with unnecessary and often uncertain regulations. Equally important, it will reduce the amount of defensive R&D that has been required by the past regulatory environment and thus has been diverted from more productive innovations.

There is increasing evidence that private industry now perceives R&D investments as economically advantageous and that it will increase its investments as a result of the new incentives Industrial R&D spending has exceeded Federal spending during each year since 1980. Additionally, since 1975, the average annual rate of increase in industrial R&D investments, measured in constant dollars, has been almost double the annual increase in the Federal investment rate—5.7 percent versus 2.3 percent. The ratio of company-funded R&D to sales has remained relatively constant at 2 percent, suggesting that improvements in the economic climate will stimulate increased investments.

The long-term innovative capacity of the industrial sector also depends on the continued availability of new scientific concepts and data and on the adequacy, in both quantity and quality, of scientific and technical personnel. Hence, the Administration is concerned with two related problems faced by the Nation's universities—instrumentation obsolescence and faculty shortages in engineering and computer science departments. Those problems could have serious adverse consequences for the strength of the entire U.S. science and technology enterprise. The Administration is also concerned about the long-term effects of the decreasing emphasis on science and mathematics in the Nation's public schools, a trend that is in sharp contrast with the situation in most other industrialized countries. These and several other science and technology policy issues that the Administration is currently addressing, including national defense, space, and nuclear energy, are discussed in detail in chapter II.

Summary of Current National R&D Expenditures

During 1981, total national expenditures for all research and development activities were estimated to be about $70 billion. As in previous years, private industry's share of the total, estimated at 49 percent, not only exceeded the Federal share, estimated at 47 percent, but also increased at a more rapid rate. The remaining 4 percent was accounted for by private foundations, universities, and other nonprofit institutions.

In 1982, the Nation is expected to invest $77 billion in research and development, 11 percent more than in 1981 and more than double the amount spent in 1975. National R&D expenditures have increased in real terms each year since 1975; the increases have averaged 4 percent annually through 1982. Those increases result largely from greater expenditures for energy, space, and defense programs as well as from general industrial growth. The increase in national R&D investments between 1981 and 1982 in constant dollars is estimated at 2 percent. The Federal share of those expenditures is expected to remain at slightly less than one-half of the national R&D effort during 1982. Figure 1 details national R&D expenditures from 1963 through 1982. More detailed information on trends in national research and development, and expenditures for R&D activities, can be found at the end of this chapter.

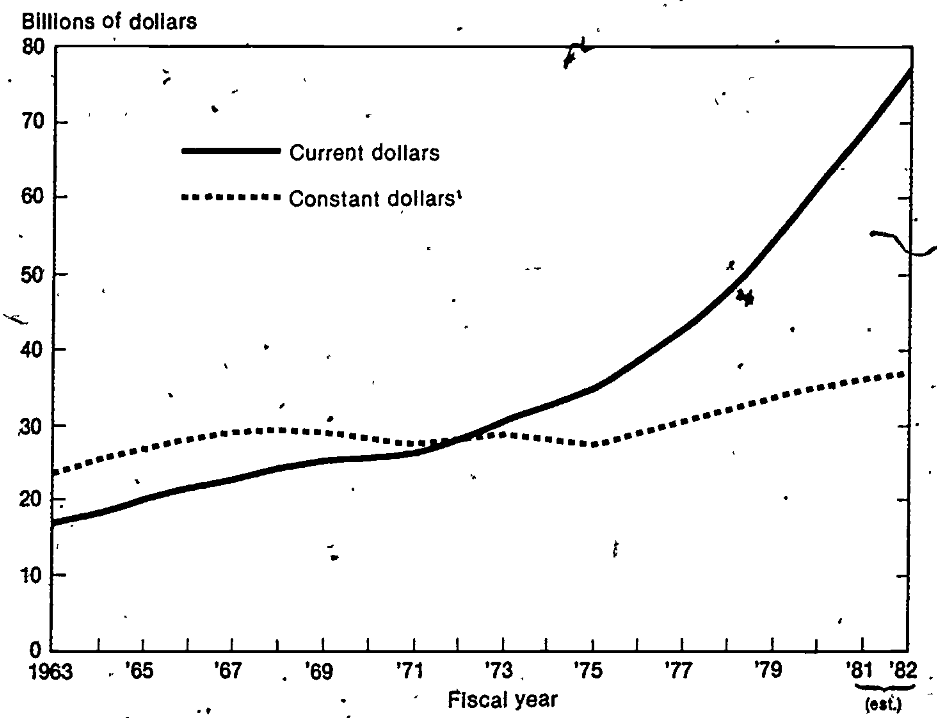
Rationale for Administration Budget Decisions for Fiscal Year 1983

The President's proposed fiscal year 1983 budget, transmitted to Congress on February 8, 1982, provides a detailed statement of the Administration's national science and technology policy guidelines. In particular, it elaborates a Federal role in R&D that is consonant with Administration actions in tax, regulatory, and fiscal policies and calls for the return of responsibility to individuals and organizations in the private sector and, concomitantly, a lessening involvement by the Federal Government in broad areas.

Highlights and Trends in the Fiscal Year 1983 Budget for Science and Technology

Federal obligations for the conduct of all R&D, including basic research but not the

Figure 1. National R&D expenditures



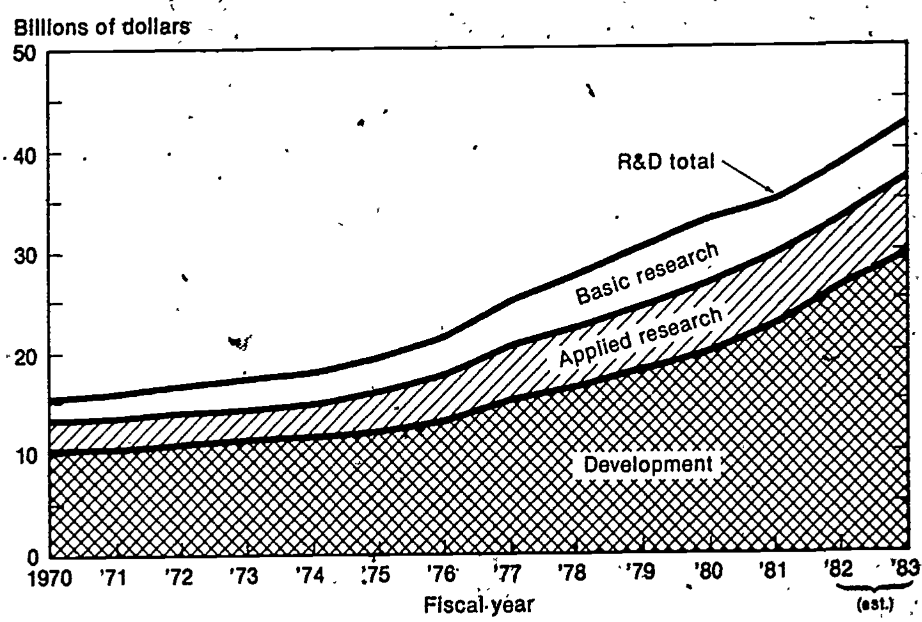
SOURCE: National Science Foundation; Science Resources Studies
[1]Based on GNP implicit price deflator.

funding for R&D facilities, are estimated to total $43 billion in 1983, an increase of $4.2 billion over 1982. Obligations for R&D facilities are estimated to be $1.3 billion in 1983, a decrease of $265 million from 1982 levels. The Office of Management and Budget's Special Analysis K, which summarizes the Federal funding of research and development across all departments and agencies, is reproduced in its entirety in the appendix.

The 1983 budget reaffirms the Administration's commitment, within current fiscal realities, to provide for the support of basic research as an investment in the Nation's long term economic growth and national security. Obligations for the conduct of basic research are estimated to increase in 1983 by $0.5 billion to $5.8 billion, or 9 percent over 1982. Figure 2 compares basic research, applied research, and development support with total Federal R&D support from 1970 through 1983.

The allocation of $5.8 billion in the 1983 budget for basic research recognizes the need not only to maintain a vigorous national research effort in all essential areas of scientific inquiry but also to strengthen basic research in specific areas of national concern and Government responsibility—for example, national security. Basic research in such fields as chemistry, physics, biology, astronomy, and materials provides the underpinning for new inventions, advances in health care, improved nutrition and agricultural production, and new technologies for defense, space, energy, and environmental protection. Special emphasis is being given to strengthening basic research in the physical sciences and engineering

Figure 2. Federal R&D obligations by character of work: FY 1970-83



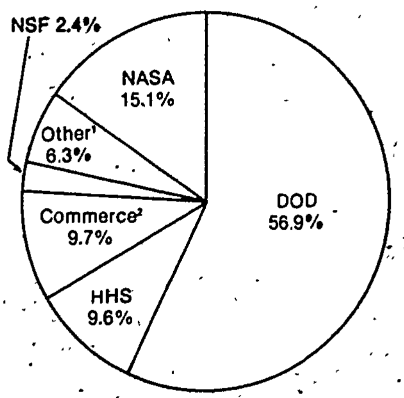
SOURCES: National Science Foundation and the Office of Management and Budget.

because of the importance of those areas to industrial productivity and economic revitalization.

The increase in funding for the conduct of R&D in the 1983 budget is reflected largely in the R&D programs of the Department of Defense. Significant increases are also proposed for the R&D programs of the National Aeronautics and Space Administration and the National Science Foundation.

Figure 3 summarizes fiscal year 1983 Federal expenditures for the conduct of research and development by the five major support agencies. Figure 4 shows trends in defense and other Federal R&D support from 1963 through 1983. Highlights of the programs of the major R&D agencies, which account for over 90 percent of the proposed 1983 R&D activities, are presented below. An overview of Federal funding of R&D facilities concludes the section.

Figure 3. Federal R&D obligations by major support agency: FY 1983

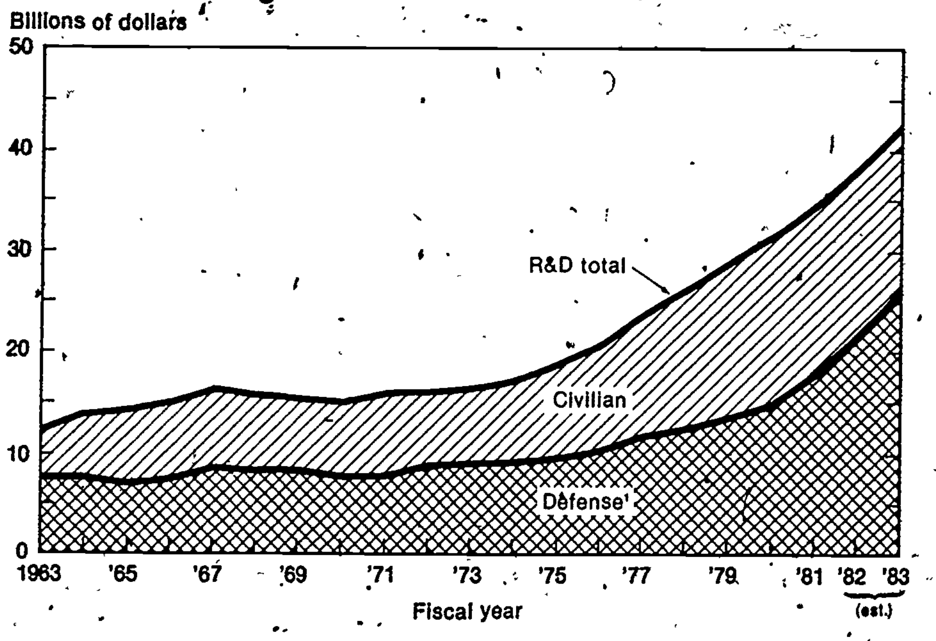


[1]Includes the Departments of Agriculture, Transportation, the Interior, Education, Housing and Urban Development, Justice, Labor, Treasury, and State, the Nuclear Regulatory Commission, the Environmental Protection Agency, the Agency for International Development, the Veterans Administration, the Tennessee Valley Authority, the Smithsonian Institution, the Corps of Engineers, the Federal Emergency Management Agency, the U.S. Office of Personnel Management, the Library of Congress, the Arms Control and Disarmament Agency, the Federal Communications Commission, the Advisory Committee on Intergovernmental Relations, and the Federal Trade Commission.

[2]Includes programs of the Department of Energy.

SOURCE: Office of Management and Budget

Figure 4. Federal R&D obligations for defense and civilian programs



[1]Includes military-related programs of the Departments of Defense and Commerce (DOE weapons programs).
SOURCES: National Science Foundation and Office of Management and Budget

Fiscal Year 1983 Budgets for Major R&D Agencies

Department of Defense. Obligations for the conduct of R&D by the Department of Defense (DOD) will rise to $24.5 billion, an increase of $3.9 billion over 1982 and 57 percent of the total Federal funding for R&D. In 1983, the Department will provide increased support for basic research and for R&D related to such advanced strategic systems as bombers; ballistic missiles, and ballistic missile defense.

National Aeronautics and Space Administration. Obligations for the conduct of R&D by the National Aeronautics and Space Administration (NASA) are estimated at $6.5 billion for 1983, $0.7 billion over 1982. Increased funding for 1983 is proposed to ensure timely transition of the Space Shuttle into an operational system and to continue the highest priority research and space exploration projects, including the further development of the Space Telescope, the Gamma-Ray Observatory, and the Galileo Mission to Jupiter.

Department of Commerce. Obligations by the Department of Commerce (DOC) for the conduct of R&D would be $4.2 billion in 1983, including $3.9 billion for programs transferred through the proposed dismantlement of the Department of Energy. The 1983 figure indicates a net decrease of $605 million for those programs, but includes increases for nuclear weapons R&D and for long-term research in energy sciences and fundamental physics. The increases are more than offset by eliminating subsidies to industry for near-term energy research and technology development. The other R&D programs of the Department of Commerce, namely measurement-related and oceanic, marine, and atmospheric research, would be reduced by $31 million below 1982 to a level of $240 million in 1983.

Department of Health and Human Services. Obligations for the conduct of R&D in the Department of Health and Human Services (HHS) are estimated to total $4.1 billion in 1983, $150 million above 1982, of which the National Institutes of Health (NIH) accounts for about $3.5 billion, $106 million above 1982. The 1983 budget for NIH continues to support a strong national effort in biomedical research, including research related to potentially hazardous occupational and environmental exposures.

National Science Foundation. Obligations for the conduct of R&D by the National Science Foundation (NSF) are estimated to total $1,033 million in 1983, an increase of $72 million over 1982. Included in the total is $984 million for the support of basic research, an increase of $72 million over 1982. The 1983 budget for NSF proposes increased support of research in the natural sciences and engineering and selected retrenchment of relatively lower priority programs.

Funding of R&D Facilities

Obligations for R&D facilities in 1983, including the construction or renovation of facilities and plants and the acquisition of major equipment will total $1.3 billion, a decrease of $265 million below 1982.

Significant changes in facilities support are being proposed in 1983, primarily for programs being transferred to the Department of Commerce as part of the proposed dismantlement of the Department of Energy. In those programs, support will be maintained generally for such basic research facilities as those for high-energy physics. However, significant reductions are proposed for facilities used for demonstration of energy technologies. Those reductions are largely in keeping with the policy of relying more on industry investment. The 1982 budget includes funds to bring many energy demonstrations to an orderly close or to help industry take over the support of the facilities used for such demonstrations.

Chapter II

Emerging Policy Issues in Science and Technology

National Bureau of Standards

This chapter discusses nine issues of particular interest to the Administration, selected because they are both timely and important, and because the Federal Government shares a legitimate and significant role in current and future policymaking on the issues. Taken as a whole, the discussions illustrate some of the ways in which the Administration's new national science and technology policy guidelines, highlighted in chapter I, are being brought to bear on a wide range of national problems.

Issues to be addressed are:

- *Science and Engineering Education;*
- *Scientific Instrumentation Obsolescence;*
- *The Role of Federal Laboratories;*
- *Stimulating Industrial Research, Development, and Innovation;*
- *Military Research and Development;*
- *Space Science and Technology;*
- *Nuclear Energy,*
- *Genetic Engineering; and*
- *International Cooperation in Science and Technology.*

The issues are important in themselves and also fall into three overlapping categories, each of which reflects a principal theme of the Administration. The three categories are. strengthening national capabilities in science and technology; clarifying public and private sector roles and responsibilities for science and technology; and considering international implications of the new science and technology policy guidelines.

The National Bureau of Standards' 130 MeV Electron Linear Accelerator (LINAC) is operated as a user's facility for fundamental nuclear studies, activation analysis, radiation dosimetry, and neutron measurements and standards activities

Introduction

The diverse, decentralized set of institutions that constitutes the U.S. national system for educating scientists and engineers has many fundamental and enduring strengths. It is characterized by a remarkable degree of adaptability as compared with similar institutions in most other countries, and it has provided an indispensable basis for the superlative achievements of U.S. science and technology during the past 40 years. At present, 670,000 full-time equivalent scientists and engineers are employed in this country, and that number is projected to grow by at least 40,000 in the next decade. Given the increasing technological complexity of our society, many occupations and professions in addition to science and engineering require some reasonable level of sophistication in science and mathematics. Clearly, the adequacy of the Nation's institutions for science and engineering education must be assessed in terms of their capacity to carry out the tasks implied by these needs, and thus continue to contribute to present and future national goals. Unfortunately, those institutions face critical problems that could limit their ability to carry out their diverse educational tasks.

Perhaps the most serious, long-term educational problem is the declining emphasis on science and mathematics at the precollege level, a trend in sharp contrast with other countries. There are also significant problems associated with the numbers of professional scientists and engineers graduating in certain key, expanding high-technology fields, particularly electronics and energy systems. Problems associated with engineering education are immediate and acute. They result from several factors, among the most serious being engineering faculty shortages and the obsolescence of instruments needed for instruction and research.

The principal initiatives for remedying the problems of science and engineering education at all levels must originate from the institutions themselves, from private industry, and from State and local governments. Any Federal financial support must be carefully planned to provide maximum leverage where the national need is most significant.

Engineering Education

The recent increased demand for engineers, particularly in the electronics and energy industries, has raised entry level salaries and also boosted college enrollments in engineering. Engineering colleges cannot indefinitely increase their numbers of undergraduates within the constraints of existing facilities and faculty levels. Many have already limited their enrollments to maintain an acceptable quality of education.

The increase in industrial demand for engineering graduates with bachelor's and master's degrees has reduced the number of students continuing to the doctorate level. Many of the vacancies for doctoral candidates have been filled by foreign students, who are receiving about 50 percent of the engineering doctoral degrees awarded in this country. Increasing numbers of those foreign students are returning home for a variety of reasons and are not being employed in the United States.

The lure of industry for the decreasing numbers of U.S. students who do receive doctorates in engineering has resulted in a documented and significant shortage of engineering faculty, particularly junior faculty. Academic salaries being offered to faculty at the entry level are usually below industrial starting salaries for holders of bachelor's degrees. As a result, there were, at the start of the 1980-1981 academic year, approximately 1,600 unfilled full-time engineering faculty positions, or about 10 percent of the total, in U.S. colleges. Overall shortages would be far greater were it not for the availability of foreign engineers: among junior engineering faculty, almost one-quarter received their bachelor's degrees outside the United States.

Rising undergraduate engineering enrollments and static or contracting numbers of faculty are resulting in heavier teaching loads, increased student-teacher ratios, and, in many cases, the cancellation of courses formerly offered in engineering schools. These pressures are occurring at a time when leaders in U.S. industry are stressing the need for new types of curricula to provide better preparation in manufacturing and process design, particularly in electrical, chemical, and mechanical engineering, and computer science, to support productivity growth in the commercial sector.

The effects of faculty shortages on undergraduate teaching are being exacerbated by the obsolescence and deterioration of equipment for teaching and research in many institutions (This problem is discussed in more detail later in this chapter.) Thus, industry has had to assume increasing responsibility for training new engineers to use the state-of-the-art apparatus that, a few months ago, those engineers would have encountered in the normal course of their undergraduate careers.

These trends, if uncorrected, could have several negative consequences. First, they could degrade the quality of engineering education in the United States. Indeed, increasing numbers of engineering schools are already losing accreditation for these reasons. Second, a further decline in the attractiveness of college teaching careers could lead still larger numbers of prospective American Ph.D. candidates to decide against advanced study in engineering. Finally, declining Ph.D. enrollments, increasing faculty vacancies, and obsolete research instruments are obvious barriers to academic research, with the result that universities are losing their capacity to conduct such research in important frontier areas. Private industry has thus far been able to conduct much of the engineering research required for its own needs. However, a good deal of industrial research is focused on relatively short-term problems and is concentrated where industry perceives a specific need. Thus, it seems unlikely that full responsibility for conducting the bulk of the long-term engineering research needed to undergird future technologies will be assumed by industry. Ultimately, the shortage of doctoral-level engineers could also limit the ability of industry to carry out its own research and development programs.

The current high demand for new engineers (and for new Ph.D. scientists in certain critical subspecialties) could also have particularly serious consequences for the quality of the Nation's defense capabilities. Because of the lucrative industrial job market, the armed services—which cannot offer competitive salaries—continue to experience difficulties both in recruiting engineers and scientists into military service and in hiring civilians for in-house defense laboratories. The growing shortage of engineers and scientists in fields critical to defense also affects essential defense contractor programs. Retention of engineers and some scientists is also a problem. For example, loss rates for military engineers increased by 20 percent during 1979 alone.

Precollege Science and Mathematics Education

Only about one-sixth of U.S. high school students currently take both science and mathematics courses during their junior and senior years, and most who do are intent upon careers in science and engineering or in such closely related fields as health care. Thus, by default, a large fraction of U.S. students cut themselves off, at age 16, from careers in the rapidly growing fields of science and engineering. The dropout rate at the 10th grade level is particularly severe for girls and for students from most minority groups.

Thus, most students who do not choose science-related careers are also being denied the opportunity for any genuine understanding of science, mathematics, and technology. The relatively few students who have a strong interest in such careers are studying and learning as much science and mathematics as they ever did. However, the much larger group who end their formal study of those subjects early in high school are performing considerably less well than a decade ago on achievement measures covering even the low-level subjects they *have* studied. As the pace of scientific and technical change in this coun-


3 2 1 Contact!

Research is conducted for 3-2-1 Contact!, a science series for children produced by the Children's Television Workshop

try and throughout the world continues, a deeper understanding of science and technology will become increasingly important in a wide range of occupational and professional pursuits that formerly had little or no scientific or technical content. Thus, the growing scientific and technical illiteracy among the U.S. population could have severe negative consequences for our future national productivity.

The growing weakness of precollege science and mathematics education in the United States is the result of several factors. Realistic information on which students, teachers, parents, and guidance personnel can base judgments about the science and mathematics prerequisites for various types of careers is generally lacking. There is a mismatch between the content of the science and mathematics curricula used in most high schools and the needs and interests of the large number of students who do not plan to become scientists and engineers. Surprisingly little use is being made of the potential of the modern electronics capabilities for education in science and mathematics. There are severe shortages of trained mathematics and physical science teachers throughout the country. Surveys conducted in 1981 revealed that 22 percent of high school teaching posts in mathematics were vacant and that 26 percent of the occupied posts were filled by teachers who were uncertified or only temporarily certified to teach mathematics. Finally, there has been a steady erosion of the support systems that formerly provided a measure of quality control and assistance to teachers with pedagogical problems.

The decreasing emphasis on science and mathematics in the U.S. public school system contrasts sharply with the situation in other industrialized countries where deliberate attempts are being made to attain a high level of technical competency among the general population. In Japan, about 25 percent of classroom time in grades 7 through 9 is devoted to science and mathematics, and nearly all college-bound students take three natural science courses and four mathematics courses during their 3-year high school career. The general preparation is similar in West Germany In the Soviet Union, there are national elementary and secondary curricula in science and mathematics that, in content and scope, surpass those of any other country. Algebra and geometry are taught in the 6th and 7th grades, and advanced algebra and trigonometry in grades 8 to 10. Calculus is part of the high school curriculum for over 5 million Soviet students. In addition, all secondary school students are required to complete courses in physics, chemistry, and biology.

Options for Federal Action

The problems associated with college and university science and engineering education and with precollege science and mathematics education have been developing for a decade or more. They are thus unlikely to be solved either quickly or easily or by means of stopgap measures. Also, the long leadtimes characteristic of the educational process preclude instant results from remedial action.

High rates of inflation and demographic trends underlie problems at all levels of education. For colleges and universities, operating costs have continued to mount while undergraduate enrollments—and, therefore, tuition income—have leveled off or, in some cases, declined. Likewise, few public schools have the financial resources to develop and implement new curricula in science or mathematics, to equip school laboratories adequately, or to provide other types of support for science and mathematics teachers. Given the range of attractive career options open to college graduates with degrees in mathematics or physical science, very few elect to become high school teachers.

Both producers and users of science and engineering personnel—schools, colleges, universities, the Federal Government, State and local governments, and private industry— must play an active role in solving the problems of science, mathematics, and engineering education. In the long run, many of those problems—particularly at the professional level—should solve themselves. Indeed, to a large extent, the market for science and engineering personnel is acting as it should. Undergraduate engineering enrollments continue to increase as qualified secondary school students respond to their perceptions of attractive career opportunities, with the result that increasing numbers of the new engineers required by industry are graduated each year. However, Federal action may be necessary as a catalyst where market responses are slow or where the problems are particularly difficult for the private sector to solve.

A good deal of Federal support for the education of science and engineering personnel will derive from grant and contract support for research to universities. In addition, the Government is providing limited, targeted support to help solve the engineering graduate student and faculty problems. For example, the National Science Foundation has initiated a special new engineering faculty research incentive program designed to attract new, high-quality Ph.D. engineers into academic careers. Also, the Department of Defense has increased both the number of graduate fellowships offered in engineering and science and the amount of each stipend in order to make full-time graduate study a more attractive option.

Other Federal actions to address both the national education situation and, in particular, science, mathematics, and engineering education are under way. The Secretary of Education established, in August 1981, a National Commission on Excellence in Education composed of school, college, and university educators, State and

Bowling Green University

High school students working with macrophotography in a university laboratory

local officials, and leaders in a range of professions. That Commission, which includes a panel on science and mathematics, is conducting an 18-month study and will make recommendations for action at all levels of government aimed at restoring excellence throughout the U.S. educational system. In addition, the National Science Board is establishing a Commission on Precollege Education in Mathematics, Science, and Technology. Its first task will be to help develop criteria for education in those areas.

Diversity and adaptability to changing circumstances have been hallmarks of the U.S. educational system. Local communities, in concert with industry and professional groups, will have to decide how best to allocate scarce resources in order to emphasize excellence in all educational endeavors, including instruction in science and mathematics, to assure the future vigor of their own regions and the Nation as a whole. Universities must decide whether their goal will be to protect excellence by a more selective distribution of scarce resources or to spread those resources ever wider and thinner. In the case of publicly supported universities, State governments will have to decide whether resources will continue to be allocated on a student credit hour basis, which means they are driven solely by undergraduate enrollments, or on the basis of a long-range review of each university's role in the State and Nation.

Much of what should be done has already been started. Whether still more attention and resources will be devoted to sustaining the quality of U.S. science and engineering education depends in large measure on public perceptions of the importance, to the Nation, of maintaining scientific and technological leadership internationally, and on a better understanding of the central importance of scientific and technological activities—and science and technology literacy—to our national needs and goals.

Introduction

Instrumentation is at the heart of experimental research. Modern instruments with qualitatively superior capacities for analysis and measurement can open up whole new fields of scientific inquiry and can greatly reduce the time necessary to carry out research projects. In some scientific areas, access to the most advanced scientific instrumentation determines in large measure whether scientists can work at the leading edge of the field. Furthermore, the ability to engage in frontier research in some of those areas often requires not just individual instruments, but clusters of expensive instruments

There is currently concern within the Administration and among leaders of the scientific community that many of the instruments costing $100,000 to $1 million at U S research universities are rapidly becoming obsolete. As a result of increasing costs (due mainly to inflation), increasing sophistication of instruments required to do frontier research, and decreasing sources of funds, those instruments will be difficult to replace with the state-of-the-art equipment necessary to ensure the progress of scientific research required to fulfill national needs.

The growing obsolescence of research instrumentation in U.S universities is a problem not just for the universities, but for the Nation as a whole. To the extent that such obsolescence impedes the progress of fundamental research, its effects will be felt by the Nation in such critical areas of application as agriculture, medicine, biotechnology, engineering, energy, and national defense. Since over half the basic research performed in the United States is carried out at universities, a decline in the research potential of the universities could result in a significant decline in the general rate of the Nation's scientific advancement and ultimately its technological innovativeness.

Trends and Developments

Although it is difficult to derive quantitative measures for assessing the severity of the direct and indirect effects on training and industrial innovation of the obsolescence problem, a number of recent studies suggest that its magnitude is substantial.

Costs of Instrumentation

The difficulties faced by research universities in acquiring and maintaining adequate research instrumentation are compounded by the increases in costs brought about by inflation and are in a very real sense tied to the health of the Nation's economy. Recent studies have addressed the increasing costs of scientific instrumentation in the universities.

(1) A 1979 Department of Health, Education, and Welfare survey of nine universities concluded that there was an unmet deficit of instrument needs and facilities of $225 million and indicated that similar unmet needs would persist over the next 3 to 5 years.

(2) A National Science Foundation study projected a catchup need of about $420 million for the next 5 years in the physical sciences alone.

(3) A 1979 article in *Science* showed that instrument costs have increased fourfold since 1970, excluding the development of new technologies that have come into general use since 1970.

(4) A study matching university research laboratories in a number of disciplines with nonuniversity laboratories found that among the sample institutions selected, the median age of university instrumentation was twice that of instrumentation at comparable industrial laboratories. The same study cited evidence that American universities are now becoming less well equipped than those in other countries, particularly Japan and Western Europe.

The costs of providing up-to-date research instruments go far beyond the price of a particular piece of equipment. Several other factors are involved. First, once an instrument is purchased, additional funds are needed for its operation and maintenance. It has been estimated that the additional cost of equipment ownership, including maintenance, replacement parts, staff salaries, and equipment operation expenses, runs about 7 to 8 percent of the original cost per year. However, studies have pointed out that maintenance funding in universities has become scarce, that shops for in-house maintenance are deteriorating, and that the costs of service contracts are increasing above the rate of inflation.

Second, as equipment becomes more complex and computerized, operation, maintenance, and repairs may be beyond the abilities of researchers and students. When repairs cannot be made quickly because of a lack of available funds, essential equipment may be unavailable for use for substantial periods, and thus valuable research time may be lost.

Third, Federal grants rarely provide for such support equipment as oscilloscopes and vacuum leak detectors, equipment not necessarily involved directly in the research itself, but necessary to test, calibrate, or provide an appropriate environment for the core research instruments. Without up-to-date support equipment, research instrumentation can be far less useful.

Finally, research universities must find funds to provide adequate facilities for the housing and support of instrumentation. Instrument housing costs include the construction of buildings or new wings, construction of animal facilities, renovation of plumbing and electrical systems, and installation of air-cooling units for sensitive computers. Some costs arise from the need to renovate existing facilities to accommodate more sophisticated instrumentation, others become necessary because of changes in the legal or regulatory requirements for research housing. Since the 1960s, Federal resources for the construction of facilities have been declining, placing an ever-increasing strain on institutional funds. The universities themselves thus far have not filled the gap, despite the need to renovate and create new facilities.

Effects on Training

In addition to the problems in state-of-the-art instrumentation for research and doctoral-level training, the quality of instrumentation for training engineers and technologists is also deteriorating. This is especially so for students who will eventually be employed by industry. If students are not conversant with up-to-date equipment, retraining may be necessary. Thus, the increasing sophistication and cost of instrumentation has placed our Nation's universities in a critical position both in teaching and in conducting research.

Policy Options

The scientific instrumentation obsolescence problem and the potentially negative impacts it can have on such national objectives as economic revitalization and productivity make it an area of special national concern. The universities themselves and the corporate sector, with some limited assistance from the Federal Government, will have to take the initiative to alleviate the problem.

The University Role

University efforts to find solutions to the instrumentation problem have centered on the improved management and the potential redistribution of available resources. The Administration believes that the scientific community, working with supporting agencies, must decide which of its needs are most important and how those needs can be met best. To ensure the proper capitalization of all research activities, including the financing of equipment and facilities, a university may be forced to decide whether its equipment needs are important enough to justify an offsetting reduction in some other category of support or, possibly, in the total number of projects supported. While such decisions are surely not easy, a more sustainable ratio of capital to operating funds for research support must be achieved. Recently, two new methods of innovative financing have been tried as partial solutions to the problems of funding university research instrumentation. The new methods—debt financing with user charges, and limited partnerships—

have had some success, but their ultimate effectiveness in reducing the magnitude of the problems has not as yet been assessed. However, they should be viewed as parts of a more complex university effort to solve the instrumentation problem. In addition, cooperation within and among universities can also improve the availability of instruments to researchers. Similarly, universities will need to develop more effective means of local and regional cooperation, including sharing of expensive equipment and facilities. A related mechanism is the development of brokerage systems through which equipment can be transferred readily from one university to another.

The Industry Role

Corporations and research universities find themselves beneficially interrelated in many ways. Corporations need the trained engineers and scientists that universities produce, and they use the advanced techniques that university researchers develop. Universities need the financial support and input of corporations in pursuing their research and training functions. University and industry cooperative arrangements enable scientists to work together on projects of joint interest and to learn each other's techniques while sharing sophisticated equipment.

Since research relationships between universities and industrial firms are of obvious benefit to both parties, they often result in an increase in direct financial support for university research, which can be used to purchase advanced equipment. Corporations may also assist universities through the donation or sharing of equipment and through financial assistance to special funds set up for the purchase of advanced equipment. However, research funding, including support for instrumentation, available from industry will, of course, be skewed toward engineering

Center for University of Massachusetts Industry Research on Polymers

Two scientists work with the Fourier Transform Infrared Analyzer. This apparatus was cooperatively funded by government, university, and industry sources and is being used in the research program of the Center for University of Massachusetts-Industry Research on Polymers.

schools and those scientific subdisciplines likely to have the most immediate impact on product development for the corporations involved, leaving large segments of the university research enterprise relatively unaided by industry.

The Federal Role

The Administration recognizes that some of the key equipment and instrumentation available in the universities for both research and instruction is outdated and often obsolete. Although no new Federal initiatives are appropriate, a special Interagency Working Group on University Research Instrumentation, managed by the National Science Foundation, has been established to assess the status of research instrumentation and facilities at universities and to design means for encouraging private and public sector support for their modernization. In addition, less direct actions have been taken by the Federal Government to ameliorate the instrumentation problem. For example, the Economic Recovery Tax Act of 1981 contains tax incentives for contributions of industrial equipment to academic institutions. While the relationships between universities and corporations are voluntary in nature, the Federal Government can play an indirect role in influencing the conditions under which such linkages develop. Federal policies to increase the advantages to corporations of providing assistance to research universities is consistent with the Administration's objectives regarding the revitalization of industry and enhancement of the potential for scientific research to stimulate industrial progress through innovation and discovery. Among the options that could have a potential impact on the situation are tax incentives and increased flexibility in Federal-funding mechanisms.

In the final analysis, universities must assume the major share of responsibility for dealing with instrumentation obsolescence. They need to take the initiative in seeking cooperation from industry and to propose more flexible Federal funding mechanisms. Most importantly, they need to optimize their internal allocation of resources to achieve the appropriate balance between operating funds and equipment. Proposed Federal funding for university research is increasing in real terms, and instrumentation must be considered within that funding context, not in addition to it.

The Role of Federal Laboratories

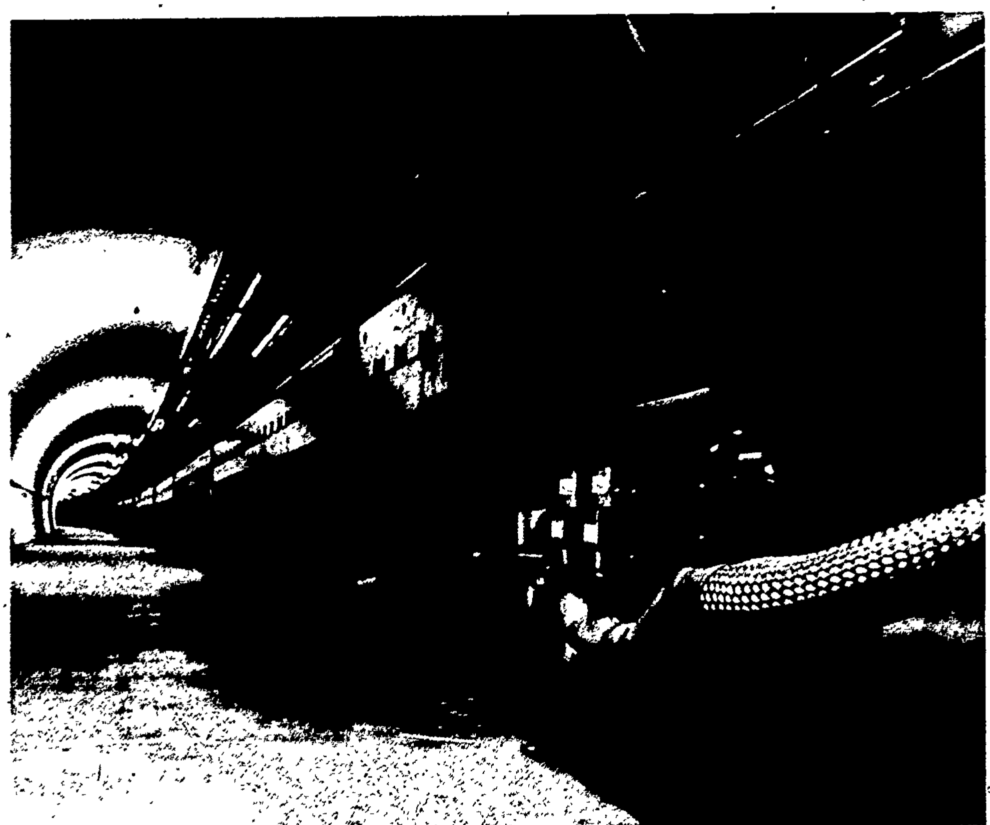
Introduction

The Federal Government owns more than 700 laboratories of various sizes engaged in what can be generally described as research, development, testing, and evaluation. Most are operated by Federal employees, but some of the largest facilities are operated by contractors. More than 70 percent of the laboratories have fewer than 50 professional staff members, and fewer than 20 percent have more than 100 professionals Slightly more than one-third of the annual Federal R&D budget is allocated for the laboratories. a portion of those funds ends up in universities and industry for activities that support the laboratories' missions.

All the laboratories were originally established to meet specific needs related to the missions of their parent agencies. Their activities include agricultural research, consumer product testing, weapons development, energy research, biomedical research, and development of standard weights and measures, to mention only a few. Some, most notably those concerned with agriculture, were established in the 19th century, while others, particularly those involved in space technology, are of recent origin. Their accomplishments have been impressive, and they employ a significant fraction of the Nation's best trained and most qualified scientific and technical personnel. As a group they form a national resource of which the United States can be justly proud.

Trends and Developments

Over the past 10 years there has been an upward trend (in constant dollars) in Federal funding for R&D in the three major performing sectors: industry, Federal laboratories, and universities. The fraction



Fermilab Photograph

Energy saver magnets at the Fermi National Accelerator Laboratory, Batavia, Illinois.

going to Federal laboratories has been relatively constant over that period. In general it may be said that industry is principally involved in development, the Federal laboratories in applied research, and universities in basic research. There are, however, many exceptions. The overlapping capabilities among the three performing sectors in many areas of endeavor make it increasingly difficult to identify capabilities truly unique to any one sector. In addition, all sectors need to maintain some level of activity in basic science and engineering to support the more applied aspects of their work.

Policy Issues

Although having overlapping capabilities is evidence of our national strength in science and technology, this overlap creates problems of choice in allocating Federal resources. The Federal laboratories were established originally to do work that could not be performed by, or was inappropriate for, the private sector. With the passage of time, however, many of the original objectives have been met, some of the missions are no longer relevant, and industry and the universities now have significantly greater research capabilities. The Federal laboratories have responded to changing environments in different ways, as have industry and the universities. Some laboratories have remained static, while others have ventured far afield from their original assignments. In such a dynamic situation, the Federal Government must strive to ensure that its resources are being allocated to the most relevant activities and to the most appropriate performing sectors.

Along with the challenge of effective allocation of Federal R&D funds, there also exists the challenge of improving cooperation among the performing sectors. The total national capability in science and technology must be harnessed efficiently if the United States is to continue its scientific and technological leadership. That means creating a synergistic relationship among industry, Federal laboratories, and universities, capitalizing on the strengths of each. It involves rethinking the traditional interactions and overcoming a number of institutional barriers.

Another issue pertaining to Federal laboratories is the vitality of the laboratories and their ability to do high-quality work, both now and in the future. Although the laboratories operate in different environments, each agency should be able to measure the productivity of its laboratories against an accepted set of criteria. A realistic assessment of the laboratories is necessary in determining the extent of their current and expected contribution to the Nation's science and technology endeavors. The Nation needs to be assured that funds allocated to Federal laboratories are indeed yielding a significant return.

These and similar issues have not been generally addressed for at least 20 years, and now is an appropriate time to explore them. Finding ways to make our R&D institutions more productive and better able to work together in maintaining U.S. scientific and technological leadership is a national challenge.

Introduction

The prosperity and security, as well as the international stature and competitiveness of the Nation, depend upon the steady growth of industrial productivity. That growth requires the continuous introduction of advanced concepts, processes, and technologies leading to new products, new processes, and whole new industries. Unfortunately, while innovations in some industrial sectors remain impressive, the overall rate of growth in industrial productivity in the United States is low, both from a historical perspective and relative to the Nation's chief industrialized competitors. One significant reason for the lag in innovation and productivity in some sectors of U.S. industry appears to be a rate of investment by industry in long-term scientific research that is less than adequate to keep up with developments overseas.

While there is no doubt that technological innovation must build upon the results of scientific research, we still lack the knowledge that would allow us to trace, with certainty, all the relationships in the complex process leading from fundamental research, through technological development, to the production of commercially viable products. What is certain, however, is that industry, and not Government, has the necessary experience and incentive to relate research and development programs to marketing strategies. Moreover, the activities that constitute industrial R&D and industrial innovation are highly diverse and disaggregated. For these reasons, the most effective Federal actions to stimulate greater long-term industrial investments in R&D are those that remove, where possible, the barriers to such investment, through both the provision of incentives and the elimination of disincentives, rather than those that would intervene directly in the market.

The Administration is committed to restoring the health and vitality of the U.S. economy. Its approach is supported by the consensus of the research literature on the industrial investment process, which cites overall level of sales as the single most important determinant of investment activity. Not only does this determinant provide a high demand for innovative products, but the rate of investment affects the demand for new equipment, which in turn can induce innovative activity in the capital goods sector of the economy.

In addition to support of sound fiscal and monetary policies that will reduce business uncertainties about long-term R&D investments, the Administration has supported tax incentives and is working on regulatory relief. All of these measures are designed to stimulate the risk-taking and innovativeness of the private sector and to increase industrial productivity.

The Failure of Government Support for Commercial R&D

The role of the Federal Government in supporting R&D has sometimes been expanded to include support of general economic and social needs. An example is direct Federal spending to stimulate industrial innovation per se for the sake of the Nation's economic and technological health. The model for such a role extension has been the number of new technological products and processes with important commercial applications—among them, jet engines and numerically controlled machine tools—that have been generated by R&D funded by the Government, primarily for its own purposes. However, history continually points to failures of governments, both here and abroad, to improve upon the performance of the market when they have chosen specific technologies to develop for the primary use of the private sector. Attempts to correct perceived market failures through direct Government intervention have, in an unfortunately large number of cases, been unsuccessful and have, in some cases, even led to new market distortions.

There are two broad classes of actions that the Federal Government can use in support of innovation: technology push actions, where the government directly supports the development of new technology or the modification of existing technology; and demand pull actions, where the Government provides an appropriate environment for increased private sector investment and economic growth. Dedicated Federal programs of support of major new commercial technologies (technology push efforts)—the nuclear ship "Savannah", the personal rapid transit system in Morgantown, West Virginia, and "Dial-a-Ride" in Haddonfield, New Jersey, for example—have dismal commercial track records. Demand pull, however, covers a variety of opportunities for Federal action, including regulatory process reform and tax incentives, that leave the ultimate R&D and decisions about new products to the private sector.

Tax Incentives

Changes in both corporate and individual income tax policy relate to two aspects of the innovation process:

- incentives for investment in R&D; for example, immediate expensing of R&D plant and equipment, provision of tax credits for R&D, and application of the investment tax credit to all R&D expenditures; and
- incentives for investment in new plant and equipment; for example, increases in accelerated depreciation allowances, increases in the investment tax credit, or liberalized tax treatment of business losses.

Section 174 of the Internal Revenue Code permits business taxpayers to deduct "Research and Experimental" costs as they are incurred. Alternatively, a firm with little or no current income may choose to amortize R&D expenses over a period of 5 or more years. Since expenditures for R&D represent an investment in knowledge that can be expected to yield a stream of future benefits, the option to treat them as operating costs, rather than investment costs, is considered to be a special tax incentive and to encourage R&D activity. The option to expense immediately does not apply, however, to purchases of equipment for R&D or to purchases of patents or processes. Those expenses can be amortized for tax purposes in the same way as other depreciable assets purchased by the firm. Purchases of new plant and equipment needed to initiate a new production process or produce a new product are eligible for the same tax treatment as other investments in physical capital. The benefits conferred by the investment tax credit and accelerated depreciation are therefore favorable to investment in industrial innovation.

The Economic Recovery Tax Act, signed by the President on August 13, 1981, contained R&D tax credits, further accelerated depreciation schedules, and other incentives designed to stimulate increased corporate investment in research, development, and innovation. Among those other incentives is one that allows the losses of R&D-intensive firms that cannot be used for tax credits to be transferred to profitable firms, thus increasing capital availability. It has been estimated that incentives under the Economic Recovery Tax Act, plus other Administration actions, will stimulate an additional $3 billion in corporate R&D spending over the next 5 years. Additionally, the Administration supports pending patent reform legislation that assigns to private sector organizations the rights to patents developed under Federal R&D funding. It is thought that the legislation will remove a major disincentive to the participation in important national R&D efforts by a broad array of highly skilled industrial scientists and engineers.

Regulatory Processes

Concern has arisen in recent years over the inhibitory impact of regulations (primarily environmental, health, and safety regulations), and the uncertainties inherent in the enactment and modification of regulations, on the rate, direction, and composition of technological innovation in industry. Not only are the laws themselves numerous (23 major Federal environmental regulatory statutes were enacted between 1968 and 1977), but there are many enforcement agencies, including the Environmental Protection Agency (EPA), the Department of Transportation (DOT), the

Department of Commerce (DOC), the Department of Energy (DOE), the Department of Agriculture (USDA), and the Army Corps of Engineers. The concern is not so much the overall necessity for regulation as its unpredictability and the fact that the regulatory process is frequently so cumbersome as to add unnecessarily to the time and cost required to introduce a new product.

The Administration's overall approach is to allow the marketplace to make economic decisions wherever feasible and, where necessary, to strengthen the scientific basis for regulatory decisionmaking. Regulatory approaches that embrace market incentives and disincentives for compliance with environmental, health, and safety (EHS) standards have a number of advantages over direct regulatory approaches that impose legally enforceable absolute standards of performance. The advantages include the improvement of economic efficiency in the use and depletion of societal resources, the allocation of the costs of mitigating societal hazards to those responsible for their generation, the stimulus to industrial innovation that may result from possible cost savings or process or product improvements unrelated to attainment of regulatory standards, and greater administrative flexibility and possible lower cost. In certain situations, some degree of direct regulation may be unavoidable, since particular EHS risks may be socially unacceptable even if compensated for by industry, or some hazards may be too great to entrust to the forces of the market. Too often, however, a direct regulatory approach fails to take sufficiently into account the societal costs of meeting unrealistic standards, and an economic incentives approach encourages more explicit valuations of EHS costs and benefits.

The traditional approach to regulation adds a further dimension of risk and uncertainty to that already facing industry in its decisionmaking on R&D investments and technology innovation. Under the impetus of legislative directive, EHS regulations are set and implemented, then challenged administratively and in litigation, often with little or no reliable scientific basis relating the regulatory action to its intended beneficial effect. The uncertainty of industry in shooting at a constantly moving target serves as a strong inhibition against investing in technological innovations to meet standards because the standards may well have changed before the innovation can be fully incorporated. The knowledge base regarding both the technological feasibility and the cost of meeting standards that are legally enforceable is also limited. Federal or federally sponsored R&D is needed to obtain better information on which to base regulatory standards and to accelerate the acquisition of information that may indicate the need for modification of existing standards. Finally, R&D on the efficacy and safety of high-technology products and processes may be prohibitively expensive and unrewarding for industry to mount, suggesting the need for a direct Federal R&D role here, too.

The Administration has sharply focused on regulatory reform as a means for encouraging greater industrial productivity. On February 17, 1981, the President issued an Executive Order calling for greater precision in assessing both the need for, and the potential impacts of, a wide range of Federal regulations. Subsequently, a broad-gauged study under the auspices of the President's Task Force on Regulatory Relief, chaired by the Vice President, was initiated. The Science Adviser is chairing a Task Force work group on science and technology, which includes the heads of all five major environmental, health, and safety regulatory agencies. The objective of regulatory reform is to reduce the overall burden on industry of compliance with unnecessary and often uncertain regulations by strengthening the scientific basis for regulatory decisionmaking. Equally important, it is hoped that reforms will reduce the amount of R&D aimed at compliance purposes and diverted from more productive efforts.

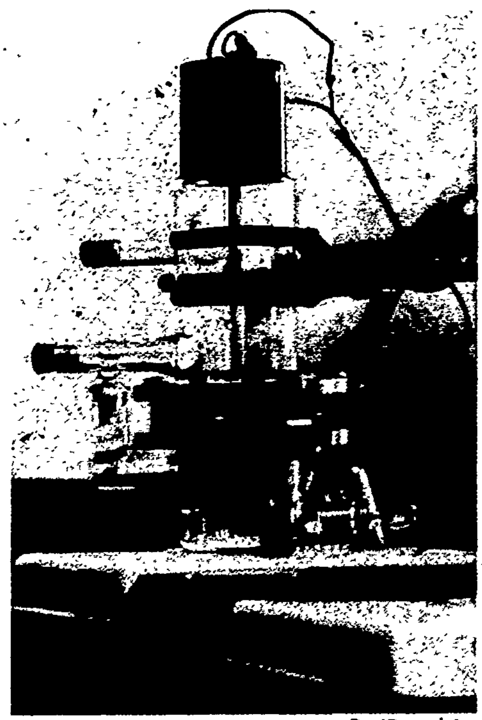
Other Factors

In addition to providing tax incentives and removing regulatory disincentives to innovation, there are a number of other areas—Federal procurement, international competition, and sectoral considerations—where the Government can further innovation.

Federal Procurement and Support of the Technology Infrastructure

Many of the most dramatic examples of the Government's influence on industrial innovation, especially in defense and space-related products, have occurred primarily because of an intermingling of the effects of Government R&D with the effects of Government procurement. For example, in both semiconductor and computer technologies, heavy underwriting by the Federal Government of R&D early in the technology's life, as well as Government's purchase of a large percent of the initial output, were very influential in the rapid growth of the fields. Virtually none of the major innovations in semiconductors has been a direct result of defense-sponsored projects. Rather, defense procurement and support for R&D together helped to create a climate conducive to more rapid change. That finding is consistent with the Administration's emphasis on market-based decisionmaking.

It has been argued that standard setting, as part of centralized planning and control by some foreign governments (notably, Japan and France), in key areas of high technology reduces uncertainty among potential customers and thus stimulates rapid market growth. It does so by limiting the alternatives at an early stage in technological development. The Administration agrees that codifying industrial standards is a legitimate role for the Federal Government, but it does not believe that such standards should preempt the opportunity for the marketplace to select among alternative systems, except in those cases where, as a result of a direct Government need, the procurement process determines, de facto, the subsequent industrial standard. Such cases could include manufacturing processes, measurement methods and standards, properties of materials, and interface standards (between word processors and computers, for instance). Other



Bend Research, Inc.

Synthetic membranes developed at Bend Research, Inc., under the National Science Foundation's Small Business Innovation Research Program, are used to measure rates of metal extraction from polluted streams.

ways in which the Federal Government may support the technology infrastructure include technology transfer from the Government to the private sector and the granting of exclusive patents or licenses to those willing to commercialize technology developed with Government funds.

International Competition

Japan and some nations of Western Europe (notably, West Germany and France) have chosen specific technological product areas for exports. The target industry strategy in Japan, for instance, means coordinated Government support and industrial efforts to develop specific product lines for both world and domestic markets. Government supports have included access to capital, funding for basic and applied R&D, and favorable import/export policies and financing.

The basic commitment of the United States to a free market system, in the belief that it can respond most effectively and rapidly in a changing technological environment, precludes that type of industrial policy. The Administration believes that the Nation is best served by a solid Government commitment to the support of basic research, and a healthy economy that will encourage long-term R&D and innovation investment by the private sector.

Sectoral Considerations

Because of the complexity of the innovation process and the diversity of U.S. industry, incentives may have a different impact on small firms than large firms, and the rationalization of regulations may relieve high-technology industries differently than less R&D-intensive ones. Government sensitivity to such variation is best reflected by a market-based approach rather than direct intervention.

Conclusion

The economic vitality and international competitiveness of the Nation depend on a strong, innovative industrial sector. It is the policy of the Administration to strengthen the industrial sector and to stimulate its innovativeness, not through direct Federal subsidies and intervention in corporate decisionmaking, but through the provision of a variety of market incentives and the elimination of disincentives, both of which will encourage the full exploration of new ideas and new opportunities.

Introduction

The strategy of the Administration for improving the Nation's defense posture, stated in the most basic terms, is to focus on modernization and readiness. Research and development will play a key role in achieving both objectives. The vast and continuing Soviet programs for developing and deploying advanced technological capabilities make it mandatory to continue, and in some areas to expand, our comprehensive military R&D programs. The Administration is committed to advance, apply, and deploy, more successfully than in the past, those areas of science and technology essential to rebuilding our national defense capability.

The support of programs and institutional capabilities—in the universities, in industry, and in the national laboratories—that seek, nurture, and capitalize on the kind of new knowledge that supports development of new technologies will be of particular importance. The Administration will also continue to evaluate the Nation's overall science and technology program—both civilian and military—to make sure that the flow of knowledge is adequate to meet future defense needs.

Current Trends and Developments

The Nation's military R&D activities have two principal purposes. One, at which most of the effort is directed, is the development, testing, and evaluation of new and improved weapons systems and other military equipment. Those activities are part of the acquisition process through which new systems and equipment are procured for enhancing the capabilities of the armed forces of the United States.

The other main purpose of military R&D is the maintenance and strengthening of the technology base for future development, testing, and evaluation programs required to meet defense needs in the future. Programs supported within the broad technology base range from basic scientific investigations of new phenomena, materials, and devices to feasibility demonstrations of new system concepts in military environments, which can lead to the development of promising future systems. The technology base program thus provides the essential know-how needed to acquire technologically advanced weapons. Countering our adversaries depends on these weapons. The basic knowledge gained will also enable us to avoid adverse technological surprise.

Military research, development, testing, and evaluation (RDT&E) is, of course, mostly under the management control of the Department of Defense (DOD). Each of the military services has an RDT&E establishment comprising laboratories, development centers, and test ranges that perform about 30 percent of DOD's total RDT&E work. The three services and the Defense Advanced Research Projects Agency (DARPA) also have technical management and administrative structures to oversee the 70 percent of defense RDT&E performed outside DOD laboratories; most of such research is done by industry contractors, but a significant amount is performed at colleges and universities. Additionally, the National Aeronautics and Space Administration (NASA) conducts aeronautical research in support of both military and civil applications and is developing the Space Shuttle to meet the needs of both sectors. Responsibility for RDT&E of nuclear weapons and of nuclear propulsion for naval ships and submarines, currently vested in the Department of Energy and proposed for transfer to the Department of Commerce, is carried out through selected national laboratories and industrial contractors.

A central and difficult problem in formulating the overall defense program is to determine what proportion of the budget should go for development, testing, and evaluation projects leading directly to the procurement of new or improved capabilities to meet requirements and challenges now clearly apparent, and what proportion should be applied to the preservation and enhancement of the technology base to provide more and better future options. The problem is not one of seeking a tradeoff between research and development, but rather one of determining the proper amount for each activity within the total program. The Administration's defense program recognizes both needs. Development, test, and evaluation budgets have been increased to expedite the acquisition of new and higher performance systems. Technology-base activities have also been maintained at a high level in spite of other heavy demands on the defense budget, especially the need to improve operational readiness and procure more modern equipment for our forces. In addition, considerable effort is being expended to assure both the high quality and the pertinence to mission of those R&D efforts upon which funds are expended.

The Administration's allocation of resources for technology-base programs is impressive, but our defense needs are so broad that stringent selection criteria need to be applied to the various activities that are undertaken. Many of the projects supported by current DOD budgets involve advanced, long-range research intended to provide a broad base for evolving defense technologies. Others have been selected because of their direct potential for contributing significant improvements in our future military capabilities. Specific projects presently being emphasized include these:

(1) A new generation of integrated circuits is being developed under the Department of Defense's Very High Speed Integrated Circuits (VHSIC) program to provide a dramatic improvement in signal- and data-processing capabilities for military systems. VHSIC processors will provide significant improvements in the performance of airborne tactical radar, sensors for guided missiles and munitions, and automatic communication, navigation, and battlefield systems.

(2) A foundation for a new generation of sophisticated, intelligent weapons and support systems is being established through research in artificial intelligence and robotics and their applications to systems automation. Systems concepts range from automatic devices for assisting tankers, pilots, artillery crews, and air defenders, to autonomous systems for manufacturing and ammunition handling.

(3) Research in materials and structures science is leading to the development of,

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The unique internal structure of a super high strength organic fiber, which is stiffer than steel, is shown by electronmicroscopy Researchers are developing processes to use this fiber in a variety of military systems applications.

and improvements in, a number of advanced materials, including carbon/carbon composites, metal-matrix composites, and ordered, self-reinforced polymers. Use of the new materials promises to improve the strength, durability, survivability, and efficiency of many types of military equipment. Some of the materials are equivalent or superior to presently used alloys that contain such critical elements as cobalt and chromium, available primarily from foreign sources.

(4) Research in strategic laser communications focuses on developing the necessary technology to provide communications support, via satellite, to submerged strategic missile submarines without compromising their immunity to detection. Research on high-energy lasers aims to define the potential of laser weapons for forward battlefield ground combat, air defense against bombers, and space defense and other space-related applications.

(5) A major technology thrust is directed toward significantly improved aircraft performance capabilities. The integration of new electronics systems with the airframe can improve the combat effectiveness of tactical aircraft by combining flight,

fire control, and navigation systems to achieve greatly improved maneuverability and enhanced air-to-ground strike capability.

(6) Research programs are under way to protect U.S. military systems and personnel in the event of attacks with chemical or nuclear weapons. Another current research thrust is to assess the effects of high-altitude nuclear weapons detonations on the survivability and durability of military command, control, communications, and intelligence systems.

(7) Research on electromagnetic, seismic, and acoustic sensors underlies technologies for a wide range of strategic and tactical surveillance needs. The principal emphasis in current research on space surveillance is on advanced visible and infrared systems that can provide enhanced target detection in highly cluttered scenes. Research in nuclear arms verification technology focuses on the development of advanced sensors and instrumentation for deployment in remote areas and the evaluation of combinations of seismic and hydroacoustic sensors for ocean-based surveillance systems. Research in near millimeter wave imaging and tomography aims at the development of sensors, for use on the integrated battlefield, that can identify targets partially screened by foliage, netting, or debris.

Continuing Issues

Whereas the goal of the Nation's military R&D programs is to improve national security, the programs will continue to have major impacts in the civil sector as well. Conversely, restoration of our national defense capabilities requires that private industry be able to maintain the capacity to carry out a great deal of the requisite advanced development work. Thus, the Administration's commitment to a revitalized economy has a direct and important bearing on the achievement of its national security goals. Additionally, the relationship between the Department of Defense and the Nation's universities, which is of intense interest to both parties, has been given a high priority in DOD. A Defense Science Board Task Force report on university responsiveness to DOD needs will be transmitted to Congress in the near future.

The Administration recognizes that there are clear substantive commonalities in military and civilian R&D. Such areas of prime military technological interest as aviation, communications, electronics, and computers also are each the focus of a major U.S. industry. Oceanographic and atmospheric research are examples of scientific areas in which both military and civil sectors have strong interests.

In such areas of common interest, military and civil R&D are generally mutually supporting. In some instances, the military has taken discoveries or inventions made in civil R&D and developed them to a point where they have been widely and beneficially used in both military and civil applications. The invention and subsequent development of integrated circuits is an example. In many other cases, R&D conducted under military auspices has formed the basis for major advances in civilian as well as military technology. The development of lasers and the development of composite materials are two examples. In still other cases, there have been useful technology transfers in both directions. For example, commercial aviation has historically benefited enormously from advances in military aeronautics, but the impetus for developing, first, low-bypass and, later, high-bypass ratio turbofan engines came from their projected importance for air transport applications.

Transfer of military technology to civilian purposes takes place most effectively when military contractors in the private sector are also engaged in related civilian businesses. In such cases, subject to security constraints, contractors are able to incorporate advanced military technologies into their civilian product lines. Another class of interactions arises from the fact that military and civil research is performed at many of the same universities across the country. A university department may have grants or contracts from both civil and military agencies of the Government, usually for separate projects but sometimes for closely related work or even jointly funded projects.

Military R&D and civilian R&D also face many common problems, which the Administration is addressing. Maintaining continuity of effort is a principal concern, as is assuring the adequacy of the overall national technology base. The Administration accepts the major share of the responsibility to support basic research, which is a major contributor to the technology base. It is also committed to the view that for applied research, exploratory development, and advanced technology development and demonstration, all of which are also essential parts of the technology base, the Nation's principal reliance must be on the normal functioning of a strong free enterprise economy. It has therefore taken steps, outlined in chapter I and elsewhere in chapter II, to rejuvenate our economy.

The Administration is also concerned with maintaining the ability of the Nation's universities both to perform much of the basic research required to undergird future military systems and to educate scientists and engineers for employment by the Nation's industrial defense contractors and by in-house defense laboratories. It has encouraged closer interactions aimed at a better understanding of mutual needs and interests between DOD personnel and representatives of universities, professional societies, and industry groups, as well as between the staffs of DOD and those of other Federal agencies responsible for the support of basic research in universities.

Programmatic initiatives by DOD to maintain university capabilities include increasing research grant support to this sector for fiscal years 1981, 1982, and 1983. Additionally, a $30 million per year initiative starting in fiscal year 1983 aims to update and replace obsolete university research instrumentation. There are also special joint industry/DOD programs in selected technologies, including microwave tubes, composite materials, propulsion technology, vertical lift technology, computer sciences, and manufacturing technology, to support university research and graduate education.

Introduction

The U.S. space program has aimed to meet a wide range of scientific, commercial, and national security objectives, as well as international interests. The Nation's space activities during the past two decades have expanded and refined our understanding of the planetary system and the universe as a whole, have provided unique technical information and data to improve our understanding of the Earth, and have served national security needs.

As in other fields of science and technology, application of the criteria of scientific excellence and pertinence, as measured against significant national goals and needs, as well as an emphasis on the potential for significant private sector involvement, provides the overall context for the Administration's space policy. Consistent with its broad commitment to further fundamental scientific research, the Administration also will continue to support selected space exploration projects likely to yield appreciable scientific returns. The Administration will deemphasize those programs for which future exploitation appears unlikely.

Trends and Developments

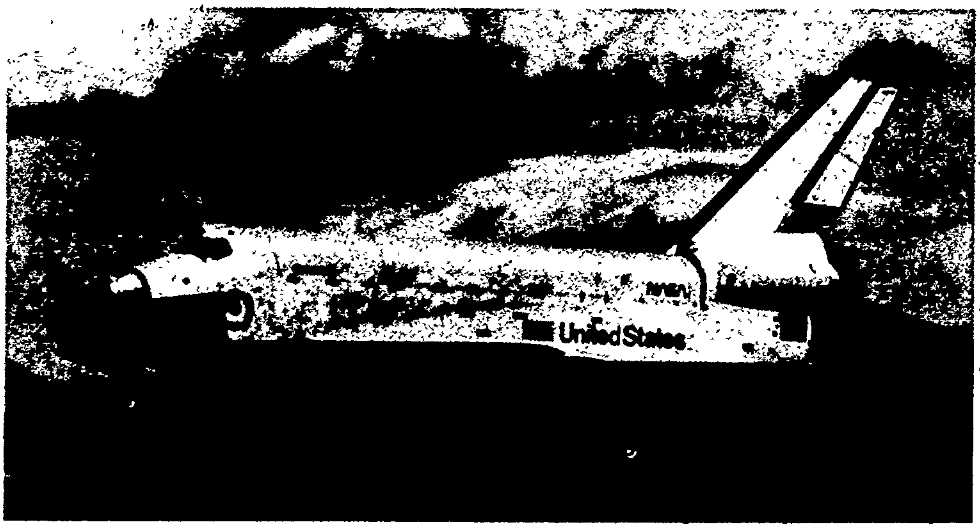
The creation of a viable infrastructure to support the development of space technologies has been influenced by both national security and civilian program objectives. tives. Most notably, the Space Shuttle was conceived of and is being developed with the objectives of both in view. Satellite remote sensing also serves both civil and national security interests of the United States. Advances in space-assisted communications and information technologies have been important both for national security reasons and for the development of a major new element of the civilian communications industry.

The Space Shuttle and, ultimately, the full Space Transportation System, the capabilities of which are highlighted in the space section of chapter III, will provide the primary foundation for the U.S. space program into the 1990s. By the mid 1980s, the Space Transportation System should be fully in place. As currently planned, it will include four reusable orbiters similar to the Columbia, two launch pads and landing sites, space control centers, and all of the extensive infrastructure necessary to process, manage, and integrate shuttles, payloads, and upper stages. The estimated maximum flight rate of the system when fully in place will be several times the current capacity.

The capabilities of the Shuttle will be exploited in the near future to further national security needs. For example, the principal emphasis in current Department of Defense programs on space surveillance is on advanced, satellite-borne, visible and infrared systems. One promising approach for satellite-based space surveillance is exemplified by the Defense Advanced Research Projects Agency's Teal Ruby experiment, designed for testing subsonic aircraft detection from space in conjunction with one of the Shuttle's early operational missions. Satellite-based laser communications will also be tested using the Shuttle.

The Administration's space program is also intended to encourage international cooperation. The Shuttle is already providing unique opportunities for such cooperation. Its remote manipulator arm, successfully tested on Columbia's second flight in November 1981, was developed by Canada at a cost of $100 million. The 10-nation European Space Agency is developing Spacelab I at a cost of $1 billion, and Japan is developing a $20 million plasma accelerator for use with this facility. Given the complementary capabilities that Europe and Japan are developing in response to the leadership that the United States has taken in space, it is likely that there will be increased opportunities in the 1980s for more international cooperative space activities. Such projects may also be richer in their return of scientific knowledge on which all nations can draw.

The Shuttle has significant potential for increasing private sector involvement in space. The feasibility of processing such materials as pharmaceuticals, semiconductors, and special glasses in the microgravity environment of space is one of the most



National Aeronautics and Space Administration

After completing its second mission, the Columbia Space Shuttle touches down at Edwards Air Force Base, California.

promising areas of space exploitation under consideration by the private sector. The Shuttle will facilitate developments in this area by functioning as a unique laboratory. Eventually, it also might serve as a vehicle for building up space platforms, factories, or even space industrial parks. While the latter possibilities are being explored only for the distant future, space processing of materials is of considerable current interest because of the unique products that might be produced and because of its potential for independent private sector involvement in space. The McDonnell Douglas Company and Johnson & Johnson have entered into an agreement with the Federal Government for a materials processing experiment to be carried by the Shuttle. That joint venture, in which no funds will be transferred between the public and private parties, commits the participants to provide specific materials and services. It could provide one possible model for future joint public-private sector cooperation.

Public and Private Sector Roles in Exploiting Space

The evolution of space activities in the United States has involved private industry in several roles; for example, as contractor and supplier to the government, as developer of secondary services (e.g., value-added processing of remote-sensing imagery), and as transformer of space technologies into new commercial ventures and applications. Complete private sector ownership and operation have already been achieved in satellite communications, where the contributions of satellites to the development and expansion of the Nation's communications capability serve as an encouraging example of the payoffs possible from timely R&D investments and industrial involvement in the exploitation of new technologies.

The Federally supported civil remote-sensing program, for example, is currently being reviewed to determine the extent of continuing Federal role and the degree to which transfer of all or part of its operating authority to the private sector is possible. Such other space activities as full-scale space industrialization, which are beyond the promising but still relatively limited space-processing ventures described in the previous section, are regarded as potential candidates for commercialization. Conditions required for exploitation by the private sector might well prevail in the near future.

Further, some form of private sector involvement in the management and operation of the Space Shuttle—and the full Space Transportation System—is already being considered an option for the future. An alternative strategy might involve consideration of a plan through which the Space Transportation System would be leased to a private operator through a Government-owned, contractor-operated arrangement. Such an arrangement would, however, require the establishment of a management and operations plan that would be adequately responsive to national security needs. In all areas of space activity, a key question addressed by the Administration is what constitutes a fair burden for the taxpayers in the development of technologies that are designed to serve multiple purposes for the Nation.

Encouragement of greater private sector involvement in space, as in any other high-risk, high-technology area, can best be achieved by a coherent cluster of policies designed to attract very long term investments. Current inhibitions to greater private industry involvement in space may be attenuated by policies that encourage such innovative institutional arrangements as private consortia for space research, development, and operations; joint ventures; and public-private corporations. Such arrangements could also relieve the Federal Government of at least a portion of the financial burden it now assumes in underwriting the civilian components of the U.S. space program.

Effective private sector involvement in a variety of space ventures will help rationalize the costs of the currently heavy Federal investments in space R&D. It will also facilitate the achievement of such other policy objectives as determining future exploitable directions for the space program, encouraging development of appropriate markets, accelerating the design of services and systems to meet the criteria of commercial operation, and, contributing in a variety of other ways to reducing the total amount of public support required for space activities.

Introduction

The President's nuclear policy statement of October 1981 constitutes a strong endorsement of nuclear energy. The policy holds that nuclear energy is no longer an energy resource of the last resort but is one of the best potential sources of new electrical energy supplies for the coming decades. That endorsement of nuclear energy is based on the recognition that the revitalization of the U.S. economy requires stable and economical supplies of energy, particularly electricity.

Nuclear energy supplies about 11 percent of the electricity generated in the United States. With the approximately 70 to 80 new plants expected to be operating by the end of the decade, nuclear generation should supply over 20 percent of electricity demand by 1990. Nuclear energy is a major source of clean, affordable, safe electricity, and U.S. dependence on it is increasing.

Further growth of nuclear energy, however, requires resolution of a number of policy issues. Although nuclear power generation will increase in the immediate future, the U.S. nuclear industry is experiencing severe contraction. Major nuclear power equipment vendors are reducing their manufacturing capabilities. Private sector R&D activities are dwindling, and architect-engineers who play significant roles in the design and construction of nuclear power plants are frantically competing for foreign jobs. Subcontractors and component suppliers are rapidly disappearing from the market. Nuclear engineering schools are hard pressed to find American students. If these trends are allowed to continue, the foundations of the U.S. civilian nuclear capability will be seriously undermined. A reversal of the decline of the nuclear industry is necessary if we are to maintain a nuclear power generation capability. The President's nuclear policy is designed to revitalize the nuclear power industry and, more broadly, the technical infrastructure necessary for further development of nuclear energy.

To address the problems unique to the nuclear power industry, the President has taken five initiatives that form the basis of a new approach to nuclear policy:

- improvements in the nuclear facility regulatory and licensing processes;
- continued development of breeder reactor technology, including construction and operation of the Clinch River Breeder Reactor;
- resumption of commercial fuel reprocessing in the United States;
- early deployment of facilities for storing and disposing of commercial high-level radioactive wastes; and
- identification and removal of deeply rooted obstacles that prevent the increased use of nuclear energy.

The key scientific and technological issues faced by the U.S. nuclear power industry are to operate existing reactors safely, improve the quality and control the cost of reactors under construction, and maintain the technical readiness of the utility industry to supply a larger fraction of the Nation's electricity needs from nuclear energy in the future.

Issues and Approaches

In the following sections, five major issues and approaches related to the future of nuclear energy in the United States are discussed: regulatory reform, international aspects, radioactive waste and reprocessing, breeder and advanced reactors, and nuclear fusion.

Regulatory Reform

The first and most frequently discussed remedy for the U.S. nuclear industry is the reduction or removal of regulatory delays and uncertainties that have excessively burdened the utility industry. During the past two decades, the construction time for nuclear power plants has more than doubled. Under the present trend, it will take 10 to 14 years to build a nuclear plant scheduled for completion around 1990. Delays due to multiple hearing requirements, redesigning, and retrofitting have depleted the financial and managerial resources of the industry. Consequently, utility executives are reluctant to order new nuclear generating plants.

Reduction of construction time can be accomplished in many ways. Substantial time can be saved by deleting unnecessary licensing processes and by keeping hearings within a reasonable schedule. Existing legislation allows the Nuclear Regulatory Commission (NRC) considerable room for such regulatory reform. In addition, there are several specific proposals for rationalizing and simplifying the regulatory process that may require legislative approval. They include "one-step" licensing, "precertification" of sites, and licensing of standardized plants. While legislative approval may be needed, those actions would not only streamline the nuclear regulatory process, they would also advance the practice of nuclear plant design and construction.

One-step licensing would require only one permit for construction and operation of nuclear power plants, instead of the present requirement for two separate permits. The Nuclear Regulatory Commission's responsibility would be to conduct the required licensing activity and closely inspect construction sites to assure adherence to the original design. That would eliminate uncertainty over the future of nuclear power plants under construction.

Precertification of sites, or "early site review," would allow utilities to designate a number of prelicensed sites for use at a later time. Some site preparation might even be allowed before utilities commit themselves to construction, thus enabling utilities to clear up problems of local politics before committing substantial resources to nuclear construction projects. It would also simplify multiple siting of nuclear plants at existing single-plant sites. The ability to designate a large number of precertified sites, a "site bank," would remove uncertainties over availability of plant sites and thus help stabilize the nuclear power industry.

Independent site licensing implies the decoupling of plant licensing from site licensing. Nuclear power plant designs can be prelicensed in the same way that potential sites can be precertified. That would, however, be a departure from the present practice. Most U.S. nuclear power plants are custom designed on the theory that local geological conditions dictate custom engineering of safety-related features. But experience has proven that a more standardized approach to design may now be possible.

These ideas for regulatory reform are subject to intensive study and discussion. To implement them, substantive engineering analyses will have to be performed in advance. Furthermore, utilities, engineers, and vendors need to establish new working relationships. Although carrying out the suggested measures will be challenging and at times difficult, it would definitely have a major impact on the competitive posture of the nuclear power industry.

International Aspects

The main focus of the prior Administration's nuclear policy was on nonproliferation of nuclear weapons technology and discouragement of other nations' nuclear power generation programs; it was believed that this would decrease the proliferation of nuclear weapons. To justify the policy, domestic reprocessing of nuclear fuel was suspended, and the construction of the Clinch River Breeder Reactor was delayed indefinitely. It is now evident that the policy was not realistic and had a deleterious impact on the U.S. nuclear power industry.

The President has expressed a strong commitment to the fundamental objective of nonproliferation and has exhibited unfailing support of the Non-Proliferation Treaty as well as the International Atomic Energy Agency efforts. But this Administration's approach to nuclear safeguards is based on the premise that the United States will continue to be the leading supplier of nuclear technology and maintain its stature in the international nuclear arena. By leading the way for the peaceful development of nuclear energy, the United States can exert a more constructive influence to deter the spread of nuclear weapons by controlling the flow of nuclear technology, materials, and equipment.

Present U.S. nuclear power technology still compares favorably with that available from the other nuclear supplier nations. Other governments are trying to support their developing nuclear industries by supplementing their domestic markets with subsidized exports. Under such policies, some of those supplier nations will be able to develop their nuclear capabilities on a par with those of the United States.

Recognizing the challenge from abroad, this Administration is spurring research and development on nuclear power plant design and nuclear fuel cycle technologies. Unleashing the inventive and innovative strength of the American private sector is the key policy instrument for maintaining U.S. leadership in international nuclear technology.

Radioactive Waste and Reprocessing

Disposal and safe management of radioactive wastes have been major issues for the nuclear power industry in the United States. The issues have drawn great public interest in spite of the fact that adequate technology now exists for disposal of both low-level and high-level radioactive wastes. There exists a great need to bolster public confidence in the technology and its responsible application.

In comparison to other hazardous wastes, wastes generated by the nuclear industry are the smallest in volume and the best characterized and understood. Their physical and chemical characteristics are well defined, their containment barriers are highly developed, and long-term depository technologies are available to ensure their safeguarding for thousands of years. What remains to be done is implementation of formulated plans to relieve public concern over disposal of nuclear wastes.

To revitalize the nuclear energy industry, it is time to proceed with the implementation of waste management technology. Utilities with operating reactors are currently storing spent fuels on site. Available on-site storage capacities are being filled, and it is time to proceed with off-site waste disposal facilities. Retrievable surface storage is the preferred option for spent fuels, which still contain valuable energy resources.

Reprocessing of spent fuels has long been considered a way to recover the energy remaining in them and to dispose of the high-level radioactive wastes. The President's initiative in removing the ban on commercial reprocessing is an important step toward assuring the development of a closed nuclear fuel cycle. That initiative was a signal to utilities and industry that the Federal Government will eliminate unnecessary impediments to a rational, integrated approach to nuclear energy.

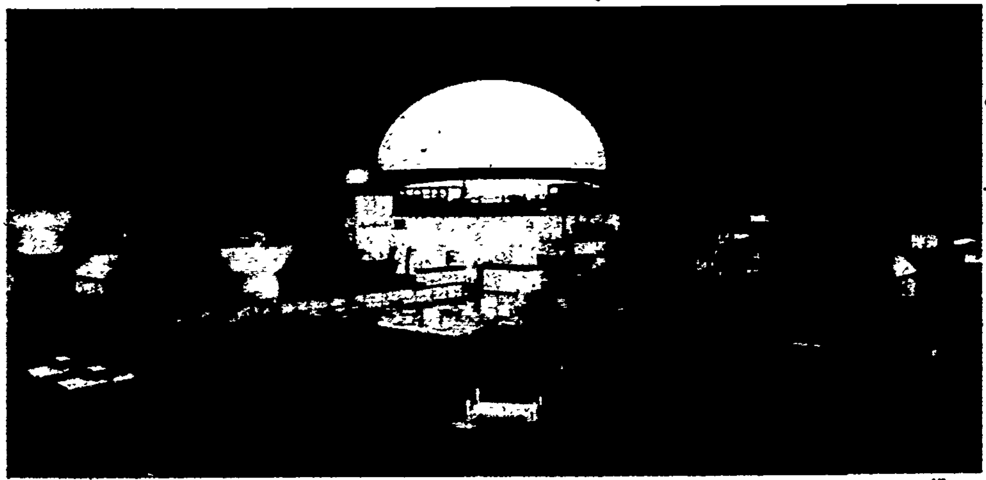
Under the new policy, the Federal Government will encourage the development of private industry's capability in reprocessing. Such incentives as guaranteed purchase of plutonium by the Federal Government, allowance of foreign participation, and financial support for R&D activities are under consideration.

Low-level radioactive waste disposal programs, which do not require high-level technology, are also being implemented. The 1980 Low-Level Waste Policy Act encourages regional arrangements for disposal of low-level wastes. The Federal Government is helping each State arrange for regional disposal sites for low-level wastes, which are produced not only by nuclear power generation but also by the many medical, industrial, and research uses of radioactive materials.

The judicious implementation of currently available technologies will resolve the problem of nuclear wastes. The public must be convinced that those technologies are indeed adequate and safe. The message should be clearly communicated that it is time to proceed with deployment of nuclear waste disposal facilities.

Breeder and Advanced Reactors

The President, looking to the long-range needs of the Nation, has directed demonstration of breeder reactor technology and completion of the Clinch River Liquid Metal Fast Breeder Reactor. Breeder reactor technology enables the use of plentiful and inexpensive fertile uranium-238 isotopes and thorium for fuel, thereby essentially eliminating the problem of long-term fuel supply for the nuclear power industry. The technology will unleash vast energy sources, much larger than all the fossil fuels known to exist.



U.S Department of Energy

The Fast Flux Test Facility at Hanford Engineering Development Laboratory in Richland, Washington, is a sodium-cooled fast flux reactor designed specifically for irradiation testing of fuel and components.

Besides the liquid metal fast breeder, there are other types of breeder technologies. The key problem for developing any breeder or advanced reactor concept, however, is that it takes a long time and large financial and resource commitments to realize commercial potential. The previous approach, which divided technical and financial resources among many different options, has not proven successful for the U.S. nuclear industry. The time has come for strong and decisive leadership in setting priorities for the various technological options and focusing American ingenuity on attaining commercial success. The nuclear policy of the Administration is to deliver that leadership, and completion of the Clinch River Breeder Reactor is the key preparatory step. The strategy for the long-term development of breeder technology and advanced reactor concepts should be finalized only after evaluation of operating experience at Clinch River and an intense assessment of the relative merits and feasibility of the available options.

Fusion

Nuclear fusion is one of the promising prospects for future energy supply. Once successfully harnessed and commercialized, fusion can provide an inexhaustible energy supply. Fusion is capable of delivering central station power and liquid fuels with minimal environmental burden, since it will not generate high-level radioactive wastes. Fusion R&D is genuinely long-term, high-risk, high-payoff research.

The United States has been an international leader in fusion research during the past 30 years. The Administration intends to continue support for fusion research as a cornerstone of the long-term energy research policy. It is important to consider, however, that much basic research remains to be done before the transition from scientific research to large-scale engineering development can be accomplished. There are also a number of potentially revolutionary ideas that deserve further research and close examination. In view of the current diversity of expert opinion on fusion reactor technology, care should be given to avoid prematurely fixing reactor configuration. In contrast to nuclear fission, where the technology is mature, fusion R&D requires flexibility to incorporate scientific and technological innovations. Private industry has responsibility for the eventual commercialization of nuclear fusion technology. Therefore, it is beneficial to increase the private sector's participation in fusion energy development. Also, U.S. fusion researchers should continue to participate in the fusion R&D programs of other nations and design international cooperative programs more carefully to optimize mutual benefits from such collaboration.

Perspectives and Conclusions

The short-term policy actions announced by the President would begin the revitalization of the U.S. nuclear program. The U.S. nuclear industry will be able to plan a strategy for a healthier and more stable future. Also, with firm implementation of overdue Federal programs in nuclear energy, public confidence will gradually be restored. When additional nuclear power plants are brought on line and the industry maintains its exceptional safety record, nuclear technology will be accepted as a major cornerstone of the U.S. energy system.

The long-term prognosis for the competitive posture of U.S. nuclear technical capability is uncertain unless new vigor and enthusiasm can be instilled among nuclear scientists, engineers, and technologists. To attain such a resurgence of scientific and technological activity, the Administration is pledging sustained support for research at national laboratories, universities, and private institutions. A continuing effort to improve public understanding of nuclear technology and its importance in the American economy would reinforce nuclear initiatives. Only in this way can the important benefits of safe, clean nuclear energy be achieved by the Nation.

Introduction

In 1953 Watson and Crick provided the understanding necessary to "crack the genetic code." In doing so, they were able to explain the basic structure of deoxyribonucleic acid (DNA), the molecule in all living things that contains the genetic information that programs their development. DNA was discovered to be a long, twisted, ladder-shaped molecule (double helix) whose rungs always consist of pairs of the same four subunits. Differences between the genetic program of one species and that of another is due to the varying arrangements of these basic subunits.

The unit that determines a specific characteristic of an organism is called a gene and is frequently made up of a number of adjacent rungs on the DNA ladder. One of the gene's functions is to program repeatedly the creation of a specific protein in the cell (for example, a hormone), which in turn has its own specific function in the organism.

National Institute of Arthritis, Metabolism, and Digestive Diseases

A Staff Fellow at the National Institutes of Health examines a model of a DNA molecule.

With that basic knowledge and understanding, the door to a new era opened. Molecular biologists began developing a new set of techniques, known as genetic engineering or recombinant DNA technologies, whereby specific genes can be removed from one species and spliced into the DNA of another. Once such a genetic transfer is successful, the recombined DNA can indefinitely replicate as the host reproduces. Recombinant DNA (r-DNA), gene splicing, or genetic manipulation techniques allow one to transfer genetic information not only within species, but among species belonging to widely different kingdoms of life. In this way, science has overcome the species barrier to genetic transfer that heretofore had seriously limited the development of new strains of organisms. Thus, genetic engineering provides virtually unlimited prospects for the development of new strains that can be modified to serve human needs either in their acquisition of useful characteristics or in their production of new products. The insertion of a single gene into a bacterium, causing it to produce a targeted product, will be a common example of recombinant DNA technology.

Recombinant DNA techniques, which have been used in the laboratory to produce such substances as human insulin, growth hormone, and interferon, are now being used to introduce new products into the marketplace. Indeed, the prospects for applying the techniques to medicine, agriculture, energy, and other fields seem virtually limitless and have spawned the emergence of an aggressive new industry. Potential applications include production of new vaccines, control of genetic disorders, improvement of agricultural yields, and production of new energy sources. The largest markets are likely to develop in the chemical and agricultural industries.

Along with the opportunities, the sudden emergence of this innovative technology will also generate problems and anxieties with which society will have to grapple. A great deal of time and effort has already been devoted to anticipating and assessing the risks inherent in the technology and the potential biohazard that could accompany its widespread application. That assessment is clearly a process that will need to continue and be reevaluated periodically.

This discussion focuses on the specific benefits and advances that can be expected in the near future from the now rapid commercialization of recombinant DNA technology. It also points out the initiatives the Federal Government may need to take to maximize the benefits and minimize the risks to society.

Current and Likely Applications

The potential applications of recombinant DNA methods are expected to affect significantly medicine, industrial chemistry, and agriculture in the near future. Longer term applications include mining, pollution control, and the conversion of plant matter to usable fuels. It is anticipated that over 50 nonexclusive licenses will be granted in 1981 on the basic patent underlying genetic manipulation held by Stanford University and the University of California.

At the moment, the United States leads in the fundamental science of genetic manipulation, but that lead could be short-lived. International competition is heavy. Furthermore, the United States now lags behind Japan and, to a lesser extent, Europe in fermentation technology. Japan holds 80 percent of the patents in the fermentation industry, and it is a world leader in the production of antibiotics and enzymes. However, Japan has not yet established an organized thrust into research on applications in genetic engineering and will most likely rely on the research of others, at least in the short term. By contrast, a number of European countries, including England, France, Switzerland, and Germany, are actively pursuing genetic engineering programs, and all have established research and testing companies in applied genetics.

Medicine

It is impossible to assess with any confidence, or in any detail, the future commercial significance of genetically engineered products. Both the substances and the production techniques yet to be developed may be quite different from the ones now being used. A striking example, however, gives some understanding of the excitement that has been stimulated by the techniques and the products that might be produced through their use. The hormone interferon, known to be effective as an antiviral agent and under study as a potential anticancer agent, is now being made by conventional extraction and purification techniques at a cost of 40 thousand dollars per milligram. Once genetically engineered interferon-producing bacteria are available in commercial quantities, the price per milligram is expected to be about 10 cents. Interferon from such bacteria has already been tested on humans with some success, and it is expected to be on the market in a few years.

However, that spectacular early success in biomedicine may not be typical of other areas of application for several reasons. First, the substances that have been produced thus far are "one-gene" products—that is, the genetic material responsible for their manufacture is readily inserted into bacteria which then can rapidly reproduce in fermentation tanks. Second, money for research and development, both private and Federal, has been readily available. Finally, there exists an active community of highly skilled researchers, trained both in recombinant DNA technology and in biomedical research, who are strongly motivated to develop approaches with the potential of curing a variety of genetically determined diseases.

A number of commercially valuable biomedical products already made in the laboratory by recombinant DNA techniques will go into production in the very near future. They include human insulin, human growth hormone, interferon, and a vaccine for hoof-and-mouth disease. It is thought that the commercial availability of many other therapeutically useful products is simply a matter of time.

Genetic engineering will not only make possible the production of useful substances at affordable prices, it will also allow the development of far more precise methods for detecting genetic diseases in utero. Even direct intervention in the genetic makeup of fetal cells to repair genetic damage at an early stage of development may eventually be possible. While it is still too early to know how successful such gene therapy will be, there are, in theory, no insurmountable technical obstacles to the diagnosis and treatment of genetic disease at the cellular level. However, no successful experiments involving laboratory animals have yet been reported, and clinical trials with human subjects cannot proceed until clear-cut successes are achieved with animals, and the potential risks to humans are adequately identified.

Industrial Chemicals

The production of some industrial chemicals is expected to be transformed by genetic engineering techniques. Industrial chemicals can be produced by either fermentation (biological synthesis) or chemical synthesis. Essential ingredients are petrochemicals, which provide the feedstock, and heat and pressure, which are required to overcome the energy activation barriers and to speed reactions. The high cost of fossil fuels provides a great incentive to develop fermentation methods for synthesizing industrial chemicals. Also, biological processes require less energy, are far more product-specific, and pollute less than present chemical production techniques. The new knowledge of fermentation processes gained, and the novel organisms produced, will improve the internationally competitive market position of U.S. commercial fermentation.

Agriculture

Agriculture stands to benefit greatly from applications of genetic engineering. Genetically engineered plants can, in theory, be made to fix their own nitrogen, eliminating the need for the energy-intensive and costly ammonia-based fertilizers on which most high-production agriculture depends. It is thought that plants can eventually be modified through genetic engineering to flourish in salty water, extreme heat or cold, short growing seasons, and other adverse conditions. Success would open great tracts of previously unusable planting sites to agricultural production and development.

U.S Department of Agriculture

A plant showing adequate nitrogen fixation is contrasted with one that has a deficiency.

While genetically engineered plants of commercial value have yet to be developed, the fact that such companies as Shell, Occidental, Atlantic-Richfield, Sandoz, Upjohn, Pfizer, and Ciba-Geigy have established agrigenetic programs suggests the seriousness of corporate interest in the future of genetic engineering in agriculture. At the present time, advances are handicapped by gaps in the fundamental knowledge of plant physiology at the molecular level, particularly with regard to genetic traits of agricultural importance. Perhaps partly for that reason, some of the major seed companies are moving into the new technology slowly, suggesting that classical plant-breeding techniques will continue to be important for the foreseeable future.

The Development of the Commercial Enterprise

In 1971, a group of scientists and investors, recognizing the potential commercial importance of developing improved strains of microorganisms for use in the preparation of pharmaceuticals, formed the first company specifically addressed to such developments. The company, Cetus, Inc., applied advanced technology to sort through vast numbers of random mutations hoping to find commercially promising ones.

Two years later, in 1973, Professors Boyer, at the University of California, and Cohen, at Stanford University, invented techniques for splicing together genetic material from two different life forms. By removing a section of DNA from one species and combining it with DNA from another, they efficiently created their own aimed-for variants.

Through that discovery, a new industry was created. By 1975, Cetus and several other companies were exploring the vast potential of the new field. Today there are approximately 100 small firms and divisions of established companies applying the techniques of gene manipulation to produce commercially valuable products, many of which are otherwise unavailable or available only in limited quantities at high costs.

While the original scientific accomplishments achieved through intensive research were supported by the Federal Government, the growth of genetic engineering as an industry has been richly aided by money from the private sector. As of 1981, a total of approximately $400 million of private capital, not including public stock offerings, has been invested in 25 companies. Venture capital firms have played a major role in funding the startup of many research-oriented firms and have provided them with financial, organizational, and marketing skills. In 1980 alone, about $100 million was invested by venture capital firms. Large corporations in the drug, oil, chemical, and agricultural industries have also invested money and management consulting efforts in small research companies. For them, this is an efficient way to gain entry to the field. It is estimated that of the total amount invested to date, about $250 million has been committed in this way. In addition, two of the leading companies, Cetus and Genentech, have raised millions of dollars through recent public stock offerings.

However, it is expected that the rate of new investment in genetic engineering by venture capital firms will decline. Such firms have probably already made their commitments to the field. Since most products are still a long way from the marketplace, a return on investment based on actual sales is unlikely for most in the short term. Future funding for the already-established small companies will likely come from stock sales to the public and from continued investments by large corporations. Those changes in funding patterns do not necessarily mean that the number of startups will drastically drop, since companies catering to specialty markets will no doubt continue to be formed.

Research in the application of recombinant DNA methods is not the exclusive domain of small entrepreneurial firms. In addition to those already mentioned that are active in the agricultural area, a number of other large, established corporations are developing their own serious in-house efforts. They include Merck, Hoffman & La Roche, Eli Lily, Du Pont, General Electric, and J.D. Searle. An example of a successful endeavor by a major corporation is the recently developed and patented bacterium that can decompose oil to aid in the cleanup of spills. This new life form was developed at General Electric using a combination of early genetic engineering techniques.

Clearly the range of applications possible in genetic engineering is broad enough and is developing fast enough that both the large and the small commercial enterprises can continue to flourish. It is nonetheless expected that in the longer term, the major firms are likely to take over large-scale production efforts, while the smaller firms cater to demands for specialty products and develop new substances for trial or clinical evaluation.

Industry-University Cooperation

Federally supported basic research conducted in university laboratories was primarily responsible for creating the genetic engineering industry, and academia will no doubt continue to play a crucial role in its development. Though the technology is in its infancy, the theoretical knowledge base on which that technology depends is growing rapidly. In other areas, as a new industrial technology emerges from science, there is usually a gap of several years between the fundamental results achieved in the research laboratory and the development of the practical applications. While the full-scale manufacturing of viable products in the industrial domain is largely in the future, the initial application of the results of university experiments in genetic engineering has been almost immediate. There is, consequently, great demand by both small and large firms for close collaboration with university scientists and their students.

Collaboration between the two has become extensive. Some university faculty members, who are active researchers in genetic science, are financially connected with one or more of the relevant commercial ventures. Others share ownership in newly formed entrepreneurial firms, participate on corporate scientific boards, or are consultants for the industry. For those who have involved themselves in the private sector, those roles have become a significant part of their professional activities. Some have even left the university altogether for positions in industry, where salaries are higher and research facilities are often more elaborate and up to date. If this exodus from university teaching becomes a trend, it could threaten the future conduct of basic science in genetic engineering and the continued education and training of new scientists vitally needed in the field. The current tug of war between industry and universities for molecular biologists is a striking indication of the pressures that can develop.

Nonetheless, industrial organizations are providing needed funds to enable universities to extend their research activities. Some recent examples of major financial interactions have been widely and often critically discussed. Harvard University recently decided to forego participation in a direct contract with Du Pont for the sharing of research activity in genetic engineering. Subsequently, a somewhat different arrangement, involving a grant by Du Pont of six million dollars, was agreed upon by the Harvard Medical School.

As another example, Hoechst & Company, a West German chemical firm, entered into a 50-million-dollar, 10-year contract with Massachusetts General Hospital, a teaching hospital for Harvard Medical School. The money is to help develop teaching and research in genetic engineering. While the research is not to be product-oriented, any proprietary rights that develop will belong to Hoechst. In addition, the Massachusetts Institute of Technology has recently accepted a sizable contribution from a Greenwich, Connecticut, industrialist, Edwin C. Whitehead, to establish near the university an independent institute for biomedical research, which will in part be engaged in genetic engineering research. These are only three examples of a wide variety of possible university-industry arrangements under consideration at numerous academic sites around the Nation.

These kinds of interactions are being viewed with mixed emotions. Intimate industrial involvement with university research has occasionally been referred to as a "Faustian bargain." The university's role is to foster free and independent research by faculty and students in the quest for knowledge and to disseminate openly to society the results of that research. Industry, on the other hand, is concerned primarily with profits, focusing on product-oriented research and protecting through proprietary or trade secrecy the information its researchers discover. Since those goals seem, at least on the surface, incompatible, a university's acceptance of industrial money has been viewed by some as jeopardizing its essential research role, and academicians are beginning to worry if university research will, with industrial support, become closed and narrowly product-oriented.

Some of the concerns being raised are far more subtle. Will there be, perhaps, subconscious pressures on researchers and their graduate students to change their priorities to favor investigations with higher commercial rather than intellectual potential? Will free communication with colleagues outside the commercially supported institute or center be subtly compromised? Will the "honeymoon period" that currently characterizes university-industry arrangements gradually turn sour as the difference in expectations of the two sides becomes more apparent?

Others argue that different academic disciplines—physics and electrical engineering, in particular—have faced the same challenges without being unduly compromised, and it might be expected that the same would happen in the biological sciences. The birth of genetic engineering has been compared to the previous emergence of computer technology or of laser and semiconductor science from university laboratories two and three decades ago. There were some problems, but fruitful cooperation was the predominant result. In addition, it should be noted that a number of industrial laboratories have a good history of conducting open, fundamental science and of interacting well with universities.

However, the case of genetic engineering is different in some rather important ways from the university-industry cooperative development of lasers and semiconductors. In these earlier cooperative developments, industry was independently facile with the new science and hence not as dependent on academic participation. Furthermore, the path from university research to actual use and extensive commercial application took substantially longer than appears to be the case with genetic engineering.

Possible solutions to potential or existing conflicts inherent in university-industry cooperative agreements include: providing for the free and open publication of results, once patentability has been reviewed; vesting patent ownership in the university (possibly in partnership with the faculty researcher); and giving the industrial sponsor exclusive royalty, a free right to practice the patent, and sublicensing privileges. While such solutions could never be institutionalized, general discussion of the issues by the corporate and academic communities could save interested parties from having to handle such problems on a case-by-case basis.

The Federal Government also has an important role to play in enhancing such cooperative arrangements by providing a base of support for the most fundamental research upon which university and industry researchers can build. It is noteworthy that when university-industry interaction in laser and semiconductor science was so fruitful, Government support for the fundamental, basic research component of laser and semiconductor science was plentiful. Thus, the Government can be quite critically involved in encouraging a healthy coupling between the university and industry. The recently enacted Patent and Trademark Amendment Act of 1980 is considered a good example of this kind of involvement. The act stimulates applications and allows effective industry cooperation by giving patent rights on inventions stemming from federally supported research to universities or small businesses. Perhaps most importantly, the act permits the granting of exclusive licenses under certain specified conditions. Exclusivity can at times be a crucial factor in providing an incentive for commercial development of a patent originating in a university lab. It should be noted, however, that the burgeoning genetic engineering industry would probably not have been possible without the changes in patent policy introduced by the National Institutes of Health (NIH) in 1977. It was the new NIH patent policy that made it possible for universities to own patents based on NIH-supported work and to license them exclusively to commercial firms for development.

Legal Issues

The patentability of manmade life forms or scientific techniques involving life processes, is not obvious. Although there is some precedent derived from the patentability of plant hybrids, it was only in 1980 that the first patent of a genetically engineered life form was granted in a narrow 5-4 decision of the Supreme Court. The case was an appeal of the initial rejection of the patent for General Electric's oil-decomposing bacteria. Shortly thereafter, Professors Boyer and Cohen were awarded the patent for their 1973 basic gene-splicing technique. Those two patent awards establish that not only the organisms created by genetic manipulation, but also the general techniques or processes themselves, are eligible for patent protection. It is expected, however, that the application of the present laws to the new techniques will be beset with confusion.

A basic problem in patenting living things is the intrinsic variability and complexity of organisms and life processes. It will be exceedingly difficult to be sure what constitutes patent infringement. When one has a patent on a specific microorganism, it may be quite difficult to say whether another's organism is or is not a descendant—or even, for that matter, whether it is identical. Once an organism, no matter how difficult to create, is out of the lab, it can readily be grown in a suitable culture. The problem will be particularly acute in agriculture, where seed is widely disseminated. The validity of patents on genetically engineered products will continue to be challenged. Furthermore, spontaneous mutations can and do occur in nature, and they will further complicate the entire issue. In addition, international law may play a role, given the degree of foreign and domestic cooperation in the area.

Uncertainty is a serious concern for people in the industry. Patent law determines to a significant extent the commercial value of technical discoveries and, therefore, some of the motivation to seek such knowledge. Patent law also helps determine the timing and nature of technical publication and the extent of proprietary or trade secrecy. Some decades ago, the patent laws were modified by Congress to include specially bred plants. It seems reasonable to consider now whether another modification may be in order.

Technical Personnel

If the industry based on the new genetic engineering technology is to develop and grow in the United States, it will require a substantial pool of highly trained people in several scientific and engineering disciplines. Molecular biologists, cell biologists, plant geneticists, and plant physiologists are all central to the present scientific aspects of the field. Physical and analytic chemists and biochemists will be increasingly needed to perfect the laboratory processes. As the movement to commercial-scale production takes place, biochemical engineers, process engineers, and experts in fermentation techniques will be needed in large numbers.

The educational caliber of the people required at present and in the near future is exceedingly high. Almost 20 percent (some 300) of the employees of the top 10 new research companies started be-

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An Agricultural Research Service biochemist inoculates a sunflower plant with Agrobacterium. This technique has been successfully used to transfer genes via bacterium fragments.

tween 1975 and 1979 have Ph.Ds. With increasingly intensive activity directed toward the agricultural and chemical markets, the availability of people with the required skills may soon be sorely taxed. Some believe that the most critical personnel shortages will be in agricultural areas, and in especially short supply will be individuals with scientific and engineering backgrounds in fermentation technology.

Potential Hazards and Social Anxieties

The techniques of splicing one organism's genetic material into another allow creation of new species, types that never may have come about as a result of natural processes. The recognition of certain possible risks associated with the processes has induced concern among researchers and the public that a hazardous organism might be created, released unwittingly, and spread uncontrollably. The potential danger of such a scenario originally appeared far greater than that posed by hazardous chemicals, since in theory a microscopic amount of the released organism could conceivably multiply undetected throughout the environment.

Adding to the intensity of the concern was the fact that a large fraction of the experiments conducted in the mid-1970s were being done using *E. coli* as the host organism into which DNA from other species was introduced. *E. coli*, a bacterium that normally resides benignly in the human intestinal tract, is the most thoroughly understood of all bacteria, and for that reason it has long been the laboratory guinea pig of microbiology. Nonetheless, it was feared that if a pathogenic strain of *E. coli* were created, the new organism might escape into the environment and cause an epidemic of unprecedented proportions. This was of particularly great concern since genes affecting antibiotic resistance and tumor formation were targets of research at the time, and no previous experiments of that kind had ever been conducted.

Several scientists, including Paul Berg, who won the 1980 Nobel Prize in Chemistry for his research on genetic manipulation methodology, voluntarily halted certain of their own experiments and initiated a public debate on the issue. The forum that received the most attention was a meeting of the leading genetics researchers, to which the press was invited, held at Asilomar, California, in 1975. In response to a statement negotiated and adopted by those attending the Asilomar Conference, the National Institutes of Health promulgated a set of guidelines for the conduct of genetic manipulation experiments. The guidelines classified experiments into four hazard levels and specified the precautions to be taken for each level. All scientists funded by NIH were required to comply. Although research conducted in industrial laboratories did not officially come under the restrictions, essentially all researchers in the United States voluntarily complied.

Work conducted since the establishment of the NIH guidelines has resulted in a greatly improved understanding of the potential hazards associated with genetic engineering. In fact, experiments sponsored by NIH have established the risk parameters for certain types of activity. A great deal of evidence exists today that genetic manipulation experiments are probably not as dangerous as was originally feared, although a continual reevaluation of the risks will be needed for all existing and future projects.

There are two basic reasons for the relaxation of concern, especially among researchers. First, attenuated strains of *E. coli* were developed. They do not survive outside the laboratory and can grow only under special conditions. The attenuated strains are now widely available as the hosts for gene insertion. Second, it is now understood that there is a basic difference between the structure of the genes of higher organisms and the genes of bacteria, a difference that prevents the lower organisms from expressing genes of higher organisms, and vice versa. The incompatibility can be circumvented, but only with difficulty. It would not come about accidentally, as had been feared. There remains, of course, the possibility that a person with high technical competence, working either alone or in a team, could intentionally set out to do mischief. That is, however, equally true in many other areas of scientific inquiry, and the problem is not unique to genetic engineering.

A number of researchers are now asking for a reduction in the stringency of the NIH guidelines, or even for their rescission. The procedures mandated by the guidelines can be quite expensive and can appreciably slow the progress of research. An advisory committee to NIH recently recommended that the guidelines be all but removed. The recommendations specified that violations of any guidelines be enforced through peer pressure. The committee further recommended that university biosafety committees, to which all proposed gene manipulation experiments now must be submitted for approval, no longer be required. The NIH Recombinant DNA Advisory Committee reconsidered these recommendations in early 1982 and voted to retain mandatory federal controls on gene-splicing research while relaxing their provisions somewhat. Most researchers in the relevant fields appear to support the advisory committee's recommendations, but a minority have expressed strong reservations, agreeing that the hazards are less than were once feared, but preferring to move slowly until much more is understood.

The Federal Role

Substantial fractions of modern technology, health care, and agriculture can trace their origins to research supported by Federal funds. Rarely, however, has there been an example as clear-cut as genetic engineering. Only a few years ago, virtually this entire field of research in the United States was Federally supported. Nonetheless, there were critics who argued at the time that the Federal Government was wasting millions on support of research to satisfy the curiosity of molecular biologists, with no prospect of useful technology. There is every reason to believe that a decade from now we will see genetic engineering as a prospering and socially beneficial technology with vastly greater payoffs than the total research investment.

The Federal Government has a role in the support of both fundamental research focused on acquiring new knowledge and applied research directed toward specific socially useful ends not appropriate for support by the private sector. When research has the likelihood of sufficient commercial application to attract the investment of substantial private funds, Government funding is no longer appropriate. The area in which this funding situation is true for genetic engineering is so large that care will have to be taken that important but not readily commercializable research does not get overlooked in the overall program.

Of the $150 million annual budget devoted to genetic engineering research by the Federal Government through its granting agencies, most goes to universities. The National Institutes of Health, the Department of Energy, and the National Science Foundation are the major suppliers of grant funds in genetic engineering. Research funds are also available to industry through special small business innovation and research programs, through cooperative university-industry research programs, and by direct grant application. NIH has recently begun accepting grant applications from industry. However, the needs for research funding in this rapidly developing field probably change faster than funding distribution channels can adapt. In summary, genetic engineering provides an excellent case study of an area in which, through judicious funding of the most excellent basic research and the fostering of university-industry cooperative arrangements through patent legislation reforms and tax incentives, the Federal Government has played a critical role in leveraging the development of exciting scientific discoveries.

Introduction

The United States allocates more of its resources to research and development than any other country, and its total national R&D investments, in absolute terms, exceed those of Japan, West Germany, and France combined. It also employs more scientists and engineers in its labor force than any other free world nation. The magnitude and diversity of those resources will continue to make cooperation with the United States in science and technology at individual, institution, and governmental levels attractive and important to scientists from other nations.

Policy Context for Cooperation

The guidelines that shape the international components of the Administration's science and technology policy are substantially the same as those that apply to its purely domestic components. International cooperative programs supported by the Government must be consistent with the President's commitment to maintain fiscal responsibility in the public sector and enhance incentives for private sector investment. They must be characterized, on the U.S. side, by a clear distinction between appropriate public and private sector roles. International research projects will be subject to criteria of excellence and mutuality of benefit. International applied research projects will also be subject to the criterion of pertinence to national economic and social goals and needs.

Two corollary aspects of those criteria bear special emphasis. First, one of the realities of the 1980s is that whereas the United States retains international preeminence in many areas across the spectrum of science and technology, we no longer hold undisputed dominance in virtually all fields. Nor do we have a monopoly on the world's scientific and engineering talent. The Western European nations and Japan have reestablished the intellectual and productive capacities they lost during World War II, and several less developed countries have built their own capabilities for carrying out scientific and technological activities in selected areas of special concern to them. The United States can benefit from healthy competition, as well as cooperation, among scientists of all nations and must be prepared to meet the challenge of making the best possible use of resources abroad to help ensure continued progress in science and technology in this country.

Second, international cooperation is not synonymous with Federally sponsored cooperation. American scientists and engineers cooperate in a great many international ventures—often through the universities or the industrial firms that employ them—in which the Federal Government acts, at most, as a facilitator. An important aspect of the Administration's science and technology policy is to encourage such cooperation. The Administration recognizes the unparalleled contribution made by U.S. universities to the development of science abroad. It also recognizes that international cooperation among industrial firms in transportation, space commercialization, communications, and energy production can serve important U.S. national and international interests, as well as the interests of the firms involved. Indeed, new forms of private, multinational arrangements may well be needed to develop and commercialize expensive future technologies—in space and energy—that can benefit many countries, including the United States.

The ways in which the Administration's broad policy guidelines apply to cooperative science and technology programs with particular countries will depend in each case both on the specific concerns that the United States shares with that country and on that country's science and technology policies, resources, and capabilities. The industrialized democracies share concerns about sustained economic growth, improved environmental quality, and enhanced national security, for example. Hence, in those cases, the emphasis of the Administration's policy is on sharing R&D resources to maximize the return on investments to all cooperating parties. Such middle-income countries as Mexico, Brazil, Israel, and South Korea have made impressive strides in

Karl Schumacher, the White House

President Reagan is greeted by Mexican President Lopez Portillo at the International Meeting on Cooperation and Development in Cancun, Mexico

developing their capabilities in certain aspects of science and technology. As is the case with Western Europe, Canada, and Japan, increasingly fruitful cooperation involving scientists and their institutions in the United States and their counterparts in the middle income countries is envisioned.

U.S. policy with respect to cooperation with the less developed countries was articulated by the President in his address at the International Meeting on Cooperation and Development in Cancun, Mexico, in October 1981. On that occasion he emphasized the need for such countries to strengthen their own productive capacities, and he stressed the vital role of the private sector in international development. Thus, the Administration is emphasizing the development of indigenous policies and capabilities for conducting scientific and technological activities and for applying those capabilities to the solution of urgent internal problems, particularly those of food, energy, natural resources, and health. That approach will enable the less developed countries to enjoy a greater degree of self-reliance in applying science and technology to their current and future national problems. Additionally, stronger capabilities for science and technology will permit individual scientists and scientific institutions to cooperate more substantially with their foreign colleagues and counterparts and thus, for example, use more effectively the vast university, industry, and Government resources for science and technology available in the United States.

China is a prime instance of a country that has been able, by emphasizing indigenous capabilities for science and technology, to establish a wide range of cooperative projects with U.S. scientists and scientific institutions. Additionally, the development of those bilateral programs provides an example of the importance of science and technology in furthering broad U.S. foreign policy objectives.

The Soviet Union provides a counter-example of the linkages between cooperation in science and technology and overall political relationships. The Soviet Union invests heavily in R&D, particularly for national defense, and has made notable contributions in a number of fields of science and technology. Moreover, in the past there have been some fruitful cooperative projects between U.S. and Soviet scientists.

The nature of Soviet society has, however, precluded many of the most important types of cooperative exchanges that U.S. scientists and their colleagues in the industrialized democracies have long enjoyed. Even when the overall political climate was favorable, American scientists were often frustrated by the bureaucratic controls and secrecy of Soviet society and were frequently denied access to the best scientists and facilities. More recently, the Soviet Government's blatant disregard for fundamental human rights, made manifest with the trials of such Soviet scientists as Orlov and Scharansky and the internal exile and continued harassment of Sakharov, has led many American scientists to conclude that they cannot participate in scientific exchanges with the Soviet Union.

On the official level, the Administration has stated that the Soviet Union bears a heavy and direct responsibility for the repression in Poland and that concrete political and economic measures affecting our relationship with the Soviets must be taken. On December 29, 1981, the Administration announced that three official cooperative programs with the U.S.S.R. would not be renewed this spring: one in space, one in energy development, and one covering a number of specific individual projects in science and technology.

Scientific Cooperation with the Industrialized Democracies

Scientific cooperation within the NATO alliance provides a means both for helping address common broad security concerns of the United States and its allies and for sharing scientific resources and knowledge. In defense, the Administration is emphasizing specialization in particular R&D areas by individual members of the alliance as a means for rationalizing the common approach to fulfilling military requirements and making more effective use of limited resources.

Space offers an important arena for international cooperation. The successful test launches of the U.S. Space Shuttle in April and November 1981 ushered in a new era in the scientific exploration and commercial applications of space; they also heralded new opportunities for scientific cooperation. The Shuttle's remote manipulator arm, successfully tested on the second flight, was developed by Canada at a cost of $100 million. The 10-member European Space Agency (ESA) is developing Spacelab I, at a cost of $1 billion, and Japan is developing a $20 million plasma accelerator for use with that facility. Spacelab, expected to undergo its first flight on board the Shuttle in 1983, will, with the Shuttle, constitute a new Space Transportation System, destined to meet many of the needs of the United States and its partners into the 1990s.

Space also provides an arena in which U.S. capabilities are likely to be challenged by the increasing capabilities of Europe and Japan. Ariane, an expendable launch vehicle developed by France in cooperation with other ESA countries, will enter operational service during 1982; it is the most impressive example of the significant space capabilities being developed abroad. Additionally, France has developed impressive capabilities for remote sensing, and Japan has made significant strides toward the next generation of satellite communication systems. Activities such as these augment the pioneering leadership of the United States and, by offering the challenge of new scientific ideas, can also stimulate more imaginative efforts on our part.

Research underlying the development of advanced energy sources is also a fruitful area for international cooperation among the industrialized countries. No other country has had the resources to maintain as broad an energy research program in both public and private sectors as the United States, and few are so richly endowed with fossil fuel reserves. As a result, there has been a greater degree of specialization overseas on options considered appropriate to specific national situations. The keystone of U.S international energy cooperation is the International Energy Agency, where technical collaboration forms one element of a broader strategy for reducing dependence on oil imports. The Organization for Economic and Cultural Development's (OECD) Nuclear Energy Agency serves as the focus of our technical collaboration on nuclear energy problems.

The United States has also entered into several bilateral research programs as one means for establishing broad scientific capabilities on which to base its future energy options. In particular, this country can, through cooperative arrangements, draw on the results of promising work abroad on advanced nuclear energy systems—particularly European research on breeder reactor technology—and, for the more distant future, European and Japanese research on nuclear fusion. Regarding the latter, Japan has invested $60 million in the Doublet III Tokamak magnetic fusion research facility at General Atomic in San Diego in recognition of the advantages that can result from pooling resources for scientific research.

The United States has an informal but increasingly effective program of science and technology cooperation with the Commission of the European Economic Communities. That program, for the most part, consists of Memoranda of Understanding between the Commission and the Department of Energy calling for the exchange of information on nuclear energy. In at least one case, actual interchange of materiel is involved. Similar information exchanges also exist in health services, materials research, carbon dioxide contamination of the atmosphere, and nuclear fusion.

Cooperative projects involving individual American scientists and their foreign counterparts also provide an effective means for expanding the scope of U.S. efforts in basic research in science and engineering. There are costly, specialized facilities abroad that would be prohibitively expensive or even impossible to duplicate here. It is therefore logical for American scientists to carry out research using those facilities, just as it has been routine for scientists from all over the world to conduct research using U.S. facilities. High-energy physicists in this country and abroad have long since recognized that imperative. American astronomers routinely make use of unique observation facilities in the Southern Hemisphere. More recent specific bilateral arrangements have given Americans access to other types of specialized facilities. Japan's Building Research Institute, for instance, where engineering design tests are intended to lead to the development of more earthquake-resistant structures, or unique Canadian facilities, where options for the underground disposal of nuclear wastes are being developed and tested. With constrained research and development budgets facing many nations, joint research projects in many other areas of common concern will surely become increasingly attractive.

Scientific Cooperation with the Middle-Income Countries

Even as European scientists in an earlier era made immeasurable contributions to the development of scientific capabilities in the United States, so have U.S. scientists contributed, in the more recent past, to the development of research capabilities abroad. The strong, competitive resources for the conduct of research that exist throughout the world are a tribute to science as an enterprise that transcends national boundaries and is a vital factor in the social and economic development of all nations.

Several countries in addition to the United States, Canada, the Western European nations, and Japan have, in recent years, developed scientific and technological capabilities of sufficient strength and sophistication to enable them to cooperate on an equitable basis with U.S scientists and thus take advantage of the vast resources available in this country. For example, South Korea, through its own efforts and through the judicious use of U.S. technical assistance, has now become one of the largest exporters of high-technology products outside the United States, Western Europe, and Japan. Israel and the United States have jointly endowed three binational foundations for the support of R&D projects of interest to investigators in both countries. Official scientific exchange programs with Mexico span a range of projects in energy, instrumentation, information sciences, railway transportation, and agriculture. The agricultural projects encompass research on the management of arid and semiarid lands, control of desertification, and the conservation of soil and water.

Scientific cooperation with those and other middle-income countries results in direct benefits to the United States. American scientists are closely monitoring programs to produce alcohol from agricultural waste products in Brazil and synthetic fuels from coal in South Africa. Bilateral arrangements with Israel provide U.S. scientists with some access to the facilities and expertise of Israel's strong academic and industrial solar R&D program. Joint research with Mexico on arid lands management and the control of desertification could result in improvements in agricultural productivity on both sides of our common border.

Scientific Cooperation for Development

The United States has made enormous contributions to economic development throughout the world. During the 1970s we provided $57 billion to the developing countries—$43 billion in development assistance and $14 billion in contributions to multilateral development banks.

As the President noted in his October 1981 address at Cancun, the contribution made by the United States through trade has been even more significant than its direct assistance contributions. This country absorbs about one-half of all manufactured goods exported by the non-OPEC developing countries to the industrialized world, even though our market is only one-third of the industrialized world market. In 1980 alone, U.S. imports from developing countries totaled $60 billion—more than twice the official development assistance from all OECD countries combined.

Throughout the developing world there is and will continue to be a strong demand for applications of science and technology. Experience in many countries has shown, however, that science and technology can only be effective in helping to bring about modernization in countries that have appropriate policies and that are willing to devote adequate resources to their own indigenous capabilities. The cases of South Korea, Israel, and Mexico, noted above, and several other middle-income countries illustrate the crucial importance of strong, indigenous capabilities in science and technology. Countries that have developed such capabilities are able to cooperate more fully with scientists and engineers in the industrialized countries. Scientific and technological capabilities provide the knowledge base and expertise that developing countries need to set realistic objectives for using science and technology for development, to negotiate technical contracts with foreign suppliers, to weigh subtle choices among technologies, and to adopt and use acquired technologies effectively. Finally, technology provides a basis for improvements in the manufacturing sector and thus enables developing countries to increase their participation in world trade.

The Administration's policy toward scientific and technological cooperation with the less developed countries follows from these considerations. Briefly stated, it encourages such countries to make use of the vast scientific and technological resources of the United States that are available in both the private and public sectors. Those resources include U.S. universities that have, for many years, played a critical role in the transfer of scientific expertise and technology to developing countries. The Administration is taking steps to promote a greater degree of long-term stability to those U.S. universities that provide such technical assistance through memoranda of understanding. Beyond such official programs, U.S. universities continue to provide enormous help in developing indigenous capabilities for science and technology by educating students from abroad. At present, for example, almost 200,000 foreign students enroll annually in science, mathematics, and engineering programs in U.S. universities.

The Administration's focus on the improvement of indigenous productive capacities looks toward a future in which increasing numbers of scientists, wherever they may work, can become fully participating members of the international scientific community. Meanwhile, as the President recognized at Cancun, there is a need to provide short-term assistance to help solve urgent developmental problems.

With regard to food, the emphasis of U.S. technical assistance will be, in the President's words, "on raising the productivity of the small farmer, building the capacity to pursue agricultural research, and stimulating productive enterprises that generate employment and purchasing power." That emphasis will include, in particular, "new methods of plant improvement to develop crops that tolerate adverse soils and climatic conditions, insects, and diseases; research to increase the efficiency of using irrigation water; systems for the production of several crops per year in the humid tropics; and methods of human and animal disease control to remove such serious problems as the tsetse fly in Africa, which bars agricultural production in vast areas of potentially productive land."

In the energy area, as the President also emphasized at Cancun, U.S. bilateral aid programs will "stress technical assistance rather than resource transfers. We will support energy lending by multilateral institutions provided the projects are economically viable, and they expand developing country energy production through greater private investment."

The United States "will also support selected elements of the programs of action of the (August 1981) U.N. Conference on New and Renewable Sources of Energy. These include intensified energy training programs for technicians from developing countries and efforts to help developing countries assess and more efficiently utilize their resources."

Scientific Cooperation with the People's Republic of China

U.S. cooperation with the People's Republic of China (P.R.C.) takes place within the framework of the January 1979 U.S.-P.R.C. Agreement on Scientific and Technological Cooperation. The implementation of the agreement is overseen by a U.S.-P.R.C. Joint Commission on Scientific and Technological Cooperation, cochaired on the U.S. side by the President's Science Adviser. During 1981, there was a rapid increase in the implementation of cooperative projects, in contrast to the two preceding years that were dominated by the process of protocol negotiation, orientation visits, and project planning. The scope of cooperation covered by the overall agreement was reviewed at the second meeting of the Joint Commission held in Washington in October 1981. At that time, three new protocols for cooperation were signed (in building construction and urban planning, surface water hydrology, and nuclear safety technology), bringing the total number of protocols to 17.

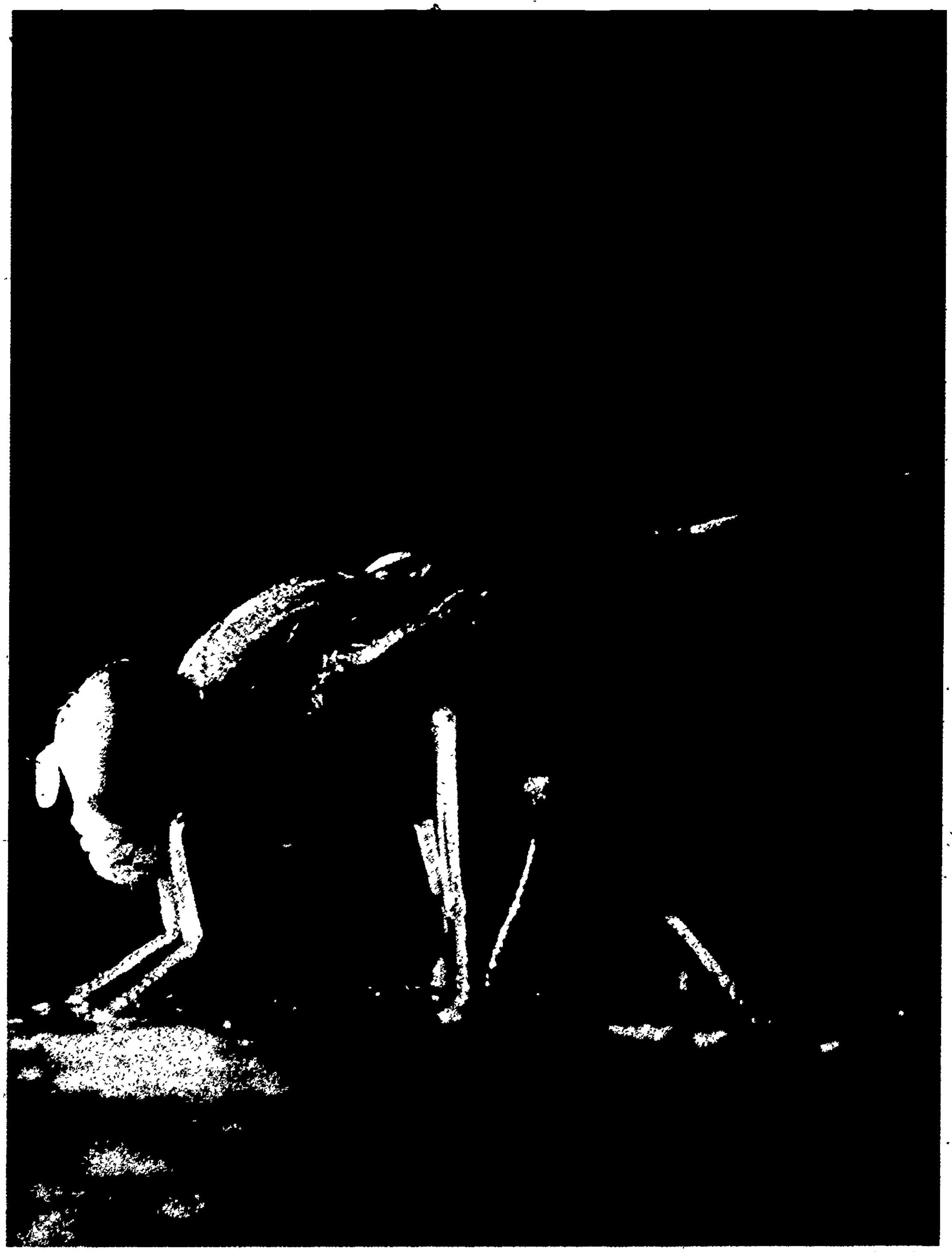
While cooperative activities covered by all 17 protocols are likely to provide long-term mutual benefits to the United States and China by enhancing contacts between their science and technology communities, certain activities stand out because of their more immediate benefits. Cooperative research projects of particular interest to the United States include projects in earthquake studies, a marine sedimentation project in the Yangtze River and East China Sea, the exchange of data on incidence of disease, the exchange of plant and soil specimens and germplasm, and projects involving Chinese archaeological and pharmacological samples. Several of the scientific projects conducted under the auspices of those bilateral agreements carry substantial potential for enhancing U.S. commercial opportunities and/or providing short-term or long-term facilitation for future commercial activities. Trade with China is already increasing dramatically. During the first quarter of 1981, that country became our third greatest export market in Asia, behind Japan and South Korea. Activities under the U.S.-P.R.C. agreement, such as the hydropower, space, agriculture, housing, and metrology protocols, have the potential for increasing trade even further. In addition, U.S. commercial prospects in the area of technical instrumentation are enhanced by virtually all projects under the cooperative agreement.

Several nongovernmental organizations in the United States also have cooperative agreements with scholarly organizations in China. Among them are the National Academy of Sciences, the American Association for the Advancement of Science, and several dozen universities. Those agreements provide Chinese scientists and engineers with access to the vast resources in this country, resources they are eager to tap. During the past year, for example, 6,000 Chinese students were enrolled in American university courses, the large majority of them in science and engineering.

The rapid expansion of scientific and technological relationships between the People's Republic of China and the United States at both the governmental and nongovernmental levels provides a significant illustration of the efficacy of the Administration's policy to help facilitate the development of indigenous capabilities for science and technology in those countries willing to focus their own resources to that end. Additionally, since relationships between the United States and China are a major component of U.S. global and regional security policies, cooperation with China also provides an example of the central importance of science and technology to broader foreign policy objectives.

Chapter III

Federal Research and Development Programs



U S Department of Agriculture

This chapter describes a broad range of Federal research and development programs directed at national problems. The 11 papers were produced by 11 task groups, each working within a particular substantive area corresponding generally to one of the budget function categories used by the Office of Management and Budget (OMB). The task groups consisted of representatives of 22 executive branch agencies with major science- and technology-related mission activities.

In making their contributions to this chapter, the agencies were asked to provide information about their recent major programmatic thrusts and accomplishments related to science and technology, confining their reports to accomplishments during fiscal year 1981 wherever possible. They were also asked for information on important new programmatic initiatives for fiscal year 1982. The 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 have occurred in federally supported science and technology programs at the agency level and point to significant developments likely to occur within approximately 1 year.

A Caribbean fruit fly lays eggs on a grapefruit peel. Researchers at the U.S. Department of Agriculture hope to develop strains of grapefruit that, like oranges, are naturally resistant to this and other costly citrus pests.

Science and technology are important components of U.S. national security and foreign policy. The Nation's supremacy in technology is a major source of its military strength. The strong research and development programs of the Department of Defense (DOD) and the related programs of other Federal agencies provide a level of technological superiority that enables the United States to develop, acquire, and employ new military capabilities. The strategy is to employ science and technology to offset the growing quantitative disparity between deployed U.S. military equipment and that of potential adversaries. Fundamental to that strategy is the fact that the United States leads by 5 to 10 years in many of the basic technologies that are critical to our advanced weapons.

The most essential function of DOD and related Federal research and development programs is to provide the technological infrastructure that is so important to the steady, evolutionary growth of our military capability. The programs are made up of hundreds of projects covering a spectrum of technologies of relevance to national security. Many of the necessary projects involve advanced, long-range research to provide technological progress on an evolutionary basis. Others have been selected for management and fiscal emphasis because of their potential for a revolutionary improvement in future military capabilities. The sections that follow highlight new initiatives and past accomplishments in national security research and development programs.

Electronics

The defense mission requires highly sophisticated electronic systems that can transmit and process information at high speeds, operate in hostile environments, resist interference and interception, be applied across the entire electromagnetic spectrum, and be highly reliable and easy to maintain.

Very High Speed Integrated Circuits

The Very High Speed Integrated Circuits (VHSIC) program is a major thrust to develop high-speed, high-density, digital integrated circuits that require little maintenance and can tolerate adverse environments. Under the program, a new generation of integrated circuits is being developed to provide a dramatic improvement (by a factor of 100) in signal- and data-processing capabilities for military systems. VHSIC processors will provide revolutionary improvements in the performance of airborne tactical radars, sensors for guided missiles and munitions, and automatic communication, navigation, and battlefield systems. In addition to performance improvements, the concept of maintenance-free electronics is nearing reality. The built-in test capabilities and fault correcting designs of VHSIC technology will provide the improvements in reliability, self-repair, and affordability needed for significant life-cycle cost reduction.

Ultrasmall Electronics Research

As one of the programs supporting VHSIC, Ultrasmall Electronics Research (USER) is pushing the frontier of solid state electronics toward a generation of devices with critical dimensions no larger than a molecule. Such small dimensions allow an increase in the density of transistors on a

Meegar Commercial Photographers

A computer chip on the end of a fingertip. Current research is aimed at producing even smaller chips with greater capabilities for use in microelectronic systems.

single semiconductor substrate and provide an increase in data-processing speed. As the critical dimensions of solid state devices are reduced, the time and space domain become so small and electric fields so large that new concepts and theories of operations need to be developed. In recognition of these needs, the USER program is centered around the physics, chemistry, and metallurgy of the geometrically constrained semiconductor structures of the next generations of integrated circuits.

Physical Electronics, Electronic Materials, and Devices

Physical electronics research provides basic understanding of the electric, magnetic, and optical properties of materials, as well as the generation, transport, and control of charge carriers. New concepts concerning such electron devices as the free electron laser and the permeable base transistor have resulted directly from this research program. The free electron laser, for example, has the potential for efficiently producing high-power, coherent radiation from the millimeter wavelength to the X-ray region of the spectrum. The permeable base transistor makes possible signal processing circuits that can add to military communications an order of magnitude improvement in jamming resistance and covertness.

Electromagnetic Propulsion

The electromagnetic propulsion program explores the application of electromagnetic force propulsion techniques as alternative propulsion sources for military guns and launchers. The primary purposes are to demonstrate a unique laboratory launcher system for accelerating appropriate payloads and, subsequently, to develop a demonstration system for air defense, armor, and artillery applications. The advantage of the electromagnetic gun is that, in principle, the exit velocity for a projectile launched by electromagnetic means is not limited as it is for a conventional gun. An unlimited exit velocity provides the potential for many new applications. An experimental, twin-rail, hypervelocity launcher and high-current, homopolar generators are being developed to launch scaled gliders and projectiles with high payload efficiencies. A variety of electromagnetic guns may meet conventional mission requirements by as early as the 1990s.

Materials

Pioneering developments in advanced materials emerging from the materials and structures science and technology programs have led to vastly improved military capabilities as well as the creation of new industries. For example, 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. These research programs concentrate on cost reduction and performance improvement with some emphasis on conservation where a dependence on foreign sources of raw materials is involved.

Carbon/Carbon Composites

Research and development activities in erosion-resistant carbon/carbon (C/C) composite materials are directed toward improving the survivability and accuracy of advanced reentry vehicles under adverse atmospheric conditions caused by severe weather or nuclear bursts. Research supported under this program includes investigations of innovative concepts for improving the construction and processing of C/C materials and changing the contents of the composites.

The technological base in C/C composites is being further exploited by the gas turbine community. The practicality of applying C/C composite materials to the hot sections of gas turbines is being investigated. In addition to performance gains because of the high-temperature capabilities of these composites, their domestic availability and potential low cost make them attractive alternates to high-cost, gas turbine superalloys. Also, since those superalloys contain appreciable amounts of imported cobalt and chromium, the use of C/C composites for this application can substantially alleviate our dependence on other nations for those metals.

Metal/Matrix Composites

The development of metal/matrix composite (MMC) materials for a variety of military applications is proceeding. Applications include helicopter transmission housings; portable bridging components; structures for missiles, mines, and torpedoes; airframes; gas turbine components; and satellite components. In addition, MMC materials show promise for an ever-widening range of applications, among them laser mirrors, lightweight gun mounts, submarine propellers, and large antennas. One of the early results emerging from this research program is the development of reinforced lead grid materials for submarine batteries. If that development proves successful, it will lengthen the submarine battery replacement cycle from 5 to 10 years, aligning it with the nuclear core replacement schedule and appreciably reducing maintenance costs.

Another significant outcome of early work is the potential substitution of MMCs for such critical or long-leadtime materials as chromium, cobalt, titanium, and beryllium. As an example, high-modulus graphite fiber-reinforced magnesium alloy composites exhibit stiffness, strength, and dimensional stability equivalent to or superior to those of beryllium. In another case, a sheet of graphite fiber-reinforced titanium aluminum alloy material has displayed structural properties comparable to those of a solid sheet of titanium 1.5 times thicker; yet, the composite required only 7 percent titanium. Such MMCs can save as much as 93 percent of the titanium normally needed in sheet materials.

Ordered Polymers

Polymer research has demonstrated the possibility of designing polymers with properties equivalent to fiber-reinforced composites, without the need for the fiber reinforcement. An example of such an ordered self-reinforced polymer is polybenzothiazole (PBT). These types of polymers possess long-range rigid chain alignment, which is responsible for their excellent mechanical properties and environmental resistance. The outstanding properties of PBT will provide a new, high-performance, lightweight structural material for missile, spacecraft, and aircraft applications.

Rapid Solidification Technology (RST)

The technology of rapidly solidified metal powders promises to produce high-quality materials for developing new types of aluminum and titanium alloys as well as previously unobtainable high-temperature superalloys for gas turbine engines. Experiments with aluminum-lithium and aluminum-nickel alloys have demonstrated the potential for producing superior superalloys with only minor amounts of critical or scarce materials.

Computers

An important area for computer research is the design of architectures (system organization) to make possible efficient multiple computer data processing, improved memory-access techniques, reliable digital transmissions, reduced costs in software, simplified operating systems, methods for parallel processing, artificial intelligence, and robotics. DOD has established artificial intelligence as a special area of interest. The program is directed toward developing "smart" computer systems with the capability to mimic man's capacities for commonsense reasoning and physical dexterity. The work is closely tied to robotics, industrial automation, and expert machine advisory services for maintenance personnel.

Artificial Intelligence and Robotics

A foundation for a new generation of sophisticated, intelligent weapons and support systems is being established through research on artificial intelligence (AI) and robotics and on their applications to system automation. The new automated weapons and systems provide new capabilities and ease manpower needs. Systems concepts range from automatic devices for assisting tankers, pilots, artillery crews, and air defenders to autonomous systems for manufacturing and ammunition handling. Automated consultant systems will assist users in such tasks as planning and scheduling air operations and diagnosing and repairing complex machines. Autonomous systems will have some capability to command, control, and conduct some aspects of military activities. Artificial intelligence involves techniques for processing symbolic data (as opposed to numeric data) and focuses on methods both for representing knowledge and for reasoning in computer systems. Specific research efforts investigate methods for representing knowledge and reasoning independently for such particular knowledge domains as image understanding. Other efforts examine issues involved in developing large AI systems using multiple computer data-processing techniques.

Embedded Computer Software Technology

Software technology has not advanced at a sufficiently rapid pace to meet the expectations generated by the dramatic advances in computer hardware technology. At the same time, the software now embedded in most military systems continues to be an increasingly important and expensive component of those systems. DOD has specialized software needs that are not shared with most commercial and industrial applications of computers. They include requirements for automatic error recovery and fail-safe execution, the need for simultaneous control of a variety of sensors and activators, critical real-time constraints, and extremely complex systems requirements that are continuously being modified.

New concepts and methods are being sought for advances in software to complement the rapid progress in computer hardware, which is expected to accelerate as a result of the VHSIC program. Also, the standardization of Ada, a high-order, common programming language, has nearly been completed. Thus, opportunities will be provided for coordinated development of generic software, significant reduction in duplication of DOD software support, and greater interoperability among military software systems. Important objectives of research are to reduce software life-cycle costs through automated software technology and to improve programming productivity and reliability. The ability to modify software reliably and efficiently will permit rapid response to changing tactical and strategic scenarios.

Computers for Training and Simulation

Those who develop computer technology for training and simulation must keep in mind the advanced technologies built into military hardware systems and the underdeveloped skills of military enlistees. More effective methods of training are feasible through the increased use of simulators and computer-based methods of instruction. Simulators permit personnel to be trained in the operation and maintenance of complex equipment with greater safety and convenience, with less wear and tear, and with less expense than using actual equipment. The use of powerful, portable computers will permit individuals to be trained at their own pace—a technique not feasible in the recent past.

Another promising area is the adaptation of computerized electronic arcade games for military training. Such games, some of which can both speak and recognize voice inputs, are known to strongly motivate people to learn. A prototype computerized system was recently demonstrated for training aircraft controllers; it uses computerized voice recognition to provide students with individualized instruction, thereby reducing both the need for instructors and the total classroom time required to master the tasks.

Simulators for hands-on maintenance training have advanced from technology demonstration to actual trainers costing 50 percent less than conventional devices.

Mobility and Space Transportation

A major technology thrust is directed toward new and revolutionary aircraft performance capabilities. Forward-swept-wing (FSW) and x-wing aircraft technologies combine reasonable cost with substantial improvements in aerodynamic performance. To relieve the pilot's workload and improve mission performance, digital electronics technology is being incorporated into aircraft control systems. Research on vehicle dynamics and hydrodynamics is oriented toward improved air, land, and sea mobility.

In comparison to existing space transportation systems using expendable boosters, the Space Shuttle offers increased reliability, payload weight, and volume capacity: the ability to recover and refurbish spacecraft; and the ability to assemble large structures in space. These unique features and the increased flexibility they offer promise an era of new operational concepts, increased effectiveness, and greater economy for military space operations.

Aeronautics

New electronics designs are being integrated with the airframe control system to achieve a significant improvement in the combat capability of tactical aircraft. That integration makes it possible to "fly-by-wire" with smaller control surfaces on more highly maneuverable aircraft; to maximize aircraft performance by automatically changing in flight the shape of such key aircraft components as wing sweep, airfoil camber, and engine inlets; to provide independent 6-degree-of-freedom control for increased agility and minimal weapon delivery errors; and to integrate the flight, fire control, and navigation systems. Those advances provide task-tailored handling qualities. Fire control information will be used to assist the pilot automatically or semiautomatically in maneuvering the aircraft into the proper launch position for a specific weapon. Additionally, the new control concepts provide improved capability for carrying out maneuvers for launching air-to-ground weapons, thereby increasing survivability against ground defense.

Forward-swept-wing technology, made possible by advanced composite structures and digital "fly-by-wire" flight control systems, offers the potential of major technological breakthroughs in structures, aerodynamics, stability, control, and configuration. After it is demonstrated that advanced composite structures can solve the aeroelastic divergence phenomenon, a static structural instability experienced by forward- but not aft-swept-wings, exploitation of the benefits of the forward-swept-wing configuration can begin. Engineering analysis indicates that an FSW tactical aircraft could be as much as 25 to 30 percent lighter than an equivalent aft-swept aircraft or could have equivalent improvement in range/payload performance. The FSW design's excellent low-speed stability and control characteristics, higher lift capabilities, and enhanced transonic performance all promise revolutionary weapons capabilities.

The x-wing concept is a major innovation in vertical/short takeoff and landing (V/STOL) aircraft design. The ability to stop the rotor in flight combines the vertical lift efficiency of a helicopter with the speed, range, and altitude performance of a transonic fixed-wing aircraft. The design, fabrication, and flight test demonstration are proceeding for vehicles of a size representative of an operational aircraft. Design analysis indicates that an operational x-wing vehicle would have approximately three times the range, speed, and altitude performance of a conventional helicopter with equivalent payload lifting capability. Such characteristics would greatly enhance all current V/STOL missions and could provide flexible sea-basing and deployment options.

Aircraft propulsion technology research is oriented toward improving reliability, efficiency, durability, and maintainability. The increasing costs both of propulsion systems and of supporting them when in operation are major concerns. The large number of parts in a propulsion system is mainly responsible for the high costs. Recent research and development efforts are aimed at reducing the number of compressor stages by improving individual stage performance. In addition, supporting costs are being reduced by increasing the life of engine components. The National Aeronautics and Space Administration (NASA) demonstrated a highly efficient turbofan compressor rated at a pressure ratio of 23:1, the most advanced one ever designed for an aircraft engine.

Space Transportation

Efficient, effective transportation to and from space is required for both civilian and military payloads. The Space Shuttle has been developed as the Nation's next generation space transportation system. This year the Space Shuttle has completed its first two orbital test flights, and it is expected to achieve full operational status in late 1982. The Shuttle is discussed in greater detail in this chapter's section on space.

Vehicle Hydrodynamics

The hydrodynamic performance characteristics of new naval ships must be far superior to those of older ships if the new ships are to meet more stringent performance criteria. Traditional methods of predicting those characteristics are often too expensive, time consuming, or inaccurate. New numerical algorithms have been developed for more effectively and accurately predicting such performance characteristics as the water resistance of various hulls, and the motions of the hull in the waves. Additionally, a methodology has been developed for designing the hull shape of low-speed, high-endurance submersibles for minimum hydrodynamic resistance. Submersibles employing those hull designs, which maximize laminar flow, would have approximately three times the range of the conventional autonomous submersibles now used for

Naval Photographic Center

The nuclear powered submarine, U.S.S. Los Angeles. Research is being conducted to develop submersibles with minimum hydrodynamic resistance.

intelligence gathering and covert delivery of payloads.

Command, Control, and Communications

The purpose of the command, control, and communications (C^3) program is to develop advanced communications technology and system architectures to improve the Nation's ability to control its fighting forces around the world. The effectiveness of C^3 depends on recent advances in information processing that allow reliable and rapid manipulation and movement of information across long distances. Efforts are devoted to the development of highly survivable, interservice operable and flexible, computer-based C^3 architectures employing packet-switched communications. Current research activities involve computer science, packet radios, combined voice and data networks, network security, interconnections to all services, and local network arrangements.

Efforts are also directed at applying artificial intelligence concepts to make information systems easier to use. For example, applications of distributed systems and automatic data processing on the battlefield are under evaluation. Another research area of special interest is the strategic laser communications technology program. An aircraft-to-submarine laser communications experiment is being conducted to verify the theory of propagation for the transmission of laser beams through clouds and water.

Computer-Controlled Communications Technology

Research on packet communications technology is exploring computer-based methods for compressing information into dense groups or packets and then controlling, allocating, and accessing a variety of information transmission means (e.g., mobile radios, broadcast satellites, coaxial and optical cables, and leased telephone circuits). Collections of networks are interconnected to each other by small computers known as gateways. Security systems for packet-switched networks and message systems using multiple transmission means and real-time packet-switched voice systems are being developed. Packet communications technology forms a sound basis for supporting these integrated voice and data communications in a multiple network environment. It is the only technology that can achieve both flexible allocation of transmission resources and efficient use of communications capacity while concurrently supporting real-time information exchange among people, among computers, and between people and computers. NASA demonstrated the technology for transmitting packet data from Earth-orbiting spacecraft to ground systems. The accomplishment involved design and development of new data systems that greatly simplify user access and reduce user cost.

Advanced C^3 Technology

The purpose of the strategic C^3 experiments is to demonstrate the feasibility of advanced technologies in survivable strategic command and control systems. An experimental system has been created in which such advanced technologies as the airborne packet radio, end-to-end network security, and distributed knowledge and data bases can be applied and evaluated. The program specifically focuses on the reconstitution of surviving command, control, and communications capabilities and strategic forces following a major nuclear attack.

Research in strategic laser communications is developing the technology to provide essential communications support to submerged strategic missile submarines, without compromising their natural immunity to detection. The communications capability is provided from satellites by blue-green laser pulses that can penetrate clouds and sea water to reach the submarines. The laser pulses are provided either directly from a satellite-based laser, which is constrained to low power levels by the limited available power in space, or from a high-power, ground-based laser, which transmits pulses to a space-based relay mirror. Key technology elements needed for an early demonstration of the best system are being determined

• The Advanced Command and Control Architectural Testbed (ACCAT) has been established to explore the applicability of advanced information-processing technology to Navy systems The testbed provides a realistic command and control context for demonstrating and evaluating a broad range of information-processing technologies, including natural language access to geographically distributed data bases; remote maintenance of software, and device-independent graphic systems

The Army Data Distribution System (ADDS) testbed experimentally evaluates the operational and doctrinal impact of information processing on the tactical battlefield. A packet radio computer communications network is connected through gateway computers to provide access to selected computing resources that support experimental field and garrison operations. Software packages with numerous applications have been developed to support field use of automated tactical reporting systems, automatic airborne load planning; recordkeeping, and resource management.

Nuclear Effects Technology

Major objectives of current research on nuclear effects are to assess the survivability of our military systems in a hostile nuclear environment, to predict the lethality criteria for confident destruction of enemy targets, and to develop technological capabilities that will enhance theater nuclear force effectiveness. Major areas of research include the following:

(1) The effects of nuclear weapon detonations, particularly those occurring at high altitudes, are of continuing concern to the survivability and endurance of military command, control, communications, and intelligence functions. Techniques are being developed for the mitigation of nuclear effects on ground communications networks, satellites, signal propagation, infrared systems, and microelectronics.

(2) The nuclear environment and issues of survivability and hardness of the MX Missile and Low Altitude Defense System (LoADS) are being addressed; MX Missile components are being extensively tested.

(3) Techniques for improving the effectiveness, survivability, security, safety, and readiness of theater nuclear forces are being developed.

(4) Efforts are being made to enhance nuclear survivability and targeting effectiveness of strategic systems. For example, the electromagnetic pulse hardness maintenance/assurance methodology will be expanded to include blast and thermal effects on aircraft. The targeting assessment for nuclear antisubmarine warfare weapons is being updated

(5) Efforts continue to lessen dependence on underground nuclear tests. Potential limitations imposed on underground tests by a Comprehensive Test Ban Treaty accentuate the importance of radiation simulators capable of operating at X-ray levels present during a nuclear detonation. A high explosive test will include large-scale thermal simulation to expose weapons systems simultaneously to simulated nuclear blast and thermal pulses. The effects of atmospheric nuclear detonations on signal propagation will be simulated with an atmospheric release of barium in the MIDNIGHT SKY experiment. In addition, there is a strong effort to develop the capability for laboratory simulations to verify missile and reentry vehicle hardness, which currently can be assessed only at underground tests.

Guidance

Research in guidance technology emphasizes the development of an autonomous adverse weather capability to counter numerically superior armor, reduce launch platform vulnerability, and improve the probability of killing engaged targets. Low-cost adverse weather seekers against land and sea targets are capitalizing on recent and projected advances in solid state electronics and signal processing. A concentrated effort on target signature characterization for millimeter-wave seekers has been started. Joint North Atlantic Treaty Organization (NATO) cooperative programs, such as the one just completed in which infrared and millimeter-wave signatures were measured for armor and other militarily important targets, are planned.

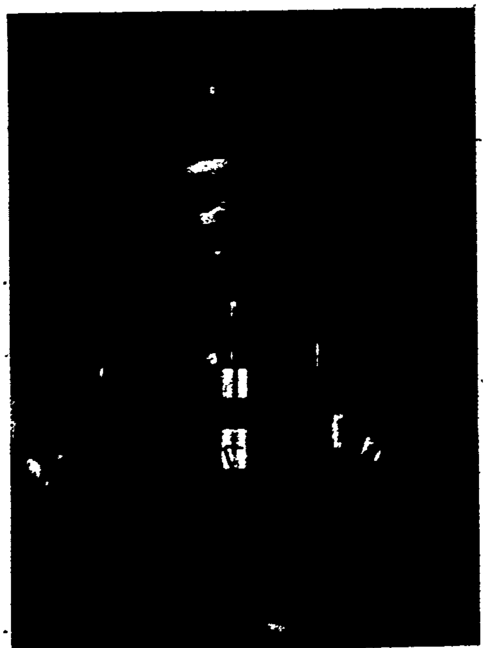
Pattern Recognition Research

Optical pattern recognition offers significant advantages for terminal guidance systems in missiles. The advantages are due to the ability of such systems to process data in real time and in parallel with a large memory capacity as well as making use of potentially lightweight and low-cost components. Developing the capability for optical pattern recognition, however, depends on improving the ability to recognize images from different types of sensors. For example, in radar-map matching, the classic problem is to locate portions of an online radar image in a stored reference aerial photograph. Similarly, guidance concepts for projectiles require the registration of radar images with images stored on black and white film. Research has demonstrated that radar images of a target scene can be correlated with previously stored photographic images of the same scene. The optical correlator, using preprocessed reference imagery and weighted matched filters, can correlate multiple sensor imagery (e.g., optical and radar) in the presence of various types of noise.

Precision-Guided Munitions

Precision-guided munitions (PGM) provide the potential for revolutionary advances in combat effectiveness. Effective exploitation of PGM technologies can significantly increase the Nation's ability to counter numerically superior forces and to deploy significant firepower economically.

Because the seekers that guide PGMs depend on atmospheric transmission of electromagnetic signals in the optical or infrared frequency band, they are more sensitive to adverse weather and dirty battlefield environments than are conventional weapons. Activities to model adverse



Harry Diamond Laboratories
The orotron, an open resonator oscillator tube in operation at the U S. Army's Harry Diamond Laboratories, is the first step toward providing a high power source of millimeter waves for military applications in target acquisition and surveillance

weather effects and to evaluate seekers under such realistic battlefield conditions as smoke, dust, and fog are important aspects of research on PGMs. The research is focusing on developing technologies and techniques to mitigate the effects of adverse weather and battlefield environments. Millimeter-wave (MMW) and infrared (IR) array technologies are potential candidates for improved seeker designs.

Millimeter-wave seekers operating at the atmospheric window frequencies for electromagnetic wave propagation offer some immunity from adverse weather and battlefield conditions. However, the development of effective MMW missile seekers has been constrained by poor resolution, the lack of maturity of MMW electronic devices, and lack of knowledge about target and background signatures. Advances in the state of the art of small, solid state electronic devices and signal-processing techniques are needed to enable detection and recognition of military targets at usable ranges. Because of the long range acquisition problem that exists with passive

MMW systems, dual mode techniques (both active and passive) have been developed to allow relatively long range acquisition of targets in the active mode, then automatically transfer guidance to the passive mode for "hit-to-kill" accuracy.

Also being emphasized are seeker systems that operate in the IR region of the spectrum. Although the adverse weather capabilities of IR systems are limited, the use of multiple detector arrays can improve the operation of IR seekers. The range capability, or sensitivity, of IR seekers is related to the number of detectors used Recent advances in imaging IR focal plane arrays offer a potential for significantly increasing the number of detectors in seekers, with a concomitant improvement in sensitivity

Autonomous Terminal Homing

Research on autonomous terminal homing is developing and demonstrating critical technologies for advanced, day-night cruise missiles. The guidance system uses an onboard IR sensor to obtain images of the target area. Those images are then compared by means of advanced scene matching algorithms with prestored reference images generated prior to launch in a highly automated reference preparation facility Researchers are also exploring the use of IR sensors for obtaining terrain-following and obstacle avoidance information, thus significantly reducing flight altitudes for cruise missiles and improving their penetration survivability. The technologies being developed are directly applicable to the current and the next generation of cruise missiles.

Directed Energy

The application of directed energy technology to new weapons concepts offers the potential of revolutionary contributions to the Nation's defense capability. Research in directed energy physics is being carried out to define and exploit that potential. Such directed energy weapons as high-energy lasers and particle beams may well contribute to air defense against bombers and antiship missiles, space defense and other space-related applications, and ground combat on the forward battlefield.

High-Energy Lasers

The high-energy laser (HEL) program involves research and development in many technology areas, including laser devices, pointing and tracking systems, laser beam propagation, and laser beam interaction with targets. Research is also being conducted on techniques for hardening systems against laser weapons. While basic feasibility has been shown, the objective of the current research program is to demonstrate laser system lethality at representative ranges against representative targets. Full-scale performance of an integrated system has yet to be demonstrated.

Current development efforts consist of a number of feasibility and lethality verification demonstrations The airborne laser laboratory will demonstrate an in-flight laser system against instrumented targets and air-to-air missiles. The Sea Lite lethality program will demonstrate generic surface-based air defense with particular emphasis on antiship missile defense. Talon Gold, ALPHA, and the Large Optics Demonstration Experiment (LODE) individually address the pointing and tracking, laser device, and large optics technologies for a space-based laser system that can perform a variety of defense missions. The Roadrunner and Forward Area Laser Weapon Demonstrator (FALW-D) programs will provide demonstrations of potential forward combat area laser weapons for battlefield applications.

Particle-Beam Technology

The objective of work on particle-beam technology is to determine the scientific feasibility of both charged and neutral particle-beam weapons concepts. The critical issue for charged particle beams is the stable, predictable propagation of relativistic electron beams in the atmosphere over distances of military interest. The thrust of neutral particle-beam research is to demonstrate the capability of generating low-divergence beams for potential space applications. Particle beams penetrate deeply into a target, without burning through from the surface, depositing damaging amounts of energy in the interior of a target in a short period of time. Potential applications of charged particle beams include antiship missile defense and defense of ballistic missile silos. Neutral particle beams offer potential applications to space-based ballistic missile defense.

Charged particle-beam research efforts have provided experimental data on low electron beam energies propagating through low-density atmospheres. The data have been extrapolated through full-density atmospheres. That research has also provided the advanced high-current linear induction accelerator technology that is essential to demonstrate propagation through full-density atmospheres. An experimental test accelerator has produced 4.5 MeV electrons at beam currents approaching 10 KA. An advanced test accelerator under construction has a design goal of 50 MeV electrons at 10 KA beam current.

The neutral particle-beam research program focuses on theoretical and experimental studies to minimize beam divergence in radio-frequency ion-beam accelerators. An accelerator test stand, which is being constructed, will provide the essential experimental tools for evaluating critical beam divergence issues for the initial stages of potential high-energy neutral particle-beam systems.

Surveillance

Advances in sensor sensitivity and signal-processing techniques provide important technology options in strategic surveillance of early missile launch, discrimination of target signatures, and the suppression of interference. Distributed radar surveillance technology for reducing primary transmitter vulnerability without a loss of signal takes advantage of digital components and new signal-processing theory. These concepts in signal processing and distributed surveillance sensors are also being applied in several major sea experiments related to submarine warfare. The broad technology base in visible, infrared, radar, and acoustic sensors provides a basis for sophisticated future surveillance missions.

Surveillance from Space

The principal emphasis in current research on space surveillance is on advanced visible systems and infrared detector arrays. The enhanced capabilities of advanced systems permit a variety of surveillance and battle management missions not possible previously. Technology development efforts are stressing infrared detector arrays with a high level of integrated signal processing, broad spectral sensitivity, large dynamic range, and high producibility. Advanced filters and signal processing are under development for enhanced target detection in highly cluttered scenes. The resulting sensors will provide improved surveillance systems.

The high-resolution, calibrated airborne measurement program (HI-CAMP) has resulted in systems to demonstrate some of the advanced sensors. The HI-CAMP sensor is an infrared measurement system for making high-resolution, two-dimensional measurements of earth backgrounds and mobile and stationary air, sea, and land targets. The HI-CAMP sensor has two types of advanced two-dimensional monolithic infrared arrays with charge-coupled device multiplexers capable of providing data in two broad infrared bands. It is integrated into the lower hatch of high-altitude aircraft to make measurements above most of Earth's atmosphere.

HI-CAMP demonstrates the infrared charge-coupled device technology and develops a data base of two-dimensional pictures of background and selected targets. In addition, HI-CAMP will provide fundamental atmospheric, target, and background measurement data; assess advanced focal plane devices, signal processing, and tracking algorithms; and support advanced technology programs associated with advanced surveillance concepts.

Nuclear Test Verification Technology

Research in nuclear arms test verification technology is responding to national requirements for enhanced capabilities for monitoring existing and future test ban treaties. Research is focusing on the development of advanced sensors and instrumentation for deployment in remote areas, data reception, management, and analysis: magnitude estimates of foreign underground explosions, countermeasures to evasive testing; and nonseismic techniques. Full-scale laboratory testing is under way for a miniaturized, rugged, broadband borehole seismometer and a sensor that combines strain and inertia data. New seismic array concepts for detection and identification are being implemented. Combinations of seismic and hydroacoustic sensors are being evaluated for ocean-based surveillance systems. In evasion and counterevasion research, theoretical and experimental evaluations of the generation of seismic waves are being used for developing improved detection and identification methods.

Target Location and Identification

Research on radar target identification has developed a technique for classifying ship models at widely separated aspect angles in laboratory experiments. The major advantage is that the natural resonances do not vary as the target aspect angle changes, thus the method works well even at broadside angles where other recognition methods usually give poor results.

A basic problem of sensors operating on the integrated battlefield is the difficulty of penetrating fog and smoke to identify targets partially screened by foliage, netting, or debris. Research in two techniques, near millimeter wave imaging and tomography, may solve the problem. Tomography, originally developed for analyzing medical X-rays, uses several images of a scene to find and accentuate an object otherwise hidden by its surroundings. The target scene is illuminated with near millimeter waves—the only electromagnetic radiation band that can penetrate smoke and fog like microwave radar waves and, like infrared radiation, can resolve images in sufficient detail to identify targets. The reflected waves form a tomograph that is then analyzed for target information. In addition, recent research in acoustics indicates that acoustic tomography may be a cost-effective way of monitoring ocean phenomena. Of particular interest are phenomena that distort sonar propagation paths, affect submarine hydrodynamic wake signatures, or cause hydrodynamic "noise," which interferes with sonar system operation.

Energy

Guaranteed access to assured supplies of energy is essential to the national defense, but meeting military energy needs is becoming increasingly difficult as energy supplies become more costly and less subject to direct control. The current and anticipated mobile equipment inventory points to continued reliance upon liquid hydrocarbon fuels, now and in the foreseeable future. There are four overall objectives of the energy research and development program: the development of rapid and improved fuel specification methods and tests to provide the ability to respond rapidly to changing fuel supplies, the development of more efficient propulsion and power-generating equipment; the broadening of the specification range of mobility fuels that can be used in military systems; and the reduction of the petroleum dependence of military installations by promoting the use of more abundant or renewable energy sources to replace liquid hydrocarbon fuels and natural gas.

The energy program has resulted in a continuous-combustion gas turbine engine, multifuel diesel engines, and the adiabatic engine. The operation of T-56, J-79, J-85, and F-101 combustors using shale-derived fuels has been demonstrated. New instrumentation for the tests has provided diagnostic tools for determining design changes necessary for burning hydrogen-deficient fuels. Tests have been performed on modified engines that show the ability to burn fuel with a wide range of specifications.

Techniques have also been developed to increase the energy utilization efficiency of ships.

Manufacturing Technology

The function of the manufacturing technology program (MTP) is to ensure the most effective use of DOD's resources for materials acquisition. By providing new or improved production processes, equipment, and methods, the MTP reduces production costs, shortens production leadtime, improves product quality and reliability, and provides alternate production sources. Substantial benefits are derived from improved production safety and conservation of critical materials.

Current research emphasizes technologies associated with the latter stages of the manufacturing cycle, when the value of assembled and tested products is highest. For example, the cost of assembly and disassembly for refurbishing turbine engines is high because it is labor intensive. Some of the technologies being applied to reduce the cost include optical recognition and metrology, computer vision, robotic controls, and nondestructive evaluation.

A nondestructive evaluation technique, vibrothermography, has been developed for helicopter quality control. The method detects the presence of small fatigue cracks or delaminations in composite helicopter blades and is sensitive enough to detect flaws long before the effectiveness of the component is threatened. It is based on the increase of temperature in a vibrating solid as observed in a thermal image recorded on a video camera. Vibrothermography can detect otherwise unobservable stress concentrations, voids, inclusions, microcracks, delaminations, and other defects in structural materials.

Research in manufacturing technology should provide fundamental knowledge to support increased productivity in the manufacture of high-technology aerospace equipment. Developments in computers play an important role. For example, higher order computer languages are being tailored specifically for the control of robots by factory personnel with a minimum of specialized training. Research in artificial intelligence is leading toward the development of "co-operation" among advanced generation robots having vision, adaptation, and locomotion. Research initiatives are focused on parts recognition, tactile sensor development, and conditional responsiveness. Optical data-processing techniques are being considered as an alternative to digital computing in order to match better the nature of image-processing algorithms. Computer-aided design (CAD) will be integrated with computer-aided manufacturing (CAM) techniques to eliminate redundancy in the generation of drawings, specifications, and amendments to process control documents. Simplified presentation of status data to production managers for decisionmaking will be studied, with emphasis on interactive query systems.

The most important accomplishments of the Nation's space program during 1981 were the first two orbital flights of the Space Shuttle and the encounter of Voyager 2 with Saturn. Attainment of full operational status for the Shuttle will continue to be a principal objective of the Government's space program for the immediate future. That objective includes developing system improvements to increase the Shuttle's performance and the services it can provide. As a result of the emphasis on making the Shuttle fully operational, the need for budgetary restraint, and a review of space program priorities, some projects in other areas have been rescheduled to later dates or postponed indefinitely There also have been some modifications in a few flight projects: for example, the United States will not provide a separate spacecraft for the International Solar Polar Mission, although the European spacecraft will carry a joint European-U.S. complement of instruments. The United States will continue to provide a shuttle launch, an upper stage booster, and flight operations support for the mission as previously agreed.

Space Transportation Systems

The Space Shuttle, in combination with Spacelab, will introduce a new era in the use of space for scientific and national security applications. Together they will provide an opportunity for conducting a greater variety of space activities, and they promise to do so more efficiently and effectively than was possible in the past.

Space Shuttle

Efficient, reliable transportation to and from space is required for both civil and national defense payloads. The Space Shuttle, a reusable, manned, space transportation system, is being developed to satisfy into the 1990s most U.S. requirements, and a large part of the free world's requirements. The Shuttle will provide transportation to space and such other services as the delivery, retrieval, and repair of free-flying satellites in space, or their return to Earth for repair or refurbishment. The remaining requirements for transportation to space are expected to be filled mainly by such expendable launch vehicles as the U.S. Delta series and France's Ariane, which entered operational service in 1981. For the United States, the Shuttle will serve national security needs as well as the civil space program's needs. The current forecast indicates that Department of Defense payloads will make up about a third of the Shuttle's payloads during the vehicle's early years.

In 1981, the Shuttle completed the first two of its four planned orbital test flights. The first, launched on April 12, was a 54½-hour flight that met all mission objectives. The second, launched on November 12, had to be shortened from its planned duration of 124 hours to 54½ hours because of a malfunction in one of the three fuel cells. All other Shuttle subsystems performed satisfactorily, and the crew, working on a revised "minimum mission" flight plan, met nearly 95 percent of all flight test objectives.

On its first orbital test flight, the Shuttle carried only instruments for measuring its own behavior and performance. On its second flight, it carried and tested the operation of the Canadian-developed Remote Manipulator System, the articulated arm that will perform such functions as deploying payloads from the Shuttle's cargo bay and retrieving objects from space for inspection, repair, or return to Earth. On that flight, it also carried a payload package containing a complement of instruments for Earth-observation studies. The data collected are now being evaluated by scientists from many different parts of the country. Preparations are in process for the third and fourth orbital flight tests, planned for March and July of 1982.

The Shuttle's operations era is expected to start in late 1982 and to continue well into the 1990s. Continuing projections of requirements for Shuttle flights show that the expected demand for Shuttle services will grow and that the needs of some Shuttle users will require increased performance. Improvements to provide that increase in performance are already planned.

They include increased power from the main engines and reductions in the weight of the external tank and the solid rocket booster cases. The additional need for high energy upper stages with increased ability to boost payloads from the Shuttle's orbit to higher orbits is under study.

Spacelab

Spacelab is the reusable space laboratory developed by the European Space Agency. It can provide several combinations of pressurized modules and unpressurized platforms called pallets that, when assembled and mounted in the Shuttle's cargo bay, will provide both a pressurized environment for space experiments tended by humans and an unpressurized environment for untended or remotely tended experiments. The long module and pallet that will make up Spacelab-1 were delivered in December 1981. Experiments for Spacelab-1 will be mounted in its racks and, in late 1982, the racks will be mated with the module and pallet. Following appropriate tests, Spacelab-1 will be ready for its first flight, scheduled for late 1983.

Life Science Studies in Space

After nearly 6 years without a U.S. manned space flight, Shuttle flights are providing not only a return to closely phased manned flights, but also an increase in U.S. capabilities for studying the effects of the space environment on humans. An issue of concern in both U.S. and Soviet space flights has been the physiological changes that occur in crew members, including motion sickness, cardiovascular and endocrine responses, loss of calcium from bones, loss of muscle mass, changes in red blood cells, and fluid shifts in the body. Space motion sickness is a particularly important consideration for Shuttle missions, since Shuttle crews will include, in addition to veteran pilots, mission and payload specialists, whose training for flight in space is less comprehensive.

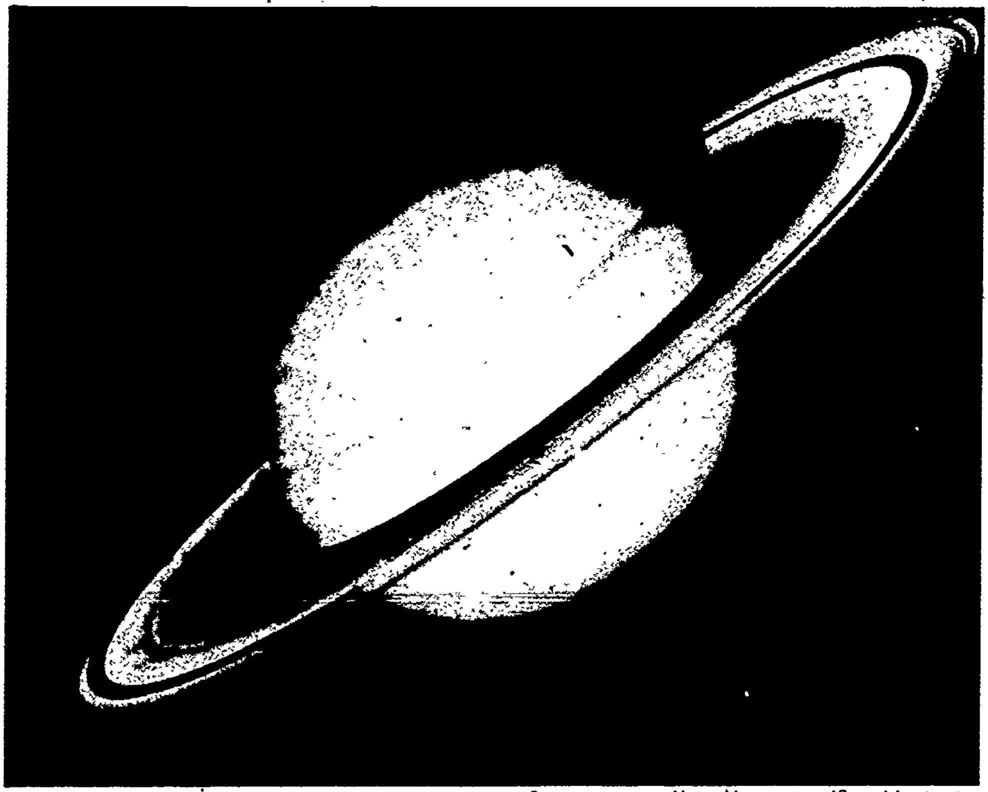
Other life sciences experiments are planned to be conducted regularly on Shuttle flights. For example, several investigators have developed experiments to explore how biological organisms sense gravity—one of the most fundamental and exciting areas in modern basic biology. The fourth Spacelab flight will provide a major opportunity for such research, since it will be dedicated to life sciences investigations. The selection of investigations to be included was completed in September and emphasizes medical areas that are of concern on short-duration flights.

Origin, Nature, and Evolution of the Universe

Data returned by space science missions in the last year continued to fuel the revolution in the way we think about the Sun, the planets, the stars, interstellar and intergalactic space, and mankind's place in the universe. For example, we acquired new information about matter-antimatter annihilation in the center of our galaxy and learned about the causes and effects of solar flares. The second Voyager's observations of Saturn gave us unanticipated new facts about that planet and its system of moons and rings. The Shuttle and Spacelab are opening the door to a new era of rapid learning in the space sciences. In addition to providing a capability for conducting a wide variety of human-tended investigations, the Shuttle will be able to deploy, retrieve, repair, or refurbish in orbit and even return to Earth the spacecraft and experiments of such missions as the Space Telescope.

Planetary Exploration

The successful encounters of the two Voyager spacecraft with Saturn in late 1980 and August 1981 were the most significant recent achievements in planetary exploration. They provided an unparalleled opportunity to make sophisticated scientific measurements and obtain high-resolution images of Saturn's rings, upper atmosphere, and moons. The abundant data they provided are still being analyzed, but early findings confirm their importance to basic knowl-



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Voyager 2 took this photograph of Saturn from a distance of 21 million miles.

edge and understanding of the universe. The rings, long thought to be uniform disks of material, are now suspected to consist of thousands of tiny ringlets. Voyager's images of Saturn's atmosphere show, in much greater detail than formerly available, circulating storm regions, dark belts alternating with bright zones, and other dark and light cloud markings—all muted by a thick upper atmospheric haze. The tiny and large moons of Saturn, some of which had never before been seen, are now known to range in size from about 65 to 5,120 kilometers and to vary in form from oblong and irregular to spherical and smooth. The next key event in Voyager 2's epic journey is its 1986 rendezvous with Uranus. A Voyager 2 rendezvous with Neptune in 1989 is also planned.

Astrophysics

The High Energy Astronomy Observatories, HEAO-2 and HEAO-3, completed their missions in 1981 and are no longer returning data. However, analysis of the acquired data continues. That analysis has already provided new insights—for example, that the energy being converted to antimatter in the center of our galaxy is 10,000 times as great as the energy generated by the Sun's consumption of its nuclear fuel.

Development of the Gamma Ray Observatory began in 1981. In that year, its design was defined, final selection of its instruments was made, and a contractor was selected for the Observatory. However, the need for budgetary restraint has delayed its proposed launch date from 1986 to 1988. Its highest priority objectives will include observing the center of our galaxy and searching for evidence of the synthesis of matter in stars.

The spectacular successes of the National Aeronautics and Space Administration's (NASA) astrophysics systems have been paralleled by many recent advances in ground-based astronomy. The National Science Foundation's Astronomical Instrumentation and Development Program's application of the latest available instrument and computer technology has enabled such activities as.

- the use of new electronic array detectors, e.g., charge-coupled devices, to map radiating sources hundreds of times fainter (hence more distant) than previously could be detected;
- the use of computers to interpret the vast quantities of data sensed by the advanced detectors—superimposing photographic and digital images, reducing noise, and removing atmospheric distortions to yield unprecedented sensitivity and resolution;
- the use of computers to combine observations from widely separated radio telescopes in a technique called very long baseline interferometry that provides extremely high resolution, and
- the dissemination to university researchers of the most advanced detectors and special computers.

Solar-Terrestrial Investigations

Solar-terrestrial physics investigations are dedicated to understanding the processes that control the near-space environment. That environment is dominated by energy from the Sun, which arrives in Earth's vicinity as electromagnetic energy and as the plasma flow of the solar wind. Those forms of energy affect Earth's atmosphere, ionosphere, and magnetosphere, as well as such more familiar characteristics as weather, climate, auroral displays, and radio disturbances

One program that is increasing knowledge of the Sun is the Solar Maximum Mission (SMM), which is studying solar flares and other types of solar activity during the present peak of the 11-year sunspot cycle. Although gyro control of SMM has been lost, three of SMM's original seven instruments continue to provide new scientific information because they require no greater directional accuracy than the torquing exerted by Earth's magnetic field. A Shuttle rendezvous with SMM is planned for late 1983 or early 1984 to carry out in-orbit repair of SMM's gyro controls.

The interaction of the Sun's energy with Earth's magnetosphere is best studied with such multispacecraft missions as the three-spacecraft International Sun-Earth Explorer and the two-spacecraft Dynamics Explorer (DE), launched during 1981 and still operating. The primary objective of the DE mission is to investigate the strong interactive processes coupling the hot, tenuous, convecting plasmas of the magnetosphere and the cooler, denser plasmas and gases corotating in Earth's ionosphere, upper atmosphere, and plasmasphere. To fulfill that objective, the two DE satellites are obtaining simultaneous measurements from different altitudes in their coplanar orbits.

Applications of Space Technology

The ultimate objective of most space projects is to develop the basic knowledge that may lead to practical applications for everyday problems. Some activities related to those objectives conducted during 1981 are described below.

Processing of Materials Under Low-Gravity Conditions

One new technology being investigated by the space program is the processing of materials in an environment where the effects of gravity are greatly reduced or eliminated. By reducing or eliminating the effects of buoyancy, sedimentation, and convection, low-gravity processing can change significantly the results obtained in alloy solidification, crystal growth, biological separations, and chemical and fluid physics. NASA has developed facilities and equipment for use in low-gravity processing experimentation and has invited industry to participate in joint investigations and projects. One concept for involving the private sector is the Technical Exchange Agreement, under which NASA and a private company agree that each will be responsible for a separate portion of a joint research project; no funds are transferred between the two. During 1981, the first Technical Exchange Agreement was signed with Deere and Company to study the effects of low-gravity processing on iron alloys.

Land Remote Sensing

The Landsat series is an experimental series of satellites developed to evaluate the remote sensing of natural resources from space. Landsat-D, the fourth in the series, is scheduled for launch in 1982. Data from the series have been tested in a wide variety of applications during the approximately one decade of its experimental use. Highlights during the past year include the following:

- use by the Statistical Reporting Service of the U.S Department of Agriculture to improve crop statistics in Iowa, Kansas, Missouri, and Oklahoma;
- development of techniques that improve both the accuracy and the efficiency of estimating the extent of areas planted in spring grains;
- production, under the interdepartmental Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) program, of the most comprehensive set of correlated data ever obtained from observations on the ground and remotely sensed from space for use in assessing crop conditions and estimating crop yields;
- completion of a cooperative project between NASA and the National Park Service that demonstrated some of the benefits remote sensing from space can provide to aid in administering U.S. national parks; and
- completion of a cooperative research venture between Government and private industry designed to evaluate the utility of remote-sensing techniques for geological mapping of areas of known mineralization. (Joint analysis of remotely sensed data acquired by the Government and verification data acquired on the ground by industry showed that imaging from space in the visible, infrared, and microwave portions of the electromagnetic spectrum can significantly improve our capabilities for geological mapping. The results have led to expanded private sector interest in the data to be collected by Landsat-D and to private sector interest in increasing spectral and spatial resolution through advances in remote-detector technology for geological applications.)

Atmosphere and Ocean Remote Sensing

Accomplishments in remote sensing of the atmosphere and oceans from space during 1981 include:

- completion of studies based on data from the Global Weather Experiment; for example, those studies have shown that incorporation of wind data from satellite observing systems may improve weather forecasting;
- demonstration of an ability to map from geosynchronous altitude the distribution of water vapor in the atmosphere to significantly improve such important predictions as sudden changes in the courses of hurricanes: a full evaluation of possibilities in numerical weather predicting, storm development, storm tracking, flash flood warning, aircraft operations, and river-state forecasting is under way;
- determination that such data as those from the cooperative Government-indus-

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Hurricane Allen, which brought devastation and loss of life to the Caribbean and other areas, and Hurricane Isis in the Pacific are shown clearly in this photo taken in 1980 by the National Aeronautics and Space Administration's GOES EAST satellite.

try Seasat Commercial Demonstration Program could satisfy needs for improved wave and weather forecasts and also provide an improved data base on ocean climatology; and

- initiation, through the successful launch of the Solar Mesospheric Explorer in October 1981, of a number of measurement programs to study ultraviolet (UV) energy input and mesospheric chemistry; measurements of UV flux variability of mesopheric ozone and of minor species are being acquired.

Shuttle Remote-Sensing Experiments

On its second test flight, the Shuttle carried a payload of land-, ocean-, and atmosphere-observing experiments designed to provide an early test of the Shuttle's research capabilities. Those experiments collected various types of remotely sensed data that are now being analyzed. The individual experiments were designed to study several kinds of phenomena, including Earth's crustal structure and composition, air pollution, distribution of nutrients in Earth's oceans, and lightning discharges associated with severe storms. Experience gained will help terrestrial and space scientists make more effective use of the Shuttle as an orbital laboratory.

Responsibility for Operational Remote-Sensing Systems

The National Oceanic and Atmospheric Administration (NOAA) is responsible for managing the Government's civil remote-sensing space systems after they progress from developmental to operational status. NOAA has been using two series of meteorological satellites as operational systems for some time. Geostationary Operational Environmental Satellite-5 (GOES-5) and NOAA-7, the latest in each series, were launched in May and June 1981, respectively. The Landsat series of developmental land remote-sensing systems will reach operational status after the 1982 launch of Landsat-D. NOAA, with help from NASA, is now making plans to transfer operating responsibility for Landsat to the commercial sector as soon as possible.

During the past year, the Department of Commerce took several additional important actions related to operational remote-sensing systems and private sector participation in them. It developed a pricing proposal for Landsat-D products and services designed to recoup, starting in 1983, the costs of operating the system. It established the Program Board on Civil Operational Remote Sensing from Space, which consists of Federal officials at the assistant secretary level from 11 agencies and departments, to help it plan and implement the Government's interim operation of the Landsat-D system and the eventual transfer of Landsat-D's operation to the private sector. NOAA conducted a series of conferences with users of remotely sensed data to refine its analysis of their data needs and requirements, held discussions with companies that may be interested in investing in operational remote sensing, and is participating in a series of regional Landsat meetings in Africa, Asia, and South America to inform users in those regions of the products and services that will be available from U.S. systems.

Participation of Local Governments in Remote Sensing

State and local governments are taking a growing interest in comprehensive management of their natural resources and are increasingly accepting space-sensed data as an important source of information essential to decisionmaking. State governments have invested $28 million in the use of Landsat data, and the amount of State funds being used appears to be increasing in comparison with the amount of State-controlled Federal funds, although these investments are still only a small fraction of the total cost of providing Landsat data to users. Capabilities for continuing use of satellite data exist in 15 States and are under development in 10 others. Typical applications have included the inventorying of land resources for use in comprehensive planning by California and South Carolina, the monitoring of urban growth and conversion of prime land by Hawaii and

Iowa, the evaluation of the effects of industrial development by Florida, the planning for conservation of such unique or sensitive resources as wetlands by New Jersey, and the siting of waste disposal areas by Maryland.

Although there are many potential uses for land remote-sensing data such as those produced by Landsat satellites, a key question that is still being evaluated is the cost-effectiveness of continuing Landsat-type technology on an operational basis. Landsat satellites and their related ground support systems are costly to build and operate, and in many instances, users have alternative and less costly means to meet their essential needs. A careful evaluation is under way of Federal needs for Landsat-type data, and continuing investments in this technology will depend upon the proven cost-effectiveness of land remote-sensing technology relative to other available methods.

Space Research and Technology

Extensive cooperative efforts between NASA and the Air Force have developed major space R&D planning tools that identify technologies needed for current and future systems. The joint planning effort has found extensive commonality of technology needs in the civil and national security space programs. A number of research and technology activities directed toward satisfying those needs are under way or planned for the near future, and some major accomplishments were achieved during the past year.

Basic Research and Technology

Basic research and technology work provides for the formulation and characterization of technologies in a laboratory environment. For example, in laser research in 1981, direct solar pumping of a laser was simulated for the first time. Repeated pulses with peak power output up to 4.5 watts were obtained. Solar-pumped lasers could revolutionize energy transmission in space, since they could be developed into closed, long-life, relatively lightweight systems. During 1982, work will focus on developing a more efficient lasing material.

In solar cell research, an extremely thin (10-micrometer), single-crystal, gallium-arsenide solar cell was successfully fabricated on a thick substrate. That cell produced a specific power of 2.5 KW/Kg, the highest ever achieved by a solar cell—and 20 times greater than that produced by other current cells. The new fabrication process that yielded the breakthrough has the potential to reduce cell cost drastically and will be developed further in 1982 to grow a thin cell on a thin substrate.

Secondary Applications of Space Technology and Systems

Space systems have a particularly strong need for parts with low weight, small size, low power requirements, high reliability, and long life—characteristics that frequently make them valuable for Earth applications. During 1981, almost 50 Earth applications in bioengineering, rehabilitation, public safety, and the environment were cosponsored by NASA and other Federal agencies, industry, and State and local governments. Some examples are:

(1) In mid year, tests in human patients of an implantable system for the controlled release of such medications as insulin directly into a patient's blood stream began. The system constantly measures the patient's critical parameters and provides timely warning or caution signals to the patient. The development of this device is being supported by NASA, the Applied Physics Laboratory of Johns Hopkins University, Pacesetter Systems, Inc., Parker-Hannafin Corporation, Novo Research Institute, and the National Institutes of Health (NIH).

(2) NASA's Ames Research Center and the Children's Hospital at Stanford's Rehabilitation Engineering Center for the National Institute of Handicapped Research developed a wheelchair-mounted speech prosthesis for the nonvocal severely handicapped. The technology for that prosthesis came from a program in which Ames developed a synthesized voice system for

National Aeronautics and Space Administration

A quadraplegic demonstrates a voice-controlled wheelchair and its manipulator that can pick up packages, open doors, turn TV knobs, and perform a variety of other functions for severely handicapped persons. This device was jointly developed by the National Aeronautics and Space Administration and the Veterans Administration

advanced cockpit systems. Testing has shown that the prosthesis has greater language capability, flexibility, and speed than existing commercial devices, It is being readied for manufacture.

(3) A hybrid wastewater treatment system based on the use of anaerobic filters in combination with vascular aquatic plants has greatly reduced the cost of such treatment. It can remove hazardous substances from industrial, mining, and urban wastewater.

(4) Three projects cosponsored with NASA were concerned with volatile hydrocarbons in connection with public safety and the environment. In the first, NASA, in cooperation with the Gas Research Institute, designed and fabricated a laser instrument capable of detecting and measuring very small leaks and emissions of methane and liquid natural gas. Initial tests indicate that the instrument will be useful to the gas distribution industry in locating small leaks, which have caused great loss and damage in the past. The second project combined the efforts of NASA, the U.S. Coast Guard, and the Department of Energy in developing detectors for measuring methane concentration and plume dimensions. The detectors have demonstrated good correlation and rapid response in small-scale spill tests. In the third project, NASA and the U.S. Coast Guard have applied knowledge on the effectiveness of various types of flame and detonation arrestors, used in systems to recover hazardous volatile-hydrocarbon vapors, to detonations in long pipes and to repeatable quenching of detonations.

Recent years have witnessed a striking increase in knowledge of living things. Indeed, it is generally acknowledged that the flood of basic discoveries in biochemistry, physiology, and medicine, combined with achievements in allied disciplines, constitutes a "revolution in biology." A major challenge facing health research managers today is to maintain the level of national research capabilities in a time of increasing research costs and finite resources, so that the exceptional scientific opportunities afforded by that revolution can be fully exploited. As noted in last year's annual report, a key element in the Federal health research strategy is to strive for a predictable level of support for investigator-initiated research project grants. This would stabilize the single largest and most important component of the health science base. Beyond knowledge development, a key Federal concern is the application of health research findings to health care services.

Illustrative examples of the rapid growth in fundamental knowledge in the life sciences and the impact of new discoveries on human health and well-being are highlighted below. Briefly considered are some of the most recent advances in biomedicine; the assessment and transfer of the new health technologies into the health care system, and international initiatives in health research.

Advances in Biomedicine

Genetics

During the past few years, discoveries about the hereditary material inside the cell have opened entirely new worlds in biology. A quantum leap has occurred in our understanding of the way genetic information is encoded and transmitted. Researchers are tantalizingly close to identifying the fundamental defects in specific genetic diseases* and to answering such key questions as how cells differentiate to serve specialized purposes, why some cells become malignant, and why cells eventually age and die. Today all the essential elements for momentous research advances in genetics are at hand: highly creative investigators, fundamental knowledge on which to build, appropriate materials for research studies (model organisms ranging from yeast to bacteria to the sea squid, and animal and human cells available in tissue culture), and increasingly powerful investigative tools, of which recombinant DNA technology is only one.

Much of the fundamental work in genetics has been funded by the National Institute of General Medical Sciences (NIGMS) in the National Institutes of Health (NIH) and by the National Science Foundation (NSF). A significant portion of the biomedical research in genetics is aimed ultimately at replacement of disease-causing abnormal genes with new genes that will code for normal function. The research, while promising, is still in a very preliminary stage. Extensive basic studies to ensure proper control of gene expression—including experimentation in animals—will be required before what has become known as gene transfer can lead to gene therapy.

One exciting area of current research concerns transposable genetic elements—so-called jumping genes. The ability of portions of chromosomes to move about and rearrange themselves has now been recognized as being responsible for the tremendous diversity of antibodies that individuals can produce. Studies are expected to shed light on genetic mechanisms resulting in mutations, differentiation of tissues in the developing human body, and genetic aberrations associated with certain malignancies. Moreover, the movable bits of DNA may provide useful markers to speed linkage studies that can track the inheritance of genetic diseases.

* The term genetic diseases covers a broad spectrum of human disorders, some arising from defects in a single gene (e.g., cystic fibrosis, Huntington's disease), others from chromosomal abnormalities (e.g. Down's syndrome), and still others from the complex interaction of individual genetic inheritance and such environmental factors as diet, smoking, pollutants, and lifestyle. The single gene disorders are relatively uncommon, though often devastating in impact; the multifactor disorders include a number of frequently occurring serious health problems—among them diabetes, high blood pressure, atherosclerosis, and several forms of cancer.

Another area of great research interest is that of genetic regulation—the processes by which organisms and their component cells control the synthesis, maintenance, and breakdown of cell constituents in response to changes in the internal and external environment. Studies make it increasingly clear that a rich fabric of regulatory activities operates within cells.

Researchers have found the cell and its hereditary material to be far more complex than had been expected. Nevertheless, there is intense anticipation that research developments in the areas outlined above—and others—will make possible effective intervention in a variety of perplexing and devastating human disorders.

Immunology and Infectious Diseases

Revolutionary hybridoma (cell fusion) techniques and recombinant DNA technologies continue to provide opportunities for vaccine development. Research is supported by NIH, with related activities conducted by such other agencies as the Centers for Disease Control (CDC) and the Food and Drug Administration (FDA). Several initiatives to exploit those opportunities were outlined in last year's annual report.

During the past year, clinical trials conducted by NIH demonstrated the safety and efficacy of a hepatitis B vaccine, which has now been licensed by FDA. Immunization programs eventually may reduce not only the incidence of acute hepatitis B (now at about 100,000 cases per year in the United States) and the pool of chronic carriers (now at about 800,000), but the morbidity and mortality from chronic active hepatitis and cirrhosis of the liver as well. At the present time, production of the vaccine requires blood from patients as a source of antigens (substances that stimulate the production of antibodies). Further research has led to a second candidate vaccine for hepatitis B, which has now been synthesized with probable greater availability at lower cost. CDC is conducting demonstration projects to test the public health use of hepatitis B vaccine on specific populations at risk. Similar efforts are,

Bruce Wetzel and Harry Schaefer, National Cancer Institute

A scanning electron microscope image of normal circulating human blood shows red blood cells, several white blood cells including lymphocytes, a monocyte, a neutrophil, and many small, disc-shaped platelets.

under way to synthesize antigens for vaccines against other microbial agents.

Studies at NIH have also established the existence of a new human hepatitis virus now designated non-A, non-B (NANB). Most hepatitis following blood transfusion has been found to be due to NANB. The virus may also be a major cause of some forms of cirrhosis of the liver. Research indicates that the exclusion of blood donors with an elevated level of the enzyme transaminase (associated with NANB hepatitis) might prevent 30 percent of post-transfusion hepatitis and reduce the donor population by only 1.5 percent.

The Veterans Administration (VA) serves a growing number of patients who may be at risk for pneumococcal disease. It is currently evaluating the efficacy of pneumococcal vaccine in high-risk patients (the elderly, diabetics, persons with chronic renal, hepatic, cardiac, or pulmonary diseases, and chronic alcoholics).

New opportunities to treat and prevent

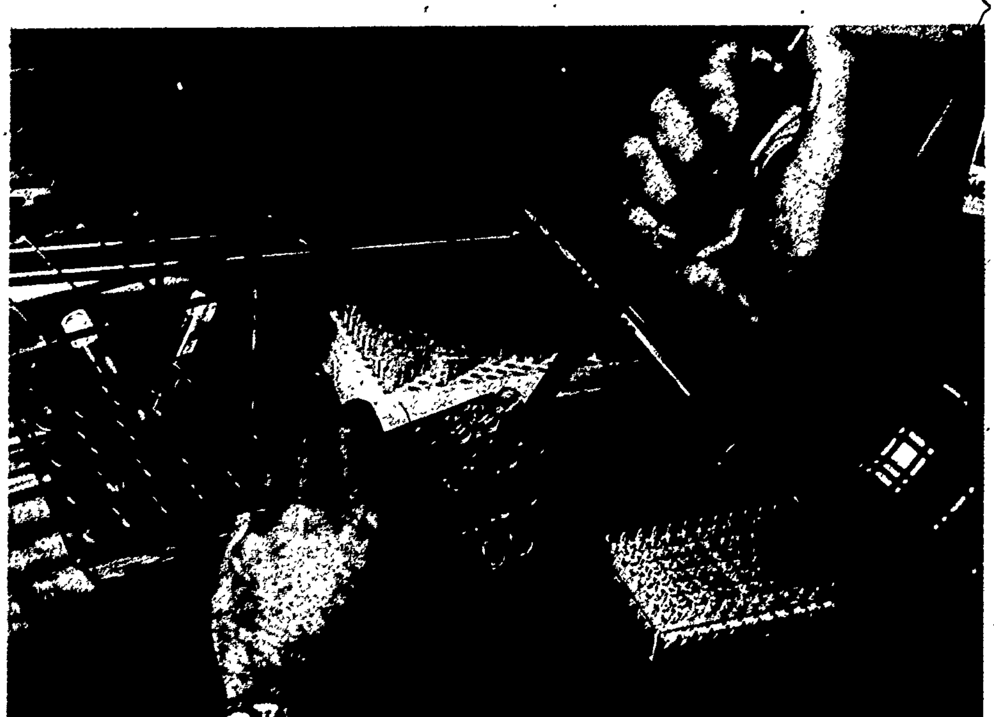
asthma and allergies have also been provided by recent research on the biochemical actions involved in allergic and other inflammatory reactions. For example, arachadonic acid, a fatty acid, now has been shown to play a key role in the production of mediators of inflammation that are medically important. Based on such research, new drugs are being designed to prevent and treat asthma and other allergic and immunologic disorders.

Cancer

Many chemical compounds, both natural and synthetic, have been found to possess the capacity to limit tumor formation. Compounds using vitamins A and C have been shown to be particularly effective, and, as a consequence, the National Cancer Institute (NCI) is systematically testing those potential chemopreventive agents. For example, vitamin A intake, whether through food or as a supplementary vitamin, has been specifically associated with low risk of cancer. Vitamin A and synthetic analogs of vitamin A are called retinoids. These chemical agents may play important roles in modifying both the initiation and growth of cancer, and research in retinoids for prevention of cancer is gaining momentum. Indeed, studies have demonstrated that various retinoids can reverse or suppress the malignant behavior induced in cultured cells by viruses, chemicals, or ionizing radiation.

Studies now in progress also suggest that it is possible to reduce mortality from cancer of the colon by dietary or chemical manipulation. For example, studies relating dietary factors with cancer incidence have indicated a slightly lower than average incidence of cancer among people with an above average intake of green leafy vegetables. At the present time, it is important to determine whether the lower cancer incidence is due to the substance betacarotene, found in green leafy vegetables; to the products retinal and retinol, which are generated from betacarotene in the intestine; or to other constituents of vegetables.

New hybridoma, or cell fusion, technology is also being exploited in cancer re-



National Cancer Institute

A scientist sorts B-cells taken from the bone marrow of a patient with Lupas as part of a process using hybridoma, or cell-fusion technology, to manufacture identical antibodies indefinitely and in large quantities.

search. That technology may permit detection of cancer at a very early stage by allowing scientists to label cancer cells anywhere in the body. The high specificity of the monoclonal antibodies produced by hybridoma techniques should permit scientists to kill cancer cells directly by means of radioactive substances or toxic chemicals attached to the antibodies. Thus, hybridoma technology holds considerable promise for cancer therapy.

Diabetes

Treatment with special diets, exercise, insulin, and other medications has extended the average life expectancy and improved the quality of life for diabetic persons. However, it has not prevented the development of such tissue-damaging aspects of that disease as heart attacks, strokes, kidney failure, gangrene, blindness, and damage to the nervous system. Most of the morbidity, mortality, and economic cost associated with diabetes is due to those degenerative tissue changes.

A long-standing, unresolved controversy exists over whether strict and precise control of blood glucose levels in diabetic persons will prevent those life-threatening degenerative changes. During the past few years, new technologies have been developed that may permit scientists, for the first time, to assess whether tight metabolic control will prevent diabetic complications. The technologies include open loop devices for delivery of insulin and the institution of systems for home monitoring of blood glucose concentration—both of which permit better metabolic regulation of diabetes than heretofore possible. With the advent of those technologies, the National Institute of Arthritis, Diabetes, and Digestive and Kidney Diseases (NIADDK) has initiated a clinical trial to determine whether long term normalization of blood glucose will prevent the chronic degenerative change in persons with diabetes. The first phase of the trial began in late 1981.

Also being emphasized are studies to determine the relationship between diabetes and obesity, diet, and exercise. Most individuals (80-85 percent) with Type II diabetes (not insulin dependent) are overweight and physically underactive. Evidence suggests that the attainment of optimal body weight, plus adherence to sound diets and regular physical exercise, will reduce the metabolic abnormalities and clinical symptoms in patients with that type of diabetes, or even prevent its development.

In addition, an ongoing clinical trial being carried out by the VA is seeking new information on the natural history of lower extremity vascular disease in diabetes. It will also provide definitive data about the efficacy of antiplatelet agents in diabetic vascular disease.

During 1980, researchers were able to reverse diabetes in mice by transplanting into them normal insulin-producing islet cells from healthy rats. Although several obstacles need to be overcome before that type of transplantation can be attempted in humans, it represents a major advance not only in the treatment of diabetes but also in overcoming the immunologic barriers to transplantation between species.

Alcoholism

Alcoholism and problem drinking are among the most serious public health problems in the United States today. Early identification of alcoholism is particularly critical in dealing with the medical, personal, social, and economic tragedy of the disease. One promising procedure now being developed by the National Institute on Alcohol Abuse and Alcoholism (NIAAA) and CDC involves a sophisticated analysis of blood chemistry profiles. The profiles can be used to classify individuals as alcoholic or not alcoholic with high precision. Other screening tests being examined include a method that relies upon the measurement of an unusual hemoglobin fraction. Unlike other biological screening tests available today, the new test can be used to detect alcohol abuse in the absence of the types of impairment that occur at the later stages of chronic drinking. Such screening tests may reveal unsuspected or unrecognized compulsive drinking, provide grounds for medical intervention, and therefore serve as a preventive measure.

NIAAA has also sponsored research dealing with the effects of alcohol on liver disease, cardiovascular disorders, alterations in the central nervous system, and fetal development. For example, recent studies with animal models have clearly disproven the hypothesis that cirrhosis in man is a disease caused primarily by nutrient deprivation, rather than induced by alcohol. Alcohol-exposed animals developed cirrhosis even though they were fed more than adequate diets. Clinical investigation is now under way to confirm a preliminary observation that prednisolone, an anti-inflammatory drug, may have therapeutic value in treating patients with severe alcoholic liver disease.

Recent studies of the effects of alcohol on the central nervous system support the view that prolonged overindulgence in alcoholic beverages affects the structure and function of the brain. At least 50 percent of the alcoholics receiving treatment are afflicted with brain atrophy. Recent studies suggest that alcohol abuse also causes learning and memory failures. Computed tomographic (CT) scanning has demonstrated a decrease in the number of brain cells and a reduction of brain size in chronic alcoholics However, several encouraging studies have shown partial reversal of both brain atrophy and neuropsychological impairment in abstinent alcoholics.

Fetal alcohol syndrome is the third leading cause of birth defects with associated mental retardation, and it is the only one of the three that can be prevented. Research is beginning to identify the risks for pregnant women of moderate and social drinking. It is known that women who consume more than a certain minimum amount of alcohol are at increased risk of bearing infants of lower birth weight and of suffering spontaneous abortions. In addition, recent research indicates that the third trimester of pregnancy appears to be a particularly vulnerable period in which alcohol can cause fetal alcohol syndrome and its related effects.

Drug Addiction

The National Institute on Drug Abuse (NIDA) has long supported investigations into the factors controlling drug addiction and the relationship between addiction and criminal behavior. Although it has been generally recognized that there is a close statistical correlation between opiate addiction and criminality, recent findings have provided solid evidence of the extent and character of that relationship. It has been found, for example, that the average narcotic addict engages in at least one criminal act not involving drugs (burglary, robbery, etc.) per day for 248 days of the year. The same individuals engaged in crime on 41 days per year when not addicted.

Evaluation of treatment effectiveness has determined that a number of well-defined treatment methods can achieve dramatic reductions in clients' drug use, with concomitant marked reductions in criminal activity and increases in employment and participation in productive activities. Of great potential as a treatment method for addicts are new drugs now being developed and evaluated that can be used as interim therapies while people are becoming totally drug free.

Mental Health

The National Institute of Mental Health (NIMH) is the agency with prime responsibility for research on mental and emotional disorders. The VA also sponsors important mental health research, as about 30 percent of VA hospital beds are occupied by patients labeled as schizophrenic.

The depressive illnesses are a major target of current clinical research. They are among the most prevalent of mental illnesses, affecting some 9 million persons in the United States. The major thrust of research is on the neurochemistry of depression (for example, the role of naturally occurring peptide substances); its physiological correlates; the elaboration of subtypes of depressions; the evaluation of pharmacological, psychosocial, and combined treatment approaches; and genetic and psychosocial mechanisms of transmission. Childhood depression and the diagnosis of depression and dementia in the aged are areas of particular significance for future research. Such investigations should provide a firm foundation for prevention and treatment strategies.

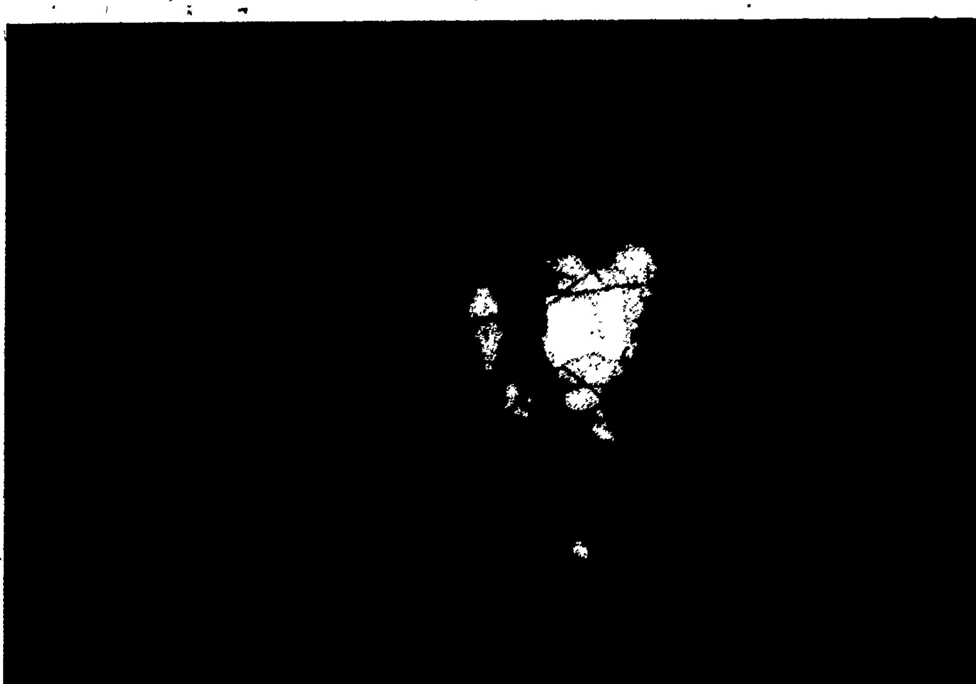
Positron emission transaxial tomography (PETT)—the new noninvasive computerized imaging technique enabling visual mapping of metabolic processes of the brain—is now being applied experimentally to the field of psychiatry. Current and potential uses include study of schizophrenic (including actively hallucinating) patients, monitoring of manic and depressive phases of disordered patients, and study of electroshock therapy. The NIMH program is undertaken in close consultation with the National Institute of Neurological and Communicative Disorders and Stroke (NINCDS), which supports an experimental PETT program at seven research centers throughout the country.

Vision Research

Scientists at the National Eye Institute (NEI) have shown for the first time that some cases of uveitis (an inflammatory disease of the inner eye responsible for 10 percent of all visual impairment in the United States) may be triggered by exposure of the immune system to a retinal protein called rhodopsin kinase, an enzyme present in all normal eyes as a component of the light-sensing cells of the retina. The discovery suggests that many cases of uveitis are autoimmune in origin—that is, they may occur because the body's immune system somehow encounters one of the normally hidden components of eye tissue, mistakes it for an invading microbe, and attempts to destroy it. With the benefit of those clues, NEI investigators have been able to test various drugs as treatments. They have discovered that cyclosporin A, a drug now used to control graft rejection in tissue transplantation, can prevent the development of uveitis in laboratory animals injected with rhodopsin kinase. To determine whether the human eye can be protected from uveitis in the same way, NEI investigators plan to conduct a clinical test of cyclosporin A in the near future.

Dental Health

Experiments with image-enhancement techniques using successively recorded X-ray



National Eye Institute

Human retina showing a type of uveitis, an inflammatory disease of the inner eye, known as "bird shot retinochoroidopathy."

images and digital computer manipulation have achieved earlier detection of dental abnormalities with lower radiation doses than conventional methods. The application of the technique to dentistry, a major research effort of the National Institute of Dental Research (NIDR), should permit not only early detection, but also earlier and more accurate assessment of treatment effects.

Premature Birth and Infant Health

Scientists supported by the National Institute of Child Health and Human Development (NICHD) have obtained evidence that bacteria that cause urinary tract or vaginal infections during pregnancy contain high levels of phospholipase A-2. Human phospholipase, an enzyme found in the membrane containing the embryo, is thought to initiate normal labor. Bacterial phospholipase from maternal infections may be responsible for premature labor. Other investigators have documented a relationship between urinary tract infections and decreased infant birthweight.

Toxic-Shock Syndrome

Studies of toxic-shock syndrome (TSS) have been under way since January 1980 as a result of its emergence and visibility as a disease of significant public health importance. The studies have been sponsored or carried out by a variety of Federal agencies, including CDC and FDA. For example, CDC has demonstrated an association between TSS and the use of tampons, and a national surveillance system has been established. Future research can be expected to provide additional information about TSS and its treatment and prevention.

Legionnaires' Disease

CDC studies have shown an association between the presence of *Legionella pneumophila* in potable water and the occurrence of Legionnaires' disease. The organism has also been identified in water from fresh water lakes and potable water systems without any apparent association with human disease. CDC and the VA are currently studying the significance of those findings for human disease and investigating means for eradicating the organisms in situations where they produce disease.

Low-Level Radiation*

In recognition of the risks associated with low-level radiation, the Nuclear Regulatory Commission (NRC) is performing research on limiting the discharge of radioactive materials from nuclear facilities. Emphasis is placed on fuel-cycle facilities that prepare the fuel for electricity-generating reactors. Significant progress in measuring effluents and assessing occupational exposures has been made.

Assessment of New and Existing Technologies

Several Federal agencies, including NIH and FDA, have responsibilities for the assessment of health care technologies. NIH, through its Office of Medical Applications of Research, conducts consensus development conferences, concerned primarily with the medical and scientific aspects (safety and efficacy) of particular technologies. Findings are made available to interested parties and groups through a variety of channels, including publication of statements in medical and lay journals and through NIH's Lister Hill National Center for Biomedical Communications. Recent NIH consensus development conferences have dealt with such topics as thrombolytic therapy in thrombosis, adjuvant chemotherapy of breast can-

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* See the *Annual Science and Technology Report to the Congress, 1980* for a description of the coordinated Federal research initiative to assess the health effects of low-level radiation. A recent study by CDC of participants in the 1957 nuclear test "Smoky" indicates a somewhat higher occurrence of cancers in that group of participants as compared to levels in the general population. A more comprehensive followup is being undertaken by the National Academy of Sciences.

cer, cervical cancer screening (the Pap smear), endoscopy in upper gastrointestinal tract bleeding, childbirth by cesarean delivery, and coronary artery bypass surgery. During fiscal year 1982, NIH plans to evaluate the following technologies through the consensus process: CT scanning of the brain, the effect of diet on hyperactivity, hip joint replacement, validation of biomaterials, treatment of insect sting allergy, and critical care medicine.

The FDA is, or will be in the near future, evaluating the following technologies from the perspective of its regulatory responsibilities:

- hybridoma technology (safety and effectiveness of new products derived from monoclonal antibodies or hybridomas),
- nuclear magnetic resonance imaging (effects of low-level exposure to electromagnetic radiation),
- recombinant DNA techniques (safety of products and scientific, medical, ethical, and political issues), and
- new approaches to risk assessment (evaluating the potentially adverse effects of technology on individuals and the environment).

Transfer of Research Findings and New Technologies

The National Library of Medicine (NLM) in Bethesda, Maryland, is the world's principal curator for biomedical research information. Nearly every country uses and contributes to NLM's program of data collection and retrieval. The demands for data management are rising rapidly, and new technical gains introduce marked jumps in need. For example, the accelerated pace of research in genetics is producing a stream of data that must be stored and made accessible so that the rich content of new knowledge can be used efficiently.

Important new medical technologies have also emerged from the Nation's space program. The National Aeronautics and Space Administration (NASA) has announced that during 1981 its Technology Utilization Program produced significant advances in bioengineering devices for implantation in human patients. One example is the Programmable Implantable Medication System (PIMS), which provides patients with a supply of medicine for several months and constantly monitors critical body parameters. Also during 1981, the following two other projects reached advanced stages of the technology transfer process: an advanced wheelchair design (a prototype chair has been made for use in airplanes through application of computer-aided design and use of advanced materials), and a wheelchair-mounted speech prosthesis for the nonvocal severely handicapped.

International Health Activities

Malaria

The United States has supported malaria eradication and control programs throughout the world since World War II, and, since 1965, the Agency for International Development (AID) has supported research to develop an effective vaccine against malaria. In the 1950s and 1960s massive efforts to eradicate the disease were mounted in Asia and Latin America. The campaigns were initially successful, resulting in a reduction by 500 million of people at risk. However, in Asia and the Americas there has recently been a resurgence of malaria, as malaria parasites on all continents have developed resistance to the drugs generally in use to combat them (e.g., chloroquine) and as mosquitoes, which transmit the disease, have developed resistance to such insecticides as DDT and dieldren. The severity of the worldwide resurgence of malaria is causing grave concern. An effective new vaccine for control of malaria would provide new hope in relieving one of the world's leading health problems.

One of the AID-supported laboratories has made the most significant advance in malaria research of recent times: the continuous cultivation of the parasite *Plasmodium falciparum*, in human erythrocytes in vitro. AID network laboratories have also immunized monkeys against human malaria (*P. falciparum*) using cultured material as a source of immunogen. Those immunizations obtained varying degrees of protection. The current focus of the program is on purification and characterization, using the latest hybridoma and genetic engineering methodologies, of antigens that may protect against human malaria.

Other International Health Activities

In addition to malaria control, the United States has participated in a variety of other internationally focused activities. The following are illustrative examples:

- Over 250,000 preschool children in developing countries become blind each year from vitamin A deficiency. The United States has recently joined in an international effort to reduce that preventable form of blindness.
- Most developing countries do not have adequate information on the nature, extent, or causes of malnutrition to permit them to design effective nutrition programs. AID has developed and tested survey and surveillance methodologies for assessing nutritional status in the populations of developing countries.
- An international symposium was convened in Copenhagen in September 1981, under the joint sponsorship of NIH, the European Medical Research Councils (EMRC), and the World Health Organization (WHO), to foster international collaboration in health care technology assessment.

The energy challenge for the near future is to provide a healthy economy and a policy environment that enables citizens, businesses, and State and local governments to make rational energy production and consumption decisions that reflect the true value of the Nation's resources. Long-term research with high risks but potentially high payoffs will continue to receive Federal support. The sections that follow highlight trends in Federal energy research and development programs.

Science and Technology Related to Energy Production

Liquid Fuels

Petroleum will continue to be one of the Nation's major energy sources for many years. The difference between consumption and gradually declining levels of domestic production will continue to have to be made up by imports, unless other domestic supplies are developed, or conservation continues to drive down oil consumption. While the country has vast resources of coal, current national foreign energy dependence is primarily on liquid fuels.

The most significant long-range source of liquids for supplementing conventional petroleum is expected to be coal. Federal assistance helped to finance pilot-scale testing of several coal conversion processes that potentially offer significant improvements in efficiency over indirect and older direct liquefaction processes. Research efforts are now focusing on more advanced concepts that can achieve significantly higher thermal efficiencies by reducing the amount of steam, oxygen, and hydrogen required. Research is also under way to further characterize and test plant effluents to determine if available control technology is adequate. The effectiveness of different levels of upgrading in destroying harmful compounds that occur in certain direct liquefaction fractions (discussed later in this chapter) is under investigation.

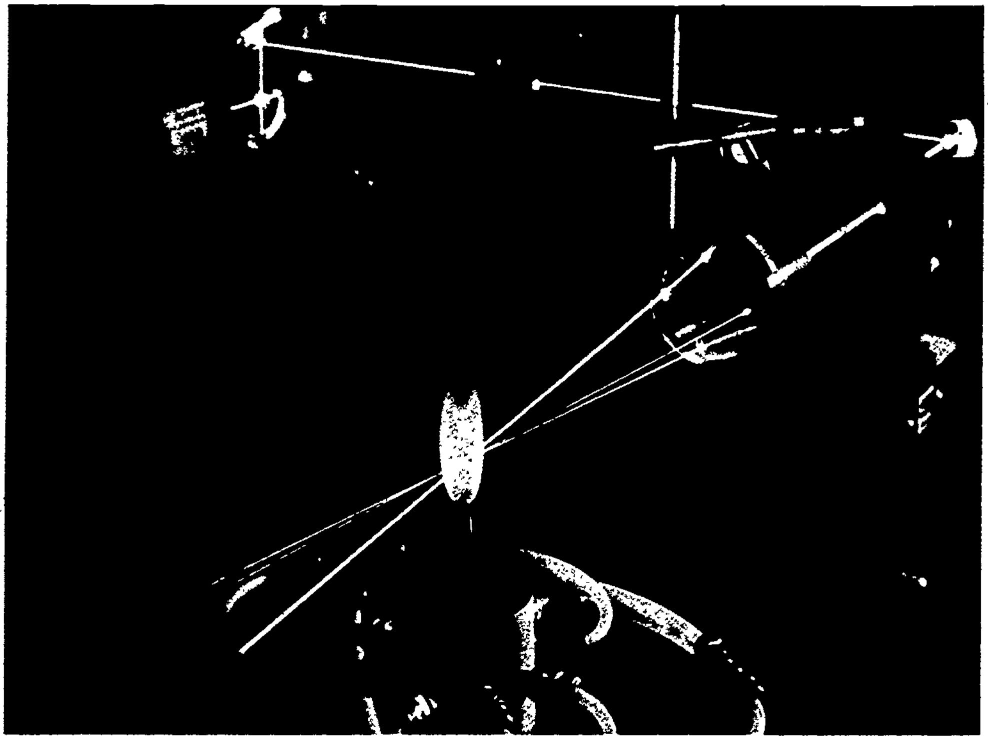
Oil shale is expected to be the most economical major source of synthetic liquids in the nearer term. An important aspect of the Federal research program is to help private industry obtain an improved understanding of the basic chemistry of oil shale retorting and the factors that affect control of the retorting process in order to develop advanced concepts for both surface and underground retorting processes. A significant component of the program is concerned with characterizing liquid and gaseous emissions, studying the long-term impact of solid disposal methods, and investigating potential problems associated with the abandonment of in-situ retorts.

Conventional petroleum techniques recover on the average only about one-third of the original crude oil in place. There are over 300 billion barrels of discovered, domestic oil that are a target for advanced recovery techniques. This may be the most economical approach for obtaining additional liquid fuel supplies in this century. Federal research efforts are focusing primarily on a fundamental understanding of how injectants designed to mobilize trapped oil perform under different reservoir conditions, with the objective of assisting the private sector in developing new injectants that can overcome problems of deterioration under reservoir conditions and bypassing significant pockets of oil in a reservoir.

Gaseous Fuels

Natural gas is the second largest source of domestic energy, accounting for 26 percent of all energy consumed and 30 percent of all energy produced in the United States in 1980. Anticipated declines in domestic conventional production in the 1990s of this clean, versatile fuel will increase pressure to import additional gas and oil.

Federal research support is concentrating on gas from coal and unconventional sources. An important aspect of the current surface coal gasification program is establishing, for different coals, the key mechanisms of coal behavior throughout a process in order to develop significantly improved concepts. Studies to determine materials that can withstand the extreme operating environments are being conducted. Effluents from advanced processes are being



U S Department of Energy

Laser Doppler Velocimetry is used to measure velocities in a diffusion flame. Scientists will be able to use such advanced lasers and computers at the Combustion Research Facility in Livermore, California, to study how and why fuels burn

analyzed to determine if controls are suitable or if gaps exist that can be filled by process modifications or new external controls.

Federally sponsored research and testing has created a substantial knowledge base applicable to the production of gas from Devonian shales, western blanket tight gas sands, coal bed drainage, and the gasification of underground coal seams. Recent Federal research has emphasized western lenticular tight gas sands. Researchers are seeking to develop the diagnostic tools necessary to measure the geological properties of underground formations, determine the resulting underground orientation of sand lenses, and achieve and determine the resulting location of fractures long enough to intersect multiple lenses.

Coal

Direct combustion of coal is expected to account for an increasingly large share of the energy consumed by industries and utilities. Federal research has sought to help private industry develop technologies that are sufficiently clean and economically attractive to displace oil and gas in certain applications or to provide a more efficient and environmentally benign alternative to existing coal technologies. The research has typically had a strong basic science component designed to augment the analytical tools and understanding available to the designers of combustion processes and equipment. Other combustion research activities include fundamental studies of fuel and sorbent behavior in order to extend fluidized bed technology to low-quality solid fuels, studies of the effects of burning coal-water mixtures, and research on advanced concepts to retrofit oil and gas combustors.

In addition to research on combustors with favorable emission characteristics, research is being performed on improved methods for cleaning stack gas emissions from conventional boilers. For such technologies as the pressurized fluidized bed combustor or the combined cycle gasifier that initially expand the combustion gases through a gas turbine, gas stream cleanup research is attempting to find improved ways to clean the gas before it reaches the turbine. Such gas stream cleanup research is also applicable to the molten carbonate fuel cell, which is being supported through Federal research and offers the potential of providing an extremely clean, modular source for electricity production.

Nuclear Power

In 1980, 75 nuclear plants generated more than 250,000 million kilowatt hours or approximately 11 percent of the Nation's electricity use for the year. An additional 92 plants now have construction permits granted or pending and, if completed, would raise peak nuclear output capacity from 56 million kilowatts to approximately three times that amount.

In accordance with the National Energy Policy Plan (NEPP), the Federal civilian nuclear energy effort is not intended to subsidize available technology or the appropriate private sector application of such technology. Rather, it focuses primarily on generic, long-range research and development undertakings that commercial enterprises (or even the industry as a whole) might not pursue on a pure investment basis, but which nevertheless are important to the country's mid-term to long-term energy future. The overriding Federal goal in regard to nuclear power (as for other energy sources) is to enable it to compete fairly in the marketplace.

For more than two decades, major breeder reactor research and development activities have concentrated on the liquid metal fast breeder reactor (LMFBR). LMFBR technology, as contrasted to other high-technology inexhaustible resource options, is well beyond the proof-of-principle stage of development and into engineering scale-up. The goal of the LMFBR research program is to develop the technology and engineering base to permit development of commercial breeder reactors. A sequence of developmental plants is required to permit an orderly scale-up of plant size and to provide the necessary focus for the development of breeder technology. Programs are under way to continue planned test operations of the Fast Flux Test Facility (FFTF) and to complete construction and operation of the Clinch River Breeder Reactor (CRBR) and other test facilities. Those plant projects will be supported by a base research and development program that provides the necessary engineering and safety analysis along with the technology improvements required for plant scale-up.

In an effort to develop technology that will significantly reduce the cost of uranium enrichment, research is being conducted on advanced isotope separation concepts. Three candidate processes—two laser isotope separation techniques and a plasma method—are being investigated. The results will lead to the selection in 1982 of one preferred process for engineering development toward an eventual demonstration facility and a production facility.

Renewable Energy Sources

R&D on renewable energy sources focuses on projects of a long-term, high-risk, high-payoff nature, which industry, given its choice of economic priorities, is unlikely to fund. Examples of program activities include:

- solar thermal technology research conducted in close cooperation with industry and others in the private sector;
- research to address production of a sufficient supply of appropriate biomass feedstocks to make conversion economically feasible without disruption of food and fiber markets, and the development of technologies to convert biomass to liquid and gaseous fuels and chemical feedstocks at competitive costs and in sufficient quantities;
- high-risk, high-payoff research to improve low-cost, high-efficiency photovoltaic energy systems; and
- R&D directed toward providing more reliable and cost-effective techniques for identifying and exploiting geothermal resources.

International Cooperation

Various Federal agencies have actively participated in such energy-related United Nations activities as the Conference on New and Renewable Sources of Energy in Nairobi in August 1981. U.S. policy has been to encourage competent analysis of potential applications of new and renewable energy sources to the energy balance of other countries and to identify means of overcoming barriers to the use of those resources. U.S. experts served on the eight technical panels that covered each of the technologies under consideration. The Energy Policy Institute of the Brookhaven National Laboratory provided scientific and economic expertise to the Conference Secretariat in preparing the synthesis of panel reports and the draft program of action for the meeting.

Energy assistance programs are being expanded to assist developing countries in addressing significant energy constraints to their development. The emphasis is on technical assistance activities for:

- analysis of needs, uses, resources, and policies;
- training and institutional development;
- site testing and demonstration of new technologies; and
- increasing energy supplies, both conventional and renewable, with significant attention to fuel-wood activities.

Involvement of the private sector and coordination and information exchange with other donors, the World Bank, and other multilateral organizations are being encouraged.

Research Base for Environment and Safety

Synthetic Fuels Production and Distribution Effluents

Coal and oil shale, the primary raw materials for synthetic fuels, are natural products, known to contain condensed ring structures. In synfuel production, coal and oil shale are heated, sometimes under pressure, to break down the megamolecules into smaller condensed ring structures called polynuclear aromatics (PNAs). Since PNAs as a class of compounds contain many known or suspected carcinogens, it has been important to know their ambient concentration levels and to estimate total exposure to human populations at risk.

With that information, Federal, State, and local officials concerned with air pollution can make the appropriate cost-benefit analysis commensurate with the degree of emission controls that may be required to minimize the risks of PNA exposure. In 1981, an interagency effort resulted in development of a miniature gas chromatograph (GC) that can conveniently monitor 10 preprogrammed organic compounds, including some environmentally important PNAs.

Other Energy Sources

Research on such health and environmental issues as diesel exhaust, the Clean Air Act, acid rain, low-level ionizing radiation, and indoor air quality is being conducted because of the potential impacts that health and environmental constraints can have on the cost and availability of energy.

Two successful demonstrations in removing sulfur dioxide through the combined use of limestone and small quantities of adipic acid have recently been completed. If that process proves successful from both technical and economic standpoints and does not create any new adverse environmental effects, it will be transferred to the private sector for utility, industrial, and commercial applications. An industrial-sized unit was tested at the Rickenbacker Air National Guard Base in Columbus, Ohio, and another evaluation was conducted at the Springfield City Utilities' Southwest Power Station in Springfield, Missouri. At the Rickenbacker site, a limestone wet scrubber increased in efficiency from 55 to 94 percent after the addition of a small amount of adipic acid. At Springfield, an average sulfur dioxide removal rate of 92 percent was attained; it had been 70 percent without adipic acid. Those successful demonstrations of adipic acid use in wet flue gas desulfurization suggest possible application in spray dryer processes. Further success would improve scrubber economics without adversely affecting sludge disposal methods.

Two-stage electrostatic precipitator (ESP) research is assessing and developing technology for effectively cleaning particulate fly ash from low-sulfur coals. Such particulate emissions are difficult to collect with conventional ESPs, but two-stage ESPs have not been used by industry because they suffer from reentrainment (the resuspension of previously collected dusts) and loss of particle-charging potential due to clogging of the charging electrodes. Two significant accomplishments in overcoming the critical clogging problem resulted from Federal research: invention of a tri-electrode precharger and a cooled precharger electrode. Both inventions are now in the pilot stage of development and evaluation.

Commercial Nuclear Waste Management

The problem of nuclear waste management and disposal is a primary issue yet to be resolved. Current policy is to assure that the capability for high-level waste isolation will be available when needed. Aggressive programs to support that goal are being conducted in all related areas of technology.

Technology is also being developed to immobilize high-level waste by converting it to forms that will provide added safety and economy of management and meet regulatory requirements for disposal. Since there are different categories of radioactive nuclear wastes—high-level, low-level, transuranic, and airborne—with differing characteristics, development of several waste forms is under way.

Regulatory research in fiscal years 1981-83 will focus on the mitigation of hazards from high-level wastes in deep repositories located in four types of geologic media: basalt, tuff, bedded salt, and domed salt. Studies on properties and acceptability of waste forms and containers, site suitability, and migration of radionuclides from shallow land-burial facilities for low-level waste will be conducted. In addition, there will be tests and studies on characterizing mill tailings and their byproducts; the pathways of toxic and radioactive materials from mill tailings, and their environmental impacts; and decommissioning techniques.

The use of nuclear material for electricity generation and for other industrial purposes is increasing inventories of nuclear wastes. In the mid-1980s, some reactors will be at capacity for storing spent fuel. That fact emphasizes the need for a nationally approved high-level waste repository. Capacity at the three low-level waste sites is also nearly used up. Thus, there is a need for new ways to reduce the size of incoming wastes and to locate new sites. Abandoned uranium mill tailing sites, contaminated by radon gases and toxic materials, have been exposed to the natural elements for years, in some cases creating a potential hazard to nearby communities. Also, currently active facilities have uncovered tailings piles with the potential for distributing radioactive and toxic materials through both air and water systems. Thus, the tailings must be isolated from the environment.

Nuclear Plant Safety

Most of the commercial power reactors operating in the United States today, and all of those under construction or planned, are light water reactors (LWRs). The LWR is a converter reactor, currently operating on the once-through fuel cycle. The Federal technical effort is directed principally toward improving LWR safety and lowering the probability and consequences of nuclear accidents. That objective is met through development of improved plant and systems designs, operating techniques, and data and risk analysis. A complementary effort is to assist in the cleanup of the Three Mile Island (TMI) plant. One of the benefits of TMI remedial action will be additional understanding of the accident, which should lead to reinforcement of safety standards and practices and improvement of postaccident recovery operations.

Energy-Supporting Research

Basic Energy Sciences

Energy-related research is sponsored in the materials, chemical, and nuclear sciences, in biological energy; in engineering, mathematics, and the geosciences, and in advanced energy projects. In addition, there is an emphasis on innovative applications of new knowledge to energy problems and on the early application of the results.

More than 1,000 projects are supported under the basic energy sciences program. While the primary results of most long-term, high-risk research are not immediately exploitable, there have been some recent accomplishments:

(1) A solar-stimulated photochemical reaction provides a practical solution to a major problem preventing large-scale application of heat to drive a series of chemical reactions to split water into its components, hydrogen and oxygen. The photochemical reaction can substitute for the step in a sulfuric acid cycle yielding hydrogen, for which no satisfactory thermally driven reaction has yet been found.

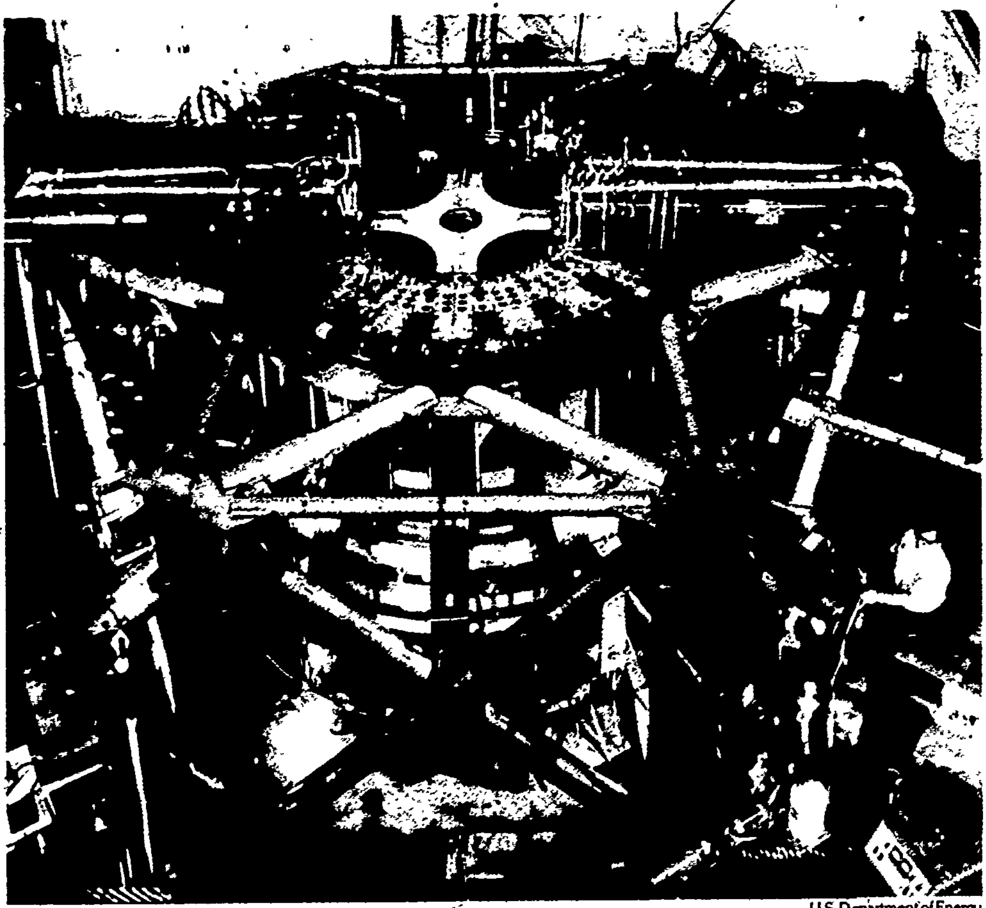
(2) The "fabricability," and hence the industrial application potential, of a class of materials called intermetallic compounds has been increased. Intermetallic compound atomic configurations are ordered arrays that are more difficult to deform without fracture than are metallic alloys of the same atomic composition but having a random atomic arrangement. One such compound, Fe_3Si, is used extensively for corrosion-resistant piping and for other components for the chemical industry. Research on the structure of materials resulted in a procedure by which the composition was modified so that a desired ordered phase was formed in a solid-state phase transformation after cooling to facilitate extrusion. The ability to make thin gauge and clad products could have important new applications in the automobile and coal industries.

(3) A new technique for seismic study of underground structures has already attracted strong interest from oil company geophysicists. The technique features a pneumatically driven oscillating piston suitable for producing either compressional or shear waves at any desired depth in an exploratory hole. A major advantage of the periodic source is that each pulse develops as much energy to the geophones as a 5 gram explosive shot. The ability to add 400 to 700 individual pulses in 10 seconds results in a seismic signal far stronger than that of the explosive charge without damaging the borehole. The new hardware is complemented by special methods for mathematical analysis of the measurements from detectors placed around the hole at the surface. Major improvements in defining underground structures in oil fields appear possible.

(4) A major nuclear data measurement effort produced a new and definitive determination of the average number of neutrons emitted per fission for the spontaneously fissioning, manmade isotope, Californium-252. Because Californium-252 is used as a standard against which measurements for other fissioning isotopes are made, the new measurement has immediate impact upon reactor fuel-cycle costs. For the commercial light water reactors, it has been estimated that additional costs attributed to the previous uncertainty in that measurement have been more than one-quarter of a million dollars for each fuel loading in each reactor.

Fusion

Great progress has been made in magnetic fusion research and development. One of the past year's major accomplishments was the demonstration of current drive in the Princeton Large Torus using radio frequency wave energy. The existence of a current in a tokamak reactor is essential to maintaining the stability of the plasma. Driving toroidal current by means of radio frequency waves may allow steady-state tokamak operation rather than present-day pulsed operation and could drastically reduce the power required for current maintenance. Both improvements could have significant positive effects on the economic projections for tokamak reactors.



US Department of Energy

The Princeton Large Torus, an advanced tokamak device, has demonstrated that generation of a substantial electric current within a confined plasma by means of radio frequency waves is feasible.

The principle of the tandem mirror concept was demonstrated at Lawrence Livermore National Laboratory. The experiment showed improvement in confinement parameters as a function of ion energy 100 times better than that of single mirror cells. Proof of that principle strengthens the fusion program in two ways: it confirms the basic design principle of the large tandem mirror fusion test facility under construction at Lawrence Livermore, and it provides the basis for a strong mirror confinement reactor candidate in addition to the tokamak concept.

Soon after initiation of the poloidal divertor experiment with beams, 8 megawatts of neutral beam power were introduced into the experiment's plasma; 5.5 megawatts were absorbed by the plasma, raising the ion temperature to approximately 70 million degrees. Such rapid availability, combined with the basic purity control capability of the poloidal divertor, has provided a powerful tool that will now be used to study reactor plasma.

Quiescent operation of the ZT-40 device at Los Alamos National Laboratory was extended from 0.2 milliseconds to 3 to 8 milliseconds along with a hundredfold improvement in confinement parameters. That change provided experimental confirmation of theoretical work on the reversed field pinch—an approach to reactor conditions that emphasizes high-efficiency plasmas and has possible advantages in some areas of technology.

Another project involved the operation of a new, very powerful steady-state microwave heating tube. A 28-gigahertz, 200-kilowatt gyrotron was developed at

Oak Ridge National Laboratory and set a world power record (by a factor of 200) for a carrier wave tube. That permitted successful scaling experiments on the Elmo Bumpy Torus-S (EBT-S), the leading alternate concept machine.

In two instances, radio frequency wave heating has been applied successfully to toroidal and mirror plasmas. Over 1 megawatt of radio frequency wave heating was applied to the Princeton Large Torus at high efficiency and with no plasma degradation. The phaedrus tandem mirror experiment at the University of Wisconsin was operated successfully using radio frequency waves at the ion cyclotron frequency, without neutral beam heating. Those two demonstrations indicate that radio frequency heating is an attractive alternative for heating plasmas to reactor conditions. Because plasma-heating equipment is a dominant cost element in reactor systems, developing cost-saving alternatives is of considerable importance to the fusion program.

Two innovative advanced technology concepts have been successfully demonstrated: a radio frequency, quadruple-focusing accelerator now being used in other accelerator applications and a flowing lithium target used primarily for a materials-testing device. Those advances constitute a large part of the research and development necessary for a major testing facility based upon the deuterium-lithium reaction.

The activity of the Federal Government in providing a balanced program of support for fundamental scientific research is an essential ingredient in the development of our knowledge base—the reservoir from which we draw for the development of mechanisms and products to satisfy a variety of human needs and to stimulate industrial innovation and productivity for economic growth. Maintaining and nurturing the U.S. scientific enterprise and its underlying infrastructure are important elements of our national science policy.

Expanding the Science and Engineering Knowledge Base

During the past year, research supported by the Federal Government and carried out in university, industry, and Government laboratories has continued to produce new knowledge and insights. Such advances are expected to expand our view of the universe and to benefit society. Some of the major new findings are described below.

Life Sciences*

We are in the midst of a biotechnical revolution; new discoveries and valuable new techniques are being announced with great frequency. Two aspects of biotechnical research have already made enormous impacts in a remarkably short time—monoclonal antibody production and recombinant DNA technology. The new techniques provide insight into long-standing and fundamental questions about living organisms. Dramatic opportunities exist for new vaccine development and for the treatment of disease, and major breakthroughs in the understanding of gene regulation, facilitated by modern recombinant DNA technology, are expected to result ultimately in applications leading to improvements in food quality and in the increased physiological efficiency of crop plants. Examples of recombinant DNA applications can be found in the sections of this chapter on health and agriculture.

Biological methods of pest control recently have received much attention because of the major economic consequences of pest infestations, particularly of crops, and the increased costs and hazards of petroleum-based pesticides. Studies of the reproductive systems of insect pests are leading to improved understanding of possible methods for sterilizing insects and thus controlling the damage they do.

Earth and Atmospheric Sciences

Research in the earth and atmospheric sciences has broad potential, both for furthering our understanding of natural phenomena and for improving our interactions with the environment. For example, federally supported research in Antarctica provides data essential for analyses of the global environment and assists in evaluating the region's potential as a source of renewable and nonrenewable resources. The U.S. Antarctic Research Program includes approximately 85 research projects annually, involving some 300 scientists and 700 support personnel. They are doing research in biological and medical sciences, upper atmosphere physics, meteorology, glaciology, geology, and ocean sciences. Published research results have formed a highly cited core of literature on magnetospheric and ionospheric processes, atmospheric chemistry, plate tectonics, and the adaptations of organisms to extreme environments.

The international Deep Sea Drilling Project, using the drillship *Glomar Challenger*, has collected deep sea cores for scientific research purposes from all over the world, thus providing greater understanding of the earth's crustal motions and internal stresses. During the past year, tests using a marine seismometer system lowered into a drillhole 1,700 feet below the ocean floor were conducted successfully. That accomplishment is a significant development in earth sciences research, providing critical

* Additional information pertaining to research in the life sciences can be found in the section on health in this chapter.

data that will expand our understanding of the dynamics of the earth and its crustal movements.

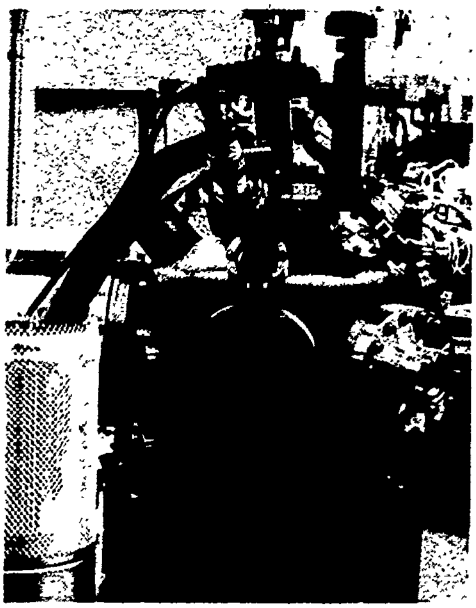
In the atmospheric sciences, a new and promising application of existing technology involving stratosphere-troposphere radars has resulted in horizontal and vertical wind (velocity) measurements with time and altitude continuity through the troposphere and lower stratosphere. That unique measurement capability, with much improved time resolution, will not only extend the base of knowledge in dynamic meteorology, but it also should permit cost-saving applications for weather service groups and air carriers (e.g., real-time tracking of atmospheric motions, including the jet stream).

The Global Weather Experiment, an element of the Global Atmospheric Research Program (GARP), concluded field operations in late 1979 and has now nearly completed final data processing and archiving. This comprehensive international research effort, in which the United States has played a lead role, has analyzed early sets of data in detail and gained a substantially improved understanding of large-scale weather patterns.

Physical Sciences and Mathematics

There has been a broad range of recent accomplishments in the physical sciences. For example, in a project involving industry and the Special Research Reactor of the National Bureau of Standards (NBS), an important new measurement method for characterizing metallic oxide surfaces has been developed. It uses angle-resolved photon stimulated desorption (PSD) to identify pathways for significant chemical reactions on the surfaces of materials. The method is expected to clarify and, potentially, help solve important problems related to substance corrosion, catalysis, and semiconductor device processing.

Other research efforts in the chemical sciences focus on energy applications and explore the effects of liquids, gases, and plasmas on the behavior of submicroscopic particles. For example, laser analyses of phenomena occurring in combustion systems are now being provided to users at a



National Bureau of Standards

Equipment used in studies of the photon stimulated desorption of ions from surfaces at the National Bureau of Standards' Synchrotron Ultraviolet Radiation Facility (SURF II).

new and unique Combustion Research Facility (CRF) at the Sandia National Laboratory, Livermore, California.

The past year witnessed significant progress in materials-related research. One of the more interesting and exciting areas involves the study of systems of reduced dimensionality. In the past, most materials research dealt with the bulk (volume) properties of matter. It is now possible to prepare and study specimens whose dimensions in one or two directions are so small (i.e., monomolecular layers) that the normal properties and phenomena of bulk no longer pertain. For example, the consequences of reducing the diameter of a metal wire on its conductivity are so profound that such specimens behave more like insulators than metals at low temperatures. In an era when the electronics industry is striving to develop devices whose primary elements are in the submicron size range, the practical importance of such drastic property changes may be extremely significant.

Additionally, scientists are exploring the properties of materials called compositionally modulated alloys. A thin film, consisting of two elements (for example, copper and nickel), is vapor-deposited in such a way that the composition varies in a continuously modulated manner across the thickness of the film. The wavelength of the modulation is typically 2 to 5 nanometers, or 20 to 50 atoms. Such films have unusual mechanical and magnetic properties. Both the elastic modulus and magnetization of the modulated structures are appreciably greater than those of either element. These observations suggest a number of interesting technological possibilities; among them are improved superconductors, membranes with a high modulus of stiffness, bulk materials with enhanced elastic moduli, and corrosion-resistant material surfaces.

High-energy physics is an exploratory field of basic research in which experimental and theoretical studies are conducted on the fundamental constituents of matter and the fundamental forces of nature in an attempt to understand energy and matter and their transformations. In recent years, great progress has been made toward understanding the forces of nature and the ultimate structure of matter, with its basic constituent quarks and leptons. In achieving those new levels of knowledge, U.S. high-energy physicists have won three Nobel Prizes in physics during the last 5 years.

Highlights among recent accomplishments in U.S.-based high-energy physics include: the discovery and confirmation of a new heavier kind of lepton (1975-78); the discovery of evidence for a new heavier kind of quark (1977-80); the completion of construction of PEP, an electron-positron colliding beam facility (1980); and the direct observation of the lifetime of particles containing "charmed" quarks (1980-81). Furthermore, U.S. physicists working at European research facilities were prominent in the discovery of evidence for the gluon, believed to hold nuclear matter together (1979-80).

In the fields of astronomy and astrophysics, the Very Large Array (VLA) radio telescope has been particularly productive. Its daily maps, with sensitivity and resolution exceeding those of other radio telescope arrays by one or two orders of magnitude, have led to important discoveries about radio stars, interstellar gas clouds, supernova remnants, galaxies with active nuclei, and quasars.

Engineering

There have been many major achievements in the engineering sciences in recent years. For example, in civil engineering, the methods of analysis and numerical simulation far exceed our knowledge of material properties and of the operative environmental influences. As the characteristic dimension or scale of engineering projects continues to increase, so does their difficulty. With such new processes as deep earth injection of hazardous wastes and the building of artificial islands for Arctic oil exploration and production, the scale and difficulty are even greater. Accordingly, there is increasing need for physical simulation of larger, more representative models and for the collection of corroborating field data. In response, a process of "modeling of models" is now being employed. The technique has been applied to the determination of wave spectra as they relate to offshore structures, wind-loading effects on structures and on water circulation patterns, and "keel-dragging" effects of ice on ocean floor pipelines.

Among the most prominent of such modeling approaches is the Federal Government's Earthquake Hazard Mitigation Program, which aims at reducing the adverse impact of earthquakes on existing and new facilities. The following are examples of recent advances accomplished with Federal support:

- By employing contained explosives, earthquakelike ground motions can be generated under controlled conditions and with a high degree of safety.
- A series of research projects is examining the potential hazard to existing facilities from earthquakes. One project has produced a computer-based procedure for examining the hazard potential for structures over four stories high.
- Methods are being developed to predict the nonlinear behavior and deformations that would occur in particular

structures vulnerable to earthquakes. Parallel with those analytical efforts are experimental studies to provide verification of analytical predictions.

Chemical engineering research in the United States is of increasing importance to the resolution of a number of national problems in such areas as synthetic fuels, minerals, and renewable resources. In addition, a portion of chemical engineering research has recently been focused on methods for reducing processing energy consumption and on better technologies for environmental controls associated with chemical processes.

The chemical industry is capital intensive, with large and expensive equipment. Considerable research effort is being devoted to finding ways to reduce expenditures for new plants. For example, a university group is working on unique and cost-effective methods for producing cobalt from low-grade ores. Others are taking new looks at methods for separating chemicals from feedstock, because distillation processes use about 3 percent of the energy consumed in the United States.

Chemical engineering research also is concerned with such areas as catalysis and particulate and multiphase processing. One mineral industry concern is the low efficiency of mineral crushing and grinding operations. Because such operations consume about 2 percent of all U.S. electric power, research is being encouraged to reduce their energy use.

Other Federal programs in chemical engineering have been initiated to provide the chemical process industries with improved measurement techniques, engineering data, and predictive methods to enable improved process design, monitoring, and control, especially as those industries convert from heavy reliance on petroleum and natural gas feedstocks to more readily available and less expensive alternatives. Emphases are on fluid engineering, thermal processes, and thermophysical properties of materials.

In the fields of electrical, computer, and systems engineering, a great number of advances have occurred. Research on high-frequency communication systems has been devoted to extending the performance of detectors by evaluating fundamental relationships between material and devices that require submicron lithographic capability. Extensive use has been made of the National Research and Resource Facility for

National Submicron Facility

A researcher operates the Electron Beam Lithography equipment at the National Research and Resource Facility for Submicron Structures at Cornell University. Industry as well as university scientists use this equipment.

Submicron Structures. Significantly improved detectors have potential scientific applications in, for example, radio astronomy, as well as commercial applications in, for example, large information capacity communication systems.

Standard protocols are being developed to enable computers, terminals, and special purpose computer systems to be interconnected and to work together. Those protocols will greatly assist users in constructing networks from commercially available equipment and in using the programs and other resources available in such a networking environment.

Related efforts, aimed at increasing industrial productivity through new measurement capabilities, have involved using a prototypical system as the basis for hierarchical control of an automated manufacturing research facility. Incorporated in a distributed network of microprocessors linked in hierarchy to a larger computer, the system now controls a single robot with sensory capabilities. In large scale, the system will control combinations and groupings of robots and metal-cutting machines.

Information and Communication Sciences

Information science and technology are in a period of revolutionary change and growth. Computer and communications technology have converged to provide a new capability for distributing and utilizing information in all forms—print, film, digital, analog, and video. Those powerful information technologies constitute an indispensable part of the web of knowledge that links our society and enables it to carry out more effectively our social, governmental, and business transactions. Research in information science and technology covers the broad range of scientific disciplines that form the basic elements of the new information technologies, including mathematical, computer, and econometric modeling; the analysis of and experimentation with hardware and software systems; and such related fields as cognitive science, linguistics, and economics. One of the most challenging goals is to increase the productivity of workers by augmenting human performance through the power of information-intensive machines, just as previous technologies have supplemented and replaced human muscle power.

New applications for data communication services coupled with deregulation of the telecommunications industry have created an urgent need for uniform methods of specifying and measuring the performance of data communication services as experienced by the user. Over the past 5 years, standards groups from the Federal Government and industry have been working together to meet that need by developing user-oriented, system-independent performance parameters and measurement methods. Results are being promulgated in the form of Federal Telecommunication/Federal Information Processing Standards and, in industry, in the form of American National Standards. Two related data communication performance standards have been developed. They should promote innovation and fair competition in the data communications industry by providing users with a practical method of measuring delivered performance, thereby enabling users to make more intelligent choices among alternative services and equipment. In many cases, the standards will lead to more realistic communication requirements, with a consequent significant savings in cost.

The Scientific and Technological Infrastructure

A highly competent and productive scientific and technological community provides a great resource for furthering the Nation's progress toward a wide variety of national goals, among them national security and economic development. The effectiveness of that resource, in turn, depends on the status of its infrastructure. That includes such elements as the quality of its personnel and the effectiveness of research and development support mechanisms, including mechanisms for transferring or communicating information among the members of that diverse community and between the science and technology community and the industries and service providers that use the information generated. A wide variety of mechanisms for maintaining and further developing that infrastructure exist. They include a broad range of activities and initiatives carried out by all levels of government and by the private sector. Discussions of many of these activities and initiatives appear elsewhere in this report, including several sections in chapter II, and in other sections of this chapter, for example, those on health and education. Below are some highlights of recent activities and new initiatives related to the maintenance and development of the scientific and technological infrastructure.

The Adequacy of Science and Engineering Personnel

For the science and technology enterprise to function in the most efficient and productive ways, it must have a strong base of high-quality participants. Not only must there be general competence, but there must also be adequate numbers of personnel trained in specific fields of need. Many of the programs for providing highly trained personnel with relevant skills are discussed in other portions of this report, including chapter II and the sections on national security and education elsewhere in this chapter. Although the primary responsibility for education in science and engineering lies with State and local governments, in some cases, such as those related to national security needs, Federal intervention has been deemed necessary. For example, the Department of Defense has instituted a program of fellowships that will support graduate students in those science and engineering fields of most direct interest to the military and national defense-related industries.

Innovative Support Mechanisms for Research

The mechanisms through which research grants are administered have long been considered important to the success of those projects, and those mechanisms are constantly being reviewed and improved. Changes in the grant and contract system are now being evaluated by a variety of Federal agencies.

For example, an experiment in research grant administration is being carried out at 12 academic institutions. The experiment aims to improve Government-university relationships and the effectiveness of federally supported research projects. It has been argued by some that, in the past, methods of funding research projects have relied too heavily on assumptions carried over from the Federal procurement system; the current project support system has a tendency to fragment research into individual projects and lacks stability and consistency over time. Thus, the National Science Foundation (NSF) is conducting an experiment that delegates to universities additional postaward authority in allocating funds. In the experiment, Government's role during performance of the research is reduced, but its role in making scientific or technical judgments on the merits of individual proposals, as well as its utilization of the peer review process, is not diminished. As a second example, the Department of Defense has been experimenting with a simplified contracting agreement that could reduce the time it takes to award contracts from 90 to 45 days.

Technology Transfer Programs

Concern has developed over the Nation's international technological position. Increased foreign competition in high-technology fields threatens U.S. markets at home and abroad. A variety of mechanisms for improving the U.S. position are discussed in chapter II. The mechanisms include facilitating the use of information derived from scientific and technological research in the development and commercialization phases.

One mechanism that may foster such transfer is the U.S. patent file. More effective domestic use of the patent file as a technological information resource could help increase the pace of innovation in

U.S. industry, improve the national technological infrastructure, and stimulate the economy. The patent file maintained by the Patent and Trademark Office contains 23 million U.S. and foreign patent documents classified into 110,000 technological categories. That immense resource of technological information forms the base for a coordinated program, involving public libraries, private sector information vendors, and government agencies, to promote wider, more effective utilization of the technology disclosed in patents.

The patent technology transfer program involves a three-pronged approach. The Nation's growing network of Patent Depository Libraries (now numbering 37) is being strengthened. The Patent and Trademark Office (PTO) and the National Technical Information Service (NTIS) are cooperating to help private information services obtain patent information and to encourage them to begin or expand their existing patent information services. Specific efforts at the PTO (through the Technology Assessment and Forecast program) and at NTIS (through the Applied Technology and Patent Information program) are being geared to increase public awareness and provide directly a range of patent information products and services.

Industry-University Cooperation

Fostering the creative interaction of university and industrial researchers is another of the components of the Federal Government's efforts to increase the flow of scientific knowledge and ideas and technological innovations between academic and industrial sectors, to increase the sensitivity of university researchers to industrial needs and perspectives, and to encourage industrial support for the academic research infrastructure. Ultimately, the effort is intended to improve the productivity of U.S. industry through application of university research results, as well as to strengthen the base of support for academic science.

The industry-university cooperative research center mechanism is being examined in a number of scientific and technological areas. Centers are jointly funded by industrial firms and the Federal Government, with the Government's share declining over a 5-year period until the centers are fully supported by industry. Currently, four centers are in operation: in welding research, applied polymer science, computer graphics, and basic polymer science. Those centers appear to be highly successful in meeting their objectives. Each center includes an evaluative component, and progress in meeting program goals will be carefully monitored and assessed. Several prospective centers have received planning grants, and studies of the research needs of industry and the possible utility of centers in various areas of basic and applied science and industrial technology are under way.


Ohio State University
An automated welder at the University/Industry Cooperative Research Center at Ohio State University.

Federal Laboratory Program

The Federal Government, through various agencies, operates some 750 research and development laboratories and centers throughout the United States. They employ more than 200,000 scientists and engineers. Those laboratories and centers form a vast public resource for science and technology, which, if properly utilized, could have a significant impact upon productivity and the economic health of both the public and the private sectors of the Nation. The Federal Laboratory Program was established to design, develop, and implement, on a systematic basis, mechanisms to transfer the results of federally sponsored research and development to meet the needs of the private sector, State and local governments, and colleges and universities.

For example, technical personnel from the Navy's Underwater Systems Center were assigned, under provisions of the Intergovernmental Personnel Act, to the federally supported New England Innovation Group. Those scientists and engineers, working as technical advisers to New England cities and towns, provided assistance in such diverse areas as designing community energy plans, developing online information retrieval systems, and helping the State of Rhode Island develop a statewide cable television system. In another area, the Federal Laboratory Consortium assisted the Department of Commerce's Office of Minority Business Development in identifying and transferring a medical device to a small firm.

There are extensive scientific and technological programs in the various Federal agencies with responsibilities for managing and monitoring the Nation's natural resources. Those programs provide new technologies to support the wide range of duties of the Nation's natural resource managers. Federal natural resource responsibilities are considerable. For example, much of the Outer Continental Shelf (OCS) is under Federal control, and almost 30 percent of the entire U.S. land area is federally administered public land.

The inception of the new Administration's programs early in 1981 brought a philosophical change to the natural resources area. Rather than trying to solve national problems through extensive Federal programs, the decision was made to rely wherever possible on the private sector for natural resources development. As one means for achieving both that goal and the related goal of increasing private sector innovation and productivity, a cabinet-level review was initiated to determine which Federal regulations were unnecessary and impeded private sector development of our natural resources. Extensive regulatory reforms are expected in the coming years.

A second guiding premise of the Administration's policies is that many functions previously held by Federal agencies really belong to State and local governments. In the natural resources area, the objective becomes reduced Federal involvement, which has led, for example, to revisions of surface mining reclamation policies. Those new policies reemphasize State responsibilities, in keeping with the original intent of Congress. For example, the States will be expected to support research efforts dealing with their own water resource problems and development projects.

Ocean Resources

As part of its comprehensive review of policy matters, the Administration announced in March 1981 that it was conducting a review of the draft Law of the Sea treaty, presently under international negotiation. The Administration believes that the treaty provisions concerning international control over the mining of mineral-rich nodules on the ocean floor are not in our national interest because, in part, of the limitations that would be imposed on deep seabed mining by private consortia. Discussions to explore a satisfactory compromise on this issue are getting under way. The United States has played a dominant role in developing the technology to exploit the ocean's mineral resources. To allow U.S. industry to proceed in an orderly manner to develop ocean mining while the Law of the Sea treaty issue is being resolved, Congress passed the Deep Seabed Hard Minerals Resources Act (P.L. 96-283) in June 1980. That act charges the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) with responsibility for developing interim regulatory procedures for U.S. ocean mining activities. Final regulations were issued in mid-September 1981.

One of the major highlights of 1981 ocean research activities was the discovery of several new ocean mineral deposits in the Pacific Ocean. Government scientists reported finding a large deposit of copper and other strategic metals on the Pacific Ocean floor west of Ecuador; similar lodes were reported off Oregon and probably exist off Washington. Researchers from the U.S. Geological Survey found significant

U.S Department of the Interior, Geological Survey

The U.S. Geological Survey research vessel, S.P. Lee, took this sulfide sample from the Juan de Fuca Ridge during a recent cruise.

amounts of copper, lead, zinc, and silver in ore samples taken in 7,000 feet of water from the Juan de Fuca Ridge in the Pacific Ocean, 250 miles west of Astoria, Oregon.

According to NOAA's National Ocean Survey, the discovery west of Ecuador is probably one of the richest mineral deposits found anywhere in the world. Conservative assays of samples returned by the research submarine *Alvin* show the deposit is 10 percent copper and 10 percent iron, with lesser amounts of silver, zinc, cadmium, molybdenum, lead, tin, vanadium, and cobalt. French scientists also believe that gold might be in some of the mineral samples. The deposit is marked by a forest of chimneylike cones and is judged to be at least 130 feet thick, 650 feet wide, and 3,200 feet long. It is in 8,250 feet of water and lies along a normal fault of the rift valley of the Galapagos Ridge, 240 miles east of the Galapagos Islands and 350 miles west of Ecuador.

A number of new and varied research efforts in marine resources development and marine observation and prediction are under way. Research on living marine resources is performed by the National Marine Fisheries Service (NMFS) in four broad areas: the conservation and management of marine fisheries, protection of marine fisheries habitats, protection of marine mammals and endangered species, and the economic development of the U.S. fishing industry. The research is performed at four research centers and 22 laboratories.

Forest Resources

Management of the National Forest System is carried out by the Forest Service. Research is conducted at eight Regional Forest Experiment Stations and a Forest Products Laboratory at Madison, Wisconsin. Research programs are also under way at 81 locations in the United States and the territories. Nearly 950 scientists are involved in roughly 4,000 studies. Those studies serve a broad constituency beyond the Forest Service, including other Federal land management agencies and State and private resource managers and users. Among the highlights of research efforts in 1981 was the continued development of a method to form paper out of such short-fibered trees as oaks and other hardwoods. Substituting hardwoods for softwoods in paper production can increase the supply of softwoods available for such other purposes as housing construction. Pilot plants to test the new technique are now being established.

Another major development in forest management is the improvement of productivity of loblolly pine forests through biological research. Genetic research combined with other management controls is providing important increases in loblolly pine yields. Since the turn of the century, loblolly forest yields have risen from 75 cubic feet per acre to as much as 200 cubic feet per acre on experimental plots. Over 80 million acres of U.S. forests, mainly in the South and on private lands, are loblolly pine, and their yields are increasing annually as the new technology is introduced.

In forest products research, a new, powered backup roller has been developed to lessen the losses when logs are being peeled to make plywood veneer. The power roller prevents logs from spinning out of the chuck as they are being stripped and will contribute to reducing production losses, currently estimated at 5.7 percent in the plywood industry. Boise Cascade is installing the newly developed system on a production basis.

Strategic Materials Policy

An area of great concern and a primary objective for the Administration is the development of a strategic minerals policy that will lessen U.S. imports of such minerals as chromium, manganese, cobalt, and the platinum-group metals. At the Federal level, a Cabinet council working group has been examining strategic minerals policy issues in depth, including mineral and materials research and development policies. The first report is expected to be forwarded to Congress in early 1982. The issue review is expected to stress the major role that technical innovation has historically played in the minerals area. It also will likely emphasize the need for a favorable atmosphere to encourage private sector involvement, greater cooperation between industry and Government to foster technological innovation, and the need for Government to support long-term, high-risk technology that will have application to a wide variety of material problems.

Remote Sensing of Natural Resources

The use of satellites to provide remotely sensed data has had a wide variety of uses in determining the extent of the Nation's natural resources. The experimental Landsat series of satellites, initiated in 1972, continues to be the principal civilian means of satellite sensing of land natural resources. Early in 1979, a policy was established committing the United States to the continuity of land remote-sensing data for the balance of the 1980s and to an operational land remote-sensing system similar to those that presently exist for communications and weather-monitoring satellites. Details of the plans for such an operational civil remote-sensing plan were released in November 1979. The plans give NOAA the management responsibility for the operational use of remote sensing, stating that a major U.S. goal is the eventual operation of civil remote-sensing activities by the private sector. Plans call for the civil remote-sensing system to be turned over to the private sector by the mid-1980s, if not sooner. During 1981, draft legislation to assist the changeover was prepared by NOAA and reviewed by other Federal agencies. Congressional hearings were held in late July 1981. At those hearings, a private corporation proposed a plan to restructure and unify the land and meteorological systems under its management; the proposal is under consideration.

Landsat satellite data have by now been used extensively in a wide variety of natural resource applications. Some of the highlights in 1981 were:

(1) A U.S. Geological Survey (USGS) project combined Landsat data with digital terrain data for a study site in a national forest in western Montana. The combined data served as input to a Forest Service mathematical fire simulation model that could assist in predicting site-specific spread of forest fires.

(2) A joint USGS/Corps of Engineers project used Landsat data to evaluate the growth in irrigation agriculture practices over the period 1973-79 in the Umatilla River Basin in north-central Oregon. That study allowed the Corps of Engineers to assess the annual expansion of irrigated land and estimate future water and power needs in the region—information essential to proper planning.

(3) A joint USGS/Bureau of Land Management project used Landsat data to produce a set of map overlays for a site in Arizona. The map overlays would permit land managers to identify specific locations suitable for firewood collection, wildlife reestablishment, and range improvements.

(4) In late 1980, NOAA conducted a major cooperative scientific experiment on the use of remote sensing to measure ocean waves off the North Carolina coast. Collaborators included representatives from Federal and State governments, universities, the private sector, and four foreign countries. Improved methods for protecting coastlines from erosion, designing offshore structures, and forecasting wave and surf conditions are expected from the analyses made during 1981.

Weather

NOAA's scientific efforts are conducted primarily by its Office of Research and Development, which has major programs in the weather, marine, and solar-terrestrial areas. Current research on weather observation and prediction includes the development of computer models of various atmospheric phenomena, as well as the development of such specialized observing and measuring systems as laser radars, research aircraft, satellites, and automation of surface observations. As better predictive tools are developed for severe weather and climate conditions, the techniques are transferred to the National Weather Service for application. Other research in 1981 includes a weather modification study known as the Florida Area Cumulus experiment, in which tests are being made to determine if massive randomized seeding of cumulus clouds can produce a net increase in rainfall over a large area.

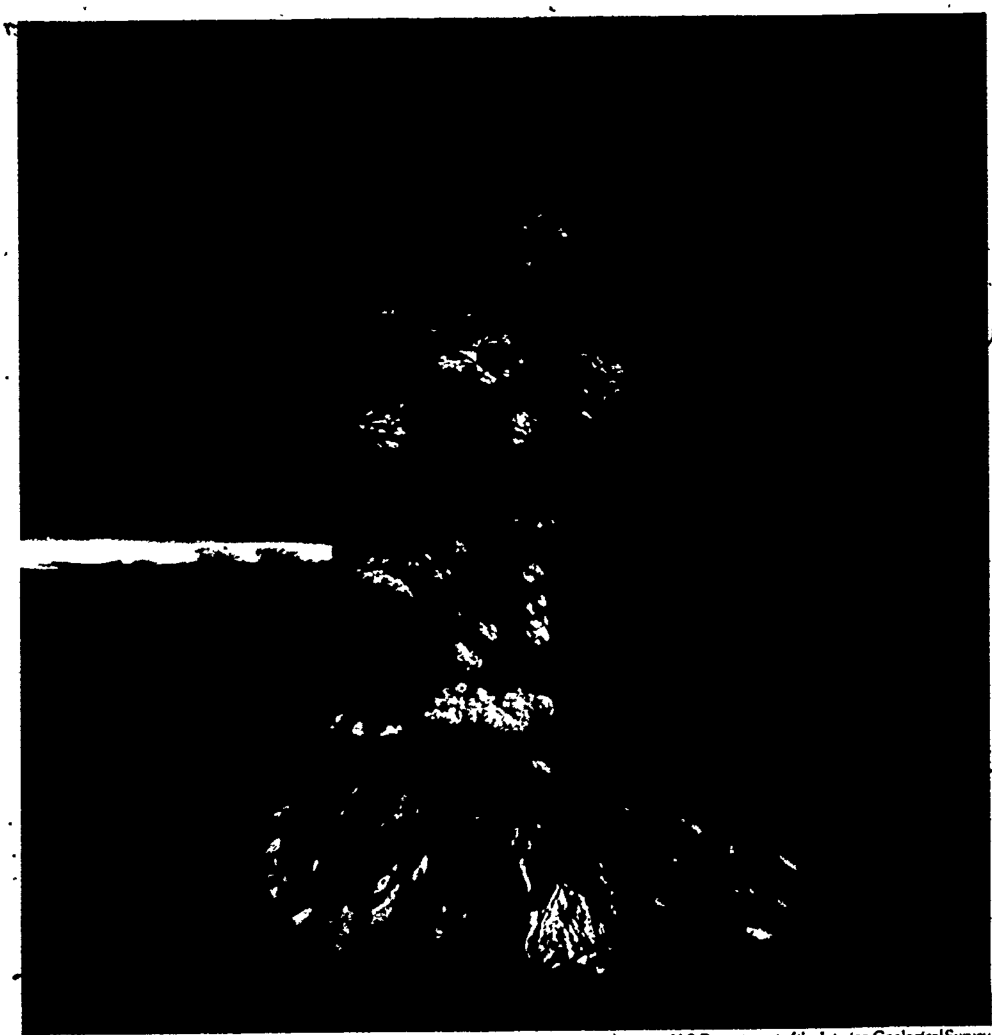
Natural Hazards

One of the Federal Government's primary responsibilities is to provide timely warnings to the public about natural hazards, ranging from such frequent events as hurricanes and tornadoes to such rare, catastrophic events as the May 1980 eruption of Mount St. Helens. NOAA's environmental satellite systems are tools used by the National Weather Service to provide timely alerts of severe weather and oceanic conditions. The Department of the Interior's USGS has the responsibility of warning the public of natural hazards caused by such geologic actions as earthquakes, landslides, volcanic eruptions, and subsidence.

Through a natural hazards program established formally in 1977, USGS has acquired the Federal responsibility to alert the public to imminent geologic hazards, as was done in the case of Mount St. Helens. In late March 1980, University of Washington seismologists working with USGS scientists detected swarms of small and moderate earthquakes near and below Mount St. Helens. The USGS's National Headquarters in Virginia contacted and daily briefed interested and responsible Washington State and Federal agencies. Field headquarters were established in Vancouver, Washington, about 45 miles from Mount St. Helens, and, with the support of the U.S. Forest Service, USGS geologists monitored the volcano's activity and briefed local emergency response officials and the news media. After the major volcanic eruption was declared a national disaster, USGS sent additional support to Vancouver to work with the Federal Emergency Management Agency's (FEMA) emergency response team. Many lessons were learned from the response to the Mount St. Helens eruptions. Some were scientific and will be invaluable in assessing future eruptions of Mount St. Helens and other similar volcanoes. The occurrence has also highlighted the value of a well-prepared response team. Therefore, during 1981, USGS drafted formal emergency response plans that detail the procedures key scientists and administrators are to follow during or in anticipation of geologically related emergencies. Those plans will be reviewed by FEMA officials to ensure compatibility with their plans and responsibilities.

An example of the type of comprehensive study that integrates natural hazard scientific studies with overall resources and environmental planning is USGS's San Francisco Bay Resources study, which was given the American Planning Association's 1981 Outstanding Planning Award. Designed to collect and interpret scientific information for the use of planners and decisionmakers, the study began in 1970 as a demonstration project in which Federal and local government agencies joined forces with other regional planning agencies in the interest of sound local and regional planning. Federal support came jointly from USGS and the Department of Housing and Urban Development (HUD). The program studied the 7,400 square mile San Francisco Bay region and, through the collaboration of interdisciplinary teams, produced 150 reports and maps that translate and communicate scientific information to nonscientists. One of the major goals of the study was to reduce the hazards associated with floods and earthquakes through improved planning.

Earth scientists unanimously agree that major earthquakes similar to the devastating 1906 Northern California earthquake (8.25 magnitude) will recur. Extensive earthquake studies by Federal, State, and university investigators have been under way for many years. In 1981, FEMA issued a report, prepared with major assistance from USGS, that stated that the probability of a major catastrophic earthquake in California in the next three decades exceeds one chance in two. Dollar losses would likely



U.S. Department of the Interior, Geological Survey

The plume from the May 18, 1980, eruption of Mt. St. Helens reached more than 60,000 feet into the atmosphere. Its initial burst released the energy equivalent of about 10 to 50 megatons of TNT.

total tens of billions of dollars, and fatalities are estimated in the thousands. In recent years, earthquake specialists have developed a "seismic gap" theory as a predictive tool, and the location and magnitude of more than a half-dozen major earthquakes have been predicted successfully. In California, USGS has 400 telemetered seismographic stations and 25 geodetic networks containing hundreds of survey lines to provide information for their models. Continued refinement and analysis of the data will lead to improved predictive capability.

Movement between the North American and Pacific tectonic plates ranges from 1½ to 2 inches per year. That movement occurs in the San Andreas and related fault systems. Precise measurement of the movement and such related phenomena as earthquakes is the objective of a major Federal cooperative program in crustal dynamics and earthquake research initiated in late 1980 among the National Aeronautics and Space Administration (NASA), NOAA, USGS, and the National Science Foundation (NSF). The Federal implementation plan is being developed, and regional deformation measurements began in 1981. Three new networks for monitoring crustal and polar motion will be established in 1983 and 1984.

The attainment, protection, and enhancement of an environment that is healthful, safe, and sustaining to Earth's natural ecosystems are the major objectives of Federal environmental programs. Environmental research and development activities provide the scientific and technological information necessary for choosing among alternative policies that will help the Nation meet its major environmental goals in a cost-effective manner. This section describes major recent accomplishments and new initiatives in federally supported environmental research and development. Particularly noteworthy have been accomplishments in sensing and measurement technologies and methodologies for performing risk/benefit analyses in support of regulatory reform efforts. Other areas where recent advances have been made include nuclear and other hazardous wastes, ground-water supplies, the atmosphere, acid precipitation, and toxic substances.

Regulatory Reform

Executive Order 12291 of February 1981 requires explicit documentation that benefits of proposed regulations exceed costs. To improve the estimation of economic benefits and satisfy other legal requirements for risk information, the Environmental Protection Agency (EPA) has undertaken a comprehensive program of research and assessment to determine the risks associated with a range of environmental pollutants. During the past few years, advances have been made in understanding and testing the neurological effects of exposure to toxic chemicals. A recently developed portable neuro-behavioral laboratory for assessing neuro-behavioral effects in field test situations will soon undergo validation. A system for modeling the behavioral effects of chemicals on the young has also been developed. Those tools will help measure the seriousness of health risks presented by the production of various chemicals.

Also supporting risk assessment are achievements in marine toxicity evaluation. Tests of toxicity using two marine organisms (oysters and polychaete) have been successfully validated. The tests provide researchers with a more rapid, less expensive tool for assessing the environmental risks posed by pollutants to marine ecosystems.

Newly developed techniques can estimate more accurately the economic benefits arising from pollution control actions, and EPA has been using them in developing guidelines to implement Executive Order 12291. Among the more successful techniques are a microepidemiological approach for determining the dollar value of reducing health damages from air pollution and a contingent valuation approach for determining visibility and intrinsic benefits from air pollution control. The Agency hopes to develop new methodologies and provide technical assistance in implementation of Executive Order 12291, with emphasis on topics not stressed in past research—including hazardous waste and toxic substance control, effluent guidelines, municipal waste treatment, ocean dumping control, and hazardous air control.

Measurement Technology

Advances in environmental sensing and measurement techniques span all media and have improved the accuracy, reliability, and validity of data used in environmental decisionmaking. A major accom-

U.S. Department of the Interior, Geological Survey
A newly refined method of radioactive "fingerprinting" of organic pollutants shows promise in tracking different sources of industrial, municipal, and agricultural carbon wastes.

plishment in environmental measurement techniques is the development of analytical test procedures for measuring toxic organic pollutants in industrial and municipal wastewaters. Refinements in gas chromatography and mass spectrometry will be used in controlling the discharge of organic toxic pollutants into wastewater.

A further accomplishment is the development of more sensitive and accurate tests of soils and other media for determining the type and quantities of toxic pollutants emanating from hazardous waste disposal sites. The improved testing techniques resulted from the establishment of monitoring criteria, the development and testing of new collection substrates, and the refinement of analytical procedures. Ultimately, those techniques will enable scientists to estimate better the risks posed by disposal sites.

A third accomplishment lies in the area of personal monitoring of human exposure to air pollutants. A miniature gas chromatograph that will enable the production of small portable monitors capable of measuring airborne organic compounds has been developed. Advances in the technology of personal monitoring are critical for allowing scientists to make more accurate estimates of actual human exposures to air pollutants.

Contaminants in drinking water must be measured accurately to allow for confident certifications of the presence or absence of environmental problems associated with water supplies. Analysis techniques must therefore be standardized among all laboratories, both public and private, that are authorized to measure compliance with established maximum contaminant levels. During 1981, the latest, best techniques were incorporated into a manual for use by all laboratories testing drinking water supplies.

Nuclear Wastes Disposal

Researchers are evaluating improved ways to dispose of different types of nuclear wastes—high-level wastes, low-level wastes, and uranium mill tailings. High-level wastes (HLW) are mainly the concentrated fission products arising from the reprocessing of spent reactor fuel, and they require thermal cooling and shielding. HLW research focuses on the stability and integrity of waste forms, the performance of packaging materials, and the capability of engineering designs to ensure the long-term containment of wastes in geologic formations. Results will help determine the form of waste matrices and packages for disposal and the types of sites and repositories that might be acceptable for licensing as disposal areas. In 1981 and beyond, research will focus on the migration and hazards of HLW from deep repositories located in four types of geologic media: basalt, tuff, bedded salt, and domed salt.

Low-level wastes (LLW) include a wide variety of radioactive materials generated in the operation of nuclear reactors and from medical, industrial, and academic uses. Such materials do not normally require cooling but generally do require special handling. Federal LLW research is aimed toward helping State governments and industry find acceptable solutions for disposal. Researchers are placing strong emphasis on identifying acceptable waste forms, determining site suitability, and preventing the migration of radionuclides from shallow land burial facilities.

Uranium mill tailings are the voluminous residues left after uranium has been extracted from the ore. They have very low levels of radioactivity but contain uncovered uranium and such other radioactive components as radium and thorium. The mill tailings also release radon-222 and radioactive particulates. 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 potentially serious. Uranium mining and milling have expanded significantly since 1977, further exacerbating the situation. In response to the problem, researchers have characterized the mill tailings and their byproducts, the pathways of toxic and radioactive materials from the tailings, and their environmental impacts. Decommissioning techniques also are being evaluated.

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 such waste products in an environmentally sound fashion, but it must also clean up existing disposal sites that may present threats to public health.

To help evaluate acceptable disposal plans, researchers at EPA, the U.S. Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA) have developed mechanisms for assessing the health and environmental damages caused by hazardous wastes.

During fiscal year 1981, new federally funded programs focused on the problems of existing disposal sites. Work was initiated on finding better ways of identifying and monitoring hazardous waste sites; developing analytical procedures to estimate the composition, size, and potential risk of sites; and determining appropriate on-site remedial actions for areas where disposal of hazardous wastes has not been adequately controlled. EPA has begun to locate existing waste sites and take steps to clean them up, reducing the risk to public health.

Atmospheric Pollution

To evaluate properly the consequences of air pollution control strategies on ambient air quality, extensive laboratory and field studies have been conducted to develop, evaluate, and verify air quality models. Air quality models are sets of mathematical equations that describe the processes of pollutant emission, reactions with and transport through the atmosphere, and ultimate disposition (or fate) of pollutants. Models are used to determine the effect of a proposed or existing emission source on the ambient air quality of a given area. The ultimate goal of this kind of research is to provide air pollution officials with accurate tools for handling a variety of air pollution problems, including single and multiple source pollution, urban and regional pollution, and air pollution problems associated with sources located in areas of complex terrain.

Modeling research activities are designed with the expectation that, in the future, State and local air pollution agencies will assume a greater role in developing air pollution abatement strategies. It will therefore be increasingly important that research programs provide reasonably accurate models that are readily accessible for the user community. Due to the extensive variety of source emissions and terrain and meteorological configurations, a number of modeling approaches have been investigated. To determine the impact of single or multiple stationary sources on their environs, a number of statistically based models have been developed and applied to problems related to sulfur dioxide and particulate matter pollution. Urban and regional scale models will be developed within the next 3 years to assess the air quality impact of photochemical oxidants and particulate matter, especially fine-fraction (less than 2.5 microns) and inhalable (less than 10 microns) particulates. Complex-terrain air-quality models will continue to be developed and evaluated to assess the air quality associated with new and conventional pollution problems related to energy production. Over the last few years, several new pollution problems have emerged that are beginning to receive increasing attention in the modeling program; among them are acid precipitation, visibility impairment, and interstate pollutant transport.

The most significant recent accomplishments in air-modeling research have been associated with the verification program on urban-scale photochemical models for ozone. Four models were chosen to represent different model classes, and, although the details of the chemistry models are slightly different in the four, the chemistry is generally compatible from model to model and uses the latest methodology. The four models were tested against a comprehensive, high-quality data base acquired through an extensive field measurement program conducted in the St. Louis area. The re-

National Center for Atmospheric Research/National Science Foundation

A National Center for Atmospheric Research chemist changes filters during an airborne sampling mission. The filters collect ammonia, sulfur dioxide, nitric acid, hydrochloric acid, and particulates for chemical analysis in acid rain experiments.

sults of the verification program will help define the models and evaluate their performance. When the models are fully evaluated and verified, State and local government officials responsible for air pollution decisions will be able to develop appropriate, cost-effective, pollutant emission-abatement strategies for urban areas in the United States where the ozone standard is exceeded.

Current atmospheric pollution research is also exploring the effects of ozone and sulfur dioxide pollutants on the production of nationally important agricultural crops to assess the resultant economic impacts. A series of nationally coordinated field studies has been designed to provide dose-response data that can correlate changes in air quality with crop production.

In those studies, crops grown under field conditions have been exposed to ambient air, various air pollution concentrations of ozone and sulfur dioxide, and air freed of pollution by charcoal filtration. Results from the first year of the program indicate that commonly occurring ambient ozone concentrations inhibit the yield of soybean, lettuce, peanut, and garden bean crops. Ambient ozone appears to cause a decrease in the yield of tomatoes, and an even greater decrease occurs when concentrations of sulfur dioxide are added. Ambient concentrations of ozone and sulfur dioxide found in many agricultural areas of the United States make these results highly relevant to maintaining and improving nationally important crop production.

Because of the widespread distribution of air pollution and the billions of dollars involved in the agricultural industry and in pollution control strategies, making appropriate decisions requires economic assessments of pollutant impacts. To quantify the economic impacts of crop loss, a valid data base for projecting the responses of crops to pollution levels and assessments of rural air quality are being developed at various regional sites. Those efforts will provide information for air-quality criteria documents and for State and local economic assessments of air pollution control.

Ground-Water Supplies

The Nation's ground water—underground water sources—is one of its most valuable natural resources, exceeding its surface counterpart both in quantity and, generally, in quality. Ground water supplies the domestic water needs of 20 of our largest 100 cities and 96 percent of rural America. Prevention of ground-water contamination is vital but complex because of the number and wide variety of sources of pollution, geological differences from place to place, difficulties in assessing the quality of water below the earth's surface, and limited knowledge of ground-water transport processes.

Research at EPA and USGS has attempted to increase knowledge of the Nation's ground-water resources. During fiscal year 1981, transport models were linked with transformation process models to form a subsurface transport and transformation prediction model, and the results were published in two scientific journals. The model was verified in an application using organic contaminants, and it will be used in assessing the risks of contamination of ground-water supplies by waste disposal sites.

Ground-water research activities during fiscal year 1982 will include selecting and evaluating indicators of underground water contamination, studying the transport and transformation of chemical contaminants in the subsoil environment, investigating the economic and technical feasibility of cleaning up polluted underground water sources in situ, and providing needed information for EPA, State, and local control activities. Issues related to the disposal of hazardous wastes will receive particular attention. Plans call for development of protocols for physical model construction and design of a two-dimensional mathematical model for predicting the mobility of contaminants and their fate.

In fiscal year 1982 and beyond, the knowledge gained about processes in and characteristics of the subsurface will be used in developing and improving methods for predicting the movement and transformation of contaminants in ground water. Transferring such knowledge and methods to the user community will continue to receive priority.

Toxic Substances

Research and development efforts on toxic substances have been planned in concert with EPA's regulatory and operational strategies, with a central emphasis on chemical testing and assessment. More specifically, research helps support the Office of Toxic Substances' multistage risk assessment processes, which are designed to select systematically chemicals for increasingly detailed levels of analysis. Using that approach, judgments can be made about the adequacy of available information and the need for control action. Implicit in the program's design is the use of data from other research efforts whenever possible, with a view toward building on it and adapting it specifically to a regulatory perspective.

In considering health and environmental effects, the types of tests being pursued and validated range from screening tests, for indicating the need for further investigation, to evaluation tests, for helping determine whether regulatory action is necessary. A significant portion of the program is devoted to improving current tests and making sure they are valid. As methodologies are validated, effects data on individual chemical compounds or groups are obtained for use in risk evaluations.

In assessing human and environmental exposures, research and development activities include analyses of environmental release of pollutants, environmental transport and fate, and exposure through use, distribution, and disposal of toxic substances. Emphases are on developing, refining, and validating tools for dealing methodically with large numbers of compounds and developing predictive capabilities through, for example, the use of chemical structure-activity relationships. Information obtained will ultimately help provide a basis for the risk and risk-reduction analyses that are part of regulatory decisionmaking under the Toxic Substances Control Act (TSCA) and other statutes.

Acid Precipitation

The atmospheric emission of pollutants, particularly sulfur dioxide and nitrogen oxides, results in increased acidity of precipitation. Potential environmental effects may include damage to lakes and streams, forests and rangelands, crops, soils, materials, and drinking water. The objective of research is to assess the magnitude, extent, and environmental effects of acid precipitation. Research activities will focus on identifying sources of acidifying precursors; modeling their atmospheric release, transport, transformation, and deposition; evaluating the health, environmental, and economic effects of acid precipitation; and, based on that information, assessing possible control technologies or mitigative strategies, if required.

The Acid Precipitation Act of 1980 (Title VII of the Energy Security Act) established the Interagency Task Force on Acid Precipitation, cochaired by NOAA, EPA, and the Department of Agriculture (USDA). In January 1981, that task force submitted a draft *National Acid Precipitation Assessment Plan* to Congress. The final plan will serve as a general strategy for acid precipitation research over the next decade.

The United States and Canada have established bilateral work groups under the Memorandum of Intent on Transboundary Air Pollution. In fiscal year 1981, the Impact Assessment Work Group produced a draft report on transboundary air pollution effects. Special emphasis was placed on assessing the effects of acid deposition on aquatic ecosystems in both countries. Attention was given to evaluating the roles of hydrogen and of nitrate and sulfate ions in causing undesirable changes to ecosystems. Also considered were ways to quantify a threshold for the sulfate deposition rate, above which adverse effects can be expected for sensitive ecosystems. In addition, the work group analyzed the potential for adverse impacts from transboundary air pollution on terrestrial ecosystems; on manmade materials, monuments, and structures; on human health; and on visibility.

The Atmospheric Sciences and Analysis Work Group produced a draft report on the applicability of mathematical models to transboundary air pollution and the relationships between pollutant sources and deposition sites for sulfur compounds. The report evaluated atmospheric transport processes in eastern North America. The Emissions, Costs, and Engineering Assessment Work Group produced a draft report that assessed the quantity of emissions released in eastern North America and analyzed the availability and cost of emission control technologies for various types of pollutant sources.

The United States has also participated in the implementation of the United Nation's Economic Commission for Europe's Long Range Transboundary Air Pollution Convention, signed in 1979 and accepted by the United States in 1981. Signatory governments have participated in the provisional implementation of the convention. The U.S. contribution has been to make available to the commission the results of its domestic acid rain research program, as well as U.S./Canadian Work Group documents developed under the 1980 U.S./Canadian Memorandum of Intent on Transboundary Air Pollution,

During 1981, a complex field study called OSCAR (Oxidant and Scavenging Characteristics of April Rains) coordinated a massive network of sequential rain samplers in the Eastern United States and Canada to assess the scavenging (cleansing) behavior of frontal storm systems. Over 3,000 rain samples are being analyzed. The information derived from OSCAR will be used for several purposes: to assess the spatial and temporal variability of precipitation chemistry in cyclonic storm systems; to provide a comprehensive, high-resolution data base for use in developing a regional deposition model; and to develop an increased understanding of the wet removal process. Another major accomplishment during 1981 was the improvement and use of regional trajectory models in the Northeastern United States, Canada, and the Mount St. Helens area.

Federal activities in transportation research and development for 1981 and subsequent years will increasingly reflect the Administration policy of expecting the conduct of research and development to be apportioned among various public and private sectors according to their appropriate roles and responsibilities. In large measure, U.S. transportation services, including airlines, most freight railroads, ship and barge lines, pipelines, trucks, intercity buses, and taxis, are privately owned and operated. The major exceptions are intracity bus and rapid transit services, which are often municipally owned and operated. Such transportation facilities as airways, waterways, streets and highways, and some ports and terminals are a public sector responsibility, but in many cases that responsibility lies with State or municipal governments rather than with the Federal Government. In those cases, the Federal Government only indirectly aids or facilitates the activities of those sectors. Furthermore, the President's Economic Recovery Program is expected to stimulate technological advancement in private industry by providing such indirect incentives as tax and patent policy changes to increase the level of R&D in areas of private sector control and responsibility. Therefore, direct Federal activities in transportation science and technology will be increasingly concentrated in those areas of its own special responsibilities, which include:

- national security and emergency preparedness;
- special areas directly required by statute;
- areas supporting direct governmental operating authority, for example, marine navigation and air traffic control;
- such recognized governmental missions as safety, where the government maintains a continuing regulatory role; and
- areas where the R&D is clearly in the national interest but where some peculiarity of the market or the industry prevents the investment from being made privately; for example, much of the work by the National Aeronautics and Space Administration focuses on long-leadtime, high-risk technology and on research requiring unique facilities where there is insufficient economic incentive for private industry investment.

The focusing of Federal transportation R&D activities will affect science and technology efforts at a wide range of agencies, including the Department of Transportation (DOT), the National Aeronautics and Space Administration (NASA), the Environmental Protection Agency (EPA), the Department of Energy (DOE), and the National Science Foundation (NSF). The following discussion highlights both recent accomplishments and new initiatives in transportation R&D programs of these agencies.

Transportation System Improvements

The Nation's transportation system is essentially developed. Rapid expansion has ceased as the interstate highway system nears completion, and emphasis has shifted to maintenance and replacement of aging components. Future system improvements will be aimed primarily at increasing efficiency, capacity, or safety of the present plant and equipment, and at evolutionary rather than revolutionary change. The high cost of fuel will remain a strong incentive for improving operating efficiency, and competition and general economic considerations will encourage improved productivity and reduction of waste in all areas.

Automobiles

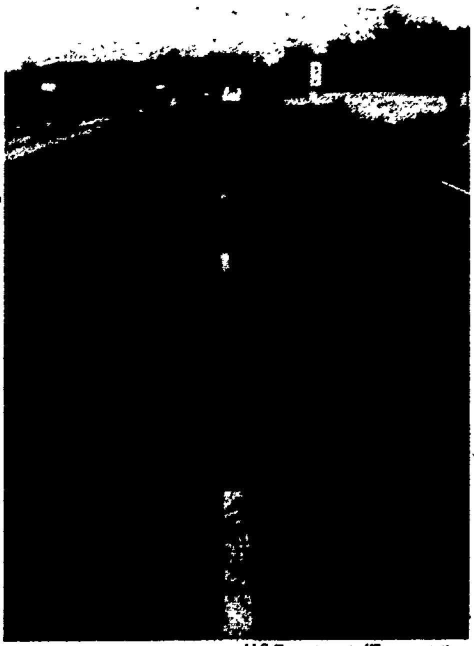
The Nation's automobile fleet is undergoing a major shift to smaller, lighter weight, more fuel efficient cars and light trucks. U.S. manufacturers are moving toward the front-wheel-drive configuration for larger cars as well as the subcompact size. Their current experimentation deals with still smaller two- and three-passenger sizes and with new, lightweight materials. Research by NASA into graphite-epoxy materials, while initially aimed at aircraft applications, might have possible long-term application for the development of new motor vehicle structural components.

The National Highway Traffic Safety Administration (NHTSA) has studied the performance of various components of motor vehicles to determine their actual and potential efficiency and their contribution to motor vehicle fuel economy. The studies include assessments of vehicles now in production as well as new concepts and prototype systems.

Through the Transportation Systems Center, NHTSA maintains an extensive data base on the U.S. automobile industry and its suppliers, including information about production facilities, product lines, finances, and future plans for new products and facilities. From that data base, the agency is able to assess the ability of the industry to produce safer, more fuel efficient vehicles and to improve its manufacturing capacity and productivity.

Highway System Improvements

Maintaining adequate pavement markings on the Nation's two million miles of paved streets and highway is a continuing expense. Conventional marking paints often fail to survive a single winter and can cause both air pollution and traffic hazard when they are replaced. The Federal Highway Administration (FHWA) has developed an epoxy thermoplastic pavement (ETP) marking material designed to replace conventional marking paints, especially in environments with heavy traffic load and/or severe weather conditions. ETP markings have 3 to 6 times the service life of conventional paints, contribute no organic pollutants, can be applied in subfreezing weather, and can take traffic immediately after application. The ETP material's low cost per gallon and long life offer substantial savings in highway maintenance costs.



U.S. Department of Transportation

The newly developed Epoxy Thermoplastic Pavement marking is exposed to normal highway wear and weathering for comparison with conventional paints.

Highway system capacity can be increased by use of the Traffic Controller Synchronizer, an electronic device designed and developed by FHWA as a low-cost means of coordinating traffic signals. Using a precision electronic timing element equipped to retain accuracy through power outages, the Synchronizer systems are far less expensive to install and have an overall 2-to-1 life-cycle cost advantage over hardwired systems. On a typical 2-mile, seven-intersection test site, use of the Synchronizer units resulted in a 7-mph average increase in speed, a 25 percent reduction in travel time, and significant reductions in emissions and fuel consumption. The Synchronizer has potential for use at 65 percent of the Nation's signalized intersections and, by smoothing traffic flow, could save as much as 2.5 million gallons of gasoline daily.

Aircraft

The NASA Composite Primary Aircraft Structures (CPAS) program is providing design and production technology and technical data on the service life of graphite-epoxy materials in aircraft structures. During the past year, the program achieved a major milestone with successful completion of tests that generated durability and maintenance data for selected components. A principal limiting factor in the design and use of composite structures has been traced to the mechanism of delamination, which has been identified as the initial mode of failure in graphite-epoxy composite materials. Experiments and analytical modeling are now under way to identify the conditions for initiation and propagation of delamination. as well as its structural consequences.

Noteworthy advances were achieved in the NASA Short Take Off and Landing (STOL) research program, which emphasizes propulsive-lift flight research with the Quiet Short-Haul Research Aircraft (QSRA). The QSRA's basic flight characteristics were documented. and flight data were found to correlate well with wind tunnel and simulator data. During fiscal year 1982, the QSRA flight research activities will be continued to provide data for developing certification criteria and design methodologies for propulsive-lift, short-haul transport aircraft

Water Transportation

Through its St. Lawrence Seaway Development Corporation (SLSDC), DOT is increasing the capacity of that waterway by extending the navigation season. This least capital-intensive means of adding capacity to the system is directed at improving ice conditions on the International Rapids section of the river and includes mathematical and hydraulic modeling of the ice control techniques for various reaches of the river. SLSDC is experimenting with U.S. Coast Guard (USCG)-developed Harbor and Harbor Entrance (HHE) navigation equipment to improve safety and reliability of the St. Lawrence Seaway and, by maintaining traffic flow, to increase the effective capacity of the system.

There has also been increased interest in navigating Alaskan Arctic waters, primarily as a result of increased oil and gas exploration. The Coast Guard is investigating the feasibility of a remote-sensing system to aid vessels in navigating through ice-infested waters.

The advanced maritime technology program of the Maritime Administration explores fundamental concepts in marine science and technology and provides scientific data on which future technology might be based. Programs include advanced ship systems, market analysis, and marine sciences. The latter program addresses propulsors, structures and hydrodynamics, and international information exchange. Ongoing research includes at-sea evaluation of a prototype stress-monitoring system and international cooperative tests of ship-maneuvering capability. The National Maritime Research Center at Kings Point, New York, includes the Computer Aided Operations Research Facility (CAORF), which provides an environment for controlled experiments in ship handling. CAORF is now investigating the use of simulator training in the mariner licensing process for the Coast Guard. The increasing size of ships and amount of ship traffic pose new accident hazards. Current information suggests that design of navigation aids and channel dimensions may be major contributing factors in harbor accidents. CAORF is concentrating on vessel maneuvering and piloting limits in narrow channels.

The Coast Guard is developing a simulator that will provide analytical data needed to assess the influence of both visual and radio aids on the movement of large vessels in restricted waters. Experienced pilots will maneuver computer-simulated ships in harbor environments, while responding to computer-generated aid displays, other vessels, and radio navigation system outputs. The results should lead to better deployment of buoys and other aids. An *Aids to Navigation* design manual, related to this work, was published in October 1981.

Mass Transportation

The Urban Mass Transportation Administration (UMTA) has supported many types of near-term and long-term research aimed at improving the technology available to the U.S. transit industry. Long-term transit research and product development are now being deemphasized by UMTA, however, since they can be done best by private enterprise. One UMTA R&D product nearing the stage for transfer to industry is the Computerized Rider Information System

(CRIS). CRIS is an automated system for providing route and schedule information to transit system patrons, including up-to-the-minute bulletins on service delays. The system uses automatic voice response and can handle hundreds of calls an hour, 24 hours a day. It is also applicable for video response over cable television, a potentially useful attribute as public service channels become increasingly available. In its initial small-scale test, system off-peak ridership increased 7 to 11 percent per year when improved rider information was provided; two larger tests are planned.

To assist local transit systems, UMTA developed a Track Geometry Measurement System at the Transportation Systems Center. The device can be attached to any transit car and will identify those portions of the track in need of realignment and improvement. The system prototype is undergoing a 2-year evaluation by the New York City Transit Authority, while specifications for an improved system are being developed jointly by industry and the Federal Government.

UMTA conducts a Service and Methods Demonstration (SMD) program aimed at improving the quality and efficiency of urban transportation by sponsoring the implementation of new transportation management techniques and innovative transit services throughout the United States. The program focuses on strategies requiring relatively low capital investment and which can be implemented in a short time. Some of the strategies have already been employed in other countries; others are based on recent conceptual or technological development by UMTA or by local U.S. transit authorities. The program is designed to perform the final critical experimental tests and development steps, where required, and to bring the innovative strategies into full operational application.

Typical of the SMD program is a series of projects seeking specialized services to meet the needs of the elderly, the handicapped, and the poor. Projects have included testing of specialized equipment to make public transportation more accessible to handicapped travelers, trials of specialized demand-responsive door-to-door services, and coordination of social service agency programs. UMTA also initiated a number of planning studies intended to help localities assess their special transportation needs, and evaluate, select, and introduce appropriate services for elderly and handicapped persons.

Transportation Safety

In terms of fatality rate relative to the volume of passenger movement, transportation in the United States ranks among the world's safest. Nevertheless, there is no cause for complacency with a system in which 54,507 lives were lost in 1980. Transportation safety has long been a major government activity at local, State and Federal levels. Safety-related activities constitute the major part of the Federal transportation science and technology effort.

Highway and Motor Vehicle Safety

The National Highway Traffic Safety Administration is responding to concerns about safety associated with the shift to smaller, lighter vehicles. Despite the strides already made in improving the structural integrity of vehicles, the laws of physics place a small vehicle at a serious disadvantage in a collision with a large automobile or truck. NHTSA concentration is thus in two areas: accident avoidance and crash survival. Major research in both areas is supported by the National Center of Statistics and Analysis. The Center collects data on the cause and mechanism of accidents through the National Accident Sampling System (NASS) and the Fatal Accident Reporting System (FARS). FARS is a census of crashes that result in a fatality, and NASS is a statistical sampling of all crashes in the country.

The National Center of Statistics and Analysis conducts detailed analysis of FARS, NASS, and other files to determine the nature and extent of the current national traffic safety problem, to describe trends and project future changes in motor vehicle safety, to support work on improved safety countermeasures, and to evaluate standards and countermeasures that are in effect. Driver and pedestrian safety programs, especially research on safe driver licensing and safe operation of two-wheeled vehicles, are aimed at developing and testing effective accident countermeasures. The agency is also designing and testing such law enforcement equipment as speed detection devices and blood alcohol level measuring devices.

In crash survival research, NHTSA is studying the relationship between the types of physical insult typical in motor vehicle crashes and human injury. Specifically, the agency is studying human tolerance levels to such injuries as rapid head rotation, neck flexion, and abdominal impacts that are related to particular forces and accelerations. The purpose is to determine the limits of human tolerance to motor vehicle crash forces and to support the development of human surrogates.

U.S. Department of Transportation

New crash test dummies will provide a more accurate simulation of the motions of living occupants and the estimation of crash forces and potential injuries.

The agency is developing a new generation of human surrogate dummies for use in vehicle crash testing. Particular emphasis is being placed on a dummy for vehicle side impact testing and a new universal dummy for testing in all crash modes. The dummies must not only simulate the kinematics of human motion, but must be capable of accurately measuring the potential for human injury in vehicle crashes.

NHTSA is also investigating the properties of various energy-absorbing materials and structures for use in vehicles for crash energy management. They include plastic foams for interior padding of vehicles, foam-filled metal structures for vehicle bodies, and other material combinations. The research is concerned particularly with finding materials that will limit forces on occupants to tolerable levels and that have a highly efficient ratio of energy-absorption capability to weight, because of the need to reduce vehicle weight for fuel economy.

The agency is also completing a program for computer-aided design of occupant restraint systems. The components of the program include efforts to simulate gas generation in inflatable restraint systems, occupant kinematics in a crash situation, and the interaction between the occupant and the restraint system in a crash. Such techniques reduce substantially the number of vehicle crash tests and sled tests required to design an effective restraint system for a new vehicle.

A self-restoring roadside barrier (SERB), developed by FHWA, offers a solution to the serious problem of conventional highway guardrails snagging the new, lightweight, front-wheel-drive cars. The new barrier incorporates a conventional post-mounted steel guardrail in a unique sloping, hinged configuration. SERB has been successfully crash tested with standard, compact, and subcompact passenger vehicles, as well as with school buses and intercity buses. The system safely redirects impacting lighter vehicles and contains heavier vehicles at speeds up to 60 mph and impact angles up to 15 degrees.

Aviation Safety

The Federal Aviation Administration (FAA) is attempting to reduce the potential for midair collisions with the development of the Threat Alert and Collision Avoidance System (TACAS). The system uses signals transmitted by either the Air Traffic Control Radar Beacon System transponder or the Mode S transponder. The goal is to provide a compatible aircraft backup to the Air Traffic Control (ATC) system to ensure separation when aircraft are operating within ATC coverage area and to provide primary protection against midair collision in areas not covered by the ATC system. TACAS will be designed to be operationally independent from ground equipment.

Marine Transportation Safety

More than half of the 4,367 marine accidents in 1980 involved collision, ramming, or grounding of commercial vessels. The Coast Guard program of marine safety R&D explores the causes of such accidents, evaluates the resultant structural damage, and includes development of up-to-date Vessel Traffic Service (VTS) technology and procedures. The program includes stress measurement instrumentation of Great Lakes ore carriers, extensive computer simulation of vessel maneuvering and vessel traffic movement, and development of conflict predictions and avoidance techniques for VTSs.

Included in the USCG R&D program are Forward Looking Infrared (FLIR) Sensors to aid aircraft and helicopters in detecting persons in distress under low visibility. At present, searches at night or in poor visibility are often ineffective if the person or object being hunted has no illuminated signaling device. The infrared equipment is independent of such a light source. Search and rescue missions will be enhanced by better search planning data and techniques aimed at improving the probability of detection.

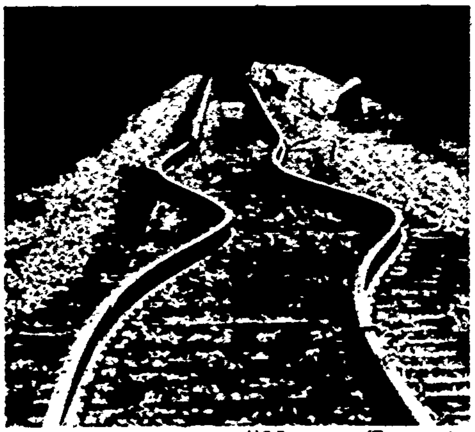
The Coast Guard is developing an airborne remote-sensing system, AIREYE, for installation on six of its new aircraft. AIREYE will include a side-looking airborne radar, an infrared/ultraviolet line scanner, an aerial reconnaissance camera, a prototype active-gated television, and a computer-controlled command console. The system will improve surveillance for ocean oil pollution and for search and rescue.

The Coast Guard has instituted a multimission R&D program that includes such items as lighter-than-air patrol vehicles, advanced marine vehicles, command and control systems, energy-saving technology applications, shore-based VHF-FM direction finding, and technology assessment/forecasts. Until the program's formation, there was no central advocate in DOT for pursuing R&D solutions with combined applicability for several Coast Guard and other agency missions. Such activities generally have higher risk but a higher payoff than the mission-specific, short-term R&D programs. Moreover, technology transfer to and from other Government agencies and the international scientific community is extensive in these programs. For example, the advanced marine vehicle project includes a joint Coast Guard/UMTA study of high-speed ferry/patrol craft technology. The command and control R&D project is evaluating long-term requirements for information processing as well as near-term feedback from users. This will provide a more effective and comprehensive information processing system that can utilize current technology, satisfy the needs of both operational and administrative users, and reduce manual processing.

Railroad Safety

Federally sponsored railroad technology research is being redirected to focus exclusively on appropriate Government functions while allowing private enterprise to conduct research on railroad industry productivity with a minimum of Government involvement. The Federal Railroad Administration (FRA) is thus concentrating its science and technology efforts on its principal mission, which is to ensure safety in railroad operations.

The program is directed toward reduction in the likelihood of catastrophic rail-



U S Department of Transportation

This section of railroad track was intentionally buckled under compressive stress to study the impact of possible in-service conditions such as temperature expansion

road accidents, improvements in track structures and in track defect detection, and methods of reducing employee and public fatalities and injuries. FRA's research is not involved in economic, operating efficiency, or product development activities, all of which are the responsibility of the private sector.

Pipeline Safety

The Research and Special Projects Administration (RSPA) of DOT is carrying out a multifaceted pipeline R&D program supporting the Department's pipeline safety responsibilities. The program involves the development and application of methods for evaluating and testing new pipeline materials and structural designs that are being studied for possible introduction by the pipeline industry. It will provide experimental data for limited development and validation of new analytical failure theories that will predict more reliably the safe operational limits of pipeline systems and components.

RSPA is studying the application of fracture mechanics technology to pipeline weld inspections as a possible alternative to the existing standards for pipeline girth weld acceptance. The goal is to improve the safety and productivity of natural gas and liquid oil transportation by a variety of R&D activities, including analysis of fatigue testing on X-70 pipe welds to assess the significance of blunt flaws, development of mathematical models of fracture mechanics, and performance testing to verify the models.

Hazardous Materials

Many materials moving through the Nation's transportation system are classified as hazardous, and those materials have the potential for serious consequences in the event of a transportation accident. Thus, research and development activities are focused primarily on preventing accidents; on detecting, containing, or neutralizing the material in the event of accidents; on minimizing the consequences of accidents to people and property; and on cleaning up spilled material. Because many hazardous materials are essential to society and the economy, the Government is interested in ensuring that such materials can move safely as needed. Many Federal agencies are involved in hazardous materials safety. Within DOT, the Materials Transportation Bureau of RSPA has primary regulatory authority over hazardous materials, but the Coast Guard, FRA, FAA, FHWA, and NHTSA all contribute to the safe movement of hazardous materials by water, rail, air, and highway. The Department of Energy (DOE) has authority over radioactive materials, the Environmental Protection Agency (EPA) has responsibility in certain hazardous materials accidents, and NASA makes research contributions to the development of safety technology.

Current science and technology activities in support of hazardous materials safety include:

(1) RSPA's project on cargo tank/portable tank integrity is attempting to investigate and identify alternative methods for improving tank safety through research activities on valve modifications, construction materials, loading requirements, and insulation techniques.

(2) NASA, in a jointly sponsored effort with the Gas Research Institute, is developing sensitive laser methods able to detect very

small methane and liquefied natural gas (LNG) leaks. Other NASA work, cosponsored by the Coast Guard and DOE, has developed and tested detectors for methane concentration and plume measurement.

(3) The Coast Guard, in efforts coordinated with EPA, is creating hazardous chemical response equipment, procedures, and techniques to prevent or reduce the discharges of hazardous substances from stricken vessels. USCG work includes research in hazardous chemical forensic identification and on analytic techniques and models for predicting the hazards posed by release of hazardous chemicals. The Coast Guard is developing and testing containment, treatment, and recovery techniques for response to hazardous materials spills and protective clothing and other systems for personnel involved in cleanup. Other efforts include examining the health effects on personnel involved in routine employment in the transportation of hazardous materials.

(4) As the use of nuclear energy grows, the transportation of nuclear fuel and radioactive waste grows with it. Although there have been no transportation incidents that resulted in any danger to the public, the expansion of transportation activity has resulted in a number of potential problems in packaging, leading the Nuclear Regulatory Commission (NRC) to increase emphasis on testing nuclear material transportation casks and improving emergency response procedures. NRC has constructed data bases on the shock forces experienced by large shipping casks in highway and rail transportation and on the safety of irradiated fuel in storage and transportation. In fiscal year 1982, the analysis of the shock forces associated with air and water shipment will be completed. Codes will be designed for analyzing impact tests of shielded shipping casks. An integrated computer code, combining thermal, criticality, and shielding models for shipping cask evaluation, will be released for use by the industry.

Transportation Mission Support

DOT, through RSPA, is conducting and supporting research to improve its capability for providing fast, safe, efficient, and convenient transportation of persons and goods at the lowest cost. A significant effort deals with systems analysis methodology.

DOT supports several science and technology activities through the University Research Program. The program is a Departmentwide effort to take advantage of the wealth of talent and resources available in the academic community. The program is designed to optimize the use of university resources in solving transportation problems, especially those problems related to the missions of the Department.

The University Research Program seeks to expand the knowledge base in a range of transportation areas. The problem areas are identified through comprehensive needs determinations by key DOT leaders, and the Deputy Secretary makes final selections. Problem areas being addressed by ongoing research efforts are transportation energy conservation, improvements in goods movement, transportation and economic development, efficiency and productivity in transportation systems, and transportation safety. In addition to research activities involving all academic disciplines, the University Research Program conducts conferences/workshops each year on major transportation issues of importance to the Department. Recent research accomplishments include the development of computer-based predictive models for improving the design and performance of passenger rail vehicle suspensions and the demonstration that fire retardants can be incorporated into paints through microencapsulation of intumescent compounds in polymer systems. Future research will focus on energy and transportation, efficiency and productivity in transportation systems, transportation system rehabilitation and maintenance, and transportation and economic analysis.

Science and technology are part of a wide range of efforts useful in meeting the Nation's needs in food and agriculture. Those needs include having enough agricultural products to meet both domestic and export demands, allowing for adequate returns to farmers, minimizing fluctuations in food prices, maintaining our soil and water resource base, and improving the efficiency and reliability of domestic and export agricultural marketing systems. Cooperative and coordinated activities of various Federal agencies and non-Federal institutions constitute a large part of the total national effort to meet those needs. Areas of major research and development activity are related to:

- improving agricultural productivity;
- maintaining and developing the quality and quantity of agricultural land and water resources;
- improving concepts for efficient preservation, protection, and conversion of agricultural goods in postharvest marketing channels;
- decreasing agricultural energy use;
- providing information about world crop and natural resource conditions; and
- improving the entire structure and overall socioeconomic situation in the agricultural communities of the Nation and the world.

Agricultural Productivity

To provide an ample food and fiber supply to meet domestic and export market needs at reasonable prices, the U.S. agricultural system must be highly efficient. The agricultural research, teaching, and extension systems contribute to improved agricultural productivity and product quality by providing improvements in biological and genetic resources, by improving the techniques for management of microenvironments, and by aiding in the control of plant and animal pests that reduce overall production efficiency.

Crop Production

The biotechnology revolution is rapidly increasing the potential for improving agricultural crop productivity. One recent dramatic accomplishment in the area of recombinant DNA technology has been an improved understanding of the controlling mechanisms of proteins in corn kernels. It has been found that the DNA controlling elements, or "transposons," responsible for moving genes from place to place within a genome (a single set of chromosomes) have a direct influence on the presence or absence of protein. In mutant strains, the protein observed in the presence of the transposon is larger than in the normal strain, and the protein is absent altogether when the transposon is absent. That finding shows that the gene product, the protein, is heavily under transposon control, which increases the possibility of using inserted mutations to alter the coding sequence of DNA. The ability to alter the DNA sequence in crop plants holds promise for improving food quality and increasing physiological efficiency.

Additional research on protein chemistry in corn has resulted in the development of a sophisticated system that permits corn lines to be "fingerprinted." The system could be used by the corn industry for quality control, the identification of seedlots, and the resolution of cases involving plant protection rights. Another recent development is the discovery of a bioregulator that increases cold tolerance in plants. Treatment with this or similar bioregulators will aid in the protection of young plants from freezing temperatures, thus protecting plants from unseasonal cold in the spring.

Recent research on the chemistry of plant pigments resulted in the isolation of an anthocyanin from the flowers of Heavenly Blue morningglory. The substance is now being used in a patented process to produce a nontoxic and stable color additive for foods and beverages, replacing previously banned red dyes No. 2 and No. 4.

Studies on the basic mechanisms of plant growth and development have improved tissue culture techniques for strawberries, blackberries, and peaches. The improved techniques will lead to lower costs in propagating those plants. Specific research on the genetics of pest resistance in soybeans has resulted in approximately 75 percent of the 1980 U.S. soybean acreage being planted with multiple-pest-resistant, high-yielding varieties. Those varieties have been developed by a number of State agricultural experiment stations in partnership with the Department of Agriculture's (USDA) Agricultural Research Service. During the past year, a large number of germplasm stocks of wheat, oat, barley, and rice have been released to breeders for incorporation into State, Federal, and industry breeding programs, and several new and improved small grain varieties were released to growers. Continuing efforts on the genetics of pest resistance have also resulted in the development of multiple pest- and disease-resistance characteristics in new varieties of fruits, vegetables, and ornamentals. The Lemhi Russett potato, for example, is a new high-quality, disease-resistant baking and processing potato that can be grown in major production areas. It out-yields the traditional Russett Burbank by more than 30 percent and has a 22 percent higher

U.S. Department of Agriculture

After thawing, the Eremocitrus hybrid produces new fruit. Less resistant varieties damaged severely during a freeze will not produce at their prefreeze capacity for 2 to 4 years.

content of vitamin C. Of further significance are new citrus hybrids, derived from cold-hardy relatives from Australia, that survived the 1981 Florida freeze of 10°F.

Crop production in other countries has continued to be of interest to the United States. The Government has continued its efforts to assist the international agriculture enterprise in order to increase productivity and to develop a set of agricultural technologies that can be quickly adapted and used by developing countries. Through the Agency for International Development (AID), the United States has assisted in the formation and maintenance of the Consultative Group on International Agricultural Research (CGIAR), which works through agricultural research centers located throughout the world. The efforts of those centers are now producing results. For example, about three-fourths of the wheat and one-fourth of the rice acreages in Asia are now planted in high-yielding varieties developed in association with the Asian and Mexican international centers. The availability of semi-dwarf high-yielding varieties of wheat has also helped India and Pakistan triple their wheat production in recent years. Central American nations are planting disease-resistant bean varieties developed in cooperation with a South American center. African nations are developing new corn varieties using materials supplied by local centers, and one center is developing minimum tillage techniques to conserve the fragile soil structure in the wet tropics. Potatoes are being planted in tropical lowlands as a result of breeding work on heat tolerance. An African center is making good progress in developing a permanent vaccine to control trypanosomiasis, which kills cattle and causes sleeping sickness in man.

Also in the international sphere, the Department of Agriculture is sponsoring research in Pakistan, Egypt, and Yugoslavia on various nematode species that pose potential threats to U.S. agriculture. One particular target is the dagger nematode, which has appeared in European vineyards and can spread to the United States. A related program of innovative research is attempting to develop new soybean varieties resistant to species of soybean cyst nematodes. Agricultural research conducted in the United States is used in many countries around the world and demonstrates the universal aspects of research.

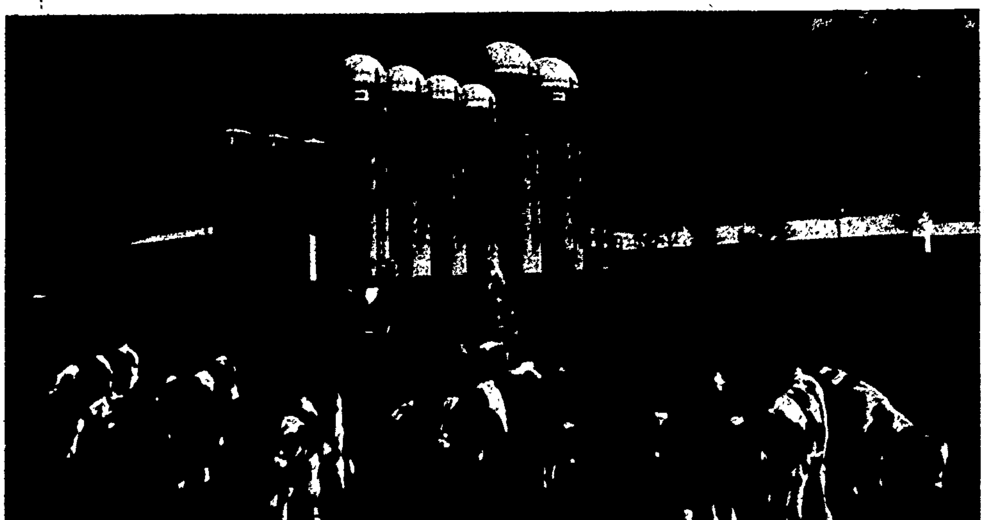
Animal Production

Major recent developments affecting animal production have been in the areas of disease prevention and control, physiology, and animal breeding. A new vaccine for Texas Fever is now available. That disease has been eradicated in the United States, but still poses a threat to U.S. cattle. If Texas Fever were reintroduced from Mexico, where it commonly occurs, the new vaccine, which contains nonviable organisms, would provide ready and safe protection. Similarly, a globulin that is antibody specific for the antigens associated with avian coccidiosis has been developed. The globulin could not only control coccidiosis, but it could also prevent the development of resistant strains. Present methods of control through medication are costly and have environmental implications, and resistant strains of coccidia continue to develop.

Understanding the basic physiological effects of hormone compounds and environmental factors, including light and temperature, has led to increased reproductive efficiency of food animals through synchronization and maintenance of estrus cycles and ovulation. As a result, lambs per ewe, calves per cow, piglets per sow, and chicks per hen per year continue to increase as the new technologies are applied. Basic research in physiological processes led to embryo transfer techniques now in commercial use, increasing the impact of superior genetic stocks.

More efficient ways of using the vast rangelands and pastures in the United States are enhancing the economic production of food of animal origin. Cultivar selection, manipulations of crop culture, and new harvest and postharvest technologies are contributing to advances in animal production.

Long-term animal breeding research in genetics, nutrition, and environmental factors has produced an initial payout in the development of the "Line 1 Hereford" variety of beef cattle. Line 1 breeding was present in 65 percent of the registered Hereford herds surveyed last year. Studies



U.S. Department of Agriculture

Sibling calves and their biological mother are shown at the USDFRC field facility in Prairie du Sac. Super-high reproduction rates are achieved through increased fertility and embryo transplants. Dairy scientists are able to raise genetically uniform groups of cows quickly by using surrogate mothers.

show that 20 years of genetic progress have resulted in a 40-pound increase in weaning weight of calves sired by Line 1 bulls.

Pest Management

Two significant frontiers in pest management are being approached simultaneously. One deals with the control of pests through programs focusing on the management, reduction, or elimination of individual pests. The other, an integrated pest management approach, seeks to develop economically and environmentally sound management systems for pest complexes associated with particular cropping systems.

A new bait toxicant for control of the fire ant has received conditional registration for areawide use in noncrop areas. The bait toxicant is essential to Federal and State fire ant control programs and will have a significant impact in those areas where the fire ant has become a severe nuisance to both people and pets.

To assist the Department of Defense in developing approaches to control ticks, research revealed that clothing impregnated with permethrin provides complete protection against ticks. The treatment has commercial application to protect hikers, campers, and recreationalists, especially in areas where ticks are known to carry Rocky Mountain Spotted Fever.

Research in biological and integrated pest management programs has also resulted in several important new developments. The chemical basis of the natural resistance of plants to certain insects has been identified for several crops. During the past year, maysin, a flavone glycoside from corn silk, has been identified as being very active against corn earworm larvae. Maysin is one among several such natural, resistant chemicals that have been recently identified. These kinds of discoveries will give direction to future plant breeding programs and may lead to improved biological resistance to pests and, thus, a reduced need for pesticides.

Other biological approaches to pest management have also experienced recent advances. For example, interbreeding of two species of cattle fever ticks has resulted in the male progeny being sterile and in the females passing on the sterile male characteristic to their progeny. The sterile trait may lead to a new method to aid cattle fever tick control programs. Progress has been made in controlling the widely distributed alfalfa weevil by introducing parasites, from countries where the alfalfa weevil originated, that destroy the weevil. Furthermore, biological weed control is beginning to show results in Missouri, Virginia, Montana, and several other States where populations of musk thistle along agricultural fields have been reduced significantly due to attack by an introduced musk thistle weevil. Basic research is also being conducted to analyze the relationship of soil microflora to seedlings as the basis for using beneficial fungi and bacteria for inoculating seeds prior to planting to reduce the effects of nonbeneficial fungi and bacteria on plants in early growth stages.

Agricultural Land and Water

With projected increases in U.S. and world populations, there is growing concern about the future adequacy of land and water resources for agricultural purposes. One major problem has been the amount of soil lost annually through erosion and the resulting long-term effects on productivity. It recently has been recognized that one of the best ways to reduce soil erosion on cropland is through conservation tillage, a system that eliminates moldboard plowing and reduces tillage to maintain crop residues on the surface. Basic research using isotopically labeled nitrogen shows that conservation tillage and crop residue management resulted in increased reserves of soil nitrogen and organic matter in the surface layers. Also, principles of cropping systems are being developed to permit a wider economic application of conservation tillage practices.

New principles have also been developed for dealing with water resource constraints in the Great Plains, where drought may occur as frequently as excessive precipitation. Grass barriers, originally designed for erosion control, have been found to trap sufficient moisture from snow so that acceptable yields of wheat and barley can now be produced during years of low precipitation.

With increasing emphasis on making the most efficient use of all available water for irrigation purposes, interest in the use of nontraditional water resources has increased. Recent studies have indicated that sewage water might be used safely for irrigation in greater quantities than previously believed. It has been found that, when applied to soils during ground-water recharge or irrigation, most enteric viruses in sewage water do not move below the surface layer, except in very coarse sands and gravels. In addition, recent experiments have found that viruses held in the soil survive no more than 5 days after the soil has dried.

Postharvest Science and Technology

Postharvest science and technology activities are directed toward greater efficiency in assembling, handling, converting, protecting, storing, transporting, wholesaling, and retailing farm and forest products. Those activities focus on the portion of the agricultural system between harvest of food and fiber products and their ultimate use by the consumer. The postharvest component of the agricultural system is critical to farmer return, consumer cost, and productivity of the total agricultural system. Recent achievements that will lead to increased conversion and handling efficiency include a better understanding of the principles of food drying at ambient temperatures and the development of two low-cost, energy-conserving, Environmental Protection Agency (EPA)-approved methods for controlling fungal growth in high-moisture grains during storage.

Under a cooperative regional project, State agricultural experiment station and Agricultural Research Service scientists are identifying toxicants that occur naturally in foodstuffs and are determining conditions conducive or inhibitory to their production. For example, recent results have shown the influence of the microclimate on fungus populations and have clarified the causes of *Aspergillis flavus* in pistachio nut orchards.

U.S. Department of Agriculture

Nearly 17 of the 42 million pounds of live weight catfish processed by industry in 1979 was waste material. Through aquaculture research, U.S. Department of Agriculture scientists have developed a liquefying process that turns the waste into profitable byproducts.

In another area, research on the chemistry and nutrient quality of agricultural wastes has shown that many wastes have a high market value. For example, waste from catfish processing can now be treated to yield fish oil, bone meal, and a high-protein feed ingredient. Two catfish processors are building facilities for this purpose. In the cotton fiber industry, research has shown that 2 to 3 percent of the useful fiber now lost during the lint cleaning operation can be reclaimed. That reduction of losses can increase a farmer's return by $10 to $12 per bale.

Federal researchers have found several alternatives to conventional chemical fumigants. Modified atmospheres composed of varying percentages of carbon dioxide or nitrogen gases have been very effective as fumigants for insect control in raw agricultural commodities. Ten quarantine treatment recommendations to eliminate the Mediterranean fruit fly from host products have also been made. Fumigation schedules for avocados, bell peppers, cantaloupes, cucumbers, nectarines, naval oranges, peaches, pears, strawberries, and tangerines have been developed.

Fumigation with ethyl formate, a natural fumigant, was shown to be a potentially effective treatment for the control of western flower thrips on fresh strawberries. Killing all live insects on strawberries is essential to meet Japanese quarantine requirements and permits U.S.-grown strawberries to be exported to Japan. Progress in protecting soybeans during transportation has also been made. Soybeans were one of the largest U.S. agricultural exports in 1980, valued at over $6.1 billion. Continuing or expanding the export market is extremely important to maintaining a favorable balance of trade. Results from a recent research project have shown that extensive soybean damage and deterioration were occurring in transit between shipping points and overseas destination ports. Information is being provided to shipping companies to foster a better understanding of where handling losses are occurring in the shipment process.

Rural Community Studies

Renewed rural population growth and economic vitality are providing the primary focus for a new emphasis on evaluating the socioeconomic aspects of rural communities. Migration rates have started to change from those that characterized the previous 50 years; rural outmigration is decreasing and rural inmigration is increasing. This turnaround is the primary determinant of change in the demography of rural populations. Demographic research, currently being conducted by USDA and State agricultural experiment stations through a system of cooperative regional technical committees, seeks basic information to help Federal, State, and local officials anticipate and adjust to changes in populations. Understanding the determinants and consequences of population change will be essential for planning the delivery of services, the development of economic opportunities, and the provision of infrastructures for community facilities. The rural area of the Nation is therefore receiving significantly renewed emphasis by the agricultural research and development community.

The productivity, security, and quality of life of the Nation depend in large part on the effectiveness of its educational system. Although primary responsibility for American education lies with the citizens, with their State and local governments, and with private educational institutions, the Federal Government plays an indirect, catalytic role in the educational process. This section addresses three areas in which the Federal Government works to provide indirect support for efforts to improve the quality of education in the United States:

- fostering academic excellence through assessing the current status of the entire educational enterprise,
- supporting educational research and development activities, and
- helping to maintain the strength of the Nation's scientific and technical human resource base.

Excellence in Education

To provide a firm basis from which future planning and programming activities might ensue at all levels of government, the Secretary of Education, in August 1981, established a National Commission on Excellence in Education. The Commission, which comprises school, college, and university educators, State and local officials, and leaders in science and engineering, will carry out an 18-month study and make recommendations to foster academic excellence throughout the American educational system. The Commission will:

- review and synthesize the data and scholarly literature on the quality of teaching and learning in U.S. public and private schools, colleges, and universities;
- examine and compare the curricula, standards, and expectations of the educational systems of other advanced countries with those in the United States;
- study college and university admission standards and their effect on educational quality in the schools;
- review and describe unusually effective college-preparatory programs; and
- review major changes in American education and events in society during the past quarter-century that have significantly affected educational achievement.

The National Institute of Education will lodge and staff the study.

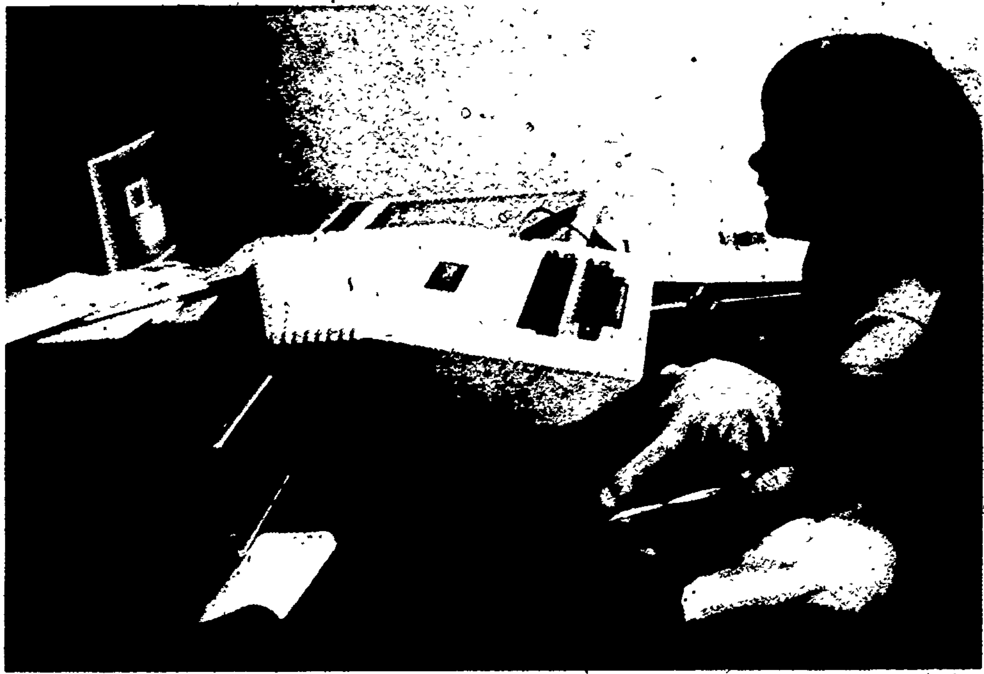
Educational Research and Development

Educational research and development has the objective of generating knowledge and techniques that aid the learning process and serve as a base for improving educational practice. Federal support for such work is concentrated principally in the Department of Education (ED). The National Institute of Education (NIE) in the Department's Office of Educational Research and Improvement (OERI) provides leadership in scientific inquiry into the educational process. The National Science Foundation (NSF) also has been concerned with research and development on learning processes to improve science education. Some recent achievements and new program initiatives in Federally sponsored educational research and development are highlighted below.

Information Technology

The Secretary of Education has assigned a high priority to fostering optimal use of the new information technology in American education. The new technology includes personal computers with graphic displays and videodisc systems, as well as broadcast and cable television. Thus, the Department of Education's plans for an educational technology initiative for fiscal year 1983 will involve research and development, plus school trials and demonstrations, in collaboration with educational publishers and information technology manufacturers.

A joint NSF/NIE program supports development of prototypes of computer-based instructional materials in many areas of mathematics, including elementary school mathematics, algebra, geometry, trigonometry, spatial visualization, logic, statistics, and



A young child uses computer technology to learn mathematical principles. Advanced Learning Technology

mathematical modeling. Examples of projects include:

- Investigators at Wittenberg University in Springfield, Ohio, are developing 10 to 15 computer games to supplement mathematics instruction in grades one through four. The games provide practice in basic mathematical skills and introduce students to problem-solving techniques.
- Researchers at the All Indian Pueblo Council in Albuquerque, New Mexico, are developing computer-based courses in mathematics and science for Pueblo Indian students in the upper elementary grades. The courses use the storytelling format, a familiar educational device in Pueblo culture.
- Scientists at Virginia Commonwealth University in Richmond are designing 15 to 20 lessons in computer graphing for high school algebra and adult trigonometry students. The lessons will enable students to see immediately the results of their equations.

Several projects involve the participation of local schools, teachers, students, and parents. Some focus primarily on the student; others on the teacher.

There is increasing interest in using computers for educational tests of far greater sophistication than those using the standard multiple-choice format, an application extensively explored in a widely distributed report of an earlier NIE conference on testing. NIE is now developing computer programs and other aids so that microcomputers can be used by teachers for classroom testing.

The Department's Office of Special Education and Rehabilitative Services is developing and adapting technology to facilitate communication for the sensorially handicapped and to improve instruction for handicapped students. For example, blind chemistry students can hear readings of scientific instruments through voice-synthesizing microcomputers and can use the computer to record notes on experiments. In addition, students with impaired upper limbs can use robots controlled by voice commands to perform laboratory operations.

Outside NSF and ED, the Agency for International Development (AID) is testing radio as the central component of an instructional system that can deliver high-quality instruction to large audiences in countries that have neither the trained teach-

Murray Kalish
A blind student reads using the Optacon. The image is transferred by the camera in the right hand to a direct tactile display of the letters felt by the left hand.

ers nor the financial resources to support a traditional school system. The rate of return on such primary education investments is very high and is associated with increased agricultural productivity and lower infant mortality. In earlier tests of a radio-based elementary school mathematics program in Nicaragua, children learned and retained more information than under traditional systems. The mathematics model is now being adapted in several countries, a language arts curriculum is being put together, and a complete radio primary school, including a science curriculum, will be tested beginning next year.

AID is also working on applying communications satellite technology to the solution of development problems in the least accessible areas of developing countries. The purpose is to demonstrate that the new satellite technologies using two-way telecommunications can provide, at reasonable cost, a breakthrough in delivery of education, information, agriculture, health, and social services to the "poor majority," the mandated target of AID assistance in the less developed countries.

Cognitive Science

Cognitive science—the new interdisciplinary science of human intellectual processes—is being applied in various ways to educational problems. For example, investigators at Carnegie-Mellon University have made precise descriptions of the processes human beings use in solving scientific, artistic, and other sorts of problems. Those descriptions are tested and refined by using them to program a computer and comparing the ways that humans and computers handle specific problems. The same methods are being used to gain insight into the critical differences between the performance of experts and that of new students in solving physics problems. A conference held in October 1980 by NIE explored the relationship between such research in cognitive science and innovative programs aimed at developing skill in thinking and learning. The skills fell into three areas: learning, comprehending, and remembering complex bodies of knowledge; thinking through and solving such complex problems as those arising in science and in composing essays; and formal reasoning, analysis, and systematic and organized approaches to intellectual tasks. The conference report forms the basis for a research program involving both contracts and grants for field-initiated projects.

Research conducted at the NIE-supported Center for the Study of Reading and elsewhere has produced a major reconceptualization of the reading process. The older view, which characterizes most current instructional practice, is that if readers can "decode" written language into oral form, comprehension occurs without further effort. Emerging theories show how good readers manage their attention and apply their existing knowledge in the additional task of reconstructing for themselves the meaning of the written text. The center, which is at the University of Illinois, is now entering a second 5-year funding period. It will maintain its focus on comprehension processes while increasing work aimed at bringing the new knowledge into school practice by a variety of means, including developing content and procedures for teacher training and continuing interaction with educational publishers.

Brain Science

The National Institute of Education and the National Science Foundation are cooperating with the Alfred P. Sloan Foundation in holding a conference in early 1982 on the brain, cognition, and education. The conference will seek to further the contribution to education of current and future research on the brain by establishing stronger links between such research and research in cognitive science and education. Three areas of central importance to education will be emphasized: attention; the acquisition, representation, and use of knowledge, broadly defined to include facts, concepts, and intellectual skills; and cognitive development as related to development of brain structures and effects of abnormalities and environment.

Education Related to Science and Technology

The maximal functioning of the science and technology enterprise depends on an adequate supply of high-quality personnel at all levels to carry out its activities. In addition, the increasingly technologically oriented nature of our society requires that all citizens have some minimal level of science and technology understanding. The education of Americans in science and technology is the responsibility of State and local governments. However, the Federal Government plays an indirect, catalytic role in that educational process in a variety of ways. For example, through grant and contract programs, the Federal agencies provide funds for facilities and equipment in the Nation's colleges and universities that may be used for instructional as well as research purposes. In addition, they sponsor technical conferences and teacher institutes, and many Federal agencies provide fellowships, traineeships, and student employment opportunities in areas closely related to their missions. They also make available their own research facilities for both research and educational purposes. All of those activities augment and facilitate the efforts of State and local governments to provide adequate educational opportunities related to science and technology.

In addition to those general kinds of activities, which have been ongoing and continue in many different agencies, the Department of Defense has recently initiated a series of new activities intended to offset an increasing shortage of scientific and technical manpower needed to fulfill national security objectives, particularly in the armed services. One cause for the military shortage of scientists, engineers, and technicians is believed to be the increasing demand for scientists and engineers in the civilian sector. That demand has increased salaries to the point that the armed services are having difficulty competing in recruitment. In addition, there are indications that the lucrative civilian job market is affecting the retention of military scientists and engineers; loss rates for military engineers have increased 20 percent in the past year.

North Carolina School of Science and Mathematics

In a workshop conducted at the North Carolina School of Science and Mathematics, high school teachers learn to use microcomputers for teaching science and mathematics classes.

With predicted increases in industrial demand for science and engineering personnel, even greater problems of recruitment and retention are being anticipated by the military service departments. As a result, the Defense agencies have been actively seeking remedies to the worsening condition of the science and engineering human resource base. Measures are being instituted to increase the supply, quality, and productivity of the science and technology work force by providing incentives to attract more science and technology personnel to military or related activities.

The Air Force, for example, has recently taken a number of significant actions: proposals have been drafted to provide bonuses and incentive pay for officers with rare and needed scientific and engineering skills, the recruiting of engineer technologists has been increased, and efforts have been made to increase the numbers of science and engineering graduates from subsidized undergraduate precommissioning programs (especially Air Force Reserve Officer Training Corps and Airman Education and Commissioning Programs). Developing new cooperative and subsidized programs and enhancing existing ones to tap the college markets once inaccessible to traditional precommissioning programs are other measures being taken. For example, the Air Force is testing a program that provides summer employment in laboratories and reserve commissioning to undergraduate engineering students. Upon graduation, the students will serve on active duty.

The Army has been working with other branches of the Department of Defense (DOD) to initiate programs to stimulate broader interest among high school students for careers in science and engineering. The objective is to provide a cooperative education (work/study) program that will afford hands-on experience in Army research, development, and acquisition activities to high school students who may choose to enter and complete basic education in science and engineering. High school students accepted for apprenticeships are paid during work periods and work directly under a mentor scientist or engineer. In addition to Research and Engineering Apprenticeships, the Department of the Army offers student work/study options through nonbaccalaureate programs in 2-year community and junior colleges and technical institutes, through baccalaureate programs, and through graduate programs.

In the Navy laboratories, needs also center on maintaining technical excellence and diverse capabilities under conditions that make it increasingly difficult to recruit and retain highly qualified people. The Navy intends to initiate a number of programs, similar to those outlined above for the Army and the Air Force, aimed at attracting more scientific and engineering technical and professional personnel. For all the defense agencies, DOD is planning a new graduate-fellowship program to support up to 400 predoctoral students by 1984.

International cooperation in science and technology (S&T) is as old as our Republic. Many Federal departments and agencies engage in joint research and other cooperative scientific endeavors with foreign countries, and many of those activities occur under umbrella agreements administered by the Department of State. There are currently 54 such bilateral agreements with 29 countries, and over 30 Federal departments and agencies are implementing scientific projects with their foreign counterparts.

America's international science and technology programs have extraordinarily varied agendas. They range from fundamental questions in basic research to practical problems of applied technology. They include the most elaborate of modern electronic devices in the industrial world and the simplest of basic machines in the third world. As a common denominator, American international science and technology programs place science and technology at the service of American foreign policy, while serving domestic goals as well.

Many of today's most important science and technology issues that have international ramifications—deep seabed mining, biotechnology, environmental pollution, transport of data by computer—were virtually unheard of 10 or 20 years ago. They have created drastic changes in the traditional political and diplomatic agenda, obliging our foreign policymakers to acquire new expertise and to remold their ways of thinking. As science progresses, new, unanticipated challenges will arise.

In his address to the opening session of the U.S./People's Republic of China Joint Commission on Scientific and Technological Cooperation, the President's Science Adviser, Dr. George A. Keyworth, summed up the relationship of U.S. science policy to the achievement of our national goals;

> .... (T)he major thrust of the Administration's economic and research and development programs is to provide enhanced incentives for, and remove disincentives to, increased industrial innovation and productivity .... (W)e believe that Government must continue to bear responsibility for the major portion of basic research since, for the most part, it is concerned with fundamental discovery in areas of long-term payoff and broad societal gain .... As we move ... from basic research to applied research to development and demonstration, we believe that the Government's role should decrease, and that the private sector will respond to market forces if the technology is needed .... While we have been making these changes in our domestic research and development policy, we have sought to continue our international cooperative research and development programs. In fact, with constrained budgets for research and development facing many nations around the world, ... collaborative scientific and technology projects will increase in importance in the coming decade.

In meeting those foreign and domestic policy goals, the U.S. science and technology enterprise cooperates with other nations of all types. Examples of some major current international cooperative programs are discussed below.

Cooperation with Developed Nations

Although the U.S. public and private sectors spent about $70 billion on research and development in 1981, that represented only a small portion of the world science and technology effort. We must now think in terms of an international division of labor, where achievements in one place can complement those in another. Through cooperation with other developed nations, we can achieve a more efficient distribution of the burden of scientific and technological research on a world scale and provide access for U.S. scientists to special or unique facilities abroad that would be prohibitively costly to reproduce at home. To facilitate such cooperation, the President's Science Adviser led a delegation of high-level representatives from a range of Federal agencies with major R&D programs to

Japan in September 1981. They met with their Japanese counterparts and identified several areas for cooperative efforts.

Examples of current productive collaboration between the United States and developed nations include:

(1) Under a radioactive waste management agreement with Canada, we have access to a Canadian underground test facility that uses granite as a repository for nuclear power wastes. Conversely, Canada benefits from U.S. work on salt deposits as a storage medium.

(2) Under the 1979 Energy Research and Development Agreement, the United States and Japan are cooperating in the "Doublet III" fusion research project. Japan is contributing $60 million over a 5-year period to upgrade the fusion facility in La Jolla, California. That contribution will enable the United States to greatly decrease its own outlays for experimental activities in fusion research.

(3) Japanese and U.S. scientists are studying methods of controlling forest tree diseases prevalent in Japan. The diseases, if introduced into the United States, could threaten U.S. forest species and cause millions of dollars in timber losses.

(4) Under an agreement signed in 1980, U.S. scientists have access to the unique facilities of Japan's Building Research Institute. The tests performed there will lead to improved seismic designs for structures.

(5) There is wide-ranging cooperation between the United States and France in oceanography covering, among other things, the ecological effects of oil spills, marine instrumentation and data buoy technology, and diving medicine under the Man-in-the-Sea Program. Mutual rescue operations of French and American research submersibles will continue to be explored.

(6) U.S. scientists are cooperating with their counterparts in Japan in studies of energy, charge, and mass of atomic particles. The Japanese resources, expertise, and facilities for preparing photographic emulsions for that work surpass any other in the world.

(7) U.S. scientists are using an Australian atomic reactor that is uniquely equipped for neutron radiography.

(8) U.S. astronomers have access to the Mt. John observatory in Australia, the only one in the Southern Hemisphere equipped for research.

(9) Australia is also the site for National Science Foundation-sponsored high-altitude balloon launches used for cosmic ray, meteorological, and other studies and for testing instruments that are later flown in satellites.

(10) U.S. scientists are using a system developed in Chile for growing plant tissues or cells in glass vessels to gain basic knowledge of cell wall development in coniferous trees.

(11) For several years, the U.S. National Bureau of Standards has cooperated with the Central Testing Laboratory for Construction Materials in Madrid in studies of the corrosion of steel in prestressed concrete structures. The information has yielded highly useful information for design of bridges, buildings, and other structures.

Cooperation with Developing Nations

The U.S. commitment to scientific cooperation with developing countries is motivated by three principal considerations. One consideration is that the scientific and technical capacities and infrastructures of those countries must be strengthened if they are to transform themselves into modern societies, a transformation that will facilitate their relationship and interaction with the United States. Whether in the management of natural resources or in the diffusion of technological techniques, we are involved with countries at every stage of development through our Agency for International Development (AID) programs under reimbursable arrangements or by other means under umbrella agreements.

AID, in cooperation with the Department of State, will place even greater emphasis on the use of science and technology in its development programs in the future. To implement its new policy, AID has created the Bureau for Science and Technology, which will seek to improve the science and technology capabilities of AID to plan and implement Agency programs both in the field and in Washington. The Bureau will emphasize the transfer of technology to developing countries and improvement of scientific expertise in the Agency.

As one example of the increased emphasis on science and technology in AID's programs, the Agency is expanding its energy assistance programs with developing countries to help them in addressing energy constraints to their development. The expansion of AID's energy programs focuses on technical assistance activities for analyzing energy needs, uses, resources, and policies; for energy-related training and institutional development; and for site testing and demonstration of new technologies.

The impact of AID's science and technology emphasis will also be felt in health programs. In response to a resurgence of malaria throughout the world, efforts to find an effective antimalaria vaccine have recently been intensified. AID-supported laboratories have recently made major advances in malaria research, including improving the background technologies on the basis of which an effective vaccine might be produced in the near future.

The second consideration involved in the U.S. commitment to scientific cooperation with developing countries is that we can enhance the competitive position of U.S. industry in third-world marketplaces through such cooperation—by orienting scientific communities in developing countries to U.S. technology and to our industrial standards, laboratory equipment, and quality controls. The long-run benefits for U.S. exports are obvious.

The third consideration is that, despite limitations of infrastructure and personnel, scientists in many developing countries are doing significant research in specialized areas from which the United States can profit. Because of their cultural and environmental characteristics, those countries can provide unique natural laboratories for collaborative studies. For example, the U.S. Public Health Service and the National Institute of Nutrition in Hyderabad, India, are planning joint studies on nutrition-related blindness. In Egypt, U.S. and Egyptian scientists are working together on the management of desert ecosystems and on the ecological implications of the Aswan Dam. Scientific exchange programs with Mexico cover a broad range of substantive areas, including energy, instrumentation, information science, rail transportation, and agriculture. These are examples of the mutual benefit to be derived from our cooperative science and technology agreements.

U.S. Science Cooperation with the People's Republic of China

Scientific and technical programs play a major role in the strengthening of ties to the People's Republic of China, where scientific, educational, and institutional links developed a generation ago have reappeared after long hibernation, becoming central to a political relationship of world significance.

U.S. cooperation with the People's Republic of China (P.R.C.) takes place within the framework of the January 1979 U.S./P.R.C. Agreement on Scientific and Technological Cooperation. The agreement's implementation is overseen by a U.S./P.R.C. Joint Commission on Scientific and Technological Cooperation, chaired on the American side by the President's Science Adviser. During 1981, there was a rapid increase in the implementation of cooperative projects, and the overall scope of science and technology cooperation was reviewed at the second meeting of the Joint Commission held in Washington in October of that year.

U.S./P.R.C. cooperation in science and technology involves many Federal agencies and is covered in 17 protocols for specific areas of cooperation. Although budgetary realignments in China have slowed some projects, including those in high-energy physics, most programs have been proceeding apace. Particularly noteworthy are the U.S. Department of Agriculture's collection in China of live specimens of natural enemies of crop pests, which are to be used in experiments on integrated pest management, and the U.S. Department of Health and Human Services' investigations in epidemiology, which should give new

Department of State

Presidential Science Adviser, Dr. George A. Keyworth II, makes closing remarks to the Second Meeting of the U.S./P.R.C. Joint Commission on Scientific and Technological Cooperation.

insights into disease prevention and control. The National Science Foundation concluded a new bilateral science agreement with the P.R.C. on December 10, 1980. It calls for cooperation during the next 5 years in the physical, life, and behavioral and social sciences, engineering, history of science, research and development management, and science and technology policy. Under the agreement, U.S. scientists will enjoy improved access to the subject matter of their studies. The proposed joint activities include the organizing of scientific meetings; the exchange of scientists, research materials, and information; and the conduct of cooperative research projects.

APPENDIX

SPECIAL ANALYSIS K

RESEARCH AND DEVELOPMENT

The Budget of the United States Government, 1983

OFFICE OF MANAGEMENT AND BUDGET
EXECUTIVE OFFICE OF THE PRESIDENT
February 1982

Note.—All years referred to are fiscal years, unless otherwise noted. Details in the tables, text, and charts of this booklet may not add to totals because of rounding.

SPECIAL ANALYSIS K

RESEARCH AND DEVELOPMENT

This analysis summarizes the funding of research and development across all departments and agencies. It consists of two parts. The first highlights the R. & D. policies and trends in the 1983 budget. The second describes in more detail the R. & D. programs of the 13 agencies whose 1983 obligations account for over 99% of total Federal funding for R. & D.

The Federal Government does not have a separate R. & D. budget. Rather, R. & D. programs are reviewed and funded primarily in the context of the missions of individual agencies and on the basis of their importance in meeting mission objectives.

PART I. HIGHLIGHTS

R. & D. activities are supported by the Federal Government in two broad categories, namely, to meet:

- Federal Government needs—where the sole or primary user of the R. & D. is the Government itself, for example, in national defense and environmental regulation.
- National needs—where the Federal Government helps to assure the strength of the Nation's economy and the welfare of its citizens through the support of R. & D. in specific areas such as agriculture, energy, and health.

The 1983 budget reflects a clearer delineation, than has been the case in the past, between the responsibilities of the Federal Government and those of the private sector with respect to R. & D. to help meet national needs.

The Federal Government has two main responsibilities with respect to R. & D. to meet national needs.

- First, it should provide a climate for technological innovation which encourages private sector R. & D. investment that best reflects the realities of the marketplace where new and improved processes and products are developed, bought, and sold. The administration is fulfilling this responsibility primarily by reducing Government spending, regulation and taxes. Thus, the administration's R. & D. policy is part of its overall economic policy.
- Second, the Government should focus its direct R. & D. support on those areas where there is substantial prospect for significant economic gain to the Nation, but where the pri-

vate sector is unlikely to invest adequately in the national interest because the benefits, in large measure, are not immediately "appropriable" by individual firms. Thus, for example, the Federal Government supports basic research across all scientific disciplines but limits its spending on technology development to technologies requiring a long period of initial development, such as fusion power, where the risk is high but the payoff to the Nation is potentially large. This strategy is reflected in the funding for R. & D. to meet national needs in the 1983 budget.

Total obligations and outlays for the conduct of all Federal R. & D. programs and for related facilities are shown in table K-1 below.

Table K-1. TOTAL FEDERAL FUNDING FOR CONDUCT OF R. & D. AND RELATED FACILITIES

(In billions of dollars)

	Obligations			Outlays		
	1981 actual	1982 estimate	1983 estimate	1981 actual	1982 estimate	1983 estimate
Conduct of R. & D.	35.0	38.8	43.0	34.3	37.4	41.1
R. & D. facilities	1.5	1.5	1.3	1.6	1.7	1.2
Total	36.5	40.4	44.3	35.9	39.1	42.3

CONDUCT OF RESEARCH AND DEVELOPMENT

The 1983 budget includes $43.0 billion in obligations for the conduct of R. & D., an increase of $4.2 billion over 1982, largely in the R. & D. programs of the Department of Defense. Smaller but significant increases are also proposed for the R. & D. programs of a number of agencies including the National Aeronautics and Space Administration, the Department of Health and Human Services and the National Science Foundation. A major further decrease is proposed in 1983 in Federal support of energy R. & D. to be funded through the proposed Energy Research and Technology Administration within the Department of Commerce. Included within the total funding for the conduct of R. & D. is support for the conduct of basic research, but not the funding for R. & D. facilities, which is reported separately in this analysis.

Highlights of the programs of major R. & D. agencies that account for 94% of the proposed obligations for the conduct of R. & D. by all agencies are presented below:

- ***Department of Defense (DOD).***—Obligations for the conduct of R. & D. by DOD will rise to $24.5 billion, an increase of $3.9 billion over 1982; this represents 57% of the total Federal funding for R. & D. In 1983, the Department will provide increased support for basic research and for R. & D. related to the development of advanced strategic systems, such as bombers, ballistic missiles and ballistic missile defense.

- *National Aeronautics and Space Administration (NASA).*—Obligations for the conduct of R. & D. by NASA are estimated at $6.5 billion for 1983, $0.7 billion over 1982. Increased funding for 1983 is proposed to assure timely transition of the Space Shuttle to an operational system and to continue the highest priority research and space exploration projects, including the further development of the Space Telescope, Gamma-Ray Observatory and the Galileo Mission to Jupiter.
- *Department of Commerce (DOC).*—Obligations by this Department for the conduct of R. & D. would be $4.2 billion in 1983, $0.6 billion below 1982. Included in the 1983 total amount is $3.9 billion for programs transferred to the Department as part of the proposed dismantlement of the Department of Energy. This represents a net decrease of $0.6 billion for these programs but includes increases for nuclear weapons R. & D. and for long-term research in energy sciences and fundamental physics. These increases are more than offset by eliminating subsidies to industry for near-term energy research and

Table K-2 summarizes Federal support for the conduct of R. & D. by agency.

Table K-2. CONDUCT OF RESEARCH AND DEVELOPMENT BY MAJOR DEPARTMENTS AND AGENCIES

(In millions of dollars)

Department or agency	Obligations			Outlays		
	1981 actual	1982 estimate	1983 estimate	1981 actual	1982 estimate	1983 estimate
Defense-military functions	16,494	20,553	24,469	15,720	18,784	22,673
National Aeronautics and Space Administration	5,407	5,841	6,513	5,279	5,696	6,460
Commerce	5,276	4,793	4,157	5,466	5,240	4,352
(Energy Research and Technology Administration)	(4,948)	(4,522)	(3,917)	(5,121)	(4,948)	(4,104)
Health and Human Services	3,973	3,972	4,122	3,991	3,935	4,039
(National Institutes of Health)	(3,332)	(3,427)	(3,533)	(3,350)	(3,390)	(3,487)
National Science Foundation	964	961	1,033	892	1,018	908
Agriculture	773	807	838	742	805	824
Interior	424	397	371	438	402	380
Transportation	420	329	366	418	321	316
Environmental Protection Agency	326	317	230	344	335	274
Nuclear Regulatory Commission	227	223	220	211	209	206
Agency for International Development	156	160	186	151	157	159
Veterans Administration	147	137	145	138	130	140
Education	91	74	76	96	94	112
All other [1]	354	279	272	366	298	280
Total conduct of R. & D.	**35,033**	**38,843**	**42,997**	**34,252**	**37,425**	**41,122**

[1] Includes the Departments of Housing and Urban Development, Justice, Labor, Treasury, and State, the Tennessee Valley Authority, the Smithsonian Institution, the Corps of Engineers, the Federal Emergency Management Agency, the U.S. Office of Personnel Management, the Library of Congress, the Arms Control and Disarmament Agency, the Federal Communications Commission, the Advisory Committee on Intergovernmental Relations, and the Federal Trade Commission

technology development. The other R. & D. programs of the Department of Commerce, such as metrology and oceanic, marine and atmospheric research, would be reduced by $31 million below 1982, to a level of $240 million in 1983.

- *Department of Health and Human Services (HHS).*—Obligations for the conduct of R. & D. in HHS are estimated to total $4.1 billion in 1983, $150 million above 1982, of which the National Institutes of Health (NIH) accounts for about $3.5 billion, $106 million above 1982. The 1983 budget for NIH continues to support a strong national effort in biomedical research, including research related to potentially hazardous occupational and environmental exposures.
- *National Science Foundation (NSF).*—Obligations for the conduct of R. & D. by NSF are estimated to total $1,033 million in 1983, an increase of $72 million over 1982. Included in the total is $984 million for the support of basic research, an increase of $72 million over 1982. The 1983 budget for NSF proposes increased support of research in the natural sciences and engineering and selected retrenchment in relatively lower priority programs.

CONDUCT OF BASIC RESEARCH

Support for the conduct of basic research is included within the overall funding for the conduct of R. & D. Obligations for the conduct of basic research are estimated to increase in 1983 by $0.5 to $5.8 billion or 9% over 1982.

The 1983 budget recognizes the need to maintain a strong national research effort in all scientific disciplines. Basic research in such fields as chemistry, physics, biology, materials, oceanography, and earth sciences provides the underpinning, for example, for advances in health care, improved nutrition and agricultural production, and new technologies for defense, space and energy.

The allocation of funds in the 1983 budget provides for the further strengthening of basic research in specific areas of Government responsibility such as defense and space. Special emphasis is also being given, in the national interest, to strengthening basic research in the physical sciences and engineering as exemplified in programs of the new Energy Research and Technology Administration in the Department of Commerce and the National Science Foundation. Such areas of research are of particular importance to long-term industrial productivity and economic growth.

The increase in basic research support will particularly encourage scientists at the Nation's colleges and universities in their efforts to advance the frontiers of knowledge and thereby also aid in the training of future scientists and engineers. About one-half of the total Federal obligations for basic research are made to support researchers in universities and colleges who conduct about one-half of all basic research performed in the Nation.

Table K-3 summarizes Federal support for the conduct of basic research by agency.

Table K-3. CONDUCT OF BASIC RESEARCH BY MAJOR DEPARTMENTS AND AGENCIES

(In millions of dollars)[1]

Department or agency	Obligations			Outlays		
	1981 actual	1982 estimate	1983 estimate	1981 actual	1982 estimate	1983 estimate
Health and Human Services	1,955	2,000	2,069	1,944	1,978	2,034
(National Institutes of Health)	(1,767)	(1,839)	(1,897)	(1,750)	(1,813)	(1,869)
National Science Foundation	898	912	984	830	972	861
Defense-military functions	603	673	781	554	616	712
Commerce	608	665	762	614	670	759
(Energy Research and Technology Administration)	(591)	(647)	(741)	(597)	(652)	(737)
National Aeronautics and Space Administration	532	580	682	538	575	661
Agriculture	314	332	359	302	337	354
Interior	80	73	68	79	73	69
Smithsonian Institution	44	45	51	41	44	51
Veterans Administration	15	13	14	15	13	14
Education	17	14	14	18	18	22
Environmental Protection Agency	10	15	10	12	12	10
All other[2]	32	27	28	29	29	28
Total	**5,108**	**5,348**	**5,821**	**4,975**	**5,337**	**5,574**

[1] Amounts reported in this Table are included in Totals for conduct of R & D

[2] Includes the Departments of Justice, Transportation, Treasury and Labor, the Tennessee Valley Authority, the Corps of Engineers, the Federal Trade Commission, the Library of Congress, and the Agency for International Development.

R. & D. FACILITIES

The successful conduct of R. & D. is dependent on the quality of instrumentation and facilities that are available to the research community. A significant amount of funding for equipment and instrumentation is included, but not separately identified, in the funding for the conduct of R. & D. Funds separately identified for R. & D. facilities by Federal Government agencies are summarized in table K-4.

Obligations for R. & D. facilities in 1983, including the construction or renovation of facilities and the acquisition of major equipment, will amount to $1.3 billion, $265 million below 1982.

Significant changes in R. & D. facilities support are being proposed in 1983, primarily for programs that are being transferred to the Department of Commerce, as part of the proposed dismantlement of the Department of Energy. In these programs in 1983, support will be maintained generally for basic research facilities, such as those for high energy physics research. However, significant reductions are proposed for facilities related to the demonstration of energy technologies, largely in keeping with the policy of relying more on industry investment. The 1982 budget includes funds to bring many energy demonstrations to an orderly close or to assist industry in taking over the support of these facilities.

Table K–4. RESEARCH AND DEVELOPMENT FACILITIES BY MAJOR DEPARTMENTS AND AGENCIES

(In millions of dollars)

Department or agency	Obligations			Outlays		
	1981 actual	1982 estimate	1983 estimate	1981 actual	1982 estimate	1983 estimate
Commerce	982	964	681	1,112	1,191	644
(Energy Research and Technology Administration)	(981)	(955)	(678)	(1,111)	(1,184)	(640)
Defense-military functions	278	285	366	238	248	320
National Aeronautics and Space Administration	114	143	116	147	135	122
Agriculture	21	35	30	39	39	34
Health and Human Services	25	62	20	43	35	38
(National Institutes of Health)	(23)	(18)	(20)	(42)	(32)	(28)
National Science Foundation	13	10	16	13	10	15
All other [1]	47	28	33	35	43	25
Total	1,480	1,526	1,262	1,627	1,702	1,198

[1] Includes the Departments of the Interior, Transportation, and Treasury, the Veterans Administration, the Tennessee Valley Authority, the Agency for International Development, and the Smithsonian Institution.

PART II. AGENCY R. & D. PROGRAMS

Presented below are summaries of the R. & D. activities of the 13 agencies that support more than 99% of Federally funded R. & D.

DEPARTMENT OF DEFENSE

The primary purpose of the Defense R. & D. program is to develop new strategic and tactical weapons and supporting systems to improve the Nation's defense. In 1983, DOD obligations for the conduct of R. & D. will increase by $3.9 billion to $24.5 billion, which represents over one-half of total Federal funding for research and development in 1983. Within the total funding by DOD for the conduct of R. & D., funding of basic research will increase from $673 million in 1982 to $781 million in 1983. Funding for R. & D. facilities will increase by $81 million in 1983 to a total of $366 million. By mission category, major R. & D. efforts for 1983 include:

Technology Base and Advanced Technology Development.—There will be substantial real growth in DOD support of these areas, above the 1982 level, to investigate promising new technologies and to avoid technological surprise. Current thrusts in very high speed integrated circuits and guided munitions capable of being operated in adverse weather will continue. Increased emphasis will be given to new technologies that offer significant opportunities to increase the effectiveness of existing military forces, such as improved information processing, better materials, and improved sensors. Other programs include work on electronic devices that will continue to operate when parts malfunction, electronics that are resistant to various types of radiation, advanced computer languages and methods of computing high-power lasers and advanced composite materials.

Strategic Programs.—The budget provides significant increases in this area for the accelerated development of ballistic missile defense, as well as the exploration of future options for MX basing—either deep underground or in continuous patrol aircraft. In addition, development efforts continue on an anti-satellite system and an advanced technology bomber. Development of the communications and control systems needed to support strategic weapons will receive increased emphasis.

Tactical Programs.—Funds will be provided in 1983 to continue the development of systems to increase the capability of U.S. general purpose and theater nuclear forces, as well as to develop the capability to project forces rapidly wherever the vital interests of the U.S. are threatened.

- Army efforts include improvement programs for the M-1 tank, chemical defense equipment and chemical weapons, and various helicopter systems, and continued development of the Patriot anti-aircraft missile system.
- The Air Force is developing deep strike interdiction versions of F-15 and F-16 fighters, LANTIRN night/all weather navigation and targeting pods for tactical aircraft, and the AMRAAM advanced medium range air-to-air combat missile.
- The Navy is developing a lightweight anti-submarine torpedo, a new destroyer and a vertical launch system for missiles. Upgrades to current subsystems to improve detection, tracking and targeting will also increase the capability of major systems now in production.

Intelligence and Communications, Program Management and Support.—R. & D. on intelligence and communication systems will focus on communication satellites, on radios that will work in the electronic noise of the battlefield, and on battlefield surveillance radars. Work will also continue on the use of technology to reduce manufacturing costs and to extend the life and capability of existing defense systems.

NATO Cooperation.—Cooperation in research and development and joint production of new weapon systems will be pursued to exploit, fully, Alliance resources. Funding for these activities is not identified separately in table K-5 but is included in the other categories discussed above.

Table K-5 provides the details of the Department of Defense military R. & D. funding.

Table K-5. DEPARTMENT OF DEFENSE—MILITARY RESEARCH AND DEVELOPMENT

(In millions of dollars)

Type of activity	1981 actual	1982 estimate	1983 estimate
OBLIGATIONS			
Conduct of R. & D.:			
Research, development, test and evaluation:			
Technology base	2,570	2,849	3,288
Advanced technology development	578	736	928
Strategic programs	3,187	4,802	6,520
Tactical programs	5,914	7,029	7,524
Intelligence and communications	1,565	2,167	2,675
Program management and support	2,096	2,289	2,849
Other appropriations	585	681	685
Total conduct of R. & D.	16,494	20,553	24,469
Total conduct of basic research, included above	(603)	(673)	(781)
R. & D. facilities	278	285	366
Total obligations	**16,772**	**20,838**	**24,835**
OUTLAYS			
Conduct of R. & D.	15,720	18,784	22,673
R. & D. facilities	238	248	320
Total outlays	**15,958**	**19,032**	**22,993**

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Through the programs of NASA, the Federal Government makes investments in R. & D. that yield new space technologies to improve the national security and the long-term scientific and technological strength of the Nation. They also provide new knowledge about the earth, the solar system, and the universe.

In 1983, the R. & D. request would continue flight missions launched in prior years (e.g., Voyagers to the outer planets) and further development of most major ongoing projects, including the Space Shuttle. Obligations for the conduct of R. & D. would increase by $672 million in 1983 to a total of $6.5 billion. Within this amount, basic research would amount to $682 million, an increase of $102 million over 1982. Obligations for construction of facilities in 1983 would total $116 million.

Space Transportation.—Shuttle development, testing and procurement of a fleet of four orbiters will continue in the space transportation systems program. The Space Shuttle is essential to exploit space effectively and will help maintain U.S. leadership in space throughout this century. It will allow retrieval, repair and service of satellites in space and the operation of space laboratories, such as the European-built Spacelab, for scientific and technology applications. Because it is reusable, the Shuttle has the potential to reduce the cost of space missions.

The Shuttle is expected to operate on a routine basis in 1983 to meet the needs of domestic and foreign users, who have already made significant investments in anticipation of its availability in the early 1980s. Also, regular Shuttle operations are important to meet civilian and national security commitments in a timely manner at the lowest total cost to the Nation. While the Shuttle is expected to replace most expendable launch vehicles, the budget continues efforts to assure adequate expendable vehicle capacity until the Shuttle becomes fully operational.

With the second successful launch of the Space Shuttle orbiter, Columbia, the U.S. clearly demonstrated that a manned reusable space vehicle is feasible. The 1983 budget provides the funds needed to make possible a timely and effective operational Shuttle system. Included are funds to:

- Demonstrate the ability to use the Shuttle for repairing a damaged satellite while in orbit;
- Enhance the payload lift performance of the Shuttle, providing users with additional assurance that its full planned capabilities will be available to both civil and national security users.
- Continue procurement of the second Spacelab (with an initial flight of the first Spacelab planned for mid-1983) and continue to develop and procure an upper stage for use with the Shuttle for high-Earth orbit and for interplanetary missions. The Shuttle will be operated from the Kennedy Space Center in Florida and from the Vandenberg Air Force Base in California.

Space Science.—In this area, in-flight projects are conducting deep space astronomy while in orbit and others are exploring the solar system. Most of these spacecraft will continue their flight missions and will gather scientific data well beyond 1983.

- The Solar Maximum Mission, launched in 1980, will continue operations and data analysis activities.
- Two Voyager spacecraft, launched in 1977, have successfully encountered Jupiter and Saturn, and Voyager 2 will continue on its way to Uranus.

- The flight of several other scientific satellites (e.g., International Ultraviolet Explorer) will be extended.

The 1983 budget supports continuation of the flight of these satellites in space and analysis of scientific data sent back to Earth. It also provides for the retrieval and repair in orbit of the partially disabled Solar Maximum Mission Satellite.

The proposed budget continues development of major flight projects to be launched in the future.

- The Space Telescope is planned for launch in 1985 and will serve as a major astronomy facility for a 15- to 20-year period.
- The Gamma Ray Observatory is planned for launch in 1988 and will enhance basic research in high energy astrophysics, providing new knowledge about objects in deep space.
- Spacelab astronomy experiments, designed for repeated use, will be conducted on the Shuttle to improve our understanding of the Sun and the universe from Earth orbit.
- Work is continuing on the Galileo mission to Jupiter; the spacecraft is composed of two segments—an orbiter and a probe to enter the upper atmosphere of Jupiter. The Galileo orbiter and probe will be launched in 1985 and will arrive at Jupiter in 1989 to carry out long-term studies of the giant planet, its satellites, and its magnetosphere.
- Experiments will be conducted using several smaller Explorer satellites, balloons, aircraft, and sounding rockets.

Space and Terrestrial Applications.—The 1983 budget continues to support research that could lead to the broad application of space technology to national needs. The 1983 budget requests continued funding for relatively fundamental and long-term research activities to:

- Improve understanding of Earth resources, climate, weather, and pollution;
- Develop agriculture forecasting techniques based on satellite data;
- Advance knowledge in materials science through low gravity experiments; and
- Extend the capability for satellite communications at higher frequencies than those employed with current satellites.

Development of the fourth and fifth in the series of land remote sensing satellites is continuing with launches scheduled for 1982 and 1985. With the completion of Landsat development activities by NASA in 1983, the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce will assume responsibility for an operational satellite data system based on the Landsat-D series of satellites. Space remote-sensing technology, such as that employed by Landsat-D, has the potential to improve our ability to manage critical Earth resources.

The climate-observing satellite program, designed to provide global measurements of the Earth's radiation, is being continued. The mission is an important part of the national effort aimed at providing a better understanding of the Earth's climate.

In addition, NASA is developing ways to use the Spacelab (to be flown in the Shuttle) for materials processing and other applications.

Aeronautical Research and Technology Programs.—In 1983, support will be focused on fundamental research in all basic aeronautical disciplines, the maintenance of specialized facilities for research and testing, and technology development and demonstration activities critical to the Nation's defense needs.

Research emphasis will be placed on:

- Aerodynamics, propulsion and avionics;
- Flight controls and human-vehicle interaction; and
- Materials and structures.

Technology development and demonstration projects with relatively near term commercial applications will be curtailed as an inappropriate Federal subsidy.

Agency-wide Support Activities.—Obligations for agency-wide support activities will increase by $168 million in 1983 to $1.9 billion. These programs include, primarily, satellite tracking and data acquisition support, all NASA civil service and administrative costs, construction and maintenance of the agency's R. & D. facilities, and R. & D. addressing fundamental space technology problems and opportunities common to a broad spectrum of space programs. For 1983, the increased obligations are needed primarily to initiate lease payments for the new Tracking and Data Relay Satellite System.

Table K-6 provides the details of NASA's R. & D. funding.

DEPARTMENT OF COMMERCE

In 1983, the scope of the Department of Commerce R. & D. activities will expand significantly as a result of the proposed dismantlement of the Department of Energy and the transfer of its R. & D. programs to the Department of Commerce, where they will be administered by the new Energy Research and Technology Administration (ERTA).

R. & D. support for the ongoing R. & D. programs of the Department is provided primarily through the National Bureau of Standards (NBS), and the National Oceanic and Atmospheric Administration (NOAA).

Total obligations for the conduct of R. & D. will decrease from $4.8 billion in 1982 to $4.2 billion in 1983. The Department's activities by area are summarized below.

Table K-6. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION—RESEARCH AND DEVELOPMENT

(In millions of dollars)

Type of activity	1981 actual	1982 estimate	1983 estimate
OBLIGATIONS			
Conduct of R & D.:			
Space transportation systems	2,729	3,090	3,468
Space science	542	568	682
Space and terrestrial applications	340	334	320
Aeronautical research and technology	271	233	232
Space research and technology	111	111	123
Energy technology	2	—	—
Tracking and data acquisition	341	402	509
Research and program management	1,071	1,103	1,179
Total conduct of R. & D	5,407	5,841	6,513
Total conduct of basic research, included above	(532)	(580)	(682)
R & D. facilities	114	143	116
Total, obligations	**5,520**	**5,984**	**6,629**
OUTLAYS			
Conduct of R & D	5,279	5,696	6,460
R. & D. facilities	147	135	122
Total, outlays	**5,426**	**5,831**	**6,582**

Energy Research and Technology Administration (ERTA).—Support will be provided by ERTA for a substantial R. & D. program related to the development and testing of nuclear weapons; a general science program comprised largely of basic research in high energy physics and nuclear sciences; and a broad energy research program focused on long-term R. & D.

Obligations for the conduct of research and development at ERTA will total $3.9 billion in 1983, a reduction of $604 million from 1982. Obligations for R. & D. facilities will total $678 million in 1983, $277 million below 1982. These decreases for energy R. & D., particularly the decrease for R. & D. facilities, reflect the proposed curtailment of Federal support for major demonstration projects (e.g., in fossil and solar energy conversion) consistent with the Administration policy that such projects are more appropriately the responsibility of the private sector. ERTA programs by major area are highlighted below.

The national defense program of ERTA supports the continued development and production of new nuclear weapons. This program also supports the development of improved technologies for monitoring nuclear weapons treaties and of improved methods for safeguarding nuclear materials. Efforts will be continued to develop improved technologies and methods for the safe storage and disposal of radioactive wastes produced by the national defense programs and to develop improved propulsion reactors for naval vessels.

Obligations for these activities are proposed to increase from $1.5 billion in 1982 to $1.7 billion in 1983 for the conduct of R. & D. to assure an effective long-term nuclear weapons program. Obligations for R. & D. facilities in this area will be $336 million in 1983, a decrease of $60 million below 1982.

The general science and research program of ERTA primarily supports research in high energy and nuclear physics. An increase of $56 million to $483 million in 1983 for the conduct of R. & D. will allow continued emphasis on advanced accelerator concepts and efforts to understand the fundamental nature and constituents of matter at about the 1981 level of effort. Life sciences research and research on nuclear medicine applications, also supported as part of the general science program, are continued at a reduced level. In addition, $117 million will be obligated in 1983 for R. & D. facilities in this area, approximately the same level as 1982.

Because of the exceptional research opportunities in high energy physics and the demonstrated excellence of the U.S. program, the administration is committed to maintaining a strong national effort in this field. The 1983 budget request of $429 million for the conduct of R. & D. and related facilities in this field represents a $65 million increase over 1982. This would provide for an increased level of utilization of existing research facilities, expeditious completion of the Energy Saver and TEVATRON I and II projects at Fermilab, research and development work at the Stanford Linear Accelerator Center leading to the planned Stanford Linear Collider project, and accelerator research and development on improved components and novel concepts. A principal thrust in this field will be accelerator R. & D. efforts at the Brookhaven National Laboratory, related to a future high energy physics accelerator project. Any decision to proceed with this project will be based on overall scientific potential and budget considerations.

The energy program of ERTA includes a broad program of support in the basic energy sciences and other long-term research to provide a scientific underpinning for advancements in energy technology by Government and industry. It also includes support for the development of selected energy technologies of a high risk but potentially high pay-off nature, such as magnetic fusion, where significant private investment is unlikely at this time.

Obligations for the conduct of energy R. & D. are proposed to decrease from $2.6 billion in 1982 to $1.8 billion in 1983. Obligations for R. & D. facilities in this area will be $224 million in 1983, a decrease of $216 million below 1982.

In the basic energy sciences, funding for the conduct of R. & D. and related facilities will be increased by $40 million to $284 million in 1983 for long-term research in such fields as nuclear science, chemistry, engineering, materials science, mathematics, biology, and geoscience. Such support is intended to strengthen the scientific and technical base for future advances in all energy technologies. In addition, emphasis will be given to providing support for the operation of several unique national user facilities, which the basic energy science program manages (e.g., the National Synchrotron Light Source at the Brookhaven National Laboratory). In 1983, the basic energy science program, for the first time, will assume full responsibility for the Stanford Synchrotron Radiation Laboratory. This facility was previously funded by the National Science Foundation.

The 1983 budget will continue the redirection of the non-nuclear R. & D. programs to emphasize long-term generic research and place greater reliance on the private sector for technology development. Obligations for the conduct of R. & D. in fossil, solar, biomass and other renewable energy sources are expected to be $315 million in 1983, down from $814 million in 1982, with an additional reduction of $95 million for demonstration projects included under support for R. & D. facilities. The budget provides $107 million for the conduct of fossil related R. & D. and associated facilities which strengthen the scientific base, in such areas as catalysis, kinetics, waste characterization, flame research and coal structure. Funding at the level of $90 million will be provided for research in support of solar energy and energy conservation.

The 1983 budget provides for a broad nuclear program of fission and fusion R. & D. The breeder reactor program will be funded at $577 million in 1983, maintaining a priority on the design and construction of the Clinch River Breeder Reactor (CRBR). In addition, long-range research will continue in support of breeder technology. Total funding for breeder R. & D. will decrease by $108 million from 1982, through curtailment of technology development in support of the follow-on Large Developmental Plant (LDP) and through phase-out of the Light Water Breeder Reactor demonstration.

In other fission R. & D., there will be a focus on safety and waste management research. The Department, in cooperation with the Nuclear Regulatory Commission, will conduct technical investigations associated with the disabled Three Mile Island (TMI) plant. This will permit a better understanding of accidents such as the occurrence at Three Mile Island and will help to prevent them in the future. The disabled TMI plant will serve as a source of useful data to aid this research. The budget includes $205 million in 1983 for the conduct of other fission R. & D., a reduction of $47 million below 1982.

The budget request for fusion R. & D. and related facilities in 1983 of $444 million is a decrease of $10 million from the 1982 level. This change consists of an increase of $66 million in the operating budget offset by a decrease of $76 million in capital equipment and construction. The increase in the operating component of the budget is based on the goal of resolving key outstanding physics and technology issues before continuing the pace of construction of new large facilities.

Finally, the energy R. & D. program of ERTA includes research on the environmental effects of energy production and use which will continue at about the same level of effort as 1982 with emphasis on determining the health effects of radiation and generic research related to synthetic fuels technology. Funding also will continue for research to determine the relationship between the CO_2 content of the atmospheric and the Earth's climate changes.

National Oceanic and Atmospheric Administration (NOAA).—NOAA will continue research programs in the development of systems and components in such areas as mapping and charting; ocean research; conservation, protection and management of endangered and threatened species in the Nation's fisheries resources; forecasting, detection and tracking of weather systems and violent storms; and air pollution. Obligations for the conduct of R. & D. by NOAA in 1983 will decrease slightly from $159 million to $152 million.

National Bureau of Standards (NBS).—R. & D. efforts for NBS are organized into four programs: measurement research and standards; engineering measurement and standards; computer sciences and technology; and central technical support.

In 1983, NBS is expected to obligate $76 million for the conduct of R. & D. This is an $11 million decrease from 1982. Most of this decrease is related to the transfer of the governmentwide ADP standards program to the General Services Administration. In addition, there will be selected reductions in activities that are more appropriate for private sector funding (e.g., automated manufacturing) and increases for basic research activities needed to improve measurement techniques and standards.

Other Commerce R. & D. Activities.—The Bureau of the Census, the Patent and Trademark Office, and the National Telecommunications and Information Administration also maintain smaller research and development programs. R. & D. funding for these areas in 1983 would be $12 million.

Table K–7 provides the details of the R. & D. funding by the Department of Commerce.

Table K-7. DEPARTMENT OF COMMERCE—RESEARCH AND DEVELOPMENT

(In millions of dollars)

Type of activity	1981 actual	1982 estimate	1983 estimate
OBLIGATIONS			
Conduct of R. & D.:			
Energy Research and Technology Administration [1]	4,948	4,522	3,917
National defense	(1,347)	(1,504)	(1,684)
General sciences	(395)	(427)	(483)
Energy research	(3,206)	(2,590)	(1,750)
National Oceanic and Atmospheric Administration	201	159	152
National Bureau of Standards	83	88	76
Other department activities	44	24	12
Total conduct of R. & D	5,276	4,793	4,157
Total conduct of basic research, included above	(608)	(665)	(762)
R. & D. facilities:			
Energy Research and Technology Administration	981	955	678
National defense	(319)	(396)	(336)
General sciences	(126)	(119)	(117)
Energy research	(536)	(440)	(224)
National Oceanic and Atmospheric Administration	1	0	0
National Bureau of Standards	0	9	3
Total R & D. facilities	982	964	681
Total obligations	**6,258**	**5,757**	**4,838**
OUTLAYS			
Conduct of R. & D	5,466	5,240	4,352
R. & D. facilities	1,112	1,191	644
Total, outlays	**6,578**	**6,431**	**4,995**

[1] Formerly, programs of the Department of Energy

DEPARTMENT OF HEALTH AND HUMAN SERVICES

The Department of Health and Human Services (HHS) obligations in 1983 for the conduct of R. & D. would increase by $150 million over the 1982 level to a total of $4.1 billion. Within this total, funding for basic research will increase by $69 million to $2.1 billion. Obligations for R. & D. facilities will total $20 million in 1983. This represents a substantial decline from the $62 million provided in 1982. However, it should be noted that the relatively higher level in 1982 was primarily due to the nonrecurring costs for a single large project—construction of new research headquarters for the Food and Drug Administration—for which $35 million was provided in 1982.

Health.—Over 85% of the Department's funds for the conduct of R. & D. and over 90% of the department's basic research funds are obligated by the National Institutes of Health (NIH) for biomedical research to advance the Nation's capabilities for the prevention, diagnosis, and treatment of disease. R. & D. programs in health-related research also are supported by several other agencies within the Department. The 1983 budget will also provide for continuation of these health research efforts in the Alcohol, Drug Abuse, and Mental Health Administration, the Food and Drug Administration, the Centers for Disease Control, the Health Services Administration, the Health Care Financing Administration, and the Office of the Assistant Secretary for Health.

The *National Institutes of Health* would obligate $3.5 billion in 1983, an increase of $106 million above the 1982 level; over one-half or $1.9 billion of NIH's total 1983 R. & D. budget would support basic research. Among the most significant activities to be supported by NIH are:

- Basic research on fundamental life processes in health and disease;
- Clinical research designed to transfer and apply the results of basic science to intervention, including development and refinement of techniques, processes, methods, and practices;
- Cooperative clinical trials of new antiviral drugs against neonatal herpes, herpes encephalitis, herpes genitalis, and rhinoviruses;
- Basic and clinical research into the cause, cure, and prevention of diabetes;
- Targeted research in epidemiology and risk estimation; and
- Test development related to reproductive toxicology, fertility assessment, and neurological toxicology.

The *Alcohol, Drug Abuse and Mental Health Administration* would conduct studies of mental disease and neurological disorders, biomedical factors and health effects of drug abuse, and causes and consequences of alcohol abuse, with emphasis on strengthening prevention activities.

Specific research areas would include:

- the use of computerized imaging techniques for mapping metabolic processes of the human brain;
- the role of endorphins and enkephalins in addiction and substance abuse;
- the role of genetic factors in alcoholism; and the role of alcohol in fetal defects.

The *Food and Drug Administration* would support research relevant to its mission of regulating food, drugs, and biological and radiological products.

The *Centers for Disease Control* would continue studies on the epidemiology and control of communicable diseases and on health promotion and disease prevention.

Other Health Related Agencies within HHS would support research in areas such as treatment and control of Hansen's disease; survey methods and techniques for analysis of health statistics; and the organization, delivery, and financing of health services. This support will be provided through programs of the Health Services Administration, the Office of the Assistant Secretary for Health and the Health Care Financing Administration.

Human Services.—The Department's obligations for R. & D. in human services programs in 1983 would be $100 million, $9 million above 1982. These funds would be devoted to research related to the missions of the Office of Human Development Services and the Social Security Administration and to policy research conducted on behalf of departmental management.

Table K-8 provides the details of the R. & D. funding of the Department of Health and Human Services.

Table K-8 **DEPARTMENT OF HEALTH AND HUMAN SERVICES—RESEARCH AND DEVELOPMENT**

(In millions of dollars)

Type of activity and organizational units	1981 actual	1982 estimate	1983 estimate
OBLIGATIONS			
Conduct of R & D:			
Health:			
National Institutes of Health	3,332	3,427	3,533
Alcohol, Drug Abuse, and Mental Health Administration	286	256	289
Food and Drug Administration	71	73	75
Centers for Disease Control	74	68	74
Health Resources Administration	5	2	....
Health Care Financing Administration	39	30	30
Office of Assistant Secretary for Health	35	20	20
Health Services Administration	19	3	1
Special Foreign Currency Program	1	2	1
Subtotal, Health	3,862	3,881	4,023
Human Services:			
Office of Human Development Services	70	56	59
Social Security Administration	23	21	25
Departmental Management	20	13	15
Subtotal, Human Services	112	91	100
Total conduct of R. & D.	3,973	3,972	4,122
Total conduct of basic research, included above	(1,955)	(2,000)	(2,069)
R. & D. facilities	25	62	20
Total obligations	**3,999**	**4,034**	**4,142**
OUTLAYS			
Conduct of R. & D.	3,991	3,935	4,039
R. & D. facilities	43	35	38
Total outlays	**4,034**	**3,971**	**4,078**

NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) primarily supports basic research in all scientific disciplines through grants, largely to scientists and engineers in academic institutions. The Foundation's support is of particular significance because it complements the basic research programs of mission agencies, such as the Department of Defense and the National Institutes of Health, and helps to balance Federal support across all fields of science and engineering.

NSF obligations for the conduct of R. & D. would increase from $961 million in 1982 to $1,033 million in 1983, an increase of $72 million above 1982. In addition, $16 million will be obligated for research facilities and major equipment in 1983, $6 million above the 1982 level. Funding for basic research programs would increase from $912 million in 1982 to $984 million in 1983.

These increases will allow primarily for cost increases due to inflation in research project support, partially offset by reductions in some lower priority activities. Specifically, the 1983 budget would:

- Provide an increase over 1982 in the support by NSF of research in the natural sciences and engineering that would more than offset the estimated cost increases due to inflation.
- Emphasize support of the mathematical and physical sciences (particularly computer sciences), engineering and the earth sciences largely because of the importance of these disciplines to the long-term technological advancement and economic strength of the Nation.
- Continue support of U.S. activities in the Antarctic—managed by the NSF—at approximately the ongoing level of effort. This support is continued because of the importance of the Antarctic as an area where a number of nations conduct valuable scientific research in peaceful coexistence under the terms of the Antarctic Treaty, of which the U.S. is a signatory.
- Continue NSF's research fellowship program, as a complement to the Foundation support of research. However, other lower priority science education activities previously supported by the NSF would be phased out in 1983.
- Provide increases in 1982 and 1983 over the previously reduced level of the administration's 1982 (March) budget for the social, behavioral and economic sciences to allow continued funding for relatively higher priority areas. Examples include maintenance of long-term data bases, methodological improvements and quantitative research which are important to the continued development of these disciplines as fields of scientific inquiry.
- Emphasize, within the funds provided for the conduct of research, support for upgrading research instrumentation.

DEPARTMENT OF AGRICULTURE

The Department of Agriculture supports research and development in several disciplines related to agriculture and forestry.

Obligations of the Department for the conduct of research and development are estimated to total $838 million in 1983, compared to $807 million in 1982, an increase of $31 million.

The Department's 1983 budget is highlighted below by agency:

The Agricultural Research Service would obligate $454 million for research on protection of plants and animals against diseases and pests, and on the conservation, use and improvement of soil, water and air resources.

The Cooperative State Research Service would obligate $223 million to maintain support of the cooperative program with the land-grant institutions and to expand the competitive grants for basic plant research.

In addition, $9 million would be provided to initiate a 5-year, $50 million, facilities improvement program for the 1890 Colleges and the Tuskegee Institute.

The Forest Service would obligate $98 million to improve knowledge needed to manage and protect forest and related rangeland resources to meet demands for their use. Research will be conducted on: genetics, silviculture and timber management, watershed management, range and fish habitats, protection for forest resources from fire and forest pests, surface environment and mining, forest engineering and utilization, and economics of forest commodity production, processing and distribution.

In addition, $62 million would be obligated for other areas, such as economic research, international cooperation and development, agricultural marketing, transportation of commodities, statistical reporting, and agricultural cooperatives.

DEPARTMENT OF THE INTERIOR

The Department of the Interior's R. & D. activities derive from a broad range of responsibilities, ranging from encouraging wise development of the Nation's energy and nonenergy mineral, water, land, and recreation resources to managing those resources on the public lands in the public interest.

Obligations for the conduct of R. & D. for the Department of Interior for 1983 are estimated at $371 million. This represents a decrease of approximately $27 million from the 1982 level, primarily in areas of geological hazards, and mining development and demonstrations.

The Department's research objectives for 1983 are highlighted below by major organization.

The Bureau of Land Management and *The Bureau of Reclamation* would continue programs in watershed conservation and development, timber and range forage production, wildlife habitat, water resources planning and research, and dam safety.

The Fish and Wildlife Service would emphasize R. & D. activities which:

- Improve the quality of habitats and the availability of fish and wildlife; and
- Contribute to population control methods and preserve endangered species of fish and wildlife.

The National Park Service would emphasize research in archeology and the natural and social sciences.

In energy and minerals R. & D., a small overall reduction in effort is proposed. Decreases are proposed in the Geological Survey and the Bureau of Mines, with a small increase for the Office of Surface Mining.

The Geological Survey research priorities would include:

- Developing accurate appraisal and exploration techniques to determine mineral resources;
- Developing basic data on geological principles and processes;
- Understanding the ways to appraise and evaluate our water resources; and
- Improving uses of satellite acquired data in Earth and marine sciences.

The Bureau of Mines would stress:

- Health and safety in mines and processing plants;
- Helping the Nation become less dependent on foreign minerals; and
- Protection of the environment during mineral extraction.

The Office of Surface Mining research plans involve studies dealing with regulations compliance, monitoring of coal mining operations and ecological investigations.

DEPARTMENT OF TRANSPORTATION

The Department of Transportation's R. & D. program is oriented toward providing the information and new technology needed for its own operational (e.g., air traffic control) and regulatory (e.g., automotive safety standards) programs. Obligations for the conduct of research and development by the Department are estimated at $366 million for 1983, an increase of $37 million over 1982. The Department's 1983 budget is highlighted below by agency.

The Federal Aviation Administration (FAA) is expected to obligate $152 million in 1983. The proposed 1983 R. & D. obigations for FAA represent an increase over 1982 of $46 million. This increase will allow greater emphasis on engineering work on the national air traffic control system, and on emerging technology to improve collision avoidance systems and enhance enroute and terminal air traffic control systems.

The National Highway Traffic Safety Administration would obligate $59 million for motor vehicle research, traffic safety research and demonstrations, and other statistical and analytical studies. An increase is proposed in 1983 for continuing the National Accident Sampling system which provides nationally representative accident and injury data, and for focusing analysis on major traffic accidents.

The Urban Mass Transportation Administration plans to obligate $44 million to assist in the development of improved mass transportation systems, equipment and procedures. Emphasis will be placed on assisting existing proven transit systems.

The Federal Highway Administration would obligate $43 million to continue research programs in highway planning, design, construction, and maintenance to insure an effective and efficient highway system. Research would also be conducted in identifying, and correcting impediments to highway safety and on improving common carrier safety.

The Federal Railroad Administration would obligate $20 million to continue its emphasis on safety research. A $16 million reduction in funding from the 1982 level would eliminate nearly all nonsafety research.

The Maritime Administration would obligate $18 million to improve the productivity and competitive posture of the U.S. maritime industries. Increased funds are provided to support icebreaking vessels in the Arctic for R. & D. and increased ship research.

The U.S. Coast Guard would obligate $15 million to support research to maintain and improve search and rescue systems, environmental protection, marine safety, and aids to navigation. The proposed 1983 figure represents a decrease of $3 million for R. & D. from the 1982 level.

The Research and Special Programs Administration would obligate $8 million to support emergency preparedness and mobilization efforts and to support the hazardous materials and pipeline safety regulatory programs.

The Office of the Secretary would obligate $8 million for broad-based policy research on domestic and international transportation issues of importance to the Nation.

ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) conducts research and development in support of the Agency's regulatory and enforcement mission to protect human health and the environment. The R. & D. request for 1983 reflects a focusing on the highest priority research areas. These areas emphasize the following themes:

- Benefit and risk assessment in support of Agency regulatory decisions and impact analysis activities;
- Scientific support and technology transfer activities to help develop and install cost-effective pollution control technologies; and
- Improved scientific quality through peer review, quality assurance guidelines, and specially designed information systems.

Total obligations for the conduct of R. & D. are estimated to decrease from $317 million in 1982 to $230 million in 1983. EPA's activities by area are highlighted below.

The air research program would be reduced from 1982 by $8 million to a level of $27 million in 1983. The research will evaluate and establish national ambient air quality standards, new source performance standards, and emission standards for hazardous air pollutants and mobile-source pollutants. EPA research into health effects of air pollution will continue past efforts to assess actual human exposure. Research on the effects of diesel engine exhaust will be reduced, reflecting attainment of EPA's current information goals for 1982.

The water quality research program expects to obligate $13 million in 1983, a decrease of $15 million from the 1982 level. In the municipal wastewater program, activities that are more appropriately conducted by the private engineering community, such as design engineering, are being eliminated. All extramural research in the water quality program will be eliminated, shifting all future activities to in-house R. & D. labs. The engineering-related extramural research of the industrial wastewater program is being reduced, due to near completion of the effluent limitations effort.

The drinking water research program would decrease by $6 million to a level of $15 million in 1983. The program will continue to evaluate data on the incidence and health effects of contaminants, evaluate alternate disinfectant techniques, provide a national quality assurance program, and carry out research related to the problems of small systems. Research on the nature and movement of contamination in subsurface waters will be expanded.

The hazardous waste program would obligate $18 million in 1983, a decrease of $4 million below the 1982 level. This research will support the development of methods and protocols for the regulatory program involving assessing risks to human health and ensuring quality control. Research will continue on developing a better understanding of the various hazardous waste control technologies.

The pesticide research program would obligate $3 million, an increase of $1 million over 1982. The research program supports development of methods for measuring and assessing human exposure to pesticides and the ecological effects of pesticides, risk assessments, and development of improved methods for detecting chemical and biological pesticides.

The radiation research program would decrease by $.5 million, to a level of $0.4 million in 1983. These reductions occur in lower priority research areas, such as nonionizing radiation, which are not directly related to statutory mandates.

The toxic substance program would total $14 million for 1983, a decrease of $6 million. Research will support the development of more effective techniques, models and data bases to predict health effects of new chemicals. Development of methodologies and models for defining exposure and risk will be continued.

The energy program, which includes activities related to the impact and regulation of fossil fuel combustion and synthetic fuels, is projected at a level of $36 millon in 1983, a decrease of $19 million below 1982. Emphasis will continue to be placed on assessing the health and environmental impacts of synthetic fuels, evaluating control technology options, and providing the regions and States with indirect technical expertise. The 1983 funding includes $12 million to support a major government-wide effort to assess the sources and effects of acid rain.

Superfund Research in 1983 shows a reduction of $6 million, to a level of $4 million. This reduction is a result of the fast start-up required to implement Superfund and the fact that much of the information needed for developing guidelines and protocols and for developing the required cleanup and safety manuals will be completed in 1982. Funds for this program are derived from the Hazardous Substance Response Trust Fund, as opposed to general revenues.

NUCLEAR REGULATORY COMMISSION

The Nuclear Regulatory Commission (NRC) performs research in civil uses of nuclear materials and facilities consistent with public health and safety, environmental quality, and national security. A major share of NRC's effort is devoted to research on the use of nuclear energy to generate electric power. Its research objective is to provide safety and analytical methods for assuring the quality of NRC's licensing procedures and regulatory work.

In 1983, NRC's obligations for the conduct of R. & D. are expected to decrease from $223 to $220 million. In 1983, key areas, such as accident evaluation and mitigation and systems and reliability analysis will be strengthened. Additionally, reactor safety research, principally on the Clinch River Fast Breeder Reactor, will be increased in 1983. The Loss of Fluid Test Facility experimental program is planned to be completed in 1982. Funding for loss-of-coolant accidents and transient research will, therefore, be reduced more than offsetting proposed increases.

Agency for International Development

Research and development activities of the Agency for International Development (AID) consist mainly of applied research to solve specific problems associated with basic human needs development and social and economic research aimed at improving U.S. and host country understanding of the major obstacles to such development.

Programs in this area reflect the administration's recognition of the importance of R. & D. in addressing the development problems faced by the Third World.

Obligations of AID for the conduct of R. & D. are estimated at $186 million in 1983, an increase of $26 million over 1982.

Most of AID's 1983 R. & D. funds will be devoted to three critical problems: Food production, with an emphasis on affecting developing country efforts to overcome the growing food crisis; population growth, emphasizing methods of controlling increasing population growth rates in the developing countries; and energy supply, emphasizing renewable and nonconventional energy sources critical for development to proceed.

VETERANS ADMINISTRATION

The Veterans Administration (VA) conducts and administers medical, rehabilitative, and health services research. In 1983 this agency would obligate $145 million, an increase of $8 million over 1982, for the conduct of R. & D.

The VA intramural biomedical research program is designed to benefit patients through increased quality and effectiveness of health care delivery. Priorities for 1983 include special research on alcoholism, geriatrics and hypertension.

In rehabilitative research, the VA works to develop and test prosthetic, orthopedic, and adaptive equipment for improving the care and rehabilitation of disabled veterans, including amputees, paraplegics and the blind.

The health services research program supports projects at VA health care facilities to improve the delivery and accessibility of health services to veterans. The preventive health program begun last year will be continued in 1983.

FOUNDATION FOR EDUCATION ASSISTANCE

The proposed Foundation for Education Assistance will continue to support a variety of R. & D. activities in 1983. Included among those activities will be basic and applied educational research; the conduct of surveys, evaluations and experiments in the field of education; the funding of developmental and demonstration projects; the assessment of the performance of children and adults in reading, mathematics, communication and citizenship skills; the collection, analyses and reporting of statistics and other data related to education; and the dissemination of information and findings. The Foundation expects, in 1983, to obligate a total of $76 million for the conduct of R. & D.

In addition to its general research and data gathering activities, the Foundation will carry out R. & D. activities related to the areas of vocational and adult education for the handicapped; education programs for persons with limited English proficiency, and development activities that provide technical support for the dissemination activities of the Foundation.

OTHER AGENCY PROGRAMS

An additional 15 agencies (listed in table K–2, footnote 1) would obligate an estimated $272 million in 1983, for the conduct of R. & D., a decrease of $7 million below the 1982 total. Obligations by these agencies amount to less than 1% of all federally funded programs in R. & D. The programs of these agencies, like those of other agencies discussed above, are closely related to the agencies' missions.

Among the agencies in this category that expect to increase their obligations for R. & D. in 1983 are the Smithsonian Institution, the Army Corps of Engineers, the Arms Control and Disarmament Agency, and the Federal Emergency Management Agency.

SUPPLEMENTARY INFORMATION

Table K–9 provides information on the long-term trends in Federal funding for the conduct of R. & D.

Table K-9. **TRENDS IN CONDUCT OF R. & D.**

(Obligations in billions of dollars)

Year	Defense [1]	All other	Total
1953	2.8	.3	3.1
1954	2.5	.3	2.9
1955	2.2	.4	2.6
1956	2.5	.5	3.0
1957	3.3	.6	3.9
1958	3.8	.8	4.6
1959	5.6	1.1	6.7
1960	6.1	1.5	7.6
1961	7.0	2.1	9.1
1962	7.2	3.1	10.3
1963	7.8	4.7	12.5
1964	7.8	6.4	14.2
1965	7.3	7.3	14.6
1966	7.5	7.8	15.3
1967	8.6	7.9	16.5
1968	8.3	7.6	15.9
1969	8.4	7.2	15.6
1970	8.0	7.3	15.3
1971	8.1	7.4	15.5
1972	8.9	7.6	16.5
1973	9.0	7.8	16.8
1974	9.0	8.4	17.4
1975	9.7	9.3	19.0
1976	10.4	10.4	20.8
1977	11.9	12.1	24.0
1978	12.6	13.8	26.4
1979	13.6	15.4	29.0
1980	15.1	16.6	31.7
1981	17.8	17.2	35.0
1982 (estimate)	22.1	16.8	38.8
1983 (estimate)	26.2	16.8	43.0

[1] Includes military-related R. & D. programs of the Departments of Defense and Commerce