

Originally Processed With FOIA(s):
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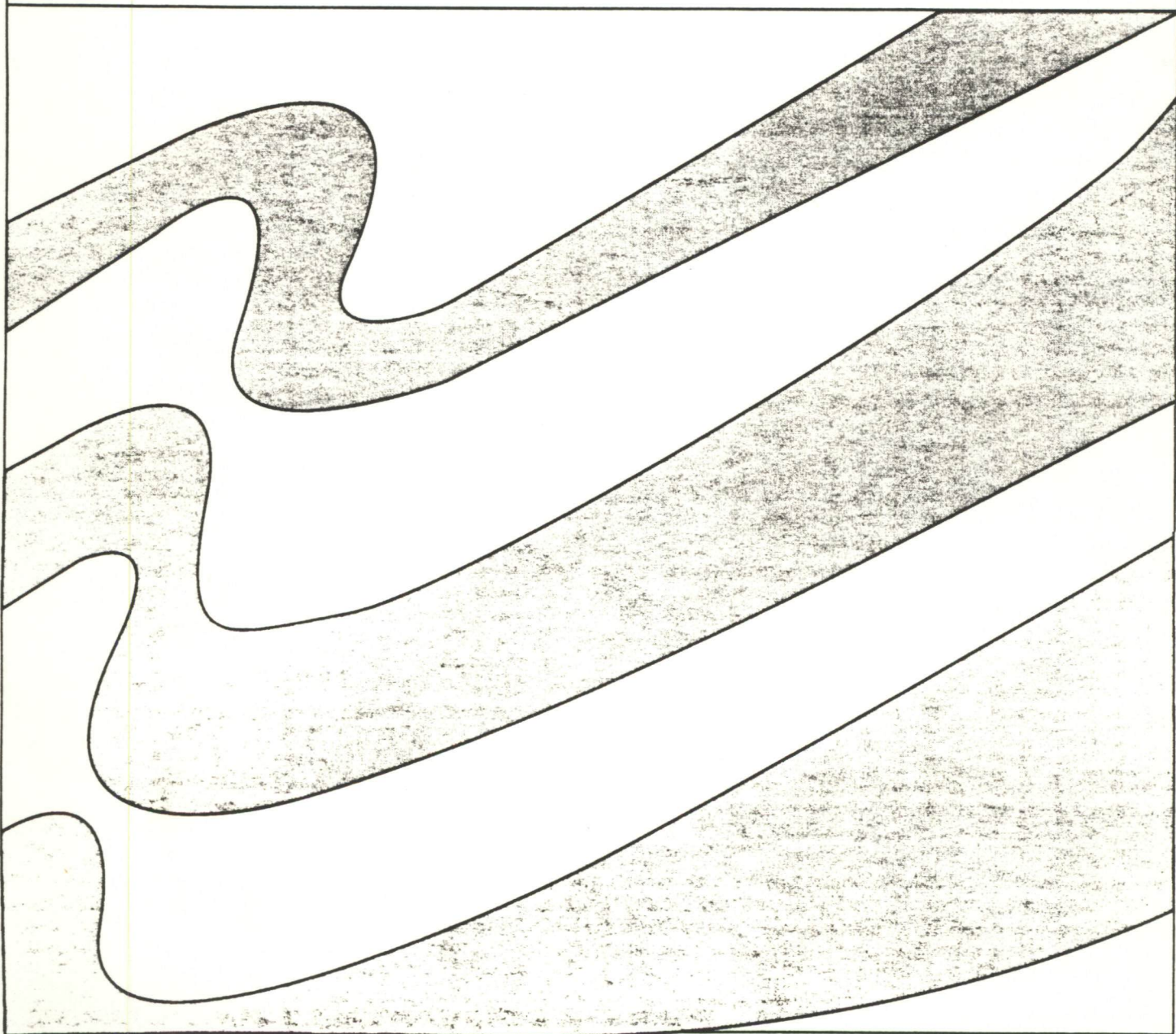
OF THE

UNITED STATES GOVERNMENT

FISCAL YEAR 1993



**ENHANCING RESEARCH AND
DEVELOPMENT AND
EXPANDING THE HUMAN FRONTIER**



ENHANCING RESEARCH AND DEVELOPMENT AND EXPANDING THE HUMAN FRONTIER

Reprint of Pages One-87 through One-146 of Part One,
Chapter 6, of the *Budget of the United States Government*,
Fiscal Year 1993

6. ENHANCING RESEARCH AND DEVELOPMENT AND EXPANDING THE HUMAN FRONTIER

It is by now widely recognized that a key to enhancing long-term economic growth in America is improving productivity. Productivity growth will enable our economy to grow faster than our population—thus making possible improvements in America's standard of living.

The Bush Administration has proposed, over the past three fiscal years, a pattern of investment in areas of research and development that will help to boost productivity and improve economic performance. This budg-

et continues that pattern of aggressive investment in both basic and applied R&D. Today new frontiers are emerging in science, space and technology, including new materials, advanced computing, manufacturing methods, space exploration, and biotechnology. By helping to expand America's knowledge base in these and other areas, and by advancing the development of new technologies, the budget lays the groundwork for growth.

This chapter discusses a range of Federal research and development programs and is-

Table 6-1. ENHANCING RESEARCH AND DEVELOPMENT AND EXPANDING THE HUMAN FRONTIER—HIGHLIGHTS
(Dollar amounts in millions)

Budget Authority	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Applied Research:					
High Performance Computing and Communications	N/A	655	803	+148	+23%
Advanced Materials and Processing	N/A	1,659	1,821	+162	+10%
Biotechnology Research	N/A	3,759	4,030	+271	+7%
Energy R&D	397	774	914	+140	+18%
Moving Fusion Energy from Science to Engineering	347	337	360	+23	+7%
Advanced Manufacturing R&D (non-defense)	N/A	252	321	+69	+27%
Transportation R&D	802	1,224	1,433	+209	+17%
Protecting the Public Health	3,482	4,757	4,849	+92	+2%
Expanding R&D at the National Institute of Standards and Technology	159	247	311	+64	+26%
Space Technology	256	273	305	+32	+12%
Basic Research:					
Doubling the NSF Budget by 1994	1,923	2,572	3,026	+454	+18%
Support for Individual Investigators (HHS, NSF, DOE)	5,884	7,273	7,939	+666	+9%
Human Genome Project	N/A	164	175	+11	+7%
Superconducting Super Collider	98	484	650	+166	+34%
U. S. Global Change Research Program	N/A	1,110	1,372	+262	+24%
Astronomy and Astrophysics	617	836	890	+54	+6%
National Research Initiative (USDA)	N/A	98	150	+52	+53%
Maintaining National Security: Defense R&D:					
Defense	38,031	40,043	40,509	+466	+1%
Energy	2,321	2,668	2,640	-28	-1%
Expanding the Geographic Frontier:					
Improving Access to Space	4,411	5,312	5,412	+100	+2%
Space Exploration	1,433	2,646	2,836	+190	+7%

sues, including space and defense, that are related to these frontiers. The budget proposes to invest over \$76 billion for *research and development*, including R&D facilities, in 1993. This represents an increase of nearly \$2 billion, or 3 percent over 1992. Within this total, Federal civilian R&D would increase by 7 percent, while defense-related R&D would increase by 1 percent. The budget proposes over \$14 billion for basic research, an increase of over \$1 billion, or 8 percent, over 1992. The budget also proposes over \$17 billion for civilian applied research and development, an increase of over \$1 billion or 6 percent.

The budget proposes several crosscutting investments that will build the base for the continuing expansion of the frontier of knowledge: a new initiative to improve the synthesis, processing and performance of both new and traditional materials; a new initiative to increase funding for biotechnology research, especially in applications; and continuation

and strengthening of initiatives in high performance computing and communications and global change research. In addition, the budget proposes to expand the initiative to improve mathematics and science education at all levels, as discussed in Chapter 4, "Reforming American Education and Investing in Human Capital."

The budget proposes to provide support for several important civil space programs, including Space Station Freedom, space science missions such as the Advanced X-ray Astrophysics Facility and the Earth Observing System, and new initiatives such as the new launch system, the National Aerospace Plane, and technology related to exploration of the Moon and Mars. Because of the President's desire to constrain the overall growth of Federal spending, however, and in response to Congressional directives, the total increase for civil space programs is only \$738 million, or 5 percent.

HIGHLIGHTS

APPLIED RESEARCH

These initiatives help to spur innovation and the movement of new products and processes from the laboratory to the marketplace.

High Performance Computing and Communications.—The budget proposes an increase of \$148 million, or 23 percent, to a total of \$803 million for the second year of an inter-agency program to help establish American pre-eminence in the fields of high performance computing and communications. This Presidential Initiative initiative, involving nine Federal agencies (in addition to the private sector), will focus on the underlying research and the academic training needed to accelerate significantly the availability of the next generation of high performance computing systems and digital communications networks. The goal is to assist in the development of computing capability with roughly 1,000 times improvement over current systems by 1996 and communications systems 100 times faster than those currently in use.

Advanced Materials and Processing.—The budget proposes \$1,821 million, an increase of 10 percent over 1992, for a 10-agency program intended to improve the manufacture and performance of materials. This new Presidential Initiative is intended to achieve advances in materials that will enable improvements in a wide range of other technologies. Emphasis will be placed on research on materials synthesis and processing, two areas critical to developing new materials and to improving the quality of all materials.

Biotechnology Research.—The budget proposes \$4,030 million, an increase of \$271 million or 7 percent over 1992, for biotechnology research programs in 12 agencies. This new Presidential Initiative capitalizes on the current U.S. leadership in biotechnology, and recognizes the key role biotechnology plays in enhancing the Nation's technological strength, economic growth, and the health and quality of life of its people. The program will emphasize potential new applications of biotechnology in health, manufacturing/bioprocessing, and the environment; will

strengthen research and infrastructure for structural biology; and will expand interdisciplinary training at the interfaces of biology, chemistry, physics, mathematics, computer science, materials science, and engineering.

Energy Technology R&D.—The budget proposes \$914 million, an increase of \$140 million, or 18 percent, for investments in targeted high-payoff technologies and strategies to increase the efficiency of energy use, to develop cost-effective alternatives to petroleum and to advance new electricity technologies, including battery technology. This investment is guided by the National Energy Strategy which was announced by the President in February, 1991.

Fusion R&D.—The budget proposes \$360 million, an increase of \$23 million or nearly 7 percent for the development of energy from nuclear fusion. This National Energy Strategy initiative maintains the strong national commitment to the International Thermonuclear Experimental Reactor (ITER) engineering design activity. The ITER experiment is carried out in partnership with Japan, the European Community, and Russia.

Advanced Manufacturing R&D.—The budget includes over \$1 billion for R&D on advanced manufacturing technologies. This includes an increase of 27 percent for nondefense-related manufacturing R&D. In addition, the budget proposes an increase of \$25 million to a total of \$105 million for the National Science Foundation for a new initiative in manufacturing research. The budget also proposes \$27 million for manufacturing R&D at the National Institute of Standards and Technology.

Transportation R&D.—The budget proposes \$1,433 million, an increase of 17 percent, for transportation R&D, funded primarily by the Department of Transportation (DOT) and the National Aeronautics and Space Administration (NASA). The increase will support continued high-priority R&D on aviation and high-speed rail projects. For R&D in DOT, the budget proposes \$498 million, an increase of 12 percent, for research programs to improve air traffic management, to increase the use of satellites for aviation navigation and communications, for improved intelligent vehicle/highway systems and for magnetically levitated

trains. For aeronautics R&D in NASA, not including high-performance computing, the budget proposes \$855 million, an increase of \$98 million or 13 percent. The increase will support continued high-priority R&D on environmental issues associated with supersonic flight and on high-temperature propulsion materials. The budget also includes \$80 million for continued technology development for the joint NASA/DOD National Aerospace Plane program, leading to a future decision on a flight research vehicle.

Protecting the Public Health.—*Biomedical Research:* The budget proposes \$4.8 billion for applied research and development at the Department of Health and Human Services, an increase of \$92 million, or 2 percent. The budget includes a total of \$10.6 billion for basic and applied research and development at the Department of Health and Human Services. *Women's Health Initiative:* The budget includes an 80 percent increase for a recently-launched NIH study on women's health, which is designed to answer difficult questions about how best to prevent deaths from cancer, heart disease, and the bone fractures common with advancing age in women. *HIV/AIDS:* The budget proposes a 4 percent increase to over \$1.2 billion for biomedical and behavioral research on Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome. (The budget proposes a total increase of \$565 million, or 13 percent, for HIV/AIDS research, treatment, prevention and income support.)

Expanding R&D at the National Institute of Standards and Technology.—The budget proposes a 26 percent increase to a total of \$311 million for NIST. The 1993 proposal will continue an effort begun in 1991 to expand NIST's ability to perform generic applied research and technology development and to address a growing number of important standards and measurement issues. In addition, the budget proposes \$68 million for the Advanced Technology Program, an increase of 36 percent over 1992.

Creating Technology for Space and Earth.—The budget proposes \$305 million, an increase of 12 percent, for NASA space technology development. This increase recognizes the central role of new technology in the future of the U.S. space program. Strengthening cur-

rent investments in technology will later pay off in new capabilities for scientific research, communications, robotics, launch vehicles, and other space-related areas.

BASIC RESEARCH

These initiatives lead to the creation of new knowledge which will enable future innovation.

Doubling the National Science Foundation (NSF) Budget by 1994.—The budget proposes an increase of 18 percent overall for NSF, including a 21 percent increase for basic research. This will continue the Administration's commitment to double NSF's budget by 1994. This increase is targeted toward investments in the people, equipment and unique research facilities that underpin the U.S. scientific enterprise.

Increasing Support for Individual Investigators.—The budget proposes nearly \$8 billion for the support of individual investigators funded by the Departments of Health and Human Services and Energy and the National Science Foundation. This is an increase of over 9 percent over 1992. Individual investigators are the backbone of the U.S. scientific and engineering enterprise. These researchers, located primarily at the Nation's colleges and universities conduct most of the fundamental research on which technological progress is founded. In addition, and perhaps more importantly, they educate and train the next generation of scientists and engineers.

Human Genome Project.—The budget proposes an increase of \$11 million, or 7 percent, to a total of \$175 million in the Departments of Energy and Health and Human Services (National Institutes of Health). The goal of the project is to analyze within 15 years the entire complement of human genetic material at the molecular level. The Departments are developing capabilities and tools, constructing maps, sequencing human chromosomes, developing accessible data bases, and characterizing disease-related genes. Both agencies are also addressing ethical, legal, and social issues surrounding the uses of knowledge about the human genome and are developing educational activities on genome issues for the general public.

Superconducting Super Collider (SSC).—The budget proposes an increase of \$166 million for the SSC to a total of \$650 million. This will support continued work toward the transition from prototype superconducting magnets to production and continued construction of support facilities. It will also provide for the construction of a tunnel segment for testing purposes. The funding level maintains the 10-year design and construction schedule approved last year. The total cost of slightly over \$8 billion assumes one-third non-Federal contributions including \$233 million in 1993.

U.S. Global Change Research Program (USGCRP).—The budget proposes an overall increase of \$262 million, or 24 percent, to a total of \$1,372 million for this Presidential Initiative—the most advanced program on global change research issues in the world. The proposed increase will assist efforts to understand more fully the earth's climate system. That understanding will facilitate development of sound policies concerning global environmental issues such as ozone depletion and global warming.

Astronomy and Astrophysics.—The budget proposes a total of \$890 million for these two closely related disciplines which are funded primarily by the National Science Foundation and the National Aeronautics and Space Administration. The objective of these programs is to increase our understanding of the universe. The budget proposals are consistent with the recommendations of a recent report of the National Research Council ("The Decade of Discovery in Astronomy and Astrophysics") concerning ground- and space-based astronomy and astrophysics research for the next decade, including increased operations and maintenance support for existing facilities, increased support for individual investigators, and the development of small and medium-sized instruments.

National Agricultural Research Initiative.—The budget continues the commitment to the National Research Initiative (NRI), first proposed in the 1991 budget, by proposing \$150 million, an increase of \$52 million, or 53 percent, over 1992. In 1991, \$100 million was proposed as the initial installment, to be increased by \$50 million each year to

the extent that funds were awarded competitively and not earmarked for specific sites or institutions. Six categories of research will continue to be funded: natural resources and the environment; nutrition, food quality and health; plant systems (including mapping of plant genomes); animal systems; markets, trade, and policy; and processes antecedent to adding value and developing new products.

MAINTAINING NATIONAL SECURITY

Defense R&D.—The budget proposes a total of over \$43 billion for R&D for national security activities, an increase of \$438 million, or 1 percent over 1992. This amount includes more than \$40 billion for R&D supported by the Department of Defense, and almost \$3 billion for defense-related R&D supported by the Department of Energy.

IMPROVING TECHNOLOGY TRANSFER

Accelerating the Pace of Technology Transfer.—The budget projects a continuing significant increase in the level of technology transfer activities, including almost 1,700 Cooperative Research and Development Agreements, an increase of 40 percent over the two years since 1991; about 3,300 new invention disclosures; 1,500 patent applications; and almost 500 technology licenses awarded.

Expanding the Role of the National Laboratories.—The budget assumes that the National Laboratories will play an increasing role in high priority areas of civilian applied research and development, including high performance computing, space exploration, advanced materials research, and others. The laboratories could play an important role in helping to form R&D consortia and other collaborative R&D arrangements led by industry and universities.

STIMULATING PRIVATE SECTOR R&D INVESTMENTS

R&E Tax Credit.—The budget proposes to make the Research and Experimentation tax credit permanent.

Encouraging R&D by Multinational Companies.—The budget proposes a 18-month extension in the rules for allocation of foreign and domestic expenditures for companies with foreign operations.

EXPANDING THE GEOGRAPHICAL FRONTIER: SPACE

Improving Access to Space.—The budget proposes \$5.4 billion, an increase of 2 percent, for civil space transportation. Plans for the Space Shuttle include improving its operational efficiency, updating key components to protect against obsolescence, and using the new, commercially-developed SpaceHab module to carry more experiments for microgravity research. In the area of expendable launch vehicles, NASA and the Department of Defense will jointly develop a new launch system to reduce the cost of access to space, improve reliability, increase operability and flexibility, and extend U.S. launch capability to support heavier payloads. First launch of this new system is planned for 2002. The two agencies will also sponsor research that can lead to improvements in existing launch systems. The government will continue to procure commercial launch services, including use of the new Commercial Experiment Transporter (COMET) system.

Space Exploration.—The exploration of space continues to excite and capture the imagination of people all over the world. Building on three decades of robotic and manned missions of discovery, the budget proposes a total of \$2.8 billion, a 7 percent increase, for programs leading to exploration of the Moon and the planets. Plans for 1993 include continuing work on Space Station Freedom, analyzing data from ongoing planetary missions, designing and constructing new exploration spacecraft, and advancing key technologies needed for future robotic and manned missions to the Moon and Mars. The budget proposes about \$15 billion for the National Aeronautics and Space Administration, an increase of 5 percent over 1992.

ENHANCING RESEARCH AND DEVELOPMENT

Research and development (R&D) yields new knowledge, products and processes that, over the long term, result in economic growth and an improved quality of life for all Americans. Investment in research and development is a top priority for an Administration that believes in investing in the future. Investments in research and development form the foundation for the exploration of all of the new frontiers of today and tomorrow.

INVESTMENTS IN R&D PROVIDE LARGE BENEFITS TO THE NATION

The Federal Government has a long history of funding R&D with the goal of spurring innovation. Examples can be found as far back as research sponsored by the Navy in the late 1700's. Other examples include the establishment in the 1860's of the land-grant college system with its emphasis on research to improve agricultural productivity, and the 50-year history of support for aeronautics research and technology, an effort which has contributed to today's large positive balance of trade in the aerospace sector. Since World War II, the Federal Government has been a major sponsor of R&D performed by industry, either directly or indirectly such as through the tax code.

It is widely accepted that R&D investments lead to new knowledge and innovation, which, in turn, leads to economic growth. For example, recent work (Romer) has emphasized this relationship by showing that new knowledge is as important an investment as capital and labor in determining the output of the economy. Romer asserts that increased knowledge, like increased capital, raises the return on investment, and, in turn, more investment spurs the creation of new knowledge. There is also strong analytical evidence that R&D is an important contributor to productivity growth. Studies by Griliches (1973), Sherer (1982), Terleckyj (1982), Sveikauskas (1982) and Mansfield (1984), *inter alia*, have shown that R&D tends to be the strongest and most consistent positive influence on productivity growth.

The Bureau of Labor Statistics (BLS) prepares and publishes official measures of productivity growth and carries out research to improve them. The results of a study by Sveikauskas (BLS, 1989) suggest that privately-funded R&D in the non-farm business sector has resulted in average annual productivity improvements of 0.15 percent between 1948-1973 and 0.14 percent from 1973-1987. The contribution of R&D to productivity calculated by BLS appears to account for roughly 14 percent of the total multifactor productivity growth over these time periods. Significantly, the BLS study also noted that the direct influence of R&D on productivity growth was greatest in manufacturing, accounting for an average annual productivity growth of 0.49 percent between 1948-1987.

Other studies (Levy and Terleckyj, 1983; Griliches, 1986) have provided evidence that Federally-financed R&D also has a positive direct impact on productivity, albeit somewhat smaller and more difficult to find with consistency.

In addition, empirical evidence from as far back as the 1950's indicates that increased governmental R&D funding can result in increased private R&D funding. Recent work (Leyden and Link, 1991) offers some evidence that not only is there a complementary relationship between governmental and private R&D, but that governmental R&D affects the behavior of private performers of R&D, i.e., it stimulates more sharing of technical knowledge, and thus contributes to the greater social benefit of the Nation.

All of the scholarly work has identified R&D as a major positive influence on productivity. But much remains to be learned about this phenomenon, particularly with respect to: (1) the differences between direct benefits (i.e., to the financing firm or sector) and indirect benefits (i.e., to firms downstream); (2) between product and process R&D; (3) the mechanisms and the time frame over which R&D (and even different types of R&D) depreciate; and (4) the most accurate way to deflate research expenditures over time. BLS, NSF and others will support research on these problems during 1993.

THE NEED FOR INCREASED R&D INVESTMENTS

The goals of R&D are to generate new knowledge; train the future skilled workforce; and to provide a catalyst for economic activity. Taken together, these goals provide the most compelling rationale for increased Federal support for R&D.

The combination of public and private national investments in R&D have contributed to the unprecedented advance of human knowledge and improvement in the quality of life for much of the world. All of the available empirical evidence suggests that "more is better" in that (1) increased total R&D investment adds to the productivity of the Nation, and (2) Federal R&D investments are important. Thus, there is ample justification for increased Federal investment in R&D as well as for Federal action to increase the levels of private R&D investment.

One measure that historically has been used to gauge the appropriate level of R&D is the total size of the national R&D investment relative to the Gross National Product (GNP). Using this measure, R&D as a share of GNP stood at about 2.7 percent in the early 1960's, fell during the decade of the 1970's, and returned to that level in the 1980's. Total U.S. R&D investments have increased in absolute terms over that period. Compared with our major trading partners, U.S. R&D as a percent of GNP is less than that of Japan and Germany, but larger than France or the United Kingdom.

Over the past decade, the ratio of Federal R&D outlays to GNP has hovered at about 1.2 percent. In each of the past three budgets, President Bush has proposed increases that would have increased this share. Congress has not fully funded these requests.

Recently, the Federal Government has begun to use the Gross Domestic Product (GDP) as an indicator of the overall strength of the economy, rather than the more traditional GNP. When a similar comparison is

made to GDP, it shows that R&D as a share of GDP declined through the 1970's and most of the 1980's. Since 1989, R&D has been steadily increasing as a share of GDP. The budget provides increases and incentives designed to continue to increase R&D investment as a percent of GDP.

THE FEDERAL R&D BUDGET: OVERVIEW AND TRENDS

The budget proposes to allocate \$76.6 billion for R&D, including R&D facilities. This is an increase of nearly \$2 billion, or 3 percent, over 1992. Within this total, \$14.3 billion will be allocated for basic research, an increase of over \$1 billion, or 8 percent, and over \$59 billion for applied research, an increase of about \$1.5 billion, or 3 percent, over 1992. Federal civilian R&D will increase by 7 percent while defense-related R&D (in the Departments of Defense and Energy) will increase by 1 percent.

As a percentage of total Federal domestic discretionary spending, total civilian R&D has declined from a peak of 26 percent in the Apollo years to a trough of 10 percent in 1983. It has begun to increase again to about 14 percent in recent years. The President proposed to increase this share to 15 percent in 1992, but Congress cut this request. The budget seeks to increase this share once again to 15 percent in 1993.

The Federal Government currently accounts for about 44 percent of the total U.S. investment in R&D. Industry, academia, and non-profit organizations make up the remaining 56 percent. In 1991, it is estimated that total U.S. R&D expenditures, Federal and non-Federal, were \$151.6 billion, an increase of over 4 percent over 1991. In total, the U.S. investment in R&D is about 2.7 percent of GDP. Trends in industry R&D funding, and initiatives to spur increased industry investment through making permanent the tax credit for research and experimentation, are discussed later in this chapter.

**Table 6-2. THE BUDGET PROPOSES AN INCREASE OF \$2.5 BILLION
IN FEDERAL INVESTMENT IN RESEARCH AND DEVELOPMENT**

(Dollar amounts in millions)

Department or Agency	Budget Authority					Outlays				
	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Government-wide totals:										
Conduct of R&D:										
Basic Research	10,615	13,254	14,322	+1,068	+8%	10,255	12,491	13,405	+914	+7%
Civilian	9,650	12,053	13,086	+1,034	+9%	9,312	11,325	12,142	+817	+7%
Defense ¹	965	1,201	1,236	+35	+3%	943	1,166	1,263	+97	+8%
Applied Research and Development	51,298	57,839	59,302	+1,463	+3%	50,626	53,890	56,253	+2,363	+4%
Civilian	11,620	16,257	17,313	+1,056	+6%	11,030	15,132	15,958	+826	+5%
Defense ¹	39,678	41,582	41,988	+406	+1%	39,596	38,758	40,295	+1,538	+4%
Subtotal, Conduct of R&D	61,913	71,093	73,624	+2,531	+4%	60,881	66,381	69,658	+3,277	+5%
R&D Facilities	2,293	3,498	2,933	-565	-16%	2,054	3,286	3,189	-96	-3%
Total, Conduct of R&D and Facili- ties ²	64,206	74,592	76,557	+1,965	+3%	62,935	69,666	72,847	+3,181	+5%
Conduct of R&D by Agency:										
Defense-military	38,031	40,043	40,509	+466	+1%	37,545	37,175	38,847	+1,672	+4%
Health and Human Serv- ices	7,894	10,216	10,649	+433	+4%	7,486	9,468	10,199	+731	+8%
Energy	5,362	6,514	6,578	+65	+1%	5,692	6,195	6,219	+23	—
National Aeronautics and Space Administration	5,303	7,706	8,673	+967	+13%	4,975	7,272	7,710	+438	+6%
National Science Founda- tion	1,671	1,967	2,375	+408	+21%	1,557	1,840	2,056	+216	+12%
Agriculture	1,050	1,328	1,332	+4	—	1,021	1,245	1,285	+40	+3%
Interior	467	583	552	-31	-5%	478	580	546	-34	-6%
Environmental Protection Agency	389	496	525	+29	+6%	345	454	495	+41	+9%
Commerce	417	580	614	+34	+6%	363	542	582	+40	+7%
Transportation	313	446	498	+52	+12%	322	410	457	+47	+11%
Agency for International Development	261	322	325	+3	+1%	379	314	303	-11	-4%
Veterans Affairs	212	230	245	+15	+7%	187	247	262	+14	+6%
Other Agencies ³	542	662	750	+88	+13%	532	639	699	+60	+9%

¹ Includes the military-related programs of the Departments of Defense and Energy.

² Components may not add to totals because of rounding.

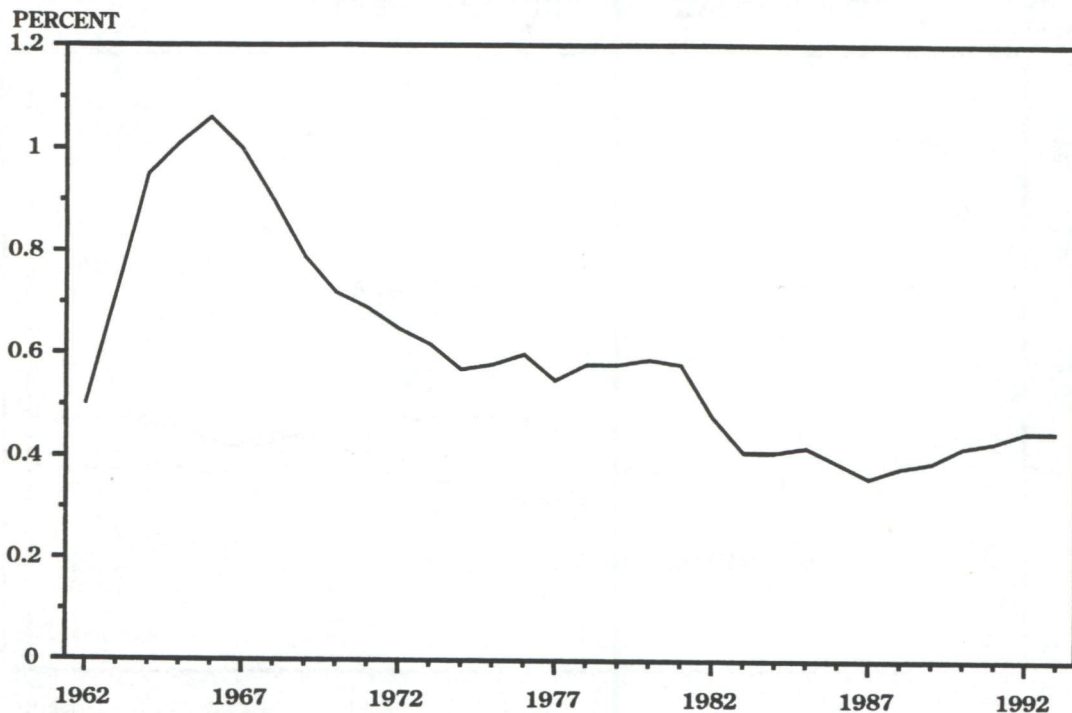
³ Includes the Departments of Education, Justice, Housing and Urban Development, Labor, the Treasury, the Nuclear Regulatory Commission, Tennessee Valley Authority, Smithsonian Institution, and the Corps of Engineers.

APPLIED R&D: EXPANDING THE FRONTIER OF TECHNOLOGICAL DEVELOPMENT

Federal investments in applied research and development provide a strong foundation for the development of new technologies, which, when successfully applied by the private sector, can yield large benefits in terms of productivity improvements, economic growth

and new jobs. In total, the budget proposes about \$59.3 billion, an increase of about \$1.5 billion or nearly 3 percent to support R&D investments across a wide range of technology areas.

RATIO OF FEDERAL CIVILIAN R&D OUTLAYS TO GROSS DOMESTIC PRODUCT



SOURCE: National Science Foundation, Office of Management and Budget

The Administration has sought to foster technological advancement through a multi-faceted technology policy that includes:

- increased Federal investments in high-payoff applied research and development, including increased emphasis on pre-competitive, generic technologies;
- increased government-industry collaboration, including both formal consortia arrangements (such as the Advanced Battery Consortium) and informal interaction (such as the Computer Systems Policy Project);
- accelerated technology transfer from government laboratories;
- greater emphasis on investments in new technologies as part of several National Strategies to address transportation and energy issues, and to advance the U.S. space program;
- support for incentives to encourage greater private sector R&D investments including

making permanent the R&E tax credit, expansion of the National Cooperative Research Act (NCRA) to include joint production ventures, and the proposed reduction in the taxation rate for capital gains.

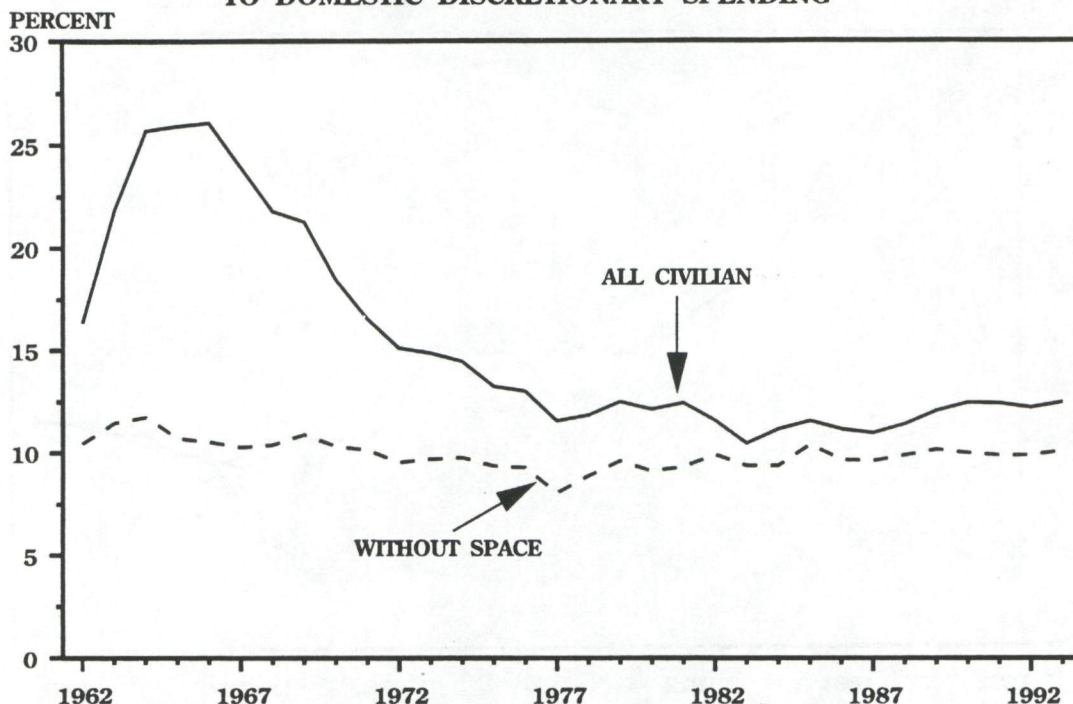
Elements of this policy are embodied in each of the budget initiatives in applied research and development.

Overview of Applied Research and Development

The principal strategy for the Federal applied civilian R&D programs is to invest in areas of R&D that support agency mission requirements, but also have potentially broad applications in the private sector, even though the commercial applications themselves would not be funded by the government. In such cases, the Government's role is to support the development of generic or enabling technologies at the pre-competitive stage of R&D:

- generic or enabling technologies have the potential to be applied to a broad range of products or processes across many firms

RATIO OF FEDERAL CIVILIAN R&D OUTLAYS TO DOMESTIC DISCRETIONARY SPENDING



SOURCE: Office of Management and Budget

or industrial sectors; and, because the benefits are not necessarily appropriable to individual firms, the private sector is likely to underinvest;

- pre-competitive R&D is the stage of the R&D process where the results can be shared widely within and between industrial sectors, without reducing the incentive for individual firms to develop and market commercial products and processes based upon the results.

Many of these generic technologies have been identified as "critical" technologies that are important to a number of industries. Lists of these technologies have been compiled by both Federal agencies (Defense, Commerce), by private groups (Council on Competitiveness), and by the National Critical Technologies Panel. These lists provide a useful benchmark, but should not necessarily be viewed as definitive. Technology breakthroughs can occur in new fields long before such areas are widely recognized as "critical technologies", e.g., high-temperature

superconductivity. The Federal Government has invested in many of these "critical" technologies for many years, e.g., biotechnology, computer hardware and software, rocket propulsion.

Mechanisms for Government-Industry-University R&D Collaboration

There are a number of different mechanisms that the Federal Government may use to support generic applied research and technology development. These include: cost-sharing of individual projects; formation of R&D consortia (often involving government, industry and university laboratories); and more informal government/university/industry collaboration.

Industrial R&D Collaboration.—Strategic alliances and partnerships among industries are not new. Individual firms have often looked to other companies for new technology, innovation and new markets to complement their own efforts. But in order to be successful over the longer term, such alliances must provide

mutual, and generally comparable, benefits to the partners. The National Cooperative Research Act (NCRA) of 1984 enabled private companies to form research alliances (consortia, joint ventures, partnerships) among themselves without the fear of per se antitrust violations. As of December 1991, a total of 263 private sector consortia had been registered with the Justice Department.

The Administration has supported legislation to expand the NCRA to include joint production ventures. In addition, the Department of Commerce has proposed an initiative, the Strategic Partnerships Initiative, to promote voluntary R&D collaboration among private firms for the development and application of large-scale enabling technologies, with no direct Federal funding.

In recent years, a number of authors (Ouchi; Coase; Porter; Badaracco; Dertouzos, Lester and Solow) have written extensively on industrial R&D cooperation and consortia. These authors have noted the potential benefits of increased R&D collaboration, particularly where the industrial technologies are not fully "appropriable" to individual firms, or where there are generic problems or agreed-on multiple research paths which must be explored to enable new technologies to be developed.

They have also noted the limitations of R&D collaboration. Consortia may not be beneficial if allowed to extend to product development, or if the collaboration is not well-defined in advance, or if excessive reliance on collaboration results in inhibiting competition. The Federal Government has had limited involvement in consortia, but generally has had success in those consortia in which it has participated. For example:

- *The Concurrent Supercomputing Consortium* acquires computers with unprecedented capabilities and uses them to enable member scientists to tackle new classes of computational problems. This consortium, which consists of numerous government agencies (Defense, Energy, NSF, NASA), and academic and industrial institutions, has combined its resources to acquire the Intel Touchstone Delta System, the world's first general-purpose computer with a peak speed of 30-gigaflops.

- *The National Aerospace Plane joint-venture partnership* merged the best ideas of five contractors into a single design and permitted the sharing of advances in materials and propulsion technology and aerospace design. It also has helped ensure that there will be a broad U.S. industrial base for future operational hypersonic and aerospace vehicles.
- *In Energy R&D*, the Administration has pursued several R&D consortia. For example, the Administration recently initiated the *Advanced Battery Consortium* with the major U.S. auto companies, battery manufacturers and electric utilities. Over the past several years, the Administration has supported a collaborative R&D program in *photovoltaics technology*, including both individual cost-shared contracts as well as a consortium arrangement. In addition, the Administration proposed funding in the 1991 budget to establish an R&D consortium for *geosciences research* in support of advanced oil and gas recovery, but Congress did not support the request.

Because U.S. R&D consortia are relatively new, there is no firm track record to measure success. There is continuing debate about the role of R&D consortia in innovation and economic growth.

For example, in an informal survey of a number of senior industry officials conducted in 1990 by the National Research Council, many of these officials expressed doubt that generic research conducted in consortial arrangements with other companies and universities would offer significant commercial advantage, since the results would have to be shared broadly and are too remote from the marketplace. These officials were much more enthusiastic about the benefits of more informal researcher-to-researcher collaborations.

In addition, several articles have questioned the effectiveness of the Sematech consortium, and recently two of its member companies have withdrawn. However, many of the issues surrounding Sematech appear to be unique to it, and cannot be extrapolated to all consortia.

There are attributes of joint research alliances that may increase the likelihood of long-term success. In the case of Federally-supported consortia, such attributes would include the following:

- The private sector participants should agree to share at least half of the total costs of the R&D.
- The area of interest for the consortium should be supportive of Federal missions, and should complement Federal R&D programs.
- The R&D itself should use existing Federal, private or university laboratories and research expertise.
- The R&D should not involve technologies where one or more of the private sector participants has a strong proprietary position or existing commercial production.
- The setting of R&D priorities within the area of interest should be led by the private sector participants.
- The R&D should be focused on generic or enabling technologies which have the potential to benefit a broad range of companies, processes or products.

These attributes are clearly embodied in the most recent Federally-supported R&D consortium, the U.S. Advanced Battery Consortium, and can be found in other Federal R&D consortia as well. Because consortial R&D arrangements are new, it will be necessary to experiment with different forms of collaboration, and the performance of each will need to be continuously assessed.

The Role of the National Laboratories in Cooperative R&D.—As a result of the major changes now taking place in the world, there are new opportunities to redeploy the Nation's national security R&D assets in support of broader objectives. In particular, the government's National Weapons Laboratories, which have historically been at the forefront of the development of advanced defense-related technologies, could make significant contributions to advanced generic technologies for a broader range of government and commercial applications. The National Laboratories could serve as catalysts in the formation of new, industry-led consortia that could make important tech-

nical contributions in a variety of the applied R&D areas discussed in this chapter. In this way the U.S. economy may benefit and receive additional return from the investments which have been made developing defense technology.

The National Laboratories already have a solid base of expertise in a number of critical technology areas, including biotechnology, advanced materials including both semi- and superconductors, advanced manufacturing, high performance computing including massively parallel processing, and advanced optical technologies, including flat panel displays. The R&D programs of the National Laboratories are discussed further in the section on "Maintaining National Security" later in this chapter.

Other Technology Policy Activities.—The technology policy principles embodied in the 1991 budget are, in part, an outgrowth of the U.S. Technology Policy statement issued in September, 1990 by the Office of Science and Technology Policy. To further assist in the development and implementation of this policy, the budget proposes \$1 million for the Critical Technology Institute (CTI). The CTI, a new Federally-funded research and development center, will undertake studies and analyses that can assist Federal agencies in determining whether increased investments in these technologies will serve both agency mission needs and broader national needs. Together with funding provided in prior years, a total of \$7.6 million will be available to the CTI in 1992 and 1993.

In addition, the budget proposes \$6 million, an increase of 32 percent, for the Technology Administration within the Department of Commerce. This Administration was established in 1990 in recognition of the importance of technology to the Nation's long-term competitiveness and the need to integrate and manage numerous Department of Commerce technology functions. The enhanced budget will allow the Technology Administration to pursue more aggressively its efforts to coordinate Federal programs and activities which facilitate commercial application of existing and emerging technologies. In addition, it will allow the Technology Administration to enhance its efforts to stimulate greater co-

operation among private sector entities with the aim of fostering better quality and higher productivity in U.S. manufacturing.

Budget Initiatives in Applied Research and Development

High Performance Computing and Communications.—The budget proposes \$803 million for the second year of the High Performance Computing and Communications (HPCC) program. Planning and execution for this program has proceeded through nine participating Federal agencies working under the Federal Coordinating Council on Science, Engineering and Technology (FCCSET). The HPCC program focuses on the underlying research and the human talent needed to develop and apply the next generation of supercomputer systems (including hardware, software, and networks).

The goal of the HPCC initiative is to meet, by 1996, the needs of Federal research agencies to investigate and understand a wide range of fundamental scientific and engineering "grand challenge" problems: fore-

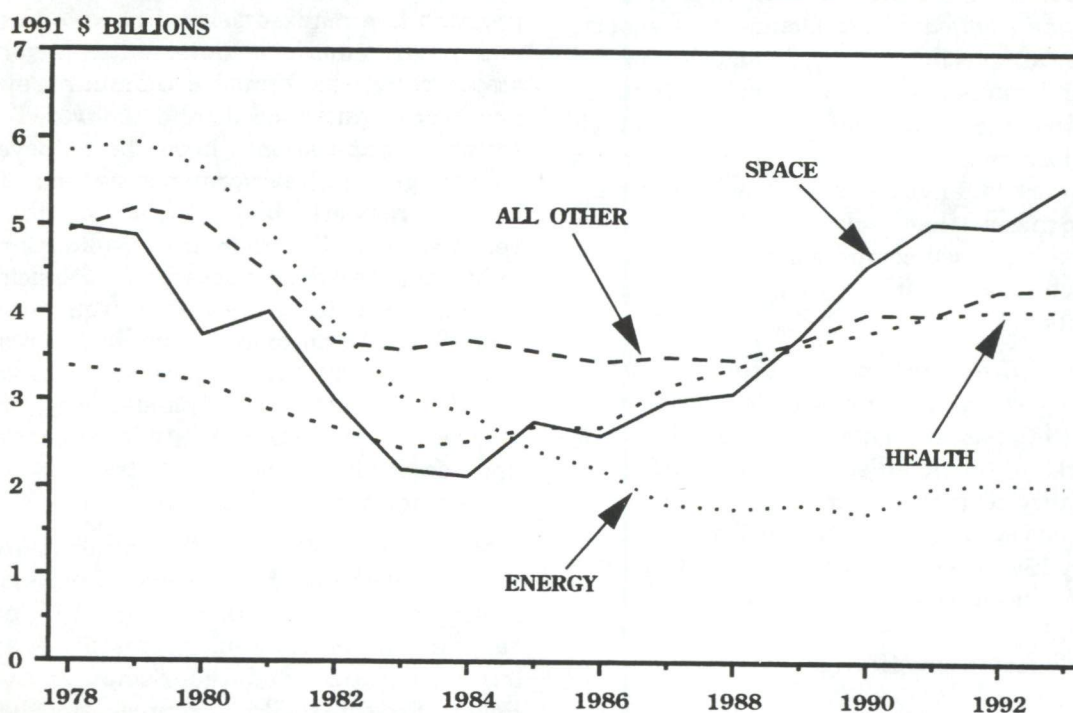
casting severe weather events; solving the molecular riddle of the genome; predicting new superconducting materials; minimizing air pollution; designing better aircraft; improving energy conservation; designing and packaging new computer chips; understanding and predicting global change.

Achieving this goal will require a 1,000-fold improvement in computing capability and 100-fold improvement in communications. These advances will also permit the private sector to "leap frog" over the otherwise incremental improvements in supercomputers and networks.

Investments in research and technology development are planned in four HPCC program components:

- **High Performance Computing Systems (Hardware):** Development of the underlying technology required for scalable parallel computer systems capable of sustaining trillions of operations per second on large projects (a thousand-fold improve-

FEDERAL CIVILIAN APPLIED RESEARCH AND DEVELOPMENT BUDGET AUTHORITY



SOURCE: National Science Foundation, Office of Management and Budget

Table 6-3. THE BUDGET INCLUDES INITIATIVES IN SEVERAL KEY AREAS OF APPLIED R&D

(Dollar amounts in millions)

Initiative	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
High Performance Computing and Communications ...	N/A	655	803	+148	+23%
Advanced Materials and Processing	N/A	1,659	1,821	+162	+10%
Biotechnology Research	N/A	3,759	4,030	+271	+7%
Energy R&D	397	774	914	+140	+18%
Moving Fusion Energy from a Science to Engineering	347	337	360	+23	+7%
Advanced Manufacturing R&D (non-defense)	N/A	252	321	+69	+27%
Improving the Efficiency of the Transportation Sector through Technology	802	1,224	1,433	+209	+17%
Protecting the Public Health: Health Research and Disease Prevention	3,482	4,757	4,849	+92	+2%
Expanding R&D at the National Institutes of Stand- ards and Technology	159	247	311	+64	+26%
Space Technology	256	273	305	+32	+12%

ment in computing capability). These systems will be the bases for the commercial supercomputers and workstations of tomorrow.

- *Advanced Software Technology and Algorithms (Software)*: Development of generic software technology and algorithms for grand challenge research applications to realize the performance potential of high performance computing systems in a networked environment. This component recognizes that software improvements have increased computational performance much more than have hardware components.
- *National Research and Education Network (Networks and Communications)*: Upgrade of the existing federally supported networks to provide distributed computing capability to research and educational institutions and further advanced research on very high speed gigabit (billion bit per second) networks and applications. Ultimately, this technology will be the foundation for sophisticated commercial networks.
- *Basic Research and Human Resources (Research/Training)*: Support long term basic

research, increase the number of students in computational science, and transfer technology for industrial grand challenge applications.

In the first year of operation, the HPCC program has realized several notable technical and programmatic achievements. Major new scalable high performance computing systems have been announced and delivered. New software applications have been developed for emerging high performance systems. Traffic on the network has doubled in the past year, as has the number of interconnected local and regional networks. Participating Federal agencies have begun solicitation to fund high performance computing research groups, centers, and consortia on various grand challenge problems, and a large number of researchers, scholars, students, scientists, and engineers have been trained to use these emerging new technologies.

Moreover, additional substantial advice and recommendations have come from various industrial, professional, and scientific organizations such as Educom, representing numerous universities, and the Computer Systems Policy Project (CSPP), representing leading U.S. computer companies. As an example of the dynamism and flexibility of the HPCC

program, many of the CSPP recommendations presented in December 1991 are already being incorporated into the program. The CSPP has noted that the HPCC program is a significant, critical and necessary undertaking by the Federal Government, and have provided four valuable recommendations:

- *Expand the vision of the HPCC to include research on generic, enabling technologies to support a wider range of applications such as better health care, lifelong learning, improved services for senior citizens, enhanced industrial design, and broad access to public and private databases.* In recognition of the importance of these applications, the program is investing in many of the supporting advanced technologies such as open scalable systems, portable software, mass data storage, and advanced network protocols. In addition, the HPCC program is also providing opportunities for industry and academia to propose specific grand challenge applications such as those listed above.
- *Establish a technology and policy foundation for an information and communications infrastructure for the future.* To address this issue, the Federal Networking Council, an interagency coordination group that supports the National Research and Education Network, has formed a policy committee to address critical network issues such as security and privacy, intellectual property rights, and network access, interoperability, and technology transfer.
- *Improve management and governance of the HPCC program and increase opportunities for industry participation.* To improve management in the near term, the HPCC program will strengthen its current management structure. This should provide a clearer emphasis on implementation of policies and plans, enable monitoring of progress towards goals and objectives, better satisfy Congressional reporting requirements, and serve as a single point-of-contact for industry, academia, and other government agencies. Over the coming months, the Administration will be exploring new management approaches that might bring better coordination and accountability to the program. To improve

technology transfer, the Department of Energy is supporting the development of a model Cooperative Research and Development Agreement (CRADA) that will ease significantly the exchange of computing technology between private industry and government laboratories.

- *Reorder the HPCC budget priorities to achieve a more balanced program.* In response to this recommendation, the budget proposes the largest dollar increase (\$68 million) of any of the HPCC program components for software research. The program will continue to support basic research, generic technologies, and broad applications, but will work in the coming year to achieve the appropriate funding balance between software research and computer equipment and facilities.

The HPCC effort received added impetus in 1991 with the enactment of a multi-year authorization, the High Performance Computing Act of 1991 (Public Law 102-194). Passage of this legislation is yet another example of the broad national support for this program.

Advanced Materials and Processing Program.—The budget proposes \$1,821 million, an increase of 10 percent, for a new interagency program to improve the synthesis, processing and performance of materials.

Everything is composed of materials. Faster, smaller semiconductor chips; flexible concrete skyscrapers; a biomaterial artificial hip; and strong, lightweight aircraft and spacecraft are but a few of the advances made possible through improved materials. New methods of preparing materials, virtually atom by atom, have become available in the past few years, which offer unprecedented opportunities for tailoring materials to meet the needs of society.

The Federal Government has long played a supporting role in materials science and engineering. The importance of strengthening the Federal commitment to materials R&D to take advantage of the unique scientific opportunities now present has been widely recognized. The National Critical Technologies Panel identified materials technology as one of six broad technology areas, and materials

Table 6-4. THE BUDGET PROPOSES A 23 PERCENT INCREASE FOR ALL ASPECTS OF HIGH PERFORMANCE COMPUTING

(Dollar amounts in millions)

Description	Budget Authority			
	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Program Components				
High Performance Computing Systems	152	178	+26	+17%
Advanced Software Technology and Algorithms	278	346	+68	+24%
National Research and Education Network	92	123	+30	+33%
Basic Research and Human Resources	132	156	+24	+18%
Agency				
Defense (DARPA)	232	275	+43	+18%
National Science Foundation	201	262	+61	+30%
Energy	92	109	+17	+18%
National Aeronautics and Space Administration	71	89	+18	+25%
Health and Human Services	41	45	+4	+8%
National Oceanic and Atmospheric Administration	10	11	+1	+10%
Environmental Protection Agency	5	8	+3	+60%
National Institute of Standards and Technology	2	4	+2	+95%
Total, All agencies	655	803	+148	+23%

figure prominently in lists of key technologies prepared independently by the Departments of Defense and Commerce.

To address these opportunities and needs, a multi-year program involving 10 Federal agencies has been initiated within FCCSET to enhance R&D efforts in materials science and technology. The Advanced Materials and Processing Program (AMPP) will also focus increased attention on the interfaces between universities, government laboratories and industry, and on transferring technology from basic research to application.

The program targets four areas of materials science and technology for enhancement. The budget proposes to increase funding for: Synthesis and Processing of Materials by \$65 million (9 percent); Theory, Modeling, and Simulation by \$30 million (13 percent); Materials Characterization by \$29 million (6 percent); and funds for Education and Human Resources in materials science and engineering by about \$6 million (27 percent). Specific programs within these areas were selected

for enhancement through a FCCSET inter-agency coordination and evaluation process. The evaluation criteria used in that process included technical merit, environmental/social merit, readiness, costs, and linkages to existing programs.

Over the course of the next year, the Federal agencies plan to work closely with the private sector to identify in more detail specific R&D priorities and to develop specific collaborative R&D programs.

Many of the programs cannot be assigned solely to specific classes of materials. Nonetheless, the classes of materials that will receive the largest increases in the budget proposal are: polymers (\$10 million or 12 percent over 1992), ceramics (\$18 million or 14 percent over 1992), composites (\$24 million or 13 percent over 1992), biological materials (\$21 million or 13 percent over 1992), and electronic materials, including semiconductors (\$15 million or 9 percent over 1992).

Table 6-5. THE BUDGET PROPOSES A 10 PERCENT INCREASE FOR A NEW INITIATIVE IN ADVANCED MATERIALS AND PROCESSING

(Dollar amounts in millions)

Description	Budget Authority			
	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Program Component				
Synthesis and Processing	683	748	+65	+9%
Theory, Modeling and Simulation	224	253	+30	+13%
Materials Characterization	474	503	+29	+6%
Education/Human Resources	21	27	+6	+27%
National User Facilities	257	291	+33	+13%
Agency				
Energy	603	678	+75	+12%
Defense	449	432	-17	-4%
National Science Foundation	266	319	+53	+20%
National Aeronautics and Space Administration	125	154	+29	+23%
Health and Human Services	77	82	+5	+7%
Agriculture	57	66	+9	+16%
Commerce	46	48	+2	+4%
Interior	25	24	-1	-4%
Transportation	9	16	+7	+76%
Environmental Protection Agency	3	4	+1	+33%
Total, All agencies	1,659	1,821	+163	+10%

Biotechnology Research.—Biotechnology is a set of powerful tools that can ultimately lead to products for conquering disease, easing world hunger and reducing pollution. Broadly defined, biotechnology includes any technique that uses living organisms to make or modify products, to improve plants or animals, or to develop microorganisms for specific use (Office of Technology Assessment, 1984). New biotechnology involves recombinant DNA, DNA transfer techniques, macromolecular structure, and bioprocessing, among other fields.

If projected technical advances are realized, the effect of biotechnology on society and the economy is likely to be dramatic. In 1991, according to a report by Ernst and Young, sales of biotechnology products approached \$4 billion and sales are expected to increase to over \$50 billion during the next ten years. Not only are new vaccines and drugs being developed, but biotechnology

techniques have enabled the development of a new generation of methods for disease diagnosis including the genetic causes of disease.

Nationwide, hundreds of companies representing every industrial sector from agriculture to energy and manufacturing are using biotechnology to develop products and processes. Central to U.S. efforts in biotechnology is Federal support for research in scientific and engineering disciplines that will underpin future advances.

In early 1991, the President's Council on Competitiveness issued its "Report on National Biotechnology Policy." The report described three areas of concern: (1) science and technology; (2) risk-based regulation; and (3) a flourishing free market for biotechnology. The budget proposals are responsive to the Council's recommendations on science and technology. In the area of regulatory policy,

the Council's Biotechnology Working Group considers proposals to remove unnecessary regulatory burdens by improving interagency coordination, streamlining the regulatory agencies' evaluation processes, and reevaluating regulations. Descriptions of Federal policies for the commercialization of food, animal, plant and microbial products will be published soon.

The budget proposes a total of about \$4 billion for biotechnology research, an increase of \$271 million or 7 percent over 1992. These resources will be contributed by 12 Federal agencies with biotechnology programs in a number of research areas as part of a set of FCCSET coordinated programs. A number of these programs are new and their various foci provide evidence of the growing and diverse applications of different biotechnology techniques. Examples of these programs include: biological sensor technology (funded by Defense) to improve threat detection at sea and drug interdiction efforts; conservation and renewable energy research (funded by Energy) to develop cost-effective biofuels; forensic DNA analysis for identification and testing (funded by Justice) to develop reliable and valid methods for conducting DNA profiling; and engineering research in the areas of bioprocessing and applied biotechnology (funded by NSF).

Coordination of agency programs maximizes the effectiveness of the total Federal effort. For example, nine agencies have existing programs in environmental biotechnology and eight have existing programs in manufacturing/bioprocessing. These programs have been developed in response to individual agency missions and, although they are largely complementary rather than duplicative, their independent existence indicates the need for enhanced interagency coordination.

While the first effects of biotechnology R&D have been felt in the areas of human health and disease, the impact of biotechnology will also soon be felt in many areas besides health. The next decade will see unprecedented applications of different biotechnology to agriculture and aquaculture, the restoration and protection of the environment, and the production of chemicals and fuels.

- *Environment.*—Biotechnology products hold great promise for environmental restoration and protection. The budget proposes \$83 million for research on environmental biotechnology, a 20 percent increase over 1992. Environmental biotechnology research has a direct and fundamental role in developing applications like bioremediation, biorestitution and development of other environmental diagnostics. Examples of recent developments in this field include the engineering of microorganisms that degrade specific toxic organic chemicals and others that emit visible light signals when they encounter specific chemicals in the environment.
- *Manufacturing/Bioprocessing.*— Industry is just beginning to apply biotechnology to a wide spectrum of manufacturing processes. Biotechnology research in manufacturing/bioprocessing is likely to have increasingly important applications to the manufacture of pharmaceuticals, food-related products, chemical feedstocks, fuels, and a variety of novel products such as biomolecular materials. Modern bioprocessing is able to achieve economically efficient manufacture of many desirable products by using renewable resources and biocatalysts that minimize energy consumption and reduce waste products. The budget proposes \$124 million for manufacturing/bioprocessing research, an increase of 25 percent over 1992.
- *Health.*—The basic science and health components of biotechnology represent a powerful driving force in health care technologies today. Earlier basic research on recombinant DNA (rDNA) has already come to fruition. The first generation of rDNA drugs included proteins such as insulin and white blood cell stimulators. The near future may see the use of animals as factories to produce large quantities of these proteins at lower cost. It is now possible to use these techniques to make biomaterials such as synthetic collagen to preserve liver cells in a matrix, thus creating alternatives to whole organ transplants for liver failure. A better understanding of the molecular basis of disease will lead to the identification of specific

targets for disease intervention. The budget proposes nearly \$1.7 billion in this area, an increase of \$86 million or 5 percent.

- *Agriculture.*—Agricultural biotechnology research is applicable to food, feed, fiber and forestry production. While USDA has the primary responsibility within the Federal Government, seven other agencies support agricultural biotechnology research. Traditional biotechnologies have been practiced in agriculture since the beginning of civilization to improve plants and animals. New techniques vastly expand this potential. However, the knowledge base for application of modern biotechnology to plants, animals and microbes of agricultural significance has not been put to commercial use to the same degree as that for human health and medicine. Agricultural techniques now exist to produce better quality food and fiber, foods with higher nutrient content, crops and animals with greater tolerance to stresses, and better soil productivity and waste management. The budget proposes \$208 million in this area, an increase of \$17 million or 9 percent.
- *Energy.*—Decreasing petroleum reserves, coupled with increasing consumption, have made this country increasingly dependent on imported oil. The National Energy Strategy promotes conservation and the development of alternative energy resources. Biotechnology offers one key to such development through the use of products from plants and microorganisms. Energy-related biotechnology research is aimed at developing methods to produce and convert biomass (cell wall material of plants) to liquid fuels and chemical feedstocks, enhance petroleum recovery, and convert coal into environmentally benign fuels. The increased use of biological systems for energy will maximize the efficient and economic use of both renewable and fossil resources. The budget proposes \$107 million, an increase of \$27 million or 33 percent.

The Future.—The Federal investment in biological research of the past thirty years has contributed to the foundation for today's strong biotechnology enterprise. The U.S. is currently

poised to exploit the promise of biotechnology. During 1993, the Federal Government will continue to coordinate and encourage research into unexplored areas and identify areas of opportunity for Federal investment.

Advancing New Energy Technologies.—

A major element of the Administration's National Energy Strategy (NES) continues to be increasing investment in energy technology R&D. The budget proposes \$914 million, an increase of \$140 million or 18 percent, for increased investments in R&D in support of the Administration's NES R&D initiatives.

The Department of Energy's (DOE) NES related R&D strategy is intended to foster a results-oriented approach, based on the following key elements:

- an emphasis on R&D areas that, if successful, could lead to significant reductions in U.S. oil vulnerability;
- selection of R&D areas based on high R&D payoff potential, i.e., the potential to achieve significant cost and performance improvements;
- a comprehensive, interagency R&D program that includes both technology enhancements, e.g., more efficient engines, and more fundamental system changes, e.g., the potential for high speed rail and Maglev systems to displace automobile and air travel (rail and highway transportation systems are discussed later in this chapter in the section on Transportation R&D);
- a collaborative, cost-shared approach to research in applied areas where private industry ultimately will be responsible for the commercialization of the technology. This approach is intended to involve industry more in R&D planning and management to obtain significant cost sharing, with the research performed by industry or universities (except in situations where Government labs, such as DOE's National Laboratories, have unique research and testing capabilities). DOE encourages Government-assisted R&D consortia when they meet the criteria outlined earlier in this chapter.

**Table 6-6. THE BUDGET PROPOSES A 7 PERCENT INCREASE IN
FEDERAL INVESTMENTS IN BIOTECHNOLOGY**

(Dollar amounts in millions)

Description	Budget Authority			
	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Program Component				
Research Areas	3,759	4,030	+271	+7%
Agriculture	191	208	+17	+9%
Energy	80	107	+27	+33%
Environment	69	83	+14	+20%
Manufacturing/Bioprocessing	99	124	+25	+25%
Health	1,594	1,680	+86	+5%
General/Foundations	1,418	1,500	+82	+6%
Social Impact Research	9	9	—	—
Infrastructure	301	320	+19	+6%
Agency				
Health and Human Services	2,963	3,125	+162	+6%
(National Institutes of Health)	(2,801)	(2,944)	(+143)	(+5%)
Agriculture	179	168	-11	-9%
National Science Foundation	174	206	+32	+18%
Energy	182	243	+61	+34%
Veterans Affairs	86	90	+4	+5%
Defense	81	87	+6	+7%
National Aeronautics and Space Administration	37	45	+8	+22%
Agency for International Development	21	31	+10	+48%
Environmental Protection Agency	16	18	+2	+13%
Commerce	13	13	—	—
Interior	5	5	—	—
Justice	2	2	—	—
Total, All agencies	3,759	4,030	+271	+7%

DOE estimates that the NES R&D Initiative can be expected to lead to reductions in oil consumption by the year 2030 of 5-8 million barrels per day, depending on the success of the proposed R&D programs.

The NES initiatives include:

- *Electric and Hybrid Vehicles.* On October 25, 1991 the President and members of the U.S. Advanced Battery Consortium (USABC) announced a jointly-funded, four year, \$260 million research effort to develop a new generation of batteries that would enable electric vehicles to be widely available within the next 10 years. These

improved batteries could improve the practicality of electric cars by extending their range up to 120-200 miles. In 1993, proposed DOE funding for the second year of the USABC and supporting battery research is increased by 56 percent to nearly \$42 million. The Federal investment will be matched on a 50:50 basis by the private sector.

The budget also proposes funding for the creation of a new Government-industry R&D consortium for hybrid vehicle propulsion technology. This new generation of vehicles would use combinations of battery technology with other systems such as fuel

Table 6-7. THE BUDGET PROPOSES AN 18 PERCENT INCREASE FOR NATIONAL ENERGY STRATEGY R&D INITIATIVES

(Dollar amounts in millions)

Initiative	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Displacing Oil in the Transportation Sector	171	326	464	+138	+42%
Surface and Air Transportation Efficiency	121	226	299	+73	+32%
Electric/Hybrid Vehicles R&D	14	43	75	+32	+74%
Improved Vehicle Propulsion Technology	33	40	44	+4	+10%
Intelligent Vehicle/Highway Systems R&D	0	28	38	+10	+36%
High Speed Rail/Magnetic Levitation	0	20	28	+8	+40%
Energy Efficient Air Traffic Control R&D	24	32	46	+14	+44%
Energy Efficient Aeronautics R&D	50	63	68	+5	+8%
New Fuel Sources	50	100	165	+65	+65%
Fuels from Biomass	13	35	46	+12	+35%
Alternative Fuel Utilization	2	17	32	+15	+88%
Advanced/Enhanced Oil Recovery	24	37	47	+10	+27%
Natural Gas R&D	11	12	40	+28	+233%
Increased Energy Efficiency in Buildings and Industry	64	146	160	+14	+10%
Targeted Industrial Energy Efficiency R&D	30	97	105	+8	+8%
Targeted Buildings Energy Efficiency R&D	34	49	55	+6	+12%
Advanced Electricity Technology	162	302	290	-12	-4%
Photovoltaics	35	60	64	+4	+7%
Superconductivity R&D	22	21	22	+1	+5%
Advanced Light Water Reactor R&D	26	63	59	-4	-6%
Advanced Reactor Concepts R&D	79	158	145	-13	-8%
Total, All activities	397	774	914	+140	+18%
Total, Energy	323	626	725	+99	+16%

cells or gas turbines. The effort will be aimed at producing technologies which lead to economical, environmentally friendly vehicles by the end of the century. If successful, it could also contribute to a technological and economic rejuvenation of the U.S. auto industry.

- *Improved Vehicle Propulsion Technology* through research on high temperature diesel engines and gas turbine engines. Conventional spark-ignited and diesel engines have efficiencies of up to 31 percent. Technologies are being developed, such as gas turbines, which could achieve efficiencies approaching 40 percent.
- *Advanced Transportation Fuels from Biomass* research programs will demonstrate use of industrial and agricultural waste

feedstocks, including woody materials, to produce alcohol fuels on a scale which can verify the technology and its commercial costs. The production of ethanol from food crops is currently not cost effective without substantial Federal tax subsidies. The goal of this R&D initiative is to get the production cost of ethanol from non-food crops down to levels that are competitive with current fuels. In 1993 DOE will expand its research effort to include more industry involvement in order to study advanced conversion technologies. Additionally, DOE has signed a cooperative research and development agreement (CRADA) with a major oil company to demonstrate the economics of ethanol production from industrial waste.

- *Alternative fuels utilization* will continue vehicle testing activities that will provide the information to facilitate greater use of alternative fuels. In addition to this testing program, in 1993 the Department of Energy is requesting \$15 million for the purchase of alternative fuel vehicles by Federal agencies. These funds will be used to pay for the incremental cost of the vehicles. Several thousand vehicles for Government use are expected to be purchased, thus helping to create "market pull" for U.S.-manufactured, alternative-fueled vehicles.
- *Advanced/Enhanced Oil Recovery Technologies* research will improve reservoir understanding to better target oil drilling and develop better instrumentation, chemical injectants and reservoir interpretation techniques. Currently, up to two-thirds of oil resources remain in the ground after conventional production is completed. It is estimated that up to 3 million barrels per day in incremental production could be recovered through advanced/enhanced recovery techniques by the year 2010. In 1993, DOE will increase NES-related advanced oil recovery research to nearly \$47 million, more than 25 percent over 1992.
- *Natural Gas Research and Development* will increase substantially in 1993, emphasizing advanced production and extraction from conventional reservoirs and improved utilization technologies. The NES concluded that expanded use of domestically abundant and environmentally acceptable natural gas resources could increase energy security and improve the environment. The new gas program will speed achievement of these goals by focusing on the recovery of the resource and developing ultra high efficiency technologies for its consumption. DOE will increase funding for gas-related R&D to \$40 million, over 230 percent above 1992.
- *Energy Efficiency in Buildings and Industry* can be improved by developing advanced technologies. The industrial and building sectors account for about two-thirds of all U.S. primary energy consumption. DOE's R&D efforts are aimed at assisting the building sector in developing advanced technologies in lighting, heating and cooling, e.g., solar heating and lighting, advanced heat pumps, and more efficient lights, as well as to assist industry in developing advanced industrial processes which reduce both waste streams and energy use. Building and industry-related R&D is proposed to increase to \$160 million, or 10 percent over 1992.
- *Photovoltaic Research* will continue to advance efforts to increase the cost-competitiveness of photovoltaic (PV) systems. Past research by industry and DOE has enabled today's PV systems to compete successfully with primary batteries, small engine generators, and utility line extensions in many remote applications. In 1993, \$64 million is requested, an increase of 7 percent over 1992, to help U.S. industry develop photovoltaic technology and systems, particularly those materials and devices that will reduce electricity generation costs and serve a growing energy market in the process.
- *Advanced Light Water Nuclear Reactors* research will continue in 1993 to develop passive safety features in a standardized design. This will reduce the time needed to license new plants, while assuring that safety issues are adequately addressed. The Department of Energy is also using existing funds to continue first-of-a-kind engineering work that will assist companies in their efforts to achieve safety of new standardized designs that will meet the requirements of the Nuclear Regulatory Commission.
- *Advanced Reactor Concepts* will have safety features that go beyond the standardized designs currently before the Nuclear Regulatory Commission. High Temperature Gas Cooled Reactors use specially-coated fuel elements that will not fail even under the high temperatures that could occur during an accident. Liquid metal reactors use liquid sodium as the heat exchange medium. Researchers have demonstrated that both reactor types can shut themselves down safely under conditions that would be extremely serious for present-day reactors. The Department of Energy continues R&D support for both

of these advanced concepts. In addition, the budget provides funding for DOE to continue its assistance to university nuclear engineering departments and students by providing fellowship and scholarship support.

The NES R&D initiatives are supported by increased investments in related areas of basic research. Basic research in areas such as advanced materials, superconductors, geo- and biosciences, and catalysis research will be continued in 1993.

The NES R&D initiatives encompass a broad range of new technologies that would permit the more efficient use of energy, or the substitution of petroleum with other energy sources. While these advances have the potential to make significant improvements in the Nation's energy security, it should be recognized that other significant, even larger, improvements can be achieved through more fundamental system changes in the transportation sector. Several of these changes, such as development of maglev and high speed rail as an alternative to air and surface transportation and improvement in airspace management are discussed elsewhere in this chapter and in Chapter 7, "Improving the Transportation Infrastructure."

In addition, other changes, such as telecommuting, offer great energy savings potential. The Federal Government, and others, such as the State of Washington, are experimenting with the use of telecommuting centers as alternative worksites to reduce commuting. Currently, about 50 percent of total U.S. vehicle miles traveled (VMT) is work-related, and there are estimates that telecommuting may be possible for about 46 million persons. The energy savings potential of telecommuting is enormous. For example, a 50 percent reduction in the miles traveled by a single individual represents the equivalent of a doubling of the fuel efficiency of his or her vehicle.

Moving Fusion Energy From Science to Engineering.—Fusion energy offers the potential to be a clean, plentiful fuel for the production of electricity for the longer term. Fusion is expected to be more environmentally benign relative to fission or fossil sources of electricity. The development of fusion as a

power source is an important part of the National Energy Strategy.

The budget proposes \$360 million for fusion, an increase of nearly 7 percent over 1992. Funding is included for conceptual design and R&D on a small tokamak experiment at Princeton University to understand basic physical principles of fusion. Much of the increase will support the strong U.S. commitment to the International Thermonuclear Experimental Reactor. This 6-year collaboration among four equal partners (U.S., European Community, Japan, and Russia) is a model for international cooperation in science and technology. Such a joint project has the advantages of sharing knowledge and personnel, reducing the financial burden for each party, and optimizing the use of special facilities and capabilities for the common goal of achieving energy from fusion.

Enabling New Products and Processes—Advanced Manufacturing R&D.—The budget proposes \$1.1 billion for advanced manufacturing R&D, a key enabling technology. This includes an increase of over 27 percent for non-defense related manufacturing R&D. For the purposes of this initiative, advanced manufacturing R&D includes activities within two broad areas: (1) efforts designed to use technology to improve the efficiency or quality by which a product is brought from design to completion; and (2) activities directed at expanding the technical capability to bring a product (which is new and fundamentally different in character from existing products) from design to completion.

In an effort to focus on those programs which are exclusively devoted to manufacturing R&D, the budgetary resources shown for Advanced Manufacturing R&D exclude funding for projects included in other cross-cutting efforts (e.g., Advanced Materials and Processing). As a result, these resources cannot be directly compared to resources reported for Advanced Manufacturing in the 1992 budget (which included all manufacturing-related R&D).

Improvements in U.S. manufacturing technology can increase productivity and quality, leading to new or more competitive products. While industry has the central role in R&D to improve manufacturing technology, an ap-

propriate role in such R&D exists for the government as well. The Federal role in advanced manufacturing R&D lies in supporting (1) generic manufacturing technologies which have broad applications and (2) those technologies which are directly applicable to the procurement needs of government programs.

The budget proposes increases for several agencies, including a \$25 million increase, to a total of \$105 million, for the National Science Foundation for a new manufacturing R&D effort that will focus on the next generation of manufacturing systems. The results of this research will shift the present focus on automating and linking separate mechanical components to integrating entire new systems based on advanced computers and information technologies (e.g., sensors, visualization, information management systems, artificial intelligence, networks). This research will be conducted in concert with industry and other Federal agencies and will develop several state-of-the-art manufacturing experimental testbeds for research, education, and training. The budget also proposes a \$27 million increase for manufacturing R&D at the National Institute of Standards and Technology. This increase will be devoted to generic manufacturing R&D such as development of standards for electronically communicating the design of products. In addition, a portion of the increase for NIST will provide matching funds for industry-led and performed R&D projects.

In addition, the Federal agencies have undertaken a new initiative to exchange manufacturing R&D information with industry, and to improve coordination of government-industry efforts. The initial step was a conference held in December, 1991 on Intelligent Processing Equipment. Other conferences are planned for 1992 in flexible computer integrated manufacturing; micro- and nanofabrication; and systems management technologies.

Improving the Efficiency of the Transportation Sector through New Technologies.—With increasing demands on the nation's highways and at airports, and with the high cost of building or expanding new facilities, the Federal Government is concerned

with stimulating transportation technologies that can alleviate the burdened infrastructure. In addition, new transportation technologies offer significant opportunities to move people and goods more efficiently, reducing petroleum consumption.

Two agencies, the Department of Transportation (DOT) and the National Aeronautics and Space Administration (NASA), support the majority of transportation-related R&D. DOT's programs span the modes of transportation, both ground and air. NASA's aeronautics program focuses on research and technology for both civilian and military aircraft. The budget proposes a total of \$1,433 million for both agencies, \$498 million for DOT and \$855 million for NASA, an overall increase of 17 percent, for transportation R&D activities.

Department of Transportation—The budget proposes \$498 million, an increase of 12 percent, for all of DOT R&D. The *Federal Aviation Administration* (FAA) funds research to improve airport and airspace utilization. FAA research includes projects to explore and define the next-generation of aviation technologies, including the use of satellites in aviation navigation and communications. Nearer-term projects include research to determine if the separation between two heavy class aircraft from the current 4 miles can be reduced to 3 miles to increase efficiency without a degradation of safety. FAA is also conducting research aimed at improving communications with oceanic aviation traffic. With better oceanic communications, air traffic controllers could allow more wind efficient traffic patterns, saving time and fuel and improving safety. FAA will also emphasize energy-efficient air traffic control R&D as a part of the national effort to modernize the air traffic control system. The budget proposes \$254 million for FAA R&D.

Intelligent Vehicle/Highway Systems (IVHS) are intended to increase highway safety, reduce congestion and decrease highway fuel consumption. IVHS uses state-of-the-art electronics, communications, and computer technology to improve traffic control systems, warn drivers of dangerous situations, and generally make more efficient use of the existing road system. IVHS can reduce conges-

tion, improve traffic flow, reduce idling at traffic signals, and allow drivers to choose more efficient routes to their destination. The Department of Energy National Energy Strategy analysis showed that actual on-the-road fuel economy can be significantly lower than the theoretical potential due to congestion. A study by Mobility 2000, an expert group of Federal and State highway officials and corporate and academic technical experts, estimated that IVHS has the potential to save up to 20 million gallons per day of gasoline. The budget proposes a total of \$138 million including \$38 million for R&D, and \$100 million for demonstration projects in this area.

High speed rail and Maglev systems offer opportunities to displace automobile and air travel with a concomitant increase in efficiency. A particularly promising technology is magnetic levitation trains, or "maglev." Current efforts include investigations into the economic and technical feasibility of maglev and the safety of maglev and high-speed rail. Maglev trains move above a guideway, supported and guided by powerful magnets and can achieve speeds of up to 300 miles per hour. In 1992, \$20 million was provided to DOT and the Army Corps of Engineers for maglev and high-speed rail R&D. The budget proposes \$28 million (\$15 million for DOT and \$13 million for the Corps of Engineers), an overall increase of 40 percent, for maglev and high-speed rail R&D.

National Aeronautics and Space Administration—The goal of NASA's aeronautics research and technology program is based on a strategy that calls for developing a broad technology base in support of the commercial aviation industry; enhancing the safety and capacity of the national airspace system; and helping assure U.S. aeronautical superiority for national security. Aeronautics R&D has traditionally been a highly successful close cooperative effort between the Federal Government and the private sector.

The budget proposes \$855 million for aeronautics R&D (excluding High Performance Computing and Communications), an increase of 13 percent over the 1992 enacted level. Work in focused high-speed research will

expand its emphasis on enabling propulsion materials necessary to develop future aircraft. In addition, the budget proposes increased funding for a program focused on advanced subsonic aircraft. This program will develop nondestructive evaluation technology to help ensure the safe operation of aging transport aircraft now in operation and will also provide the technology base for application by industry and certification by the FAA of fly-by-light and power-by-wire control systems.

In addition to the work proposed above, the budget proposes \$80 million as NASA's share of the joint NASA/Defense National Aerospace Plane Program (NASP). Defense will provide \$180 million in 1993. This program is focused on development of hypersonic technology, leading to a future decision on a flight research vehicle, the X-30 that can demonstrate airbreathing single-stage-to-orbit performance. The NASP industry contractors are uniquely organized under a joint-venture partnership that will permit technical innovation to be shared and will ensure a broad industrial base for future hypersonic programs. This singular focus has permitted relatively fast-paced advances in key enabling technologies such as air-breathing propulsion, advanced materials, actively cooled structures, dense fuel, and computational fluid dynamics.

Protecting the Public Health Through Biomedical and Behavioral Research

Federally supported research has helped Americans live longer, healthier lives by improving the quality of medical practice and by developing new preventive measures. The U.S. leads the world in biomedical research. Both the pace of new discoveries and America's continued dominance of scientific Nobel prizes attest to that pre-eminence.

The budget assures that the next generation will reap similar benefits by seeking substantial increases in the country's investment in basic and applied biomedical and behavioral research and development. In the Department of Health and Human Services alone, this increase amounts to \$433 million, or 4 percent, over 1992 funding levels to a total of \$10.6 billion.

Advances in biomedical and behavioral research can improve the quality of health care while helping to control health care costs. One example is the research-induced changes in medical practice which reduced coronary heart disease death rates and the duration of heart diseases-related hospital stays—saving hundreds of thousands of lives and billions of dollars. Current path-breaking research, such as the human gene therapy experiments conducted at the National Institutes of Health (NIH), proffers the hope of similar advances in human health and cost efficiency in the future. Research at the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA) into the causes of human addiction to drugs and alcohol offers hope of finding ways to reduce the human and societal toll caused by substance abuse.

The Federal investment in basic and applied biomedical and behavioral research is large. In total, the budget proposes \$10.6 billion for the Department of Health and Human Services, an increase of 4 percent over 1992. While \$5.8 billion of this research is basic, \$4.8 billion is invested in applied research and development. The applied research and development helps ensure that basic research discoveries are translated into marketable therapies. Indeed, NIH funding of clinical trials, through which promising new therapies, preventive interventions and cures are examined for safety and efficacy, will total over \$830 million in 1993. For example, since pharmaceutical companies traditionally have been slow to develop medications for substance abuse, the budget contains a \$64 million initiative for medications development in ADAMHA, a 13 percent increase over 1992.

This Federal investment in biomedical and behavioral research has increased as a proportion of GDP from 0.12 percent in 1970 to an estimated 0.17 percent in 1993.

NIH Strategic Plan. During the past year, NIH has begun to develop its first long-range Strategic Plan, to be completed in the Spring of 1992. The Plan is focused on 15 promising areas of science that hold exceptional opportunities for future breakthroughs. The Plan will also address the major policy issues that relate to the efficient and responsible conduct of

NIH-sponsored research. Broad public input is being sought on the Plan.

The Plan is not intended to direct the details of NIH-supported research, but rather to provide an overarching corporate framework—one that is dynamic and that can be changed in response to the extraordinary promise of future opportunities in biomedicine. It will help ensure that the promise of a healthier future for the citizens of tomorrow can be fully realized.

Women's Health Initiative. Three of the leading causes of death among women are cardiovascular disease, cancer and fractures related to osteoporosis. NIH has initiated a decade-long clinical trial to test three preventive approaches to reducing this toll through the adoption of low-fat dietary patterns, hormone replacement therapy, and calcium and Vitamin D supplementation. The budget proposes to increase this initiative by \$20 million, or 80 percent over 1992.

In addition to testing the effectiveness of these therapies, the study will include an observational component to study the predictors of disease and a community trial to test strategies for organizing community resources to help individuals achieve healthy behaviors of established value, including smoking cessation and prevention, improved diet, increased physical activity, and early cancer detection.

The study, which will include a cross-section of American women of all races and economic levels, will give us scientifically validated advice for women, their physicians, and public health care workers concerning healthy behaviors and treatments, and ways of achieving these behaviors.

Relating Research Investments to Selected Diseases.—Although most HHS research funds are utilized for basic research which advances knowledge for combatting many diseases, some research can be loosely classified as related to one specific disease or another, as shown on Table 6-8. By comparing these data with the data in Table 5-14 in Chapter 5, it can be seen that this investment by disease roughly corresponds to the toll these afflictions take in terms of death, illness, and human suffering.

Some have argued that a disproportionate share of health-related research dollars is being devoted to HIV/AIDS. It is true that spending per death from HIV/AIDS is high compared to that for heart disease, cancer, and stroke, the three leading causes of death in the country. HIV, however, often strikes early in life. More than 45 percent of AIDS sufferers are younger than 35, and a growing number are children. As a result, some suggest that research spending per year of potential life lost before age 65 for HIV and the three killer diseases is more comparable than that for spending per death, as shown in the following chart. In addition, a comprehensive assessment of relative funding levels must consider other factors, such as morbidity and quality of life. The chart also shows substantial investments in diabetes, a disease that is a major contributor to disability as well as the Nation's eighth leading cause of death.

Deaths and years of potential life lost attributable to the three major killers and diabetes are projected to grow, individually and collectively, by less than 5 percent over the 4 years between 1990 and 1993. In contrast, deaths and years of potential life lost due to HIV will increase much more quickly, rising by 30 to 80 percent. These projections further support the priority given to HIV research in the budget.

The Budget Includes a Major Investment to Confront Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome (HIV/AIDS).—Since the greatest hope for devising

better treatments, or even a cure or vaccines, for HIV/AIDS will come from advances in knowledge, the budget continues to place a priority on maintaining our investment in biomedical and behavioral research related to HIV/AIDS. As shown in table 6-9, governmentwide HIV/AIDS funding will increase by \$565 million or 13 percent. This includes a 4 percent increase for research and a 20 percent increase for treatment.

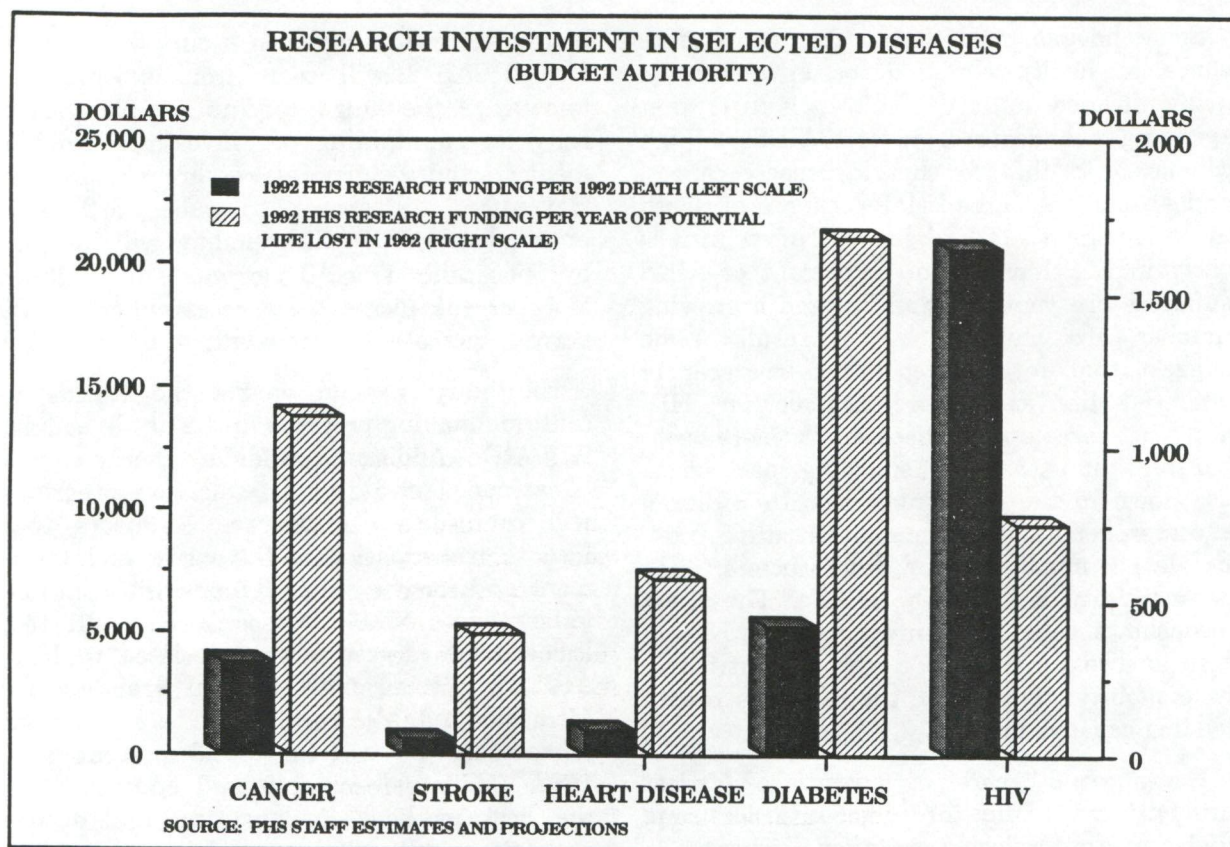
The budget would enable the Nation to continue making progress in the battle against HIV/AIDS. Additional candidate therapies will be screened and tested, education programs will continue to discourage behaviors that lead to transmission of the virus, and treatment and income support funds will continue to be made available to those already afflicted. Indeed, the largest increase related to HIV/AIDS will come from Federal spending for Medicaid and Medicare, which are projected to increase by a total of 23 percent over 1992. Additional research and education are the best methods for ensuring that future generations will not bear so heavy a burden, and the budget, therefore, makes substantial efforts in these areas.

Expanding Civilian Applied R&D at the National Institute of Standards and Technology (NIST).—The budget proposes \$311 million, an increase of 26 percent over 1992, for NIST. The R&D supported by NIST includes standards development and advanced measurement techniques, both of which are critical to improving product quality, enabling the effective use of new technologies, and en-

Table 6-8. HHS RESEARCH FUNDING ATTRIBUTED TO SELECTED CAUSES OF ILLNESS

(In millions of dollars)

Cause of Illness	Budget Authority	
	1992 Enacted	1993 Proposed
Cancer	1,984	2,042
Heart Disease	729	772
Stroke	94	100
Diabetes	279	292
Injuries	162	168
HIV/AIDS	1,164	1,211



**Table 6-9. THE BUDGET PROPOSES A 13 PERCENT INCREASE IN
FEDERAL FUNDING FOR HIV AND AIDS¹**

(Dollar amounts in millions)

	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
HIV/AIDS:					
Research	892	1,189	1,238	+49	+4%
Treatment	737	2,096	2,507	+411	+20%
Prevention	483	594	621	+27	+5%
Income Support	153	492	570	+78	+16%
Total²	2,265	4,371	4,936	+565	+13%

¹These are preliminary estimates for programs in the Departments of Health and Human Services, Defense, Veterans Affairs, Education, Justice, State, Labor, and independent agencies. Total also includes estimated obligations for the Social Security Administration.

²In addition to the spending identified above, the budget includes other initiatives, most notably those related to drugs and infant mortality, that contribute to the fight against HIV and AIDS.

hancing public health and safety. In addition, NIST supports generic applied research and technology development, often in collaboration with industry, which has the potential to benefit the U.S. economy broadly. The budget pro-

posal continues an effort begun in 1991 to expand NIST's ability to provide for generic applied research and technology development and to address a rapidly growing number of important standards and measurement issues.

The R&D performed at NIST facilities covers a wide range of technologies including electronics, manufacturing, materials science, chemistry, physics and information systems. The budget includes \$202 million, a 16 percent increase, for this in-house R&D. The research community and industry depend on NIST R&D for the precision measurement bases which form the foundation of R&D projects and industrial quality control. NIST transfers its metrology R&D to practical use through several means including sales of products, data and services. In 1991 NIST performed more than 11,000 calibration services and sold over 47,000 standard reference materials and 1700 standard reference databases (used by researchers and industry as a benchmark to calibrate their equipment). In addition, in 1991 NIST accredited 934 private laboratories to carry out specific types of tests in key areas of commerce, health and safety.

Due to the broad applicability to U.S. industry of NIST's metrology and other generic R&D, NIST often performs its research cooperatively with industry. Through 1991 NIST has signed over 150 cooperative research and development agreements and in 1991 received approximately \$65 million in in-kind contributions from industry. Over 25 of NIST's agreements are with industry consortia that further increase the impact of NIST's R&D expenditures and highlight the generic nature of its research. While NIST emphasizes widespread dissemination of its research results, protection of intellectual property resulting from NIST R&D is frequently needed in order to facilitate commercialization of its research results through licensing agreements. Since 1989 NIST R&D has resulted in over 40 patent disclosures per year.

The budget proposes \$23 million to maintain and refurbish NIST facilities, as well as to plan for the facility needs of the future. As a result of the technical obsolescence of many NIST facilities, experiments are often delayed or subject to costly reworking, and scientists often must accept levels of precision and accuracy below those desired. The budget provides for initiation of an architectural and engineering study and immediate amelioration of safety-related problems.

The budget also includes \$68 million, a 36 percent increase, for the Advanced Technology Program (ATP). This program provides matching funds to U.S. business and R&D joint ventures for industry-led, generic, pre-competitive R&D. Projects must have the potential for a broad-based economic impact. In a broad sense, the goal of the program is to help make the transition between fundamental research and the more applied research and technology development that will enable commercialization of products and processes by the private sector. Many studies have suggested that, for a variety of reasons, U.S. industry often fails to make this transition effectively, and, thus, is often unable to commercialize technology as rapidly as competitors. While the ATP is still experimental, it is intended to stimulate increased R&D at the generic, pre-competitive stage, and, thus, holds promise for improving the ability of U.S. firms to compete in global markets. The increase will allow NIST to fund approximately 25 to 35 new projects in 1993 while continuing to monitor closely and evaluate the program's impact.

The NIST Manufacturing Technology Centers are intended to enhance U.S. competitiveness by transferring manufacturing technologies to small and medium-sized business. The budget proposes \$18 million to support the continuation of the seven centers planned by the end of 1992. During 1992 NIST will contract for an in-depth study which will focus on how the centers should be structured to obtain the greatest leverage for Federal expenditures. Any decision on initiating new centers will be deferred until this study is completed.

Creating New Technology for Space and Earth: Space Technology. —A vigorous program to improve existing technologies and create new ones is essential for long-term progress in any major technological endeavor, but is particularly important in the space program. Reasons for this include the continuing need for new capabilities to support new missions and the long lead times needed to develop a new technology before it can be used with confidence in space. Consequently, the future success of the U.S. space program depends in part on near-term investments in a number of technological disciplines.

There is considerable evidence that the funding of space technology activities has not kept up with the rest of the space program. Recent spending on space technology has fallen to 2 percent of the NASA budget in 1992 from the level of over 4 percent that was sustained throughout the 1960's. This trend was viewed with concern in the report of the Advisory Committee on the Future of the U.S. Space Program: "... unfortunately, NASA has not been permitted to sustain an adequate level-of-effort program in space technology due in recent years to externally imposed budget reductions. We believe that this is a consequence of a lack of appreciation of the key role that technology development plays in enabling future missions, reducing future systems' costs and increasing America's competitiveness."

To help remedy this deficiency, the budget proposes \$305 million, an increase of 12 percent, for NASA space technology development that is not directly related to space exploration. The 1993 program emphasizes such areas as advanced materials, electronics and sensors, communications, life support, power, propulsion, and robotics. In addition, NASA is implementing a new strategic planning process to address more effectively space technology needs foreseen by potential users within NASA as well as in other government agencies and industry. The budget proposal

is based on the results of the first cycle of this planning process.

Experience shows that technologies and products developed for the space program often find useful applications here on Earth in a wide variety of fields. Medical *Magnetic Resonance Imaging* uses image-processing techniques originally developed for analyzing data from earth observation satellites. Some *health monitoring equipment* in hospitals uses technology developed for monitoring crew health in manned space missions. A *low temperature laser* that opens clogged arteries without surgery is based on technology developed for satellite-based atmospheric studies. A *tornado detector* for homes was derived from NASA electronics research. *Fire resistant materials* originally developed for astronaut garments have found uses ranging from sheets and furniture in pressure chambers to protective clothing for race car drivers and their pit crews. A *lightweight shock-absorbing material* now used in some athletic shoes was originally developed for astronaut moon boots. A new *oil-saving seal* for automobiles uses synthetic rubber material developed for interplanetary spacecraft. A highly accurate *ice detection system* to prevent aircraft accidents and some *scratch-resistant coatings* for eyeglasses and cameras are also based on NASA research.

EXPANDING THE FRONTIER OF KNOWLEDGE THROUGH BASIC RESEARCH

Future innovation, productivity growth and economic performance depend on the constant creation of new knowledge.

As Vannevar Bush stated in "Science: The Endless Frontier":

"New products, new industries, and more jobs require continuous additions to knowledge of the laws of nature, and the application of that knowledge to practical purposes. Similarly, our defense against aggression demands new knowledge so that we can develop new and improved weapons. This essential, new knowledge can be obtained only through basic scientific research.

Science can be effective in the national welfare only as a member of a team, whether the conditions be peace or war. But without scientific progress no amount of achievement in other direc-

tions can insure our health, prosperity, and security as a nation in the modern world."¹

Basic research provides new knowledge that leads to new products and processes. Basic research, especially at universities, is an essential investment in the Nation's scientific and technological future, including its future scientists and engineers. For this reason, the budget places a high priority on increasing basic research. In total, the budget proposes an increase of 8 percent, or \$1 billion, above 1992 for Federal basic research support.

¹Vannevar Bush. *Science, the Endless Frontier: A Report to the President*. U.S. GPO, July, 1945, p. 1.

The strength of U.S. investment in basic research is illustrated by several recent achievements:

- Researchers at Stanford University have developed a miniaturized process using lasers to produce small-diameter fibers of high-temperature superconducting material. These fibers may be the precursor to superconducting wire needed for motor and magnet applications of high-temperature superconductors.
- Using a recently purified, naturally-occurring bone growth factor, scientists have succeeded in using muscle exposed to this factor to form bone in a mold. This opens the possibility, long dreamed of, that replacement bones in the precise shape needed by patients may one day be grown from muscle or other specialized tissues.
- Following on last year's success with the first-ever human gene therapy on a child with a severe genetic immune deficiency, NIH scientists have now used gene transplantation to initiate the first experimental gene therapy for cancer. A gene for a natural tumor-killing substance was inserted into white blood cells that are known to seek out tumors as a way of increasing the concentration of this antitumor substance at the tumor site.

The Vitality of Basic Research

Funding Trends.—The historical trend in Federal support for basic research shows that during the 1980s such support increased overall by 50 percent in real terms, with significantly larger increases in health-related basic research. Real support for basic research has continued to climb in the early 1990's, as a result of the increases recommended by the Bush Administration.

But as the Office of Technology Assessment (OTA) notes:

"Given the extraordinary strength of the U.S. research system and the character of scientific research, there will always be more opportunities than can be funded, more researchers competing than can be sustained, and more institutions seeking to expand than the prime sponsor—the Federal Government—can fund. The objective, then, is to ensure that the best research continues to be funded, that a full portfolio of research is main-

tained, and that there is a sufficient research work force of the highest caliber to do the job."²

Measuring the Direct Economic Benefits.—Most basic research is performed in universities. Until recently, there has been no way to gauge reliably the impact of academic research on industrial innovation.

Research (Mansfield, 1991) carried out over the past two years has found that a significant proportion of new products or processes in several important sectors, including information processing, drugs, and instruments, would not have reached the market when they did without the contribution of academic research. Thus, the benefit of academic research appears to be considerable, even apart from its more traditional benefits to the education of students and to the acquisition of knowledge for its own sake.

Mansfield (1991) has estimated that the average annual social rate of return to past investments in academic R&D is about 28 percent. This finding, however, does not necessarily imply that investing more money in academic R&D will yield similarly high returns. Factors such as geographical proximity of interested industries and the strength of the research faculty in individual departments on individual campuses appear to play an important role, as noted in more recent unpublished work by Mansfield. A discussion of the specific contribution of academic institutions to the national R&D infrastructure appears later in this chapter.

Although support for university researchers is most often cited as the key indicator of the health of overall Federal support for basic research, a number of other measures have traditionally been used to measure research output (new knowledge). None of these are, by themselves, definitive indicators of the vitality of research, and none are universally accepted as an adequate output measure, since the "amount" of new knowledge contained in a research finding has no natural unit of measure. Taken together with information on support for researchers, these measures provide some insight into the overall strength of the national research enterprise. Several such measures are (1) numbers of

²Office of Technology Assessment, *Federally Funded Research: Decisions for a Decade*. U.S. GPO, May, 1991.

publications, (2) "quality" of publications as measured by citation indices, (3) patents and (4) Nobel and other prizes.

By all of these measures, the U.S. continues to lead the world in the generation of knowledge. For example:

- The number of science articles published by U.S. academic researchers (which produce about two-thirds of all U.S. science and engineering articles in major journals) has increased markedly. By this measure, the U.S. is maintaining its large share of world scientific and engineering literature.
- The influence of publications as measured by the level of citation of U.S. papers by foreign researchers suggests that U.S. researchers continue to exert a substantial impact on foreign research, and thus on the world's store of scientific knowledge.
- U.S. universities received 2 percent of patents awarded to U.S. inventors in 1988, more than double the share in 1978, thus new ideas that have potential value in the marketplace are flowing from universities in even greater numbers.
- The U.S. continues to dominate the Nobel lists, and Americans often win other major, internationally-recognized prizes such as the Fermi, the Wolf and the Lasker. This provides evidence of the strong and consistent support for basic research over the last 30 years.

This lead can be lost without adequate investment in knowledge. The Administration's strategy of investing in basic research is designed to maintain and strengthen America's leadership in scientific innovation.

The budget recognizes that the level of support for individual and small groups of investigators, primarily at academic institutions, is an important indicator of the vitality of the Nation's basic research effort. These "individual investigators" are the wellspring of many of the Nation's discoveries and inventions and they form the backbone of American science. Therefore, the Administration has proposed significant 1993 increases for this group.

Budget Initiatives in Basic Research

The budget proposes a number of major increases or new programs reflecting the President's support for basic research. These increases are intended to bolster basic research funding, especially that which supports individual investigators, and to provide those researchers with state-of-the-art equipment and specialized world-class research facilities. Overall, the budget proposes over \$14 billion for basic research, an increase of over \$1 billion, or 8 percent, over 1992.

Doubling the Budget of the National Science Foundation by 1994.—The President remains committed to doubling the budget of the National Science Foundation (NSF) by 1994. The budget proposes \$3,026 million, an overall increase of \$454 million, or 18 percent, over 1992. Over 70 percent of NSF's budget supports basic research, primarily at universities and colleges. These funds provide support for individual investigators and small groups (\$1,581 million), research centers (\$148 million) and research instrumentation and specialized research facilities (\$483 million), including the National High Field Magnet Laboratory, the Laser Interferometer Gravity Wave Observatory, and two matched 8-meter optical telescopes. Each of these elements are keys to maintaining the preeminent U.S. position in science and basic research.

The budget proposes \$33 million for NSF's instrumentation initiative. This initiative, funded at about \$17 million in 1992, will continue to provide state-of-the-art instrumentation, costing from \$200,000 to \$4 million, to university researchers through a merit-based competitive process. The Federal funding will be matched 50:50 from non-Federal sources.

NSF also plays a significant role in the government-wide initiative to improve the quality of science, mathematics, and engineering education, particularly at the precollege level. These education activities are highlighted in Chapter 4, "Reforming American Education and Investing in Human Capital".

Increasing the Support for Individual Investigators.—The budget proposes a significant increase for individual investigators located primarily at universities and colleges.

Table 6-10. THE BUDGET INCREASES FUNDING FOR BASIC RESEARCH¹
(Dollar amounts in millions)

Department or Agency	Budget Authority					Outlays				
	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Health and Human Services (National Institutes of Health)	4,413	5,459	5,800	+341	+6%	4,234	5,143	5,541	+398	+8%
National Science Foundation	(4,052)	(5,019)	(5,328)	(+309)	(+6%)	(3,988)	(4,748)	(5,109)	(+361)	(+8%)
Energy	1,563	1,839	2,221	+382	+21%	1,455	1,730	1,917	+187	+11%
National Aeronautics and Space Administration	1,383	1,789	1,859	+70	+4%	1,377	1,695	1,771	+76	+4%
Defense-military	1,385	1,860	2,068	+208	+11%	1,346	1,715	1,851	+136	+8%
Agriculture	951	1,170	1,203	+33	+3%	929	1,134	1,230	+96	+8%
Other Agencies ²	486	611	639	+28	+5%	477	576	589	+13	+2%
Total	434	526	532	+6	+1%	438	498	505	+7	+1%
	10,615	13,254	14,322	+1,068	+8%	10,256	12,491	13,405	+914	+7%

¹ Amounts reported in this table are included in totals for conduct of R&D.

² Includes the Departments of Interior, Commerce, Veterans Affairs, Education, Labor, the Treasury, Justice, the Smithsonian Institution, Environmental Protection Agency, Tennessee Valley Authority, Agency for International Development, and the Corps of Engineers.

Three agencies support the majority of individual investigators: the National Science Foundation, and the Departments of Health and Human Services and Energy. In total, the budget proposes over \$7.9 billion, an increase of over 9 percent, for these investigators.

For HHS, the budget proposes \$5.9 billion, an increase of \$389 million, or 2 percent real growth, for investigator-initiated research. This sizeable increase will allow a record total of 24,600 grants to be supported, an increase of 500 over 1992's record levels. For NSF, \$1,581 million is being proposed in this area, an increase of \$230 million or 17 percent over 1992. For Energy, the budget proposes a total of \$482 million, an increase of 11 percent, for support of university-based basic research by the Office of Energy Research.

Increasing Basic Research in HHS.—HHS is the largest supporter of both government basic research and individual investigators in the Federal Government. The budget continues to focus on basic biomedical and behavioral research at HHS, and proposes \$5.8 billion in 1993. Building on the record levels reached in 1992, this \$341 million, or 6 percent, increase will allow HHS research agencies to further extend the frontiers of knowledge which

will enable future life-extending and life-enhancing therapies to be developed. By focusing these additional resources on basic biomedical research, the budget helps to ensure that continued advances against disease will take place.

Unlocking the Secrets of Human Heredity—the Human Genome Project.—The budget proposes a 7 percent increase, to a total of \$175 million, for the fourth year of this 15-year effort to decode the information locked in the chemical building blocks that form human genetic inheritance.

The Project is being conducted jointly by the Departments of Energy and Health and Human Services. The budget proposes a total of \$175 million for the project, \$65 million at Energy and \$110 million at Health and Human Services. These funds are also included in the totals for the broader Biotechnology Research Initiative involving many other Federal agencies.

DOE and HHS are working together to develop capabilities and tools, to construct gene "maps", to discern the chemical sequence of human chromosomes, and to characterize disease-related genes.

Concurrent with the project's efforts to advance the state-of-the-art in genetic "mapping," the project is also exploring safeguards that may be necessary as new genetic information is put to practical uses, addressing issues related to privacy of such information and fairness in its use.

Recent advances include completion of mapping of several large chromosome segments, isolation of genes for several genetic diseases, and establishment of an international Genome Data Base for maintaining and distributing genome data to researchers all over the world.

Future generations will benefit greatly from the knowledge gained through this investment. Future scientists will have tremendous amounts of new information about the molecular basis of human inheritance available to assist them in their search for therapies and cures for disease. The budget ensures that this project is able to forge ahead expeditiously.

Unlocking the Secrets of Matter and Energy—The Superconducting Super Collider and High Energy and Nuclear Physics:

The Superconducting Super Collider.—The Superconducting Super Collider (SSC) will provide a collision energy 20 times greater than the current capability, resulting in new fundamental knowledge of matter and energy. The SSC Laboratory, under construction in Ellis County, Texas, will comprise a 54-mile circular tunnel in which superconducting magnets will accelerate counter-rotating proton beams. The SSC will employ 2,500 scientists, engineers, and technicians, and host an additional 500 visiting scientists.

The budget provides \$650 million for the SSC, an increase of \$166 million over 1992. Much of the current effort focuses on research and development of the superconducting magnets. Work on other SSC components is also progressing. A segment of tunnel which will be used for magnet testing will be under construction by the end of 1992.

The total cost of the SSC has been estimated at slightly over \$8 billion. One-third of the total is expected to be contributed by non-Federal sources. The State of Texas has committed up to \$875 million for construction

of on-site facilities and other SSC systems, as well as the land required for the SSC laboratory.

Foreign partners are expected to contribute substantially to the construction and operation of the SSC, as well as to the experimental program. During 1993, follow-up delegations will continue discussions already underway with Canada, Europe, India, Japan, Korea and Russia.

The SSC holds the potential for new breakthroughs in science, technology and education. Although the primary purpose of the SSC is to acquire new knowledge, such knowledge has always resulted in developments in technology and practical products which profoundly affect the quality of life for all Americans and which enhance the economic competitiveness of the Nation. U.S. world leadership in high energy physics will be maintained far into the next century by the scientific and technological advances emanating from the SSC. For example, the SSC will introduce the first massive, U.S. industrial manufacture of superconducting accelerator magnets. The experience gained will help in the development of magnetically levitated, high-speed trains, energy storage systems for fuel conservation and low loss electrical power systems.

High Energy and Nuclear Physics.—Research in high energy and nuclear physics is directed at understanding the nature of matter and energy at the most fundamental level and the basic forces which govern all processes in nature. Much of the research program is aimed at verifying and explaining the particles, or "building blocks", that comprise the interior of atoms and the forces acting on them.

Research is conducted at universities and national laboratories. Most university funding goes to individual investigators for support of graduate students and research at university facilities or at the national laboratories. Funding provided to the national laboratories allows construction and operation of large accelerator and collider facilities which are open to researchers from other national or international sites. Industry also uses the national laboratory facilities for non-proprietary testing and development.

The budget proposes \$1 billion for High Energy and Nuclear Physics programs (other than the SSC), an increase of 2 percent over 1992. The budget reflects planned decreases as construction projects such as the Continuous Electron Beam Accelerator Facility (Newport News, VA) for nuclear physics are completed, and as other research facilities are phased down. Support for ongoing nuclear physics projects such as the Relativistic Heavy Ion Collider (Brookhaven National Laboratory, NY) increases as these projects continue on schedule.

The budget proposes for high energy physics (other than the SSC) a new Main Injector Ring at Fermilab which is currently planned for completion in 1996. Scientists are confident that this new capability will enable them to discover evidence of the "top quark", the elusive final particle in verifying the theoretical model that predicts the interaction between matter and energy. The budget provides total funding of \$246 million for all high energy physics programs at Fermilab, an increase of \$18 million, or 8 percent.

Understanding the Earth: The U.S. Global Change Research Program (USGCRP).—The USGCRP is designed to assist efforts to understand more fully the earth's climate system in order to support national and international policymaking activities associated with global and regional environmental issues (e.g., ozone depletion, global

warming). This FCCSET interagency research effort (eleven agencies) promises not only the information to aid today's policy decisions, but also to maintain the strong foundation of multi-disciplinary science required to address the unanticipated issues of tomorrow.

The budget proposes \$1,372 million for the USGCRP, an increase of \$262 million or 24 percent over 1992. The USGCRP addresses three parallel but interconnected streams of activities: 1) documenting global change through the establishment of long-term monitoring programs; 2) enhanced understanding of key physical, chemical, biological, and social processes that influence and govern the Earth's evolution, and 3) predicting global change through the development of predictive Earth system models.

Planning for the USGCRP has been shaped by a strategic and scientific priority framework that has been extensively reviewed by the scientific community. Over the past two years, this framework has been extended to include a set of integrating themes that address the scientific uncertainties identified by the U.N.-sponsored Intergovernmental Panel on Climate Change, and the economics research and important policy questions identified as a result of the 1990 White House Conference on Science and Economics Research Related to Global Change. The further integration of economics research into the USGCRP is particularly important since an understanding

Table 6-11. THE BUDGET PROPOSES A 12 PERCENT INCREASE FOR A BALANCED PROGRAM IN HIGH ENERGY AND NUCLEAR PHYSICS

(Dollar amounts in millions)

	Budget Authority				
	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Superconducting Super Collider	98	484	650	+166	+34%
High Energy and Nuclear Physics	815	988	1,003	+15	+2%
Relativistic Heavy Ion Collider	—	77	96	+19	+25%
Continuous Electron Beam Accelerator Facility	45	78	76	-2	-3%
Fermilab Main Injector Ring	—	15	30	+15	+100%
Other High Energy and Nuclear Physics	770	818	801	-17	-2%
Total	913	1,472	1,653	+181	+12%

of the relationship between global change and the economy is fundamental both to assessing the magnitude of the potential impact on human society and to developing effective responses.

During the past year, and in response to the recommendations of an independent Earth Observing System Engineering Review Committee, NASA has restructured the Earth Observing System (EOS) to fly remote sensing instruments on a series of intermediate and small spacecraft, in contrast to the original plan for a series of large spacecraft. This reconfiguration will maintain the scientific objectives of the EOS program and will allow important scientific data to be acquired earlier than otherwise would have been the case. At the same time, the program's flexibility to respond to changes in data requirements and advances in technology will be greatly increased and will reduce risks associated with single large platforms. This reconfiguration has resulted in a different temporal sequence of measurements as well as potential changes in the volume of data. The National Academy of Sciences has been asked to examine the EOS Data and Information System (EOSDIS) to ensure that its architecture, management and distribution schemes are compatible and complementary to the restructured EOS program.

The ultimate success of the USGCRP requires progress and integration of data collection, process studies, and modeling across all the various disciplines. Central to this strategy is a balance between ground- and space-based research activities. Ground-based observations and theoretical process studies will be complemented by a comprehensive space-based program to provide global observations of key environmental parameters. For example, while NASA's Mission to Planet Earth (including the Earth Observing System) is a major contributor to the USGCRP, many of the ground-based data sets will be used to calibrate the complementary Mission to Planet Earth satellite data sets.

Landsat.—Acquisition of data from land remote sensing satellites is an important element in understanding global change and for national security purposes. The Administration is committed to a policy of the continued acqui-

sition of Landsat-type data. The Administration proposes to operate the Land Remote Sensing Satellites (Landsats 4 and 5) until Landsat 6 is launched; to complete the procurement and launch of the next satellite (Landsat 6); and to initiate the procurement of the next follow-on satellite (Landsat 7).

Several agencies will provide a total of \$17 million to cover the operation of Landsats 4 and 5 through the end of 1992. Landsat 6 is expected to become operational by early 1993. Landsat 6 will be operated by, and at the expense of, the Earth Observing Satellite Company. NASA and the Department of Defense are proposing a total of \$111 million for Landsat 7, which is planned to succeed Landsat 6. The budget proposes \$86 million for DOD, which will be responsible for the acquisition and launch of the spacecraft, and \$25 million for NASA, which will be responsible for ground support for data acquisition and distribution of Landsat 7 data. These data will be used to support global change research and will be incorporated into the EOS Data and Information System (EOSDIS).

One area within global change research that has received special emphasis is Arctic research, although U.S. activities in the Arctic go well beyond the range of programs included in the USGCRP.

U.S. policy in the Arctic consists of four elements: protection of essential security interests; support for sound, rational development of the region; promotion of scientific research contributing to knowledge about the Arctic; and promotion of mutually beneficial international cooperation in the Arctic. Federal Arctic research is guided by a 5-year research plan developed by the Interagency Arctic Research Policy Committee (IARPC) in consultation with the Presidentially-appointed Arctic Research Commission and other interested groups. The most recent biennial revision of the plan was published in July 1991.

The budget includes \$147 million for Arctic research, an increase of about \$4 million over 1992. Within the total for 1993, \$58 million is proposed to implement the four integrated programs covering the western Arctic: oceans research, geodynamics, studies of the Bering Sea and land mass, and

Table 6-12. U.S. GLOBAL CHANGE RESEARCH PROGRAM

(Dollar amounts in millions)

Description	Budget Authority			
	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Program Component				
Ground-based	733	915	+182	+25%
Oceans	62	85	+23	+37%
Modeling	33	51	+18	+55%
Land Processes	80	92	+12	+15%
Human Dimensions	7	9	+2	+29%
Economics	4	13	+9	+225%
Other	547	665	+118	+22%
Space-based	378	457	+80	+21%
Earth Observing System (NASA)	188	308	+120	+64%
Other Programs (NASA)	190	139	-51	-26%
Energy	—	10	+10	—
Agency				
National Aeronautics and Space Administration	756	891	+135	+18%
National Science Foundation	109	163	+54	+50%
Energy	77	113	+36	+47%
Commerce (NOAA)	47	78	+31	+66%
Agriculture	44	48	+3	+7%
Interior	40	36	-4	-9%
Environmental Protection Agency	24	26	+2	+8%
Smithsonian	6	11	+4	+68%
Defense	6	7	+1	+5%
Health and Human Services	1	1	—	—
Tennessee Valley Authority	*	*	—	—
Total	1,110	1,372	+262	+24%

*Less than \$500 thousand.

monitoring and data collection activities. Approximately \$6 million of this amount is for ship and aircraft support in five agencies, NSF, Transportation, NOAA, Interior, and DOD/Navy. These programs support bilateral and multilateral environmental, space, oceans, and social science agreements and cooperative activities.

Observing the Universe: Astrophysics and Astronomy.—The programs of these two disciplines increase our understanding of the origin and evolution of the universe, the formation of stars and planets, and the fundamental laws of physics. Astronomy and astrophysics are currently supported by the National

Science Foundation, the National Aeronautics and Space Administration, and the Smithsonian Institution. The budget proposes \$890 million, an increase of \$54 million or about 6 percent, for astronomy and astrophysics in the three agencies.

In 1991, the National Research Council commissioned a group of astronomers and astrophysicists to survey these fields and make recommendations concerning ground- and space-based astronomy and astrophysics for the next decade. This report, "The Decade of Discovery in Astronomy and Astrophysics", was the third in a series of decadal reviews of these two disciplines. It recommended

Table 6-13. UNDERSTANDING THE ARCTIC

(Dollar amounts in millions)

Category	Budget Authority				
	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Resource development ¹	43	50	54	+4	+8%
Arctic as laboratory ²	42	69	69	—	—
National security ³	23	24	24	—	—
Total	108	143	147	+4	+3%

¹Includes the Departments of Commerce, Agriculture, Energy, the Interior, Transportation, State, and the Environmental Protection Agency.

²Includes the Department of Health and Human Services, and the National Aeronautics and Space Administration, the National Science Foundation, and the Smithsonian Institution.

³Includes the Department of Defense. The 1992 enacted level includes a one-time increase for Defense of about \$5 million specifically for upper atmosphere research and associated facilities including the High Frequency Active Auroral Research Program. For purposes of comparison with 1993 levels, this funding has been excluded.

as the highest priority increased support for operations and maintenance of existing astronomical facilities and individual grant programs. The report also recommended a balanced program of space-based observations and offered a prioritized list of future projects, consolidated from both space- and ground-based candidates. The budget addresses many of the Report's recommendations and these are highlighted below.

- *The National Aeronautics and Space Administration (NASA)* is the principal agency supporting space-based astronomy. NASA supports a broad range of astronomy and astrophysics missions, including instruments flown on large free-flying spacecraft, smaller Explorer spacecraft, the Space Shuttle, small sub-orbital rockets, balloons and aircraft. The budget proposes \$732 million for NASA activities, an increase of \$42 million or 6 percent over 1992. This will support continued development of the Advanced X-Ray Astrophysics Facility (AXAF). AXAF is the third of four NASA Great Observatories and is scheduled for launch in 1999. To date, AXAF has met or exceeded all of its design criteria. The first two Great Observatories, Hubble Space Telescope (launched in 1990) and the Gamma Ray Observatory (launched in 1991), continue to provide significant scientific breakthroughs despite

some technical problems. All of these space-based observatories have presented significant technical and budgetary challenges. The budget includes \$257 million for operations, servicing, and data analysis for the Hubble Space Telescope. The first servicing mission is planned for late 1993.

The NRC Report recommended the initiation of the fourth Great Observatory, the \$1 billion Space Infrared Telescope Facility (SIRTF), as its highest priority for a new start in the "large project" category. While the budget supports the NRC Report's recommendations for other large projects (i.e., AXAF and the 8-M telescopes mentioned under NSF), it defers a decision on SIRTF, while providing an increased emphasis on small and moderate missions. The budget proposes a 10 percent increase over 1992 to a total of \$138 million for support for individual investigators.

- *The National Science Foundation (NSF)* is the principal agency supporting ground-based astronomy. NSF supports a broad range of astronomy programs and facilities, including the National Radio Astronomy Observatory, the National Optical Astronomy Observatories, and the National Astronomy and Ionosphere Center. The budget proposes \$137 million for NSF's programs, an increase of about \$13 million or 10 percent over 1992. This increase ad-

dresses most of the priorities enumerated in the NRC report. Within this total, support for individual investigators will increase by nearly \$4 million or 9 percent. Funding will also increase for operations and maintenance of existing facilities and for research on adaptive optics. Work will continue on research leading to the design of a millimeter array for radio astronomy, and construction of matched 8-meter optical telescopes in Hawaii and Chile and the new radiotelescope at Greenbank, WV will all proceed on schedule. In 1993, the Very Long Baseline Array (VLBA) will commence operations. VLBA is a coordinated set of radiotelescopes located from Maine to Hawaii, which is expected to open new vistas to radioastronomers and to contribute to other fields such as geodesy and theoretical physics.

- *Smithsonian Institution.*—The Smithsonian Astrophysical Observatory (SAO) conducts fundamental research in astronomy and astrophysics cooperatively with the Harvard College Observatory at the Center for Astrophysics located in Cambridge, Mass. SAO also operates the Oak Ridge Observatory in Massachusetts and Fred Lawrence Whipple Observatory at Mt. Hopkins, Arizona. NASA has selected SAO to plan, develop, and operate an international center for AXAF data. The budget proposes \$21 million for SAO activities, essentially the same as in 1992. Work will continue on the development of a submillimeter telescope array and the conversion of the Mt. Hopkins Multiple Mirror Telescope to a single 6.5-m mirror. SAO will also continue to work with NASA in planning the AXAF data center.
- *Federal Funding for Related Areas.*—Apart from these three agencies, there is support for astronomy and astrophysics within the Departments of Defense and Energy for activities that complement the programs of NSF, NASA and the Smithsonian. These include research on astrometry, optical interferometry, sensor development (especially in the infrared region), and cryogenic and adaptive optics.
- *Non-Federal Support for Astronomy and Astrophysics.*—Astronomy has enjoyed a

long history of private and state support, including large philanthropic donations for the construction of major instruments, e.g., Hale 5-m telescope at the Palomar Observatory and the Keck 10-m telescope at Mauna Kea Observatory. The Keck telescope is the world's first computer-controlled segmented mirror telescope and embodies state-of-the-art technology in mirror design and computer alignment. Currently, it is estimated that private sources and the states provide about \$190 million annually for astronomy. The Keck Foundation is planning to provide funding for a second 10-m telescope adjacent to the first. When operated together, these two telescopes will provide the resolution of an 85-m telescope, making it possible to search for planets around nearby stars.

- *International Efforts.*—Astronomy and astrophysics have long been characterized by extensive international collaboration. Europe, Canada, and Japan all support major astronomical facilities that are often used in conjunction with similar instruments in the U.S. For example, the Very Large Array Radiotelescope in New Mexico is often linked to other radiotelescopes in Britain for observations of extremely distant quasars and pulsars. In these cases, essentially the entire Earth becomes one large radiotelescope. Both Europe and Japan are currently constructing major optical telescopes embodying the newest technology.

Improving the Productivity of the Nation's Agriculture (The National Research Initiative).—The budget continues the Administration's commitment to the National Research Initiative by proposing \$150 million, a \$52 million, or 53 percent, increase over 1992. With the creation of the NRI in 1991, a \$50 million increase each year was proposed to the extent that funds were awarded competitively and not earmarked for specific sites or institutions.

The National Research Initiative competitive grants program addresses research areas which are known to possess unique opportunities for improving agriculture in concert with social, economic and environmental needs. In 1991, the first year of the program,

74 percent of the funding for NRI was directed toward the basic, fundamental end of the research spectrum. The remaining funding was directed to mission-oriented research—research that bridges the basic and applied sciences, resulting in practical outcomes. Of the \$73 million appropriated for the NRI in 1991, 11 percent of total program funds were directed toward attracting new scientists into careers in high priority areas in agriculture. These funds provide support for postdoctoral fellows and new faculty and strengthen research capabilities of individuals at small and mid-sized institutions. The same pattern of distribution is expected for 1993.

Each of the six categories of research funded in 1992 will continue. Those areas include natural resources and the environment; nutrition, food quality and health;

plant systems (including mapping of plant genomes); animal systems; markets, trade, and policy; and processes antecedent to adding value and developing new products. In 1993, increased emphasis will be placed on the areas of human nutrition research and research to find new non-food, non-feed uses for agricultural products. Human nutrition research will be expanded to include the areas of food choices and food survey methodology. Within the increase for new uses, research on alcohol fuels made from agricultural and forestry feedstocks and conversion technologies will expand.

The Administration is especially concerned about the amount of special project earmarks within the USDA budget, and believes that the NRI is a more effective mechanism to address the national needs of agriculture.

MAINTAINING NATIONAL SECURITY: DEFENSE R&D IN THE BUDGET

For all defense-related R&D, including R&D supported by the Departments of Defense and Energy, the budget proposes \$43 billion, an increase of over \$438 million, or 1 percent, above 1991. Defense-related R&D will com-

prise 59 percent of overall Federal R&D funding in 1992.

Table 6-14. MAINTAINING NATIONAL SECURITY

(Dollar amounts in millions)

Department	Budget Authority				
	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Defense—military functions	38,031	40,043	40,509	+466	+1%
Basic research	951	1,170	1,203	+33	+3%
Applied research	2,541	2,995	3,056	+61	+2%
Total, Technology Base	3,492	4,165	4,259	+94	+2%
Development	34,540	35,878	36,251	+372	+1%
Energy-atomic energy defense programs	2,321	2,668	2,640	-28	-1%
Weapons Research and Development	1,050	1,183	1,143	-40	-3%
Weapons Testing	518	458	430	-28	-6%
Naval reactors	555	600	634	+34	+6%
Arms Control Research	146	181	188	+7	+4%
Environmental Restoration Technology	52	246	245	-1	—
Total, Conduct of R&D	40,352	42,711	43,149	+438	+1%

Department of Defense

A strong defense R&D program is a key element of national security strategy. As was shown in Operation Desert Shield/Desert Storm, the deployment of advanced weapons can save lives and lead to decisive victory. The Defense R&D program also provides important benefits to the nation's technology generally. In this budget, funding for conduct of DOD R&D totals \$40.5 billion in 1993.

Technology Base.—The budget proposes \$4.3 billion for the technology base, an increase of \$94 million over the 1992 level. Basic and applied research programs provide options for future military capabilities and guard against technological surprise by potential adversaries. The basic research portion of the DOD technology base supports a wide range of scientific disciplines, including mathematics, chemistry, biochemistry, meteorology and solid-state physics. It is essential for the U.S. to develop and exploit advanced technologies to maintain superiority in fielded weapon systems as force levels decline. The weapon systems used in Operation Desert Storm were made possible by technology programs started decades ago in the areas of precision guidance and navigation, night vision and stealth.

DOD technology-base R&D programs have also led to many civilian applications. These include navigation systems used by civilian aircraft and ships, advanced structural materials used in commercial aircraft and such common devices as cellular radios and computers. Defense R&D plays a lead role in developing technology to increase computer performance dramatically. This continues the pioneering efforts of the Department of Defense that led to today's advanced parallel processors and digital communications networks.

Development.—The budget proposes \$36.3 billion for development programs. This category includes funding to develop advanced systems for production and to improve existing systems. There will be special emphasis on technology development efforts and the fabrication of prototype systems.

Department of Energy

The budget proposes \$2,640 million for conduct of R&D in support of Department of Energy (DOE) Atomic Energy Defense Programs, a decrease of \$28 million, or about 1 percent below 1992, but \$319 million or 14 percent above the 1989 level. This total is comprised of several program components, including:

Weapons Research and Development.—This activity includes a wide range of basic and applied R&D that is related to new weapons systems. Almost all of these R&D activities are performed by the three DOE National Laboratories: Los Alamos, Sandia and Lawrence Livermore. The budget proposes \$1,143 million for this activity, a decrease of \$40 million, or 3 percent from 1992. Within this total, there is increased emphasis on improving the safety of nuclear weapons.

Weapons Testing.—This activity involves the testing of nuclear weapons devices. The budget proposes \$430 million for these activities, a decrease of \$28 million, or 6 percent from the 1992 level.

Naval Reactors.—This activity involves R&D related to reactor systems for nuclear-powered submarines. The budget includes \$634 million in 1993, an increase of \$34 million or 6 percent over 1992.

Arms Control Research.—The budget proposes \$188 million, an increase of \$7 million for research related to verification of arms control agreements.

Environmental Restoration Technology.—The environmental cleanup of atomic energy defense facilities is one of the fastest growing programs in the Federal Government. Technology development activities play a major role in the clean-up effort, resolving major technical issues related to effective waste management and cleanup and advancing technologies to attain and maintain compliance with current laws and regulations. The budget proposes to maintain this investment in technology development at \$245 million in 1993.

The Changing Role of the National Weapons Laboratories.—The decreases in funding for nuclear weapons research, development, and testing are consistent with the declining number and types of nuclear weapons in the U.S. stockpile and reduced requirements for new nuclear weapons. This decline, however, could adversely affect the DOE National Laboratory system, principally the three weapons laboratories. These labs have historically received 40–50 percent of their funds for nuclear weapons research, development and testing. The laboratories possess a core set of unique scientific and technical capabilities that could be applied to a wide variety of civilian R&D needs.

Over the past year, an effort has been underway within the Administration to assess the laboratories' capabilities and to examine expanded civilian missions for them. In particular, it appears likely that the National Laboratories can play a key role in a number of civilian R&D initiatives, including materials research, advanced manufacturing R&D, biotechnology and space exploration. The specific roles to be performed by the laboratories in each technology area would be determined based on: (1) the unique technical capabilities offered by the laboratories (so as to avoid duplication with work that better can be performed in industry or universities) and (2) industry-led proposals, so as to ensure that the results of the R&D will be applied by the private sector in new products and processes. In particular, the National Laboratories could serve as catalysts to form R&D consortia with industry and universities, following the general criteria discussed earlier in this chapter. Under this approach, the laboratories would be receiving increased fund-

ing from the domestic programs as direct funding from the Atomic Energy Defense programs decreases.

Two initiatives now underway include:

- ***High Performance Computing***—Energy is developing a model Cooperative Research and Development Agreement (CRADA) with the Computer Systems Policy Project (CSPP) to enable CSPP member companies (e.g., IBM, Cray, Apple) to cooperate with the National Laboratories on R&D projects in high performance computing technology.
- ***Space Exploration***—Defense, NASA and Energy are developing cooperative R&D programs at the Laboratories to develop nuclear power and nuclear propulsion technologies to support space exploration. The Energy Laboratories have recognized competency in nuclear propulsion, radiation-hardened microelectronics and robotics, which are all key technologies for space exploration missions.

It is likely that the laboratories will play an important role in other applied civilian R&D initiatives, including advanced materials and processing, advanced manufacturing, and other critical technologies. In addition, the laboratories are continuing to move aggressively to transfer new, non-sensitive, dual use technologies, funded by Atomic Energy Defense programs, to commercial use. The budget includes \$91 million, an increase of \$41 million, or 82 percent, for technology transfer activities in DOE defense programs. This funding will support cost-shared, collaborative technology transfer activities with the private sector.

IMPROVING TECHNOLOGY TRANSFER TO INCREASE THE RETURN ON FEDERAL R&D INVESTMENTS

During the past decade there has been increasing public concern about U.S. scientific and industrial strength and competitiveness in the world economy. One consequence of this concern has been enhanced efforts to encourage the transfer of technology developed in Federal laboratories to the private sector.

As new policies have been put in place to promote technology transfer, the Administration's emphasis has shifted to implementation. This section reports on progress to date in technology transfer by Federal agencies. The Administration plans to intensify

its efforts in technology transfer over the coming months.

OMB has begun a comprehensive effort to measure the extent of Federal technology transfer activities. By collecting data on technology transfer on an annual basis. For purposes of collecting this data, technology transfer has been defined as those efforts and activities intended to result in the application or commercialization of Federal laboratory-developed innovations by the private sector, State and local governments, and other domestic users. These activities may include, but are not limited to:

- Technical/cooperative interactions (direct technical assistance to private sector users and developers; personnel exchanges; and cooperative research and development agreements);
- Commercialization activities (patenting and licensing of innovations and identifying markets and users, including payment of royalties and cash awards to inventors); and
- Information exchange (dissemination to potential technology users of technical information: papers, articles, reports, seminars, etc.).

Twelve Federal agencies provided data on technology transfer activities undertaken and proposed for 1991, 1992 and 1993. The agencies submitting data include: the Departments of Agriculture (Agricultural Research Service and Forest Service), Health and Human Services (National Institutes of Health, Centers for Disease Control, Public Health Service, Food and Drug Administration), Housing and Urban Development, Transportation (Federal Aviation Administration), Commerce (National Institute of Standards and Technology), Interior, Energy, and Defense (Army, Navy and part of Air Force); NASA (Office of Commercial Programs), the Environmental Protection Agency, the Tennessee Valley Authority and the Army Corps of Engineers.

It should be noted that most of the data for 1992 and 1993 are projections that are inherently difficult to make since they are based, in part, on inventions, patents, etc. that are "in the pipeline" but not yet fully realized. As a consequence, comparison of

the data for the same year between subsequent budgets may show significant differences. Over time, however, these data should yield an historical database that can be used to measure the impact of government policies to enhance the value of government technology to the private sector.

Funding for Technology Transfer Activities.—In general, the data show significant increases in all aspects of technology transfer from 1992 to 1993. The budget proposes to allocate about \$579 million to direct support of technology transfer activities in 1993, up 3 percent over 1992, but 16 percent over 1991. Funds allocated to departmental and agency Offices of Research and Technology Applications are projected to rise 19 percent from 1992 to 1993 to a total of about \$32 million.

Cooperative Research and Development Agreements.—Cooperative Research and Development Agreements (CRADAs) are contracts between one or more Federal laboratories and one or more non-Federal parties under which a laboratory provides personnel, services, facilities, equipment or other resources to conduct specific R&D efforts that are consistent with the missions of the laboratories. All agencies were given the authority to use CRADAs in the Technology Transfer Act of 1986, although some agencies, e.g., NASA, already had statutory authority to conduct research and technology development cooperatively with industry.

Since 1986, the use of CRADAs has been on the rise. In the Department of Health and Human Services, the National Institutes of Health has entered into over 400 with private industry, primarily in biotechnology. In addition, the National Institute of Standards and Technology has entered into over 150 agreements in a broad range of technical areas.

The actual number of active CRADAs is projected to grow by 10 percent from 1992 to 1993 to a total of 1,689. The number of CRADAs with small business is projected to reach 389 in 1993, an increase of 20 percent, which accounts for 44 percent of the total increase in numbers of active CRADAs. The dollar value of active CRADAs is projected to grow 22 percent from 1992 to 1993, to \$466 million.

Table 6-15. **TECHNOLOGY TRANSFER ACTIVITIES ARE INCREASING IN 1993**

(Dollar amounts in millions)

	1991 Actual	1992 Enacted	1993 Proposed	Change: 1992 to 1993	Percent Change: 1992 to 1993 ¹
Direct funding for technology transfer activities:					
Funds allocated to technology transfer	498	561	579	+18	+3%
Funds allocated to ORTAs	22	27	32	+5	+19%
Cooperative Research and Development Agree- ments:					
Number of active CRADAs	1,215	1,538	1,689	+151	+10%
Number with small businesses	203	323	389	+66	+20%
Dollar Value (cash and non-cash) of all CRADAs	283	380	466	+85	+22%
Measures of Productivity:					
Number of invention disclosures	3,275	3,128	3,313	+185	+6%
Number of patent applications	1,423	1,515	1,546	+31	+2%
Number of licenses (exclusive and non-exclu- sive) awarded	283	358	446	+88	+25%
Royalties and other income from all licenses	9	11	13	+2	+24%
Royalties and cash awards paid to federally- employed inventors	1	2	2	—	+19%
Royalties and cash awards paid to non-federal employee inventors	8	9	10	+1	+15%
Number of new companies formed	24	31	35	+4	+13%

¹ Percent change is calculated on dollar amounts in thousands.

Measures of Productivity.—There are several indicators of the productivity of government researchers and the value of government inventions. Productivity can be measured by the numbers of invention disclosures and numbers of licenses of existing patents. The value of government inventions can be measured by the amounts of royalties collected from licensing activity and, to a lesser extent, cash awards paid to government-employed and contractor inventors. By all these measures, the technology transfer process is a healthy one, with projected increases in patents, licenses, royalties and cash awards.

Scientific and Technical Information.—The Federal Government supports the largest R&D complex in the world, which, in turn, generates the largest volume of Scientific and Technical Information (STI) from any single funding source. The information produced takes numerous forms including technical reports, journal articles, and research in

progress listings. In 1991 alone the five largest Federal R&D performing agencies (DOD, DOE, NASA, NIH and USDA) generated well over 150,000 STI items. This information represents one of the most identifiable “products” of Federal R&D and acts as a conduit for enabling the private sector to use the results of Federal R&D more effectively.

The scientific and technical knowledge base made available by the five largest R&D agencies together with the National Technical Information Service is impressively large. Through the network of agency databases, over 23 million summaries of the results of R&D can be searched to allow industry to make informed decisions based upon what is known and where future research may be needed. This includes approximately 5 million foreign STI items (obtained through exchange and translation programs) for which the Federal Government is virtually the only domestic source. This knowledge base rep-

resents the product of a multi-billion dollar investment made in the original research.

Access to the STI knowledge base maintained by Federal agencies has been considerable. Nearly 8 million items were disseminated in 1991 alone. Of those items, almost 6 million went to non-Federal users in the U.S. In addition, access through electronic databases continues to increase dramatically. Researchers gained access to references of over 81 million STI items during searches of on-line data bases provided by Federal agencies in 1991—over 10 million more than just three years earlier. Each item referenced in a search is a potential source of information which the researcher can either order directly from the Federal Government or, as is often done, simply obtain a copy from his or her company, university, or public library.

Advances in information system technology are rapidly changing the way in which STI

is created, stored and disseminated. A world once firmly linked to paper and microfiche has been rapidly shifting to electronic formats. For example, two years ago the Federal Government had never disseminated any STI on CD ROMs, while in 1991 over 1,100 were disseminated. The infrastructure for electronic storage and dissemination of Federal STI will be critical to continuing and enhanced access by Federal and non-Federal users alike. The National Research and Education Network being funded through the High Performance Computing and Communications Initiative will be an essential part of the future STI infrastructure. With such a vast knowledge base being generated and managed by numerous Federal agencies, and with the rapid changes in technology, interagency coordination in STI is critically important. For this reason, the Administration has recently moved to reinvigorate interagency coordination of STI.

STIMULATING INCREASED PRIVATE SECTOR R&D INVESTMENTS

The budget proposes making permanent the research and experimentation tax credit and an 18-month extension of the tax rules governing the allocation of foreign and domestic R&D expenditures.

Industry is the largest supporter of R&D, providing slightly over 50 percent of the total national R&D investment. It also performs much of the R&D funded by the Federal Government. In total, over 70 percent of all R&D is performed by industry.

From the early 1960s through the mid-1980s, total real industrial R&D expenditures increased significantly, mostly in development. Since the mid-1980s, however, the rate of growth in industrial R&D spending has leveled off, dropping from a rate of more than 7 percent average annual percent real growth between 1980–1985 to less than 2 percent between 1985–1991. For 1992, the Industrial Research Institute forecasts that industrial investment in R&D is likely to experience no growth, and will decline as a percentage of revenues for the first time since the mid-1980s. However, this slowdown may be

due to factors other than a simple reduction in funding for R&D. These factors could include greater efficiency in the private R&D process (embodied in a much greater use of concurrent design and engineering), and the shifting of private investment in R&D from products to process technologies.

The Federal Government can stimulate R&D in the private sector directly with increased government R&D spending. The Federal Government can also stimulate R&D in the private sector indirectly through tax incentives. The use of tax credits for R&D has been a net near-term revenue loser to the Treasury. It is anticipated, however, that in the longer-term these losses will be more than offset by the revenues from new products and processes resulting from the private investment stimulated by the credit. However, since only the short-term losses can be estimated (the long-term benefits are simply too diffuse), these incentives are essentially a form of increased Federal R&D spending in areas of greatest potential benefit to

the economy as identified by the private sector.

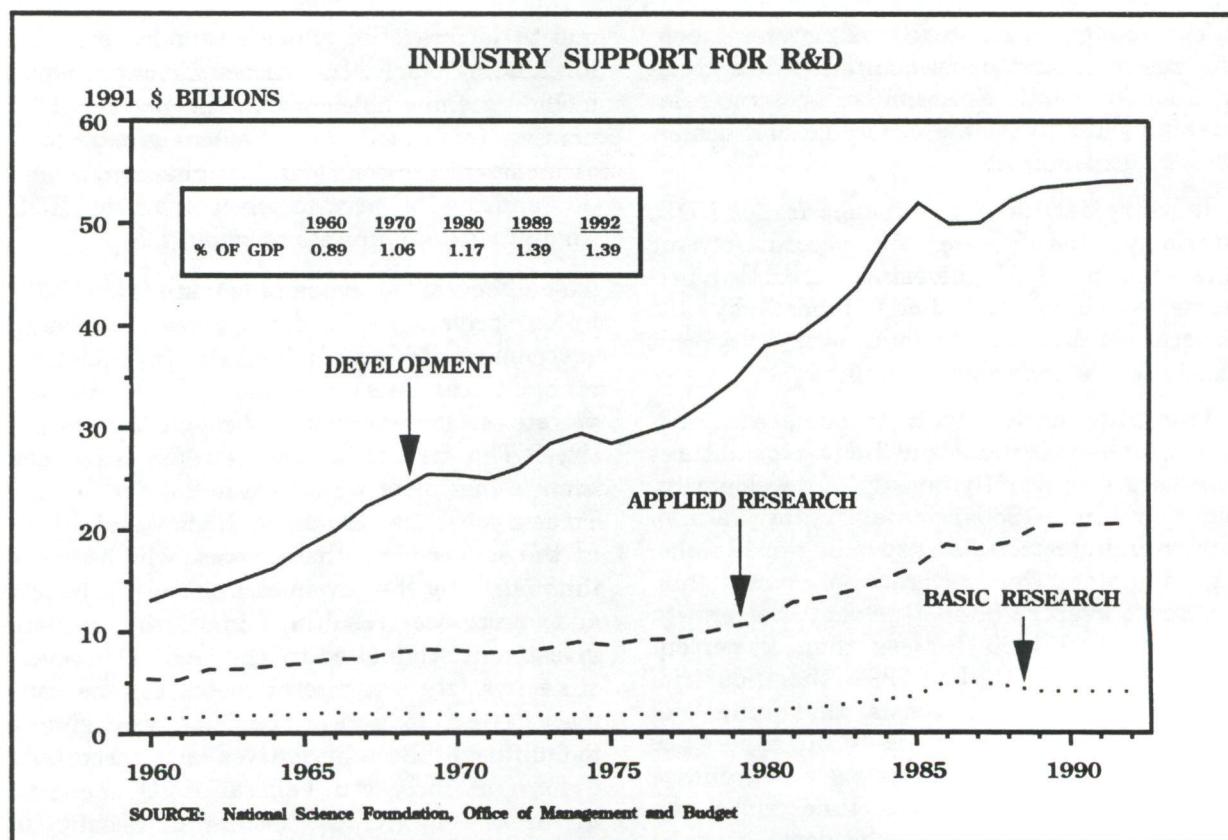
Tax Credit and Allocation Rules

The Research and Experimentation (R&E) tax credit was originally adopted in 1981 to encourage increased private R&D spending. The credit was never made permanent, but was renewed in 1986, 1988, 1989, 1990, and 1991 (only until Spring, 1992) at a lower rate than originally granted.

Tax credits prior to 1989 reduced the cost of increments to R&D for most qualifying firms by about 6 to 9 percent. In 1989 the incentives provided by the credit were improved. The version of the credit enacted in 1989, and extended in the 1990 Omnibus Budget Reconciliation Act, reduces, for most qualifying firms, the cost of increments to

R&D by 20 percent. Bailey and Lawrence have estimated that this version of the tax credit should increase corporate R&D spending in the 1990s by about 4 percent. Making the credit permanent would help reverse the recent trend toward leveling off of corporate R&D spending.

The budget proposes two changes in the tax code designed to provide additional incentives for industry to increase its investment in R&D. The budget proposes to make the 20 percent tax credit permanent. In addition, the budget proposes to extend for 18 months the rules, as extended in the Tax Extension Act of 1991, for the allocation of foreign and domestic R&D expenditures for companies with foreign operations. This proposal would apply to all tax years beginning after the current rules expire on June 30, 1992.



THE CONTRIBUTION OF ACADEMIC INSTITUTIONS TO THE NATIONAL R&D INFRASTRUCTURE

Following the end of World War II, the Federal Government adopted a set of policies that propelled academic institutions into the forefront of the national research enterprise. These policies (1) identified the Federal Government with the primary responsibility for the quantity and quality of basic research in the U.S. and (2) identified academic institutions as the primary performers of basic research which would be directly coupled to graduate education. Thus, the Federal Government invested its future in science, both in terms of discovery and talent, in universities and colleges.

This arrangement has led to nearly 5 decades of unprecedented success in scientific discovery and to world preeminence of the U.S. academic research and education system.

Today, however, new questions are being raised about both the adequacy of academic institutions to carry out forefront fundamental research and the education of new scientists and engineers, as well as the adequacy of the special partnership developed between the Federal Government and universities. These questions include: how big should the academic research and education enterprise be? How diversified, both geographically and otherwise, should the enterprise be? What is the fundamental role of universities in science and technology in a world of global economic competitors? Should other sectors assume an even greater role in funding academic research (based on perceived pay-offs), and, as a corollary, how much should the Federal Government actually pay for academic research and training, both directly and indirectly?

The answers to these questions are not clear. What is clear is that the nation's future in science and engineering continues to be inextricably tied to the vitality of academic research and education. This part of the chapter will discuss the status of funding for and issues surrounding the funding of academic R&D, the education of future scientists and engineers, the provision of the tools, both equipment and facilities, for

world-class research, and the management of R&D at academic institutions.

The total number of research grants made to individual researchers has been growing for two decades. However, the ratio of new awards made annually to the total number of proposals ("funded rate for new awards") by the two largest Federal supporters of university research, the Department of Health and Human Services (National Institutes of Health) and the National Science Foundation, has declined over the 1980's from around 40 percent to 33 percent in 1991 (adjusted to exclude both multiple submissions by any one individual and for awards for research centers, which may serve many investigators).

This decline is due, in part, to the rapid growth since 1970 in the pool of researchers seeking funding, which has outpaced the sizeable, real growth in basic research funding to academic institutions. In addition, average award sizes (both direct and overhead components), award lengths, or both, have tended to increase. This trend, while providing increased stability and productivity for a given investigator, tends also, within a relatively fixed total, to depress the number of subsequent new awards that can be made. The increases in the number of staff supported on each grant have also affected the number of grants that could be made by NIH. At least in the case of NIH, the move to longer grants was an explicit choice, made in response to the biomedical research community's calls for more stability.

Awards to groups of investigators (either small groups or larger centers) have also been increasing, driven primarily by the need for interdisciplinary approaches to scientific problems. Each of these group or center awards is counted as a single grant, even though these awards support many researchers. Thus, considering only the absolute numbers of awards is misleading. A more appropriate consideration should be the total number of researchers supported. By this measure, there are more researchers supported by

research grants today than at any previous time.

Funding for R&D at Universities and Colleges

Over the past 35 years, academic institutions have assumed a more prominent role in basic research within the nation's R&D system. Academic institutions' share of basic research expenditures (from all sources) has doubled from about 25 percent in 1953 to 50 percent since the early 1970's. In addition, total academic R&D expenditures as a percent of the GDP have risen sharply over this same period, from about 0.07 percent in 1953 to 0.30 percent in 1989. Federal academic R&D expenditures have also risen as a share of the GDP, from 0.04 percent in 1953 to 0.18 percent in 1989.

The budget proposes \$11.5 billion for Federal support for R&D at universities and colleges. This is an increase of almost \$600 million, or 5 percent over 1992, and 31 percent over 1989.

Modes of Support for Educating the Next Generation of Scientists and Engineers

The U.S. system of scientific education, particularly at the graduate level, continues to be best in the world. Foreign students flock in increasing numbers to U.S. universities seeking degrees in science and engineering, many of them choosing to stay for the rest of their professional careers. The markets for the "products" of this system, the students, include both industry and academia itself. But these students are important participants throughout our society.

The path from grade school to Ph.D. is commonly referred to as the "pipeline". Today, one-third of college graduates earn a baccalaureate degree in a field of science or engineering. Over the past 15 years, the number of Ph.D.s awarded annually increased from about 17,000 to over 20,000. However, the number of foreign students on temporary visas earning Ph.D.s has nearly doubled over that same period, to almost 5,000. Within the total of U.S. nationals awarded degrees in science/engineering fields, the number of women earning Ph.D.s has increased dramatically and the numbers of Asian and Hispanic students have also increased, but there has

Table 6-16. THE BUDGET INCREASES FUNDING FOR R&D IN ACADEMIC INSTITUTIONS¹

(Dollar amounts in millions)

Department or Agency	Budget Authority				
	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Health and Human Services	4,584	5,804	6,071	+267	+5%
(National Institutes of Health)	(4,008)	(4,922)	(5,181)	(+259)	(+5%)
National Science Foundation	1,260	1,597	1,917	+321	+20%
Defense	1,329	1,417	1,445	+28	+2%
Energy	507	629	591	-38	-6%
National Aeronautics and Space Administration ..	434	632	675	+43	+7%
Agriculture	315	425	417	-8	-2%
Other Agencies ²	343	407	387	-20	-5%
Total	8,772	10,910	11,501	+591	+5%

¹ Amounts reported in this table are included in totals for conduct of R&D.

² Includes the Departments of Commerce, the Interior, Veterans Affairs, Education, Labor, the Treasury, Justice, Transportation, Housing and Urban Development, Environmental Protection Agency, Tennessee Valley Authority, the Corps of Engineers, Nuclear Regulatory Commission, and Agency for International Development.

been no gain in the number of Ph.D.s awarded to Black students.

Since the late 1940's, the Federal Government has been the primary supporter of graduate training. There are three primary forms of such support: fellowships (awarded to students for study at the institution of their choice), traineeships (awarded to institutions to build capacity for graduate education), and research assistantships (awarded to established individual investigators as part of their research grants—the student is “employed” by the grant). Over the past 35 years, the balance between these has changed. Today, research assistantships are the dominant form, accounting for 64 percent of all students for whom the Federal Government is the major source of support.

There have been conflicting views over the past several years as to whether the supply of Ph.D.s entering the workforce, either academic or industrial, will be adequate to meet future demand. Some have predicted large “shortfalls” (relative to demand), with concomitant “shortages” in many fields, while others have projected the supply and demand for scientists and engineers to be in rough balance. However, many experts in the field of labor utilization in science and engineering have called into question the wisdom of using these projections to develop Federal policies to affect the supply of researchers—such projections are notoriously unreliable, and predicting the demand for scientists/engineers is extremely complex.

There is already some evidence—although no firm conclusions—that the production of researchers in the biomedical sciences may have outstripped the demand. Some preliminary National Institutes of Health estimates indicate that the number of post-doctoral students supported on certain types of research grants has increased 5-fold since the early 1980's. While post-doctoral study for 1-2 years is commonplace in these fields, the large increase in numbers supported on grants indicates that these young researchers are extending their “apprentice” period, perhaps partly because the demand in academia has lessened. There is also anecdotal evidence that the same situation is developing

in computer science, a field once believed to suffer from serious personnel “shortages”.

Part of the problem, at least in many fields, is that the academic model is the only one that most students are exposed to in the course of their training. A faculty member supports graduate and post-doctoral students in order to launch those students into academic research careers as faculty members training a second generation of students, and so on. However, over the past 20 years this has had the result of putting more and more researchers in competition for what must necessarily be a limited—although increasing—supply of research funds.

One way that the Federal Government can respond to this is by encouraging different models of training, such as by increasing the emphasis on interdisciplinary, team-oriented research (the industrial model), through programs such as the NSF-sponsored Engineering Research Centers (ERCs). The budget proposes to continue support for ERCs, for Science and Technology Centers and for programs in other agencies that encourage this interdisciplinary approach to science and engineering.

Even if the projections of Ph.D. supply and demand are inconsistent and, perhaps, flawed, there is no question of the need for a workforce of the future that is highly skilled, and literate in the language, if not the practice, of science and technology. Thus, it may be more prudent for the Federal Government to concentrate its science education efforts not on increasing the number of Ph.D.s, particularly American citizens, but rather on increasing the preparedness of the “pipeline” to produce Ph.D.s, i.e., the undergraduate years. This approach would appear to offer the flexibility needed for the market to respond in a timely way to demands for science/engineering skills in all sectors, as well as provide college graduates who could offer the perspectives of science and technology to other vocations.

In any case, there continues to be a compelling rationale for the Federal Government, in concert with the Nation's universities, to effect changes not so much in the size of the pipeline as in its composition. The objective should be to prepare more of our

best graduates, for industrial and non-academic careers. The scientific community and the Nation would benefit greatly by the diversity of research interests that results from continuing to increase the number of new entrants, particularly those from traditionally underrepresented groups.

Providing the Tools for World-Class Research: Equipment and Facilities

To sustain a strong national research capability and to enable expansion of research capacity, R&D infrastructure must be maintained and replenished.

Federal Support for University Research Facilities.—The Federal Government directly funds facilities and equipment necessary for the conduct of R&D at Federal facilities. Private industry and universities have primary responsibility for the R&D infrastructure under their respective jurisdictions. However, since the Federal Government supports basic research at universities, it directly funds university R&D facilities and equipment where they are closely related to federally funded research. In 1988–89, the latest period for which estimates are available, private institutions initiated \$738 million of new construction and public institutions initiated \$1.73 billion of new construction. The Federal Government provided an estimated 11 percent and 16 percent of these funds, respectively.

Expenditures for the repair and renovation of research facilities totalled an estimated \$1 billion in 1988–89, with private institutions accounting for one-third of this total (\$311 million). Direct Federal funding accounted for 9 percent of repair and renovation activity at private institutions, and 4 percent at public institutions. Added to this direct funding is indirect support for academic research facilities through payments of use allowances, depreciation and operations and maintenance expenses in allocated overhead. This funding has increased dramatically over the decade of the 1980s to almost \$1 billion in 1988.

Even with this large Federal expenditure for academic research facilities, the perception of a large “backlog” of unfilled desires for research facilities has led to increased calls from the institutions and many members of Congress for an expansion of direct Federal

support for academic research facilities. There has been Congressional action in two areas:

- “Earmarking” of Federal funds to construct new research facilities at particular institutions. The Office of Science and Technology Policy, as part of its continuing evaluation of the state of university research facilities, estimates that about \$276 million was appropriated for such projects in 1991. (The issue of earmarking is discussed in more detail in a later section of this chapter.)
- Providing direct grants for academic research facilities repair and renovation through the National Science Foundation, funded at about \$17 million in 1992.

The budget does not contain funding for either of these practices. Earmarking that does not involve merit review of any kind is an inefficient use of scarce resources. Further, it has the effect of weakening the Nation’s overall R&D effort. Funds earmarked for academic research facilities by Congress in 1992 and previous appropriations bills not only were without the benefit of merit-based review, but most often came at the expense of needed increases in support for academic researchers and in other key activities at Federal laboratories.

For example, the NASA construction of facilities budget has been burdened in 1992 by over \$60 million in unrequested, unreviewed, earmarked projects. These projects came at the expense of high priority construction, repair and renovation projects at critical space launch and support facilities. In another instance, the 1992 budget proposed \$25 million for university research facilities to be awarded by the Department of Agriculture in conjunction with its National Research Initiative. Instead, the Congress not only earmarked all of that money for special interest projects, but actually *increased* the funding to \$75 million and earmarked that entire increase, all to projects with little or no relevance to the NRI.

The Administration will continue to support direct Federal funding for construction or renovation of academic research facilities where such facilities are presented as an integral part of merit-based, competitive re-

search projects. In addition, the Federal Government will continue to provide funds that universities should invest in new facilities through payments of allocated overhead.

Federal Support for University Research Equipment.—Forefront research at academic institutions is increasingly dependent on state-of-the-art equipment. The most recent triennial survey by NSF (1991) indicated that total expenditures (Federal and non-Federal) for research equipment (costing \$500 or more per item) increased rapidly over the 1980's from about \$400 million in 1982 to about \$830 million in 1989. The amount of research equipment stock that was Federally-funded increased 46 percent in real terms between 1985 and 1989. The survey also revealed that there is substantial turnover in academic research equipment, with 40 percent of the equipment in use in 1989 had been acquired since 1985. The mean time to obsolescence is also decreasing.

The NSF survey noted that the mean purchase price of academic research equipment has increased modestly. It should be noted, however, that the mean purchase price for computing equipment has declined, but it has increased for other types of instruments, particularly in life sciences and chemistry.

Equipment is usually provided for as a part of research grants. The purchase price of equipment provided by grants, however, is generally less than \$50,000. In many fields, notably biological sciences and chemistry, there is an increasing demand for state-of-the-art instruments such as electron microscopes, surface chemistry analyzers, and DNA sequencers that are considerably more expensive, in the range of \$200,000 to \$4 million. This is far more than can be provided for in the average research grant. In addition, the purchase price represents only a part of the total "cost" of equipment. Expenditures for personnel to operate equipment and maintenance over the life of the instrument now represent a significant portion of the total "cost" of equipment.

Most Federal agencies that support R&D at academic institutions also provide funding for instrumentation. The 1993 budget proposes \$33 million for NSF to continue its initiative begun last year to provide state-of-the-art

equipment costing from \$200,000 and \$4 million.

Managing the Costs of Research at Academic Institutions

Few systematic analyses have been done to elucidate the underlying reasons why the expenses incurred by universities and researchers in conducting academic research have been increasing faster than the rate of inflation. Some justify these increases by arguing that the scientific questions that must be answered are increasingly complex, e.g., modelling completely integrated global climate phenomena instead of just oceans, or just atmosphere. Academic institutions also cite the increased cost of complying with more layers of regulation, ranging from animal care to human subjects protection to hazardous waste disposal.

It is also true, however, that some items that previously were high-cost (either the item itself or the labor needed for it) have dropped in unit cost dramatically. The best example is computing resources (both equipment and time), where computer capability costing tens of thousands of dollars just a few years ago is now available for a few thousand or less. Other examples include many laboratory chemicals and other reagents that can now be purchased off-the-shelf instead of being made laboriously by each individual researcher.

The average grant is composed of two major categories of expenditures:

- *Direct costs.*—Salaries (principal investigators, student research assistants, technicians); equipment; supplies; other direct costs (travel, services); and
- *allocated overhead payments* (payments for that portion of grantee overhead that universities allocate to research supported by the Federal Government, commonly referred to as indirect costs).—Facilities depreciation, operations and maintenance, student services, libraries, administrative expenses.

Of these, allocated overhead payments as a percentage of the total have been rising faster than have direct costs, although that growth has leveled off in recent years. Within

direct costs, salaries are, by far, the fastest growing component. This category has risen faster than the CPI for several years. In 1988, personnel expenditures accounted for an estimated 65 percent of the direct costs budgeted for individual investigator awards (RO1) at NIH. The result of all of this is that constant dollar expenditures (1988 dollars) per FTE investigator (as noted by the Government-University-Industry Research Roundtable in 1989) have risen from about \$155,000 in 1980 to about \$225,000 in 1988.

Allocated overhead payments, both the total amounts and the elements, have been a continuing source of controversy and friction between the Federal Government and academic institutions. Each institution proposes and receives a rate for these payments that is the result of often long and difficult negotiations with the cognizant Federal agencies. The rates vary widely among institutions with, on average, higher rates for private and lower rates for public institutions. In many cases there has not seemed to be an analytic basis for the difference in rates, particularly in the administrative expense category.

The controversy over allocated overhead has not only caused friction between academic institutions and funding agencies, but has also caused friction between the researchers and administrators at the institutions themselves. Researchers argue that higher allocated overhead payments increase the total cost of research but add nothing to the actual performance, while reducing the number or sizes of awards. Administrators assert that even at the negotiated rate, the expenses the institution incurs (whether by choice or necessity) in conducting Federally-supported research are not fully covered by the allocated overhead payments. The Federal Government and academic institutions could both benefit from a simpler, less contentious system for determining allocated overhead.

Current Proposals.—In 1991, the Administration implemented changes to OMB Circular A-21, which sets out guidelines for determining allocated overhead payment rates for academic institutions. These changes will be phased in over the next year as institutions begin their fiscal years. They were designed

to: (1) clarify that a number of items would not be eligible for payment, e.g., entertainment, alumni activities, donations and contributions, civic, community, or social organization memberships; and (2) set an upper limit of 26 percent on the administrative expenses portion of allocated overhead payments. This latter change was made to encourage and provide greater incentives to academic institutions to examine their administrative expenses very closely and reduce unnecessary internal bureaucracy. This change is consistent with the spirit of the Federal Demonstration Project, which seeks to reduce the Federal bureaucracy (and thus expenses) for the administration of academic research.

Future Issues.—There are still a number of issues regarding allocated overhead payments that will be examined by an interagency group over the next year. Academic institutions and organizations will be consulted during this process. The issues include:

- a further examination of administrative expenses; of current incentives for administrative efficiency and how these can be strengthened; and, whether differences among institutions and geographic regions have a bearing on allocated overhead payment policies;
- whether payments for facilities or equipment should reflect different academic fields of research and/or rates of obsolescence;
- whether there could be a better balance between elements assigned as direct costs and elements placed in the allocated overhead pool, i.e., should specific elements be reassigned from the allocated overhead pool to direct costs?

The Federal Government and academic institutions have together built a research enterprise that is without peer in the world. This enterprise has been based on the concept of a partnership, where each partner contributes and each benefits. But, as in any partnership, a periodic and thorough reexamination is both healthy and necessary, if only to revalidate the original conditions of the partnership.

To some extent, the issue of allocated overhead is a symptom of the need for

a more fundamental reexamination of the funding incentives of the academic research enterprise. The challenge for academic institutions is to consider the future in terms of the prospective funding environment and adjust their expectations accordingly. The challenge for the Federal Government is to understand and cope with rising expenditures while maintaining a strong national research capability in academic institutions. The challenge for both partners is to manage these issues in ways that will strengthen the partnership and expand the future benefits accruing to each partner. As was noted at the beginning of this section, the scientific future of the Nation rests with academic institutions. In continued strong partnership with the Federal Government, that future should be a bright one.

EARMARKING OF R&D FUNDING

The hallmark of the Federal Government's support for R&D has been the awarding of R&D grants and contracts through a competitive process. This merit-based approach is intended to maximize the potential return on these investments by selecting only the highest quality research for support.

This merit-based approach, however, has been increasingly eroded in recent years due to the Congressional practice of "earmarking", i.e., requiring that funds for R&D and R&D-related facilities be awarded to particular institutions or even to particular researchers. This practice is most visible in the area of new buildings, particularly those specified for individual academic institutions. However, the practice of earmarking is actually much more pervasive, reaching down to individual research projects.

The Office of Science and Technology Policy recently revised its detailed analysis of earmarking in appropriation bills and reports to reflect final action for 1992. The major findings of the analysis and a comparison to the results from 1991 follow.

- The analysis identified 566 "earmarks" for both facilities and research, totaling \$993 million, an increase of 23 percent over 1991. Of these 334 (totaling \$180 million) were in Agriculture, where specific ear-

marking by Congress has historically been common.

- In other areas, R&D earmarking is on the rise, with 66 separate actions in Energy and 20 to 40 each in Defense, Interior, Commerce and the Environmental Protection Agency. Noteworthy in 1992 was the large increase in earmarks for NASA, and the first appearance in some years of earmarks in NSF. In fact, the VA, HUD and Independent Agencies Appropriations bill experienced the greatest increase over 1991 in dollar value of earmarks (+\$187 million) and nearly the greatest increase in number (+79 percent), second only to the Commerce, State, Justice and the Judiciary bill. The NASA example is particularly noteworthy since a number of the projects have little or no connection to space research or technology.
- Earmarks for facilities at academic institutions appear to have increased relative to 1991. Included in the total of \$346 million is an increase of \$95 million, to a total of \$177 million, for research projects at academic institutions. This is a dangerous trend because it represents a much more serious long-term threat to the merit-based system for selection of research projects than does earmarking for facilities.
- OSTP estimates that these R&D earmarks have put an extra burden of nearly \$500 million on the R&D programs proposed in the President's 1992 budget, because the earmarks were made in programs where the overall funding level was the same or less than the President's 1992 request. The most serious impacts appear to be in Defense, NASA, NSF, and some parts of Agriculture. The other \$489 million of R&D earmarks were covered, at least in part, by Congressional increases in the affected R&D accounts, which presumably means that a corresponding reduction was taken elsewhere in the budget.
- Many of the earmarks appear to establish new centers, institutions, or other organizations. In most of these cases, continued Federal support in future years seems clearly implied. Thus, the 1992 earmarks have put a built-in burden on the 1993

and future budgets, an effect that will be compounded if additional earmarks are made in future years.

As the Office of Science and Technology Policy has noted, its information was based only on a review of the often vague information in Congressional appropriations bills and reports. Therefore, the analysis does not identify the sponsorship of the earmarks and does not provide a basis for judgments on the merits of the earmarked items or on the motivations of the earmarking. However, a recent press report (*Science*, November 1991) examined the fate of several earmarked

projects from previous years. The report noted that the projects examined: (1) have supported R&D, but not the original claims that were made for them; (2) have changed in response to technical difficulties encountered; (3) were simply outright promotion of local interests disguised as R&D projects. A more in-depth case-by-case review of other such projects, with agency and Congressional staff directly involved, would be helpful in determining to what degree each earmark was (1) a response to advocacy by a particular institution; (2) a parochial initiative of the Congress or a Federal agency; or (3) a recognition by Congress of a significant national or programmatic need.

EXPANDING THE GEOGRAPHIC FRONTIER: SPACE

The exploration of space provides tangible benefits to the Nation in the form of new materials and other scientific and technological

discoveries that will stimulate economic growth and improve life on Earth. Space also provides large intangible benefits to

Table 6-17. CONGRESSIONAL EARMARKING OF R&D FACILITIES AND RESEARCH IN 1992 APPROPRIATIONS BILLS¹

(Dollars in millions)

Agency	1991		1992	
	Number	Amount	Number	Amount
Defense	28	253	36	263
Energy	48	186	66	197
Agriculture	325	182	334	180
Commerce	14	14	38	36
Interior	25	18	42	31
Health and Human Services	2	3	1	8
Education	5	8	3	3
General Services Administration	21	61	—	—
Environmental Protection Agency	20	67	24	55
National Aeronautics and Space Administration	4	18	11	191
National Science Foundation	—	—	2	20
Housing and Urban Development	—	—	4	2
Federal Emergency Management Agency	—	—	1	3
Transportation	—	—	3	3
Office of Science and Technology Policy	—	—	1	2
Total, All Agencies	492	810	566	993
Facilities	(111)	(428)	(116)	(402)
Operations	(381)	(382)	(450)	(590)
Academic Institutions	(101)	(348)	(139)	(346)

¹ Source: Office of Science and Technology Policy

the Nation with activities that lift the spirit of people everywhere. The will to explore the unknown frontier of space, both with robotic probes and manned missions, is one measure of the vision and maturity of the Nation.

The key to the successful exploration of space is stable and sustainable funding of a balanced program of science, applications and manned space activities. The budget provides clear evidence of the President's continued commitment to his long-term space goals, and to active American leadership in space science and exploration.

The budget proposes to allocate a total of almost \$15 billion for the National Aeronautics and Space Administration (NASA). This represents an increase of nearly 5

percent over 1992. The budget continues to support the strategy laid out by the Advisory Committee on the Future of the U.S. Space Program. The budget provides increases for space activities, including research, development, and operations, to continue to explore the frontier with both manned and unmanned missions. Resources in the budget will improve access to space by supporting critical elements of space transportation (which provides the enabling infrastructure for all other space activities) and by encouraging innovative commercial ventures that will provide increased access.

SPACE EXPLORATION

This part of the space program includes Space Station Freedom and activities leading

Table 6-18. THE BUDGET CALLS FOR A 5 PERCENT INCREASE FOR MAJOR SPACE ACTIVITIES

(Dollar amounts in millions)

Objective	Budget Authority				
	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
Space Exploration	1,433	2,646	2,836	+190	+7%
Space Station Freedom	900	2,029	2,250	+221	+11%
Exploring the Frontier	533	617	586	-31	-5%
Lunar Exploration	—	—	29	29	—
Planetary Exploration	417	536	487	-49	-9%
Mission Studies	5	5	3	-2	-40%
Technology for Future Exploration	111	76	67	-9	-12%
NASA	23	31	27	-4	-13%
Energy	88	45	40	-5	-11%
Improving Access to Space	4,411	5,312	5,412	+100	+2%
Space Shuttle	4,342	4,965	4,867	-98	-2%
New Launch System	—	93	250	+157	+169%
Expendable Launch Vehicles	67	195	218	+23	+12%
Commercial Programs	2	59	77	+18	+31%
Tracking and Data Acquisition	820	918	921	+3	—
Research and Program Management	1,927	1,578	1,660	+82	+5%
Construction of Facilities	275	525	319	-206	-39%
Other NASA Programs ¹	2,192	3,441	4,010	+569	+17%
Total, All Agencies	11,058	14,420	15,158	+738	+5%
Total, NASA ²	10,969	14,320	14,993	+673	+5%

¹ Includes funding for all other NASA activities including space science and applications, space technology (excluding exploration), academic programs and aeronautics.

² Program amounts for 1989 do not reflect revised NASA budget structure instituted in 1992. Program amounts for 1992 and 1993 include funds for institutional support previously shown in Research and Program Management.

to robotic and manned exploration of the Moon and planets. Together, these programs support the long-term goal of expanding human presence and activity beyond Earth's orbit into the solar system. The budget proposes a total of \$2.8 billion, an increase of 7 percent, for space exploration. The strategy for these activities has four major elements: (1) build and operate Space Station Freedom to provide unique capabilities for life sciences and microgravity research; (2) continue robotic missions to explore the other planets in our Solar System; (3) begin several small near-term robotic missions to increase knowledge of the Moon and to provide data for planning future exploration activities; and (4) continue work on "long pole" technology building blocks that will be needed for future manned and robotic exploration of the solar system.

Space Station Freedom.—This program, the largest international R&D project ever undertaken, will enable the performance of life sciences and materials research in a premier space laboratory for extended periods. Specific experiments during the initial operation of Freedom will lead to new knowledge in semiconductor and biotechnology fields, and may lead to eventual production of unique commercial products from space. When Freedom's crew is aboard full time, emphasis will shift to life sciences research, necessary for the long-term space flights of the next century.

With core Station elements being provided by U.S. firms, Freedom will drive advancements in aerospace technology that will maintain U.S. leadership in this important area. Technologies and systems that will be advanced as part of Space Station Freedom development and operations include environmental control and life support, power generation, data storage and management, thermal control, crew health care, data processing and distribution, structures and materials, robotics and automation, and operations and maintenance techniques and logistics support. As in the past, many of the advances made in the course of this program will be quickly used in Earthbound applications.

This past year NASA instituted major adjustments in the program as a result of a restructuring activity that simplified the

design, focused on providing a quality facility for users, maintained agreements with international partners, and placed the program on a more sustainable budget path. The program is now designed to provide early use with a man-tended capability consisting of Shuttle visits and free-flyer support, and, later, a permanently manned capability with a crew of four. This phased approach with a simplified design will better enable Space Station Freedom to accomplish successfully its major objectives as a life sciences and materials research facility in space.

The budget provides \$2,250 million for Space Station. This includes an increase of 10 percent over the 1992 enacted level for development, and initial funding for Space Station operations. This amount will support finalization of detailed designs, and allow fabrication, qualification, and assembly tests of various critical components in preparation for first element launch in 1996, the attainment of a man-tended capability in 1997, and a permanently manned capability in late 2000.

Also included is funding for detailed design, schedule and cost studies for an Assured Crew Return Vehicle (ACRV). NASA will examine a wide range of options for providing this capability as an expedient means of returning Space Station crewmembers to Earth during the permanently manned phase of the program. In addition to the ACRV studies, an independent panel (the Aerospace Safety Advisory Panel), will review the justification and requirements for an ACRV in anticipation of a decision on whether to proceed with development.

Exploring the Frontier.—The President remains firmly committed to his long-term goal, articulated in 1989, of manned and unmanned exploration of the solar system. The budget reflects this commitment by proposing \$586 million for exploration activities in NASA and the Department of Energy. For 1993, the budget is based on a strategy of (1) supporting near-term small missions that will take advantage of the unique proximity and characteristics of the Moon; (2) supporting exploration of the near and outer planets in the Solar System; and (3) supporting research focused on key, long-lead technologies that will be nec-

essary for any future exploration endeavors. These technologies include: space nuclear and conventional propulsion, life sciences and life support technologies, and space surface nuclear power.

Planetary Exploration.—The objectives of these programs are to determine the nature of planets, comets, and asteroids as a means for understanding the origin and evolution of the solar system, to examine how the appearance of life is related to the chemical history of the solar system, and to provide the scientific basis for the future use of available resources in the solar system.

U.S. planetary exploration programs are guided by recommendations of NASA's scientific advisory council. These recommendations outline exploration missions through the year 2000 (i.e., inner planets, small bodies, and the outer planets). The Magellan (Venus), Galileo (Jupiter), and Ulysses (Sun) missions have been launched in the last two years and are providing exciting new scientific information. The Mars Observer mission designed to examine the geologic and climatic evolution of Mars will be launched in late 1992.

For 1993, the budget proposes \$487 million for planetary exploration, a decrease of \$49 million or 9 percent below 1992. Most of this decrease is due to planned reductions in development funding as missions are launched. The 1993 funding level will also provide for the operation of Mars Observer, Galileo, and Magellan and for support of university researchers to analyze data from planetary missions.

In the current constrained budget environment, it is unlikely that multi-billion dollar planetary exploration missions, which often span a decade or more, can continue to be sustained over the long-term. This is particularly true because these missions are often linked to immutable planetary launch "windows" in order to achieve their objectives. Long delays caused by budgetary reductions, launch constraints or technical problems, or all three, often mean that graduate students are well along in their professional careers before instruments they helped develop actually collect any data.

Thus, the budget proposes that development of the Cassini mission to Saturn be continued, but that it undergo a thorough review in 1992 which will focus on the technical and schedule risk remaining in this program. However, the budget proposes to terminate the Comet Rendezvous/Asteroid Flyby mission because the scientific benefits of this mission no longer justify the investment. In order to contain cost growth, the scope of the CRAF mission was recently reduced by deleting the comet penetrator and several other instruments. Thus, much of the planned science was already lost.

In the longer term, a robust planetary science program should emphasize more, smaller, and less costly missions. In order to give the planetary science community an opportunity to consider its future direction in a structured fashion, the budget proposes to initiate studies and research on future small planetary missions (i.e., with total costs of less than \$150 million per mission). All of these decisions are generally consistent with the recommendations of NASA's scientific advisory council.

Robotic Exploration of the Moon and Mars.—The budget proposes \$99 million, an increase of 22 percent, for exploration activities that focus on the Moon and Mars. The initial emphasis will be on the Moon for several reasons. The Moon is accessible because of its proximity and will be a useful mid-point in a long-term plan to send people to Mars. Further lunar exploration is also attractive because it offers opportunities for scientific research, and the possibility that its mineral and energy resources could one day be harnessed for use in the space program or back on Earth. The Synthesis Group, an independent advisory panel on the exploration program chartered by the Vice President, considered these factors last year when it recommended that the U.S. plan an active program of robotic and manned missions to the Moon before sending people to Mars.

As a first step, the budget proposes to start work on two small, low-cost, robotic exploration missions to the Moon. These spacecraft, to be launched in 3-4 years, will carry instruments for mapping the Moon and surveying lunar resources. NASA and

other participating agencies will continue architecture and mission studies focused on longer-term options for both robotic and manned exploration of the Moon and Mars.

Technology for Exploration.—Some future robotic exploration missions are feasible using technology that is already available. However, more ambitious missions—particularly manned exploration of the Moon and Mars—will require significant improvements and breakthroughs in space transportation and other areas. Advancing U.S. capabilities in these areas will likely require many years of focused research and engineering, so coherent long-term technology development efforts should be implemented as future needs are identified.

Some priorities for exploration-related technologies have already been identified by NASA and the Synthesis Group, which produced a comprehensive report on the Space Exploration Initiative. The budget proposes \$67 million to address many of these established priorities, particularly “long pole” technologies required to make key exploration missions feasible, or to significantly reduce their cost.

One such area is nuclear propulsion, which offers shorter travel times and more payload mass compared to conventional propulsion technologies. Technologies and mission applications for nuclear propulsion will be addressed by both NASA and the Department of Energy (DOE) in 1993. In addition, NASA will continue technology development for advanced chemical propulsion, life support and radiation protection. The budget proposes a total of \$45 million in funding by Energy and NASA for space nuclear reactor power system technology (specific allocation of this funding will be made in the Spring of 1992 after a reassessment of potential applications and technology alternatives).

IMPROVING ACCESS TO SPACE

Space transportation is the foundation for all U.S. space activities because space missions require launch vehicles to get off the ground. Consequently, the Nation’s space transportation capabilities must be adequate to meet both near-term and long-term national needs. At present, the U.S. has one manned launch system, the Space Shuttle, and a fleet of

expendable launch vehicles with a broad range of payload capabilities. Many of the latter are now operated on a commercial basis for use by both the government and private customers.

The budget proposes \$5.4 billion, an increase of 2 percent, for civil space transportation. The strategy reflected in the budget is founded on three underlying principles: (1) enhance the Space Shuttle’s efficiency and schedule predictability while increasing the reliability and lifetime of the existing fleet; (2) develop a new launch system to offer operational improvements over existing vehicles and to reduce the long-term burden on the Shuttle; and (3) encourage the commercial space sector to provide goods and services that will increase access to space for all sectors.

New Launch System.—All sectors of the U.S. space program, including scientific, exploration, national security, and commercial applications, would benefit greatly from reductions in launch system operating costs and improvements in reliability, responsiveness, and mission performance. To this end, the budget proposes \$250 million, nearly a three-fold increase, for the joint NASA/Department of Defense program to develop a new launch system with several configurations, including a heavy lift capability. The Advisory Committee on the Future of the U.S. Space Program recommended developing this capability to take pressure off the Space Shuttle and to enable new types of future space missions. In addition, developing this new family of vehicles will strengthen the technical base for improvements in commercial launch vehicles. The first launch of this new system is planned for 2002. Funding for common program elements will be shared between NASA and DOD on a 50:50 basis. Planned 1993 activities focus on continued development of a new liquid-fueled rocket engine for the vehicle. Vehicle design studies will also continue. During 1992, Defense and NASA will initiate a review of the NLS program plan to identify opportunities to reduce the total cost of the program.

Space Shuttle.—The budget proposes \$4.9 billion, a decrease of 2 percent, for the Space Shuttle, including operations. The Shuttle will continue to be important to the civil space program through at least the next decade because

Table 6-19. THE BUDGET INCLUDES FUNDING FOR 8 SHUTTLE FLIGHTS AND INVESTMENTS TO IMPROVE THE NATION'S ACCESS TO SPACE

(Dollar amounts in millions)

	Budget Authority				
	1989 Actual	1992 Enacted	1993 Proposed	Dollar Change: 1992 to 1993	Percent Change: 1992 to 1993
New Launch System	—	93	250	+157	+169%
NASA	—	38	125	+87	+229%
DOD	—	55	125	+70	+127%
Space Shuttle	4,342	4,965	4,867	-98	-2%
Space Shuttle production and operations	3,549	3,851	3,989	+138	+4%
Advanced Solid Rocket Motor	51	315	—	-315	-100%
Assured Shuttle Availability	68	105	139	+34	+32%
Space transportation capability development	674	694	739	+45	+6%
Expendable launch vehicle (ELV) services	67	195	218	+23	+12%
Commercial Programs	2	59	77	+18	+31%
SpaceHab	—	39	51	+12	+31%
Commercial Experiment Transporter (COMET) ..	—	18	22	+4	+22%
Other	2	2	4	+2	+100%
Total	4,411	5,312	5,412	+100	+2%

of its unique abilities to retrieve satellites, carry people and material to build the Space Station, and serve as a short-term orbiting laboratory for scientific research. However, the budget also recognizes that the Shuttle system has proven to be very expensive and complex to operate, and that development of new launch systems will be needed to meet long-term U.S. needs.

Because the Shuttle is a precious resource that should be conserved, its use will be limited to payloads requiring manned presence or other unique capabilities. The planned flight rate has been reduced to 8 missions per year through 1996, a level that is both realistic and prudent. The budget also proposes \$139 million, an increase of 32 percent, for the Assured Shuttle Availability (ASA) program. ASA projects are intended to prevent component obsolescence and extend the useful life of the current fleet of orbiters. Taken together, these measures will reduce the long-term risk exposure of continued use of the Shuttle system.

Several measures are proposed that will reduce the Shuttle's funding requirements

while continuing the program's strong commitment to safety and mission success. Cost reduction targets of 3 percent per year, resulting in a 15 percent reduction by 1996, have been established to improve the efficiency, and thus reduce the cost, of Shuttle operations, without compromising flight safety or the Shuttle manifest.

Termination of the development of the Advanced Solid Rocket Motor (ASRM) program as well as the construction of its production facility is proposed. The ASRM project represents major funding requirements, nearly \$500 million in 1993, over \$400 million in 1994, with a total of \$2.5 billion to reach flight status. Unlike other projects competing for these scarce budget resources, alternatives exist to offset the loss of the ASRM capability. The Redesigned Solid Rocket Motor (RSRM), which entered service after the ASRM was initiated, has already flown successfully in 20 Shuttle missions, with no safety or reliability problems. The impact on the Space Station Freedom program can be compensated for by adding several Shuttle flights using the current RSRM. It is estimated that two additional assembly flights plus

one additional utilization flight would be required to achieve the Permanently Manned Capability milestone, which would slip 9 months (from early 2000 to late 2000).

In recent years the President has requested significant increases for NASA, including funding for the ASRM program. Congress has been unable to fund fully these requests. In the Senate and Conference Reports accompanying NASA's 1992 appropriations, Congress directed that increases in the NASA budget be limited to 3-5 percent in 1993. ASRM has been recommended for cancellation, in part, to accommodate the Congressionally-imposed cap. If a higher budget allocation were to be provided for NASA in 1993 by the Appropriations Committees, the Administration would be prepared to work with the Congress toward the possibility of continued support for ASRM.

When the ASRM was proposed for development four years ago in the 1989 budget to Congress, its first use was planned for early to mid-1994, and the estimated cost up to first use was \$1.9 billion. According to the most recent plans, first use of ASRM would occur no earlier than February 1997, and estimated cost up to first use including prior year funds would be \$3.4 billion. Thus, ASRM would be available three years later than originally proposed, at 80 percent higher cost.

It should also be noted that when development funding for the ASRM was proposed four years ago, 14 Shuttle missions per year were planned after the ASRM entered service. The projected Shuttle flight rate in the late 1990's has since fallen to 9 missions per year. Thus, while it was originally thought that more than 70 Shuttle missions in the 1990s would use ASRMs, fewer than 30 would do so now if the program were continued.

Production of additional Shuttle orbiters is not planned. However, production of spare parts will continue in the near term to support the existing Shuttle fleet and to help preserve an option to acquire a replacement orbiter in the event of orbiter loss or other demonstrable need.

Commercial Space.—In the National Space Policy and its implementing guidelines, the commercial sector is encouraged to provide goods and services that will improve access to space for all sectors. A result of this policy is that NASA and other agencies are increasing their use of commercial launch services. A noteworthy milestone in late 1992 will be the first launch of the Commercial Experiment Transporter (COMET), which is being procured through the NASA-sponsored Commercial Centers for the Development of Space.

Another important planned milestone in 1993 is NASA's first use of SpaceHab, a commercially-developed, reusable module that will enable the Space Shuttle to carry more experiments. NASA has contracted to use part of this module for multiple missions, and its developer is marketing the remaining capacity to commercial customers.

The commercial sector can also benefit from launch technology activities that are planned by NASA and DOD for 1993. While planned technology work is focused on meeting future needs and objectives identified by government agencies (e.g., increasing the cost-effectiveness of space launch systems), some results of this work will also be applicable to commercially-operated systems. In addition, development of new launch vehicles (such as the new launch system being built by NASA and DOD) for the government may provide new opportunities for commercial operators in the long term.