4. GENERAL SCIENCE, SPACE, AND TECHNOLOGY

Table 4–1. Federal Resources in Support of General Science, Space, and Technology
(In millions of dollars)

Function 250	2000 Actual	Estimate					
		2001	2002	2003	2004	2005	2006
Spending:							
Discretionary Budget Authority ...	19,203	20,861	21,191	21,892	22,441	22,910	23,488
Mandatory Outlays:							
Existing law	36	94	126	158	150	92	53
Tax Expenditures:							
Existing law	3,310	7,700	8,440	7,160	6,590	4,700	3,260

More than half of the Nation's economic productivity growth in the last 50 years is attributable to technological innovation and the science that supported it. Appropriately, the private sector makes the largest investments in technology development. The Federal Government, however, also plays a role. Total Federal research and development would be at an all-time high in inflation-adjusted terms if the President's proposal is approved.

Within the General Science, Space, and Technology function, the Federal Government supports areas of cutting-edge science, through the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and the Department of Energy (DOE). The activities of these agencies contribute to a greater understanding of the world in which we live, ranging from the edges of the universe to the smallest particles, and to new knowledge that may have immediate applications for improving our lives. Because the results of basic research are unpredictable, developing performance goals for this area presents unique challenges.

Each of these agencies funds research and contributes to the Nation's cadre of skilled scientists and engineers. As a general goal for activities in this function, at least 80 percent of the research projects will be reviewed by appropriate peers and selected through a merit-based competitive process. Another important Federal role is to construct and operate major scientific facilities and capital assets for multiple users. These include telescopes, satellites, oceanographic ships, and particle accelerators. Many of today's advances in medicine and other fields rely on these facilities. As general goals:

- agencies will keep the development and upgrade of these facilities on schedule and within budget, not to exceed 110 percent of estimates; and
- in operating the facilities, agencies will keep the operating time lost due to unscheduled downtime to less than 10 percent of the total scheduled possible operating time, on average.

The budget proposes $21.2 billion to conduct activities in support of general science, space, and technology. The Government also stimulates private investment in these activities through over $8.4 billion a year in tax credits and other preferences for research and development (R&D). With the 2002 Budget, the President proposes that the tax credit for research and experimentation be made permanent.

National Aeronautics and Space Administration (NASA)

The budget proposes $13.6 billion for NASA activities in this function. NASA serves as the lead Federal agency for R&D in civil space activities, working to expand frontiers in air and space to serve America and improve the quality of life on Earth. To carry out these activities, NASA pursues this vision through balanced investment in five enterprises: Space Science, Earth Science, Biological and Physical Research, Aero-Space Technology, and Human Exploration and Development of Space.

NASA's achievements in 2000 included: launching Terra, the first mission in the Earth Observing System series of spacecraft; discovering potential evidence of recent liquid water flows on the surface of Mars from the Mars Global Surveyor spacecraft; securing the arrival of the Shoemaker Near Earth Asteroid Rendezvous mission at the asteroid Eros, the first spacecraft ever to orbit an asteroid; and continuing successful assembly of the International Space Station in orbit.

Space Science: Space Science programs, for which the budget proposes $2.8 billion, are designed to enhance our understanding of how the universe was created, what fundamental rules govern its evolution, how stars and planets evolve and die, how space phenomena affect Earth, and the possible existence of life beyond Earth. In 2000, NASA developed and launched Hubble Servicing Mission 3A, the Imager for Magnetopause-to-Aurora Expansion mission, and contributions to the X-ray Multi-Mirror and Cluster-2 missions, with an average one-percent cost overrun. The High Energy Solar Spectroscopic Imager mission and the Thermal, Ionosphere, and Mesosphere Energetics and Dynamics mission did not launch as planned in 2000 due to spacecraft development issues and launch vehicle delays. The Mars Polar Lander mission was lost when it did not land successfully on Mars as planned in 2000. Although scheduled to launch in 2000, the High-Energy Transient Explorer mission was launched shortly after the end of the year.

For 2000, the NASA Advisory Council, an independent panel, indicated that 34 of 65 performance plan objectives and 18 of 19 science objectives for Space Science have been successfully met. In 2002:

- NASA will successfully complete its performance goal for design and development of projects to support future Space Science research. These development projects represent near-term investments that will allow future research in pursuit of the strategic plan's science objectives. Completion will be demonstrated by a successful rating from the NASA Advisory Council or an equivalent senior-level external review committee. This rating will be based on achievement of six of the eight predetermined performance objectives, four of which address launch readiness for the Space Infrared Telescope Facility, the Galaxy Evolution Explorer, the Comet Nucleus Tour mission, and the Hubble Space Telescope Servicing Mission 3B.
- NASA's annual performance goals in support of strategic plan Space Science objectives will be rated as being successfully met by NASA's Advisory Council or an equivalent senior-level external review committee. Examples of these objectives include: learn how galaxies, stars, and planets form, interact, and evolve; understand the formation and evolution of the Solar System and the Earth within it; and understand our changing Sun and its effects throughout the Solar System. Each of these performance goals calls for obtaining at least 80 percent of the expected scientific data from operating missions that support the relevant science objective.
- NASA will continue to expand the integration of education and enhanced public understanding within its Space Science research and flight mission programs. Performance objectives in support of this effort call for Space Science-funded education and public outreach activities for every funded Space Science mission, which will result in projects in at least 40 States. These projects will range from elementary schools to graduate students and postgraduates. In addition, Space Science will ensure that Enterprise-funded projects are underway in Historically Black Colleges and Universities, Hispanic Serving Institutions, and Tribal Colleges.

Earth Science: Earth Science programs, for which the budget proposes $1.5 billion, focus on the effects of natural and human-induced changes on the global environment through long-term, space-based observation of Earth's land, oceans, and atmospheric processes. In 2000, NASA successfully launched five spacecraft (Terra, ACRIMSAT, the Shuttle Radar Topography Mission, and two National Oceanic and Atmospheric Administration (NOAA) weather satellites (GOES-L, NOAA-L)), and delivered four instruments to international spacecraft, with an average seven-percent cost overrun. Launches of spacecraft expected in 2001 have been delayed: Aqua until no earlier than July 2001, IceSAT until December 2001, and Triana pending shuttle availability. Users have routinely received earth science data products within five days of receipt or production of the requested data product.

The NASA Advisory Council concluded that 43 of 47 Earth Science performance targets were successfully met. In 2002:

- NASA will successfully launch and operate at least two of three planned spacecraft, IceSAT, Gravity Recovery and Climate Experiment and the Solar Radiation and Climate Experiment within 10 percent of their schedules and budgets. For those spacecraft already successfully launched, NASA Earth Science will obtain at least 80 percent of the expected scientific data;
- NASA will increase by 50 percent the volume of climate data it archives over the 2001 target of 442 terabytes, increase the number of products delivered from its archives by 10 percent over the 2001 target of 5.4 million products delivered, and make the data available to users within five days; and,
- NASA's Advisory Council will be able to rate all near-term Earth Science objectives as being met or on schedule. Examples of these objectives include: observe and document land cover and land use change and impacts on sustained resource productivity; and understand the causes and impacts of long-term climate variations on global and regional scales.

Aero-Space Technology: Aero-Space Technology programs, for which the budget proposes $1.5 billion, work with other NASA enterprises, industry, and academia to develop and test technologies that reduce risk and improve cost performance for future spacecraft and space transportation systems. In 2000, NASA initiated assembly of the X-37 flight test vehicle. The X-33 and X-34 programs did not perform flight tests as planned in 2000, due to technical problems encountered during development. Both programs have been canceled. Depending on selections, NASA will develop additional 2002 Aero-Space Technology goals based on Second Generation Reusable Launch Vehicle awards in 2001. In 2002:

- NASA will perform the rollout and begin test flights of the X-37 vehicle. This vehicle will serve as a platform on which to test and verify advanced technologies in the area of lightweight composite airframes, integrated vehicle health monitoring, and thermal protection systems.
- The Space Base program will complete working prototypes of over 40 micro-scaled and low-power electronic spacecraft and sensor components. These components can lead to future science spacecraft that are the functional equivalent or better of current spacecraft but with less than one-tenth the volume and mass.

Human Exploration and Development of Space: Human Exploration and Development of Space (HEDS) programs, for which the budget proposes $7.3 billion, focus on the use of human skills and expertise in space. In 2000, the Space Shuttle flew four successful missions, including the Hubble Space Telescope Servicing Mission 3A that replaced failing gyros on the Hubble. The Shuttle Radar Topography Mission, a joint Department of Defense/NASA payload to study the earth, successfully mapped over 98 percent of the available terrain. Two flights to the International Space Station delivered equipment and supplies to set the stage for future assembly missions and to prepare for the first Expedition crew. Improvements to the Space Shuttle system achieved an additional 10-percent increase in predicted reliability over the 1999 levels, and completed the first flight of a new upgraded cockpit. Space Shuttle operations continued to perform well and observed an average of six anomalies per flight, achieved 100

percent on-orbit mission success for primary payloads, and achieved a 12-month flight preparation cycle. The International Space Station program delivered, as planned, two-thirds of the total U.S. flight hardware to the launch site, and also conducted successful operations throughout the year. However, projected cost overruns have required a major restructuring of the program in 2002, which should control cost growth, while enabling accommodation of contributions from international partners. In 2002:

- NASA will successfully complete a majority of planned operations schedules and milestones for 2002 for the International Space Station. For example, NASA plans to conduct permanent on-orbit operations with crew support dedicated to assembly, vehicle operations, payload operations, and early research, and conduct the first Space Shuttle flight to the Space Station dedicated to research; and
- NASA will ensure that Space Shuttle safety, reliability, availability, and cost will improve, by achieving eight or fewer flight anomalies per mission, 100 percent on-orbit mission success for primary payload on-orbit operations, and a 12-month manifest preparation time. NASA will complete the implementation of the Alternate Turboprop to improve the safety of flight operations and continue safety and supportability upgrades to maintain Space Shuttle infrastructure.

Biological and Physical Research: NASA's Biological and Physical Research programs, for which the budget proposes $380 million, focus on basic and applied research to support the safe and effective human exploration of space, as well as the use of the space environment as a laboratory for increasing our understanding of biological, physical, and chemical processes. In 2000, the Biological and Physical Research Enterprise was created as a separate entity from the HEDS Enterprise to provide a greater focus on biological and physical research. The new Office of Biological and Physical Research (OBPR) and its predecessor organization, the Office of Life and Microgravity Sciences and Applications, conducted significant commercial research on the May Space Shuttle mission to the Space Station, and inaugurated the Space Station research era by conducting the first long-duration experiment on the International Space Station. In 2002:

- OBPR will continue to build a productive scientific community to utilize its space assets, expanding agency support to approximately 1,000 scientific investigations (from 877 reported in 1999); and
- NASA will collaborate with the National Cancer Institute to develop and test cutting-edge methods and instruments to support molecular-level diagnostics for physiological and chemical processes monitoring.

Management Reform Goals

To fulfill the President's commitment to make Government more market-based, NASA will pursue management reforms to promote innovation, open Government activities to competition, and improve the depth and quality of NASA's R&D expertise. These reforms, described below, will help reduce NASA's operational burden and focus resources on Government-unique R&D at NASA.

- ***International Space Station.*** NASA will undertake reforms and develop a plan to ensure that future Space Station costs will remain within the President's 2002 Budget plan. Key elements of this plan will: restore cost estimating credibility, including an external review to validate cost estimates and requirements and suggest additional options as needed; transfer Space Station program management reporting from the Johnson Space Center in Texas to NASA Headquarters until a new program management plan is developed and approved; and open future Station hardware and service procurements to innovation and cost-saving ideas through competition, including launch services and a Non-Government Organization for Space Station research.
- ***Space Shuttle Privatization.*** NASA will aggressively pursue Space Shuttle privatization opportunities that improve the Shuttle's safety and operational efficiency. This reform will include continued implementation of planned and new privatization efforts through the Space Shuttle

prime contract and further efforts to safely and effectively transfer civil service positions and responsibilities to the Space Shuttle contractor.

- ***Space Launch Opportunities.*** NASA's Space Launch Initiative provides commercial industry with the opportunity to meet NASA's future launch needs, including human access to space, with new launch vehicles that promise to dramatically reduce cost and improve safety and reliability. NASA will undertake management reforms within the Space Launch Initiative, including: ensuring vehicle affordability and competitiveness by limiting requirements to essential needs through commercial services; creating requirements flexibility, where possible, to accommodate innovative industry proposals; validating requirements through external, independent review; implementing a well-integrated risk-reduction investment strategy that makes investments only after requirements and vehicle options are well-understood, to ensure a viable competition by the middle of the decade for initial Station cargo and crew launch services; ensuring no set-aside funds for non-industry vehicles like the Space Shuttle; and achieving affordable, near-term successes in Next Generation Launch Services and Alternative Access to the Space Station and integrating these near-term activities into longer-term planning.
- ***Critical Capabilities.*** U.S. academia and industry provide a rich R&D resource that NASA can tap to strengthen its mission capabilities. NASA will develop an integrated, long-term agency plan that ensures a national capability to support NASA's mission by: identifying NASA's critical capabilities and, through the use of external reviews, determining which capabilities must be retained by NASA and which can be discontinued or led outside the agency; expanding collaboration with industry, universities and other agencies, and outsourcing appropriate activities to fully leverage outside expertise; and pursuing civil service reforms for capabilities that NASA must retain, to ensure recruitment and retention of top science, engineering and management talent at NASA.

National Science Foundation (NSF)

Under the President's plan, between 2000–2002, NSF's budget will grow by 15 percent to $4.5 billion. This significant increase is consistent with the President's support for increasing the Federal investment in basic R&D, and funding NSF as the primary agency for supporting peer-reviewed, competitively awarded, long-term, high-risk research conducted through our Nation's university systems. For 2003, the Administration will undertake a budgetary review to determine how best to support the NSF's budget in a sustained manner over time.

While NSF represents just three percent of Federal R&D spending, it supports nearly half of the non-medical basic research conducted at academic institutions, and provides 30 percent of Federal support for mathematics and science education.

NSF research and education investments are made in three primary areas:

People: Activities to facilitate development of a diverse and talented work force of scientists, engineers, and well-prepared citizens account for more than 20 percent of NSF's budget. In 2002, NSF will invest $1.0 billion in this area. NSF supports formal and informal science, mathematics, engineering and technology education at all levels, including multidisciplinary education and training for graduate students. In addition, resources support projects to develop curriculum, enhance teacher professional development, and provide educational opportunities for students from pre-K through postdoctoral work. In 2000, the three major systemic efforts implemented mathematics and science standards-based curricula in 6,348, or over 80 percent, of the 7,630 participating schools. NSF awards provided intensive professional development to a total of 89,723 teachers, substantially exceeding the performance goal of 65,000. For 2002, NSF will begin the President's $200 million Math and Science Partnership initiative.

- In 2002, at least half of the States will activate partnerships with institutions of higher education aimed at strengthening K-12 math and science education through the President's Math and Science Partnership initiative. These partnerships can

involve local school districts and will address issues such as preparation and professional development of math and science teachers, implementation of high standards for math and science, and address gaps in performance between majority and minority and disadvantaged students.

Ideas: Approximately one-half of NSF's resources support research projects performed by individuals, small groups, and centers. In 2002, NSF will invest $2.2 billion in this area.

- In 2002, results over the period studied will demonstrate significant achievement for the majority of the following indicators: important discoveries; a robust fundamental knowledge base; connections between discovery and learning, innovation, or societal advancement; partnerships that enable the flow of ideas among academic, public or private sectors; and leadership in fostering newly developing or emerging areas. NSF's performance will be determined by aggregating the performance indicator assessments provided by independent external committees of experts.

Tools: NSF will invest $1.0 billion in this area to provide state-of-the-art shared tools for research and education, such as instrumentation and equipment, multi-user facilities, accelerators, telescopes, research vessels and aircraft, and earthquake simulators. In addition, resources will support large databases as well as computation and computing infrastructures for science, engineering, or education. Nearly a quarter of NSF's budget is targeted to providing the tools required for cutting-edge research.

- In 2002, NSF facilities will continue to meet the function-wide goals to remain within cost and schedule.

Management Goals

NSF has identified management and investment process goals to address the efficiency and effectiveness of administrative activities, and to focus on the means and strategies to achieve its outcome goals. In 2002:

- at least 85 percent of basic and applied research funds will be allocated to projects that undergo merit review;
- for 70 percent of proposals, NSF will be able to inform applicants within six months of receipt whether their proposals have been declined or recommended for funding. In 2000, NSF processed 54 percent of proposals within six months; and
- NSF will increase the average annualized award size for research projects to $111,000, compared to a goal of $109,000 in 2001.

Management Reforms

To fulfill the President's commitment to make Government more results-oriented, NSF will undertake management reforms, focusing on performance and results.

- ***Study Reorganizing Research in Astronomy and Astrophysics:*** NSF and NASA provide more than 90 percent of Federal funds for academic astronomy research and facilities. Historically, NASA has funded space-based astronomy and NSF has funded ground-based astronomy, as well as astronomy research proposals. Several changes have evolved which suggest that now is the time to assess the Federal Government's management and organization of astronomical research. NSF and NASA will establish a Blue Ribbon Panel to assess the organizational effectiveness of Federal support of astronomical sciences and, specifically, the pros and cons of transferring NSF's astronomy responsibilities to NASA. The panel may also develop alternative options. This assessment will be completed by September 1, 2001.
- ***Document the Efficiency of the Research Process.*** NSF asserts that the current size of its grants and their duration might be resulting in an inefficient research process at U.S. academic institutions. Researchers might be spending too much time writing proposals instead of doing actual research. NSF has increased grant size and duration in previous years, particularly through its priority research areas; however, there is little documentation that this is having a positive impact on research output. With the assistance of U.S. academic research institutions, NSF will develop metrics to measure the

efficiency of the research process and determine the "right" grant size for the various types of research the agency funds. These metrics and grant size determination will be developed in time for consideration of the 2003 NSF budget request.

- ***Enhance NSF Capability to Manage Large Facility Projects.*** NSF has several multi-year, large facility projects awaiting approval for funding. NSF will enhance its capability to manage proposed projects, given the magnitude and costs of future projects. NSF will develop a plan for costing, approval, and oversight of major facility projects, and also will enhance its capability to estimate costs and provide oversight of project development and construction.
- ***Improve NSF's Ability to Administer and Manage its Program Activities.*** Although NSF has had robust increases in its program responsibilities and budgets in the past decade, funding for administration and management has remained relatively flat. NSF has been able to keep pace with the increased workload by investing in information technology. Both the NSF Inspector General and the NSF Management Controls Committee have expressed concern about the adequacy of staffing at a time when the agency is facing turnover and recruitment problems and management of more complex programmatic activities. They also raise concerns with systems and data management. NSF will develop a five-year strategic plan for the work force and information technology needs of the agency in time for consideration of the 2003 Budget.

Department of Energy (DOE)

The budget proposes $3.2 billion in 2002 for DOE science programs and supporting activities. DOE's Office of Science is one of the Nation's leading source of support for basic research in the physical sciences, conducting research at universities and the national laboratories. DOE also operates major scientific facilities including particle accelerators, magnetic confinement fusion reactors, synchrotron light sources, neutron sources, supercomputers, and high-speed networks that researchers use in fields ranging from the physical and materials sciences to the biomedical and life sciences. These facilities are available, on a competitive basis, to scientists and engineers in universities, industry, and other Federal agencies.

Basic Energy Sciences: The budget proposes $1.0 billion for Basic Energy Sciences (BES), which supports basic research in materials science, chemistry, engineering, geoscience, plant biology, and microbiology. As part of its mission, BES plans, constructs, and operates major scientific user facilities. In 2000, Los Alamos National Laboratory's Lujan Neutron Scattering Center delivered only 79 percent of scheduled operating time, missing its target of no more than 10 percent unscheduled downtime. A recent review found the Lujan Center staff to be seriously over-committed. In 2002:

- DOE will meet the cost and schedule milestones for construction and upgrade of scientific user facilities as confirmed by regular external independent reviews. Major ongoing projects include construction of the Spallation Neutron Source (a powerful tool to explore materials structure and properties) and an upgrade of the SPEAR3 storage ring at the Stanford Synchrotron Radiation Laboratory; and
- DOE science programs will significantly increase their funding for basic research on renewable sources of energy, to advance cost-effective means to further diversify the Nation's energy supply.

Advanced Scientific Computing Research: The budget proposes $166 million for Advanced Scientific Computing Research, which supports applied mathematics, computer science, and networking research, and operates supercomputer, networking and related facilities to enable the analysis, simulation, and prediction of complex physical phenomena.

- By the end of 2002, DOE will review the Integrated Software Infrastructure Centers, newly established in 2001, to ensure effective coupling of these centers to scientific application pilot projects and teams funded throughout the Office of Science.

Biological and Environmental Research: The budget proposes $443 million for Biological and Environmental Research, which supports basic research to identify, understand, and anticipate the long-term health and environmental consequences of energy production, development, and use. In addition to its accomplishments in genomics, DOE plays a major role in understanding the global carbon cycle.

- In 2002, DOE will develop and test a fully-coupled climate model that integrates the atmosphere with the ocean, land, and sea ice, with higher spatial resolution than is presently available; and
- By the end of 2002, the DOE Joint Genome Institute DNA sequencing will complete the high quality DNA sequence of human chromosomes 5 and 19 and produce six million base pairs of DNA sequence from model organisms to help understand the human sequence.

High Energy and Nuclear Physics: The budget proposes $1.1 billion for High Energy and Nuclear Physics, which strives to understand the nature of matter and energy in terms of the most elementary particles and forces, and to more completely explain the structure and interactions of atomic nuclei.

- In 2002, DOE will capitalize on its opportunities to discover the particle that gives rise to mass, to search for physics not adequately described by the Standard Model, and to confirm and characterize neutrino oscillations and neutrino mass.

Fusion Energy Sciences: The budget proposes $238 million for DOE's Office of Fusion Energy Sciences, which conducts research to advance plasma science, fusion science, and fusion technology. DOE will continue to reorient its fusion program to focus on developing the scientific understanding necessary to support fusion as a practical energy source.

- In 2002, DOE will study feedback stabilization as means to control disruptive plasma oscillations in the recently upgraded DIII–D fusion reactor.

Tax Incentives

Along with direct spending on R&D, the Federal Government has sought to stimulate private investment in these activities with tax preferences. The current law provides a 20-percent tax credit for private research and experimentation (R&E) expenditures above a certain base amount. The credit, which expired in 1999, was retroactively reinstated for five years, to 2004, in the Tax Relief Extension Act of 1999. The budget proposes to make the R&E tax credit permanent. It will cost $9.9 billion from 2002 to 2006 (see Table S–10).

A permanent tax provision also lets companies deduct, up front, the costs of certain kinds of R&E, rather than capitalize these costs. This tax expenditure will cost $1.7 billion in 2002. Finally, equipment used for research benefits from relatively rapid cost recovery. The cost of this tax preference is calculated in the tax expenditure estimate for accelerated depreciation of machinery and equipment.