4. GENERAL SCIENCE, SPACE, AND TECHNOLOGY

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

Function 250	1993 Actual	2001 Estimate	Percent Change: 1993–2001
Spending:			
Discretionary budget authority	17,214	20,830	21%
Tax expenditures	3,300	7,700	133%

Investments in scientific discovery and technological development both public and private have driven economic growth and improvements in the quality of life in America for as long as our Nation has existed. (See Table 4–2.) In the last fifty years, developments in science and technology have generated at least half of the Nation's productivity growth, creating millions of high-skill, high-wage jobs. Federal Government support for science and technology has helped put Americans on the Moon, harnessed the atom, tracked weather patterns and earthquake faults, and deciphered the chemistry of life.

In 1993, President Clinton took office committed to expanding investment in civilian research and development (R&D), because technological advances are key to progress and economic growth. The President's economic strategy relied upon the critical element of investing in people and proposed targeted investments to help the Nation compete in the global economy and improve our quality of life. The Clinton-Gore Administration's investments in R&D were guided by several fundamental principles, including the following: a) sustain and nurture America's world-leading science and technology enterprise, through pursuit of specific agency missions and through stewardship of critical research fields and scientific facilities; b) strengthen and expand access to high-quality science, mathematics, and engineering education, and contribute to preparing the next generation of scientists and engineers; c) focus on activities that require a Federal presence to attain national goals, including national security, environmental quality, economic growth and prosperity, and human health and well being; or, d) promote inter-

Table 4–2. Selected Research Increases
(Budget authority, dollar amounts in millions)

	1993 Actual	2001 Enacted	Percent Change: 1993–2001
National Institutes of Health	10,335	20,370	97%
National Science Foundation	2,750	4,426	61%
Total 21st Century Research Fund	29,681	44,908	51%

Note: See Table 4–4 for details.

national cooperation in science and technology that would strengthen the advance of science and achievement of national priorities.

In his first year, the President proposed and secured passage of a research tax credit to spur additional basic and applied research as well as significant investments to fund R&D in a range of fields. In keeping with the emphasis on civilian research and development, the Administration increased the share for civilian R&D investments, from 42 percent in 1993 to 50 percent in 2001. Discretionary funding in the general science, space, and technology function increased by 21 percent from $17.2 billion in 1993 to $20.8 billion in 2001. (A restructuring of budget accounts in 1998 and 1999 added $1.5 billion in 2001 for this function for Department of Energy (DOE) R&D activities. These amounts were included in the energy function—see Chapter 5, "Energy"—in 1993.) During this same period, total Federal funding for R&D across all budget functions increased by 24 percent, from $72.5 billion to $90.2 billion, while funding for defense R&D received a more modest increase of seven percent, from $42.2 billion to $45.0 billion (see Table 4–3). Defense R&D currently accounts for nearly 90 percent of federally-funded development, which decreased by one percent since 1993, from $42.8 billion in 1993 to $42.5 billion in 2001.

In 1999, the President established the 21st Century Research Fund for America (see Table 4–4), relying upon a coordinated and balanced investment strategy to provide resources for basic research at the National Institutes of Health (NIH), the National Science Foundation (NSF), and DOE, and a wide range of applied research activities in areas such as the environment, agriculture, energy, computers, communications, and transportation. In addition to allocating resources in a balanced manner across several budget

Table 4–3. Research and Development Investments [1]
(Budget authority, dollar amounts in millions)

	1993 Actual	2000 Actual	2001 Enacted	Percent Change: 1993 to 2001	Percent Change: 2000 to 2001
Funding by R&D Type:					
Basic Research	13,362	19,323	21,861	64%	13%
Applied Research	13,608	18,642	21,182	56%	14%
Development [2]	42,795	40,399	42,518	–1%	5%
Equipment	[3]	983	1,094	NA	11%
Facilities	2,727	3,728	3,552	70%	–5%
Total	72,492	83,075	90,207	24%	9%
Funding by R&D Share:					
Civilian	30,329	40,471	45,181	49%	12%
Defense	42,163	42,604	45,026	7%	6%
Total	72,492	83,075	90,207	24%	9%
Civilian (percent)	42%	49%	50%		
R&D Support to Universities	11,674	14,377	16,365	40%	14%
Science and Technology Initiatives:					
National Nanotechnology Initiative	NA	267	420	NA	57%
Information Technology R&D	728	1,543	2,006	176%	30%
Climate Change Technology Initiative	NA	1,096	1,239	NA	13%
Partnership for a New Generation of Vehicles	NA	224	236	NA	5%
U.S. Global Change Research Program..	1,326	1,692	1,700	28%	*

* = 0.5 percent or less.
NA = Not applicable.
[1] Includes funding from multiple functions.
[2] Defense R&D funding is the source of nearly 90 percent of Federal development funding.
[3] Equipment and facilities data were not collected separately in 1993.

Table 4–4. 21st Century Research Fund[1]
(Budget authority, dollar amounts in millions)

	1993 Actual	2000 Actual	2001 Enacted	Percent Change: 1993 to 2001	Percent Change: 2000 to 2001
Health and Human Services:					
National Institutes of Health	10,335	17,813	20,370	97%	14%
National Science Foundation	2,750	3,897	4,426	61%	14%
National Aeronautics and Space Administration (NASA):					
Space Science	1,770	2,193	2,508		
Earth Science	996	1,443	1,498		
Aerospace Technology	884	985	1,107		
Life and Microgravity Sciences	408	275	317		
NASA Total	4,058	4,896	5,430	34%	11%
Department of Energy (DOE):					
Science Programs	3,066	2,788	3,186		
Solar and Renewable R&D	249	315	375		
Energy Conservation R&D	346	577	626		
DOE Total	3,661	3,680	4,187	14%	14%
Department of Defense (DOD):					
Basic Research	1,314	1,161	1,318		
Applied Research	3,549	3,410	3,690		
DOD Total	4,863	4,571	5,008	3%	10%
Department of Agriculture (USDA):					
CSREES Research and Education	433	487	543		
Economic Research Service	59	53	55		
Agricultural Research Service	661	830	916		
Forest Service Research	183	218	246		
USDA Total	1,336	1,588	1,760	32%	11%
Department of Commerce (DOC):					
Oceanic and Atmospheric Research	202	298	358		
National Institutes of Standards and Technology[2]	364	534	494		
DOC Total	566	832	852	51%	2%
Department of Transportation (DOT):					
Highway Research	221	490	437		
Aviation Research	230	156	187		
DOT Total	451	646	624	38%	–3%
Department of Interior: U.S. Geological Survey	750	813	882	18%	8%
Environmental Protection Agency (EPA):					
Office of Research and Development	517	561	573		
Climate Change Technology programs	NA	103	96		
EPA Total	517	664	669	29%	1%
Department of Education: Research programs	162	319	349	115%	9%
Department of Veterans Affairs: Medical Research	232	321	351	51%	9%
21st Century Research Fund	**29,681**	**40,040**	**44,908**	**51%**	**12%**

NA = Not applicable.
[1] Includes funding from multiple functions.
[2] Does not include Manufacturing Extension Partnership.

functions, the Research Fund serves as an effective tool to ensure that complementary disciplines are funded consistent with a balanced portfolio of research activity. The Research Fund also focuses on basic research and strengthening university-based research. During this Administration, funding for programs in the 21st Century Research Fund has grown 52 percent from $29.7 billion in 1993 to $44.9 billion in 2001. During this same period, funding support for universities grew to nearly $16.4 billion in 2001, a 40-percent increase since 1993.

This Administration also promoted high-priority multiagency science and technology initiatives in strategic areas important to the future of the Nation. These efforts include investments in information technology research, nanotechnology, global change, climate change technologies, and the next-generation of fuel-efficient, environmentally-smart vehicles. These priority areas hold great promise for breakthroughs that are revolutionary, that drive the economy and that likely will change the way we think and live.

Within the general science, space, and technology function, the Federal Government supports areas of cutting-edge science and technology, through the National Aeronautics and Space Administration (NASA), NSF, and DOE. The activities of these agencies contribute to greater understanding of the world in which we live, ranging from the edges of the universe to the smallest imaginable particles, and to new knowledge that may have applications that improve our lives. Each of these agencies fund the construction and operation of major scientific facilities on Earth or in space for multiple users. These agencies also contribute to the Nation's cadre of skilled scientists and engineers. A description of the accomplishments during the Clinton-Gore Administration for NASA, NSF, and DOE follows.

National Aeronautics and Space Administration

NASA is 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. NASA pursues this vision through investments in five enterprises (Space Science, Earth Science, Biological and Physical Research, Aero-Space Technology, and Human Exploration and Development of Space) and missions to carry out these activities.

Space Science: Space Science programs are designed to enhance our understanding of the possible existence of life beyond Earth, the fundamental rules that governed the creation and evolution of our universe and its galaxies, stars, planets and life, and how changes in the Sun can affect Earth. Highlights of Space Science mission accomplishments during this Administration include:

- Using images from NASA's Mars Global Surveyor spacecraft, scientists discovered new geological features suggesting the existence of large sources of liquid water at or near the surface of Mars. This discovery, combined with microscopic evidence of possible bacterial fossils in Martian meteorites, revolutionized scientific views on the potential for life on Mars.
- Using images and other data from NASA's Galileo mission to Jupiter, scientists discovered evidence which strongly suggests that Jupiter's moon, Europa, harbors a subterranean ocean beneath its icy crust, further extending possible abodes for life elsewhere in our solar system.
- Astronomers funded by NASA and NSF discovered the first scientific evidence that planets exist in other star systems. Astronomers have identified approximately 50 stars that have evidence of planetary companions to date.
- On July 4, 1997, NASA successfully landed the Mars Pathfinder spacecraft and its Sojourner rover on Mars. The Pathfinder mission garnered worldwide interest, with almost one billion "hits" on Pathfinder's web site. The cost of the Pathfinder mission was one-sixth that of one of NASA's Viking missions that landed on Mars in 1976.
- NASA's Hubble Space Telescope took images of the most distant parts of our universe yet seen. Calculations of the distance to some faraway galaxies based on Hubble data show that our universe is expanding faster than previously understood and

have led to new theories about an unidentified energy source that is driving the expansion of our universe.

Earth Science: Earth Science programs 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. These observations provide data for refining scientific models of the Earth system that inform global climate change decision-making. Highlights of Earth Science accomplishments during this Administration include:

- NASA moved its Earth Observing System series of remote sensing satellites from planning to operation by launching Terra, the first satellite in the series, in 2000. Using data from Terra, scientists will continue to study the Earth's climate, atmosphere, oceans, land cover, and ecosystems. NASA scientists have already discovered that the growing season in Canada and Siberia increased by about one week during the 1980's, perhaps evidence of climate warming due to human influence.

- Researchers continuously tracked the waxing and waning of the El Nino phenomenon from space for the first time using NASA's Ocean Topography Experiment mission. Scientists funded by NASA and NOAA uncovered the mechanics of El Nino and will be better able to predict how future El Ninos influence rainfall levels throughout the world.

- The Tropical Rainfall Measurement Mission, a partnership between NASA and its sister agency in Japan, made the first accurate measurements of rainfall over global tropical regions. By combining these measurements with wind data from NASA's QuikSCAT mission, scientists improved models for predicting when and where a hurricane will hit land.

- NASA's Total Ozone Mapping Spectrometer tracked the annual shrinkage and growth of the areas of depleted ozone over the Earth's poles. Ozone is a key chemical in the Earth's atmosphere that blocks dangerous ultraviolet radiation from the Sun. Researchers believe certain man-made chemicals create these "ozone holes".

Biological and Physical Research: Biological and Physical Research programs conduct experiments in physics, chemistry and biology to understand how the unique conditions of the space environment affect living organisms and fundamental science phenomena. Using this information, scientists hope to reduce the risks of long-duration human spaceflight and gain new insights into biology, materials, and processes that can improve life on Earth. Highlights of Biological and Physical Research accomplishments during this Administration follow.

- A NASA researcher used a novel new state of matter called a Bose-Einstein condensate to create an "atom laser" that generates an intense beam of coherent atoms. The step from ordinary atomic beams to atom lasers is analogous to the step from the light bulb to the optical laser. The atom laser might replace conventional atomic beams and provide greater precision in atomic clocks and for tests of the fundamental laws of physics. Ultimately, it might lead to high-resolution atom deposition on surfaces for the fabrication of novel materials and nanostructures.

- NASA researchers developed the rotating bioreactor to enable the growth and study of tissue cultures in three dimensions, both in space and on the ground. The bioreactor enables tissue research in an environment that mimics the human body with much more fidelity than previous research methods. This technology has allowed a NASA/NIH team to conduct the first laboratory study of HIV inside human lymphoid tissue, allowed research on three-dimensional prostate and ovarian cancer tumors outside the body, and is enabling tissue engineering applications for cartilage, heart, liver, kidney, and other tissues for research and commercial development.

- NASA-funded scientists achieved new understanding of the phenomenon of neural plasticity by studying the rapid and apparently reversible dynamic changes in the brain as it adjusts to weightlessness in space. This work helped to reverse a long-held belief that cells in the adult central nervous system could not grow and adapt.

Continued research to identify the molecular mechanisms responsible for neural plasticity is expected to improve astronaut health and safety, and NASA is working with NIH to improve medical care for balance and postural disorders on Earth.

Aero-Space Technology: Aero-Space Technology programs work with the private sector to develop and test new technologies and experimental vehicles that promise to reduce the cost of access to space, improve space transportation capabilities, and support revolutionary new generations of spacecraft. Highlights of Aero-Space Technology accomplishments during this Administration include:

- NASA and industry developed and test-fired two new, revolutionary rocket engines, the XRS-2000 linear aerospike engine and the M-1 Fastrac engine. The engines may power future, low-cost launch vehicles.
- NASA and industry completed assembly and conducted ground and captive carry flight tests of the X-34 experimental test vehicle. The X-34 is aimed at demonstrating low-cost, fast-turnaround launch operations.

Human Exploration and Development of Space: Human Exploration and Development of Space programs provide human access to space on the Space Shuttle, develop and operate research platforms like the International Space Station, use human skills and expertise in space to conduct science and test new technologies, and support the development of space including new space applications. Highlights of Human Exploration and Development of Space accomplishments during this Administration include:

- NASA moved the International Space Station from a design plan with no hardware built to development, launch, and operation. In 1998, the first element of the International Space Station reached orbit, and in 2000 it received its first three-person crew, beginning permanent human occupancy. Most of the U.S. flight elements needed to finish assembly are now at the launch site.
- Through the Space Flight Operations Contract, NASA successfully consolidated 21 Space Shuttle contracts under a single prime contractor, reducing the Space Shuttle budget from $3.7 billion in 1992 to $3.0 billion in 2000, and safely flew 48 flights.
- NASA implemented Space Shuttle upgrades including the Super Lightweight Tank, the Alternate Turbo-Pump, and the Large-Throat Main Combustion Chamber to improve Shuttle safety by a factor of six and increase performance to the Space Station by more than two-thirds.

National Science Foundation

As the only agency of the Federal Government exclusively devoted to supporting basic scientific and engineering research and education, NSF has emerged as a leader and steward of the Nation's science and engineering enterprise. While NSF represents nearly four percent of Federal research and development spending, it supports more than half of the non-medical basic research conducted at academic institutions. NSF categorizes its investments in three strategic areas: people, ideas, and tools. Investments in these areas work in concert to support the agency's mission to maintain U.S. leadership in all aspects of science and engineering research and education. During this Administration, NSF funding increased by 61 percent from $2.7 billion in 1993 to $4.4 billion in 2001.

People: NSF is committed to facilitating the creation of a diverse, internationally competitive and globally-engaged work force of scientists, engineers and well-prepared citizens. Although only about 20 percent of NSF's annual budget is categorized as an investment in the "people" category, in actuality, every dollar NSF spends is an investment in people. Significant highlights of NSF funding for people during this Administration include:

- 36 Nobel Prizes awarded since 1993 recognize work supported by NSF (13 in Physics, nine in Chemistry, eight in Economics, and six in Physiology or Medicine). Six of the Nobel Laureates selected since 1993 began their graduate science careers as NSF Graduate Research Fellows.
- Bill Nye the Science Guy, an NSF-supported television series, received several Emmy awards including Outstanding Chil-

dren's Series. This informal education show promotes increased comprehension and application of science facts and concepts among its viewers.

- The Louis Stokes Alliances for Minority Participation program significantly increased the number of baccalaureate degrees earned by students from underrepresented groups. For example, the Florida/Georgia alliance has tripled the production of science and engineering baccalaureate degrees earned by underrepresented minorities in those States from 416 per year to 1,380 per year.

Ideas: Investments in ideas support cutting edge research that yields new and important discoveries and promotes the development of new knowledge and applications. More than half of NSF's annual budget is categorized as an investment in ideas. This includes support for individuals and small groups devoted both to disciplinary and cross-disciplinary research. Also included is funding for centers that address scientific and engineering questions and research problems that require long-term, coordinated efforts of many researchers. Significant highlights of NSF funding for ideas during this Administration follow.

- Scientists supported by NSF completed the first DNA genome sequence of the model plant, *Arabidopsis,* which will provide new information about chromosome structure, evolution, intracellular signaling, and disease resistance in plants. Among early findings is that this flowering plant has closely related versions of many human disease genes. That discovery is already offering clues about why certain human diseases produce the symptoms they do. It suggests that plants may eventually be useful not only as a source of novel medicines, but also as screening tools for testing the potential usefulness of experimental drugs.

- Clinical trials that have significantly improved detection of early stage cervical cancer were developed after an NSF-funded researcher demonstrated that fluorescence spectroscopy could be used to detect pre-cancerous cells.

- NSF-funded scientists uncovered the structural basis that explains a virus' ability to force host cells to manufacture the virus' own protein. This is important for understanding retroviruses, which are responsible for causing many cancers in vertebrates.

- NSF-funded scientists have made important contributions to our understanding of global climate change, including demonstrating that 1997, 1995, and 1990 were the warmest years since 1400 A.D. They also have shown that the 1990s were the warmest decade in the last 1000 years and that human-induced increases in greenhouse gases appear to be the dominant factor in the warming seen during the 20th Century.

Tools: Nearly 25 percent of NSF's annual budget is categorized as an investment in state-of-the-art tools for research and education, such as instrumentation and equipment, multi-user facilities, digital libraries, research resources, accelerators, telescopes, research vessels and aircraft and earthquake simulators. In addition, resources support large surveys and databases as well as computation and computing infrastructures for all fields of science, engineering, and education. Significant highlights of NSF funding for tools during this Administration include:

- The NSF Supercomputer Centers Program, and its Partnerships for Advanced Computational Infrastructure successor, have led the way in adding computational modeling to theory and experiment as means for developing scientific understanding. These centers have changed the way scientific phenomena are analyzed, modeled, and visualized.

- Two recently completed Gemini Telescopes will be used to help answer questions about how stars and planets form, the structure and evolution of the Milky Way and other galaxies, and the age and evolution of the universe. Images are among the sharpest ever obtained by a ground-based telescope, roughly the equivalent of resolving the separation between a set of auto headlights from 2,000 miles.

- The Laser Interferometer Gravitational-Wave Observatory project began as a collaboration between physicists and engineers to test the dynamical features of Einstein's theory of gravitation and to study the properties of intense gravitational fields from their radiation. Scientists eventually may be able to identify objects in deep space that cannot be "seen" from energy given off in the form of light, X-rays or other electromagnetic radiation.

Department of Energy

DOE's Office of Science is the single largest supporter of basic research in the physical sciences, averaging 40 percent of all Federal funds in this area over the past decade. The Office supports research at both universities and DOE's national laboratories across such varied disciplines as physics, chemistry, materials science, geology, environmental sciences, biology, applied mathematics, and computer science. Brief highlights of the Office of Science discoveries during this Administration follow.

- DOE, which began the Human Genome Project, is now finishing the human genetic map along with its two major partners, NIH and Britain's Wellcome Trust. DOE researchers completed a draft sequence of three of the 23 pairs of chromosomes in the human genome. The Human Genome Project has driven significant public and private developments in sequencing technology. As a result, the cost of sequencing a single base pair has fallen by more than a factor of 1,000. It is now practical to sequence the entire genome of a large number of organisms. To date, DOE has completed sequencing the genomes of 17 microbes with the genomes of another 28 microbes in various stages of completion.

- Researchers using the Lawrence Berkeley Laboratory's 88-inch cyclotron have extended the periodic table by discovering two new superheavy elements. International teams of researchers working at DOE's Fermilab have nearly completed the Standard Model of particle physics with the discovery of the top quark and detection of the tau neutrino. These accomplishments bring the total discoveries by DOE and its predecessor agency to 18 of the periodic table's 27 man-made elements and 11 of the Standard Model's 12 constituents of matter.

- DOE researchers were the first to use positron emission tomography (PET) to create functional images of the human brain at work. This has opened up exciting new opportunities in brain research. DOE has a long history of achievements in advanced imaging technologies, including the development of PET.

- Three Nobel Prizes in chemistry and two Nobel Prizes in physics awarded since 1993 recognize work supported by DOE's Office of Science or its predecessor agencies. Examples of the prize-winning work include an explanation of how cells store and release energy in the form of adenosine triphosphate, the discovery of fullerenes, and the development of neutron scattering techniques. Fullerenes, cage-like forms of pure carbon, are the basis of an entirely new area of chemistry and are playing important roles in nanoscience. Neutron scattering is an important tool for studying a wide range of economically and scientifically important materials.

- DOE science is improving our understanding of the role of ecosystem processes in the global carbon cycle. New measurements from the DOE Ameriflux network have demonstrated how the exchange of carbon dioxide between vegetation and the atmosphere varies among seasons, and by region and ecosystem. They have also shown that some ecosystems previously thought to be carbon "sources" are actually storing carbon dioxide in the biosphere.

The Office of Science also constructs and operates the Federal Government's most extensive system of R&D facilities. These include particle and nuclear physics accelerators, synchrotron light sources, neutron scattering facilities, supercomputers, and the high-speed networks that connect scientists and their data. Each year, DOE's facilities are used by more than 15,000 researchers from universities, other Government agencies and private industry. Highlights of the Office of Science's facility-related accomplishments during this Administration follow.

- Since 1993, the Office of Science has completed, on time and within budget, construction of the Advanced Photon Source, the Advanced Light Source, the Main Injector at Fermilab, the B-Factory at Stanford, the Relativistic Heavy Ion Collider, the Continuous Electron Beam Accelerator Facility, and the Environmental Molecular Sciences Laboratory. The National Spherical Torus Experiment, a fusion experimental facility, was completed below cost and ahead of schedule. Construction of these facilities represents an investment of more than $2.6 billion.

- This Administration's Scientific User Facilities Initiatives in 1996 and 2001 have helped to dramatically increase the effectiveness and productivity of DOE's facilities. As an example, DOE's light sources now serve more than twice the total number of users and four times as many users from the life sciences as they did in 1993. Structural biologists are now producing better than seven times as many protein structures in a year using synchrotron light sources as they were in 1993.

- The Office of Science installed the first supercomputer available to the civilian research community to exceed the one teraflop peak performance and supported the development of the first civilian scientific application to achieve over one teraflop actual performance.

Tax Incentives

Along with direct spending on R&D, the Federal Government has used tax preferences to encourage private investment in research. Current law provides a 20-percent research tax credit for research and experimentation expenditures above a certain base amount. The Tax Relief Extension Act of 1999 extended the credit from July 1, 1999, thorough June 30, 2004. In addition, the 1999 Act increased by one percentage point the credit rate applicable under the alternative incremental research credit, and expanded the definition of qualified research to include research undertaken in Puerto Rico and possessions of the United States. A permanent tax provision also lets companies deduct, up front, the costs of certain kinds of research and experimentation, rather than capitalize these costs. During this Administration, tax credits and other preferences for R&D increased 133 percent from $3.3 billion in 1993 to $7.7 billion in 2001.