Tools

In pursuit of its mission to provide a widely accessible, state-of-the-art science and engineering infrastructure, NSF invests in Tools. NSF provides support for large, multi-user facilities, which provide access to state-of-the-art facilities essential to the progress of research. Support for these unique national facilities is necessary to advance U.S. capabilities required for world-class research. NSF also invests in Internet-based and distributed user facilities, advanced computer resources, research networks, major research instrumentation, research resources, digital libraries, and large databases, all of which contribute to a state-of-the-art science and engineering infrastructure resource. Facilities and resources supported are shown in the table below:

(Millions of Dollars)

	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate
Academic Research Fleet	44	57	60
Advanced Networking Infrastructure	44	45	44
Gemini Observatories	8	9	11
Incorporated Research Institutions for Seismology	12	13	13
Laser Interferometer Gravitational Wave Observatory	21	19	24
Major Research Equipment	105	121	96
Major Research Instrumentation	50	75	50
National Astronomy Centers (including ALMA)	71	86	91
National Center for Atmospheric Research	70	73	72
National SMETE Digital Library	16	27	27
Ocean Drilling Program Facilities	30	31	31
Partnerships for Advanced Computational Infrastructure	71	71	71
Polar Science, Operations and Logistics	193	197	197
Research Resources	112	125	122
Other Tools[1]	109	114	116
Total, Tools	$955	$1,061	$1,024

Totals may not add due to rounding.

[1] Includes physics, materials research, ocean sciences, atmospheric sciences, and earth sciences facilities, CESR, the National High Field Mass Spectrometry Center, the MSU Cyclotron, the National High Magnetic Field Laboratory (NHMFL), the Science and Technology Policy Institute, Science Resource Studies, and the National Nanofabrication Users Network.

The FY 2002 Request for tools totals $1,024 million, a $37 million decrease from FY 2001. Operations and maintenance of multi-user facilities and research resources are funded through the Research and Related Activities (R&RA) and the Education and Human Resources (EHR) accounts; major construction projects are funded through the Major Research Equipment (MRE) account.

Academic Research Fleet

The Academic Research Fleet includes ships, submersibles and large shipboard equipment necessary to support NSF-funded research and the training of oceanographers. Twenty-eight ships are included in the U.S. academic fleet, and are operated on behalf of the research community primarily through NSF funding. Large ships are used for distant-water, expeditionary projects such as global change research; intermediate-sized ships support individual investigator research; and smaller regional ships are available for local and coastal research. Special purpose ships are used for submersible and remotely operated vehicle studies. NSF's FY 2002 support for the Academic Research Fleet totals $59.90 million, a $2.70 million, or 4.7 percent, increase over FY 2001 to provide the resources necessary for enhanced research in fields related to biocomplexity and planetary dynamics.

Advanced Networking Infrastructure (ANI)

ANI activities enable and expand scholarly communication and collaboration by providing researchers and educators with network access to high performance, remote scientific facilities including supercomputer facilities and information resources. The very high performance Backbone Network Service (vBNS), now in a three-year no cost extension phase, together with the high performance connections program, have led to the development of a new level of networking for the nation's research universities, including the UCAID/Internet2 operated network Abilene. ANI participates in the interagency Next Generation Internet activity to complement the university-led Internet2 effort jointly supported by the participating universities and the private sector. In the Next Generation Internet program, ANI focuses on advanced, high performance network connectivity between research institutions and contributes to the basic infrastructure for high-end research applications. NSF's FY 2002 support for ANI facilities is $43.91 million, a decrease of $800,000, or 1.8 percent, from FY 2001.

Gemini Observatories

The two Gemini Telescopes will offer world class capabilities and unique opportunities to the scientific community. In particular, these telescopes are optimized for operation in the infrared region and will be able to use adaptive optics, which at these wavelengths will provide a resolving power almost twice that of the Hubble Space Telescope. The northern telescope, located on Mauna Kea in Hawaii, achieved first light in December 1998 and began operations on schedule in July 2000. First light at the southern observatory at Cerro Pachon, Chile was achieved in November 2000. Normal science operations are expected to commence at the Chilean site in FY 2001. The FY 2002 Budget Request includes $11.0 million for the Gemini Observatories, $2.37 million over FY 2001, with an emphasis on support for operations at the two sites.

Incorporated Research Institutions for Seismology (IRIS)

IRIS was created in 1986 to install and operate a global network of seismometers, provide portable seismometers for regional studies, and establish a data management system to provide on-line, distributed access to data on global seismic activity. The IRIS facility serves the needs of the national and international seismology community by making available seismic sensors and data acquisition systems.

In addition, a portion of the Global Seismic Network operated by IRIS is an integral component of the nation's nuclear test ban treaty monitoring capabilities. NSF's FY 2002 support for IRIS totals $12.80 million, an increase of $200,000, or 1.6 percent, over FY 2001.

Laser Interferometer Gravitational-Wave Observatory (LIGO)

The LIGO construction project began in FY 1992 as a collaboration between physicists and engineers at the California Institute of Technology and the Massachusetts Institute of Technology to test the dynamical features of Einstein's theory of gravity and to study the properties of intense gravitational fields from their radiation. Today, several other institutions are also involved. LIGO consists of identical but widely separated detectors, one in Hanford, Washington and the other in Livingston, Louisiana, that will be used for fundamental physics experiments to directly detect gravitational waves and gather data on their sources. In FY 2002, $24.0 million is requested, an increase of $4.9 million, in accordance with the funding schedule for LIGO operations.

Major Research Equipment (MRE)

(Dollars in Millions)

	FY 2000 Actual	FY 2001 Current Plan	FY 2002 Request
Atacama Large Millimeter Array R&D	8.0	6.0	--
HIAPER	8.5	12.5	--
Large Hadron Collider	15.9	16.4	16.9
Network for Earthquake Engineering Simulation	7.7	28.1	24.4
Polar Support Aircraft Upgrades	12.0	--	--
South Pole Station	16.9	13.5	--
Terascale Computing Systems	36.0	44.9	55.0
TOTAL, MRE	$105.0	$121.3	$96.3

Totals may not add due to rounding.

A total of $96.30 million is requested through the MRE account for three ongoing projects:

- Large Hadron Collider (LHC) is planned to be the world's highest energy accelerator facility. NSF participation includes contributing to the construction of two high energy particle detectors, ATLAS (A Toroidal Large Angle Spectrometer) and CMS (the Compact Muon Solenoid). Continued funding of $16.90 million is requested in FY 2002.

- Network for Earthquake Engineering Simulation (NEES) will upgrade, modernize, expand and network major facilities including shake tables used for earthquake simulations, large reaction walls for pseudo-dynamic testing, centrifuges for testing soils under earthquake loading, and field testing facilities. Continued funding of $24.40 million is requested in FY 2002.

- Terascale Computing Systems will provide access to scalable, balanced, terascale computing resources for the broad-based academic science and engineering community served by NSF. Requested funding for Terascale facilities totals $55.0 million in FY 2002.

NSF is not requesting additional funds in FY 2002 for four projects, the Atacama Large Millimeter Array Research and Development Project (ALMA R&D), the High-performance Instrumented Airborne Platform for Environmental Research (HIAPER), the Polar Support Aircraft Upgrades and the South Pole Station Modernization program. Maintenance of the ALMA infrastructure is funded in the R&RA account. Funding for the Polar Support Aircraft Upgrades and the South Pole Station Modernization program is completed. No new starts are proposed. Additional information can be found in the MRE section.

Major Research Instrumentation (MRI)

The Major Research Instrumentation Program is designed to improve the condition of scientific and engineering equipment for research and research training in our nation's academic institutions. This program seeks to improve the quality and expand the scope of research and research training in science and engineering, and to foster the integration of research and education by providing instrumentation for research-intensive learning environments. In FY 2002, NSF requests $50.0 million, a decrease of $24.83 million from FY 2001, for continued support of the acquisition and development of research instrumentation for academic institutions.

National Astronomy Centers

The three National Astronomy Centers receive approximately 93 percent of their funding from NSF. The FY 2002 Request includes $102 million (including support for Gemini):

The main facility of the National Astronomy and Ionosphere Center (NAIC) is the 305-meter-diameter radio and radar telescope located at Arecibo, Puerto Rico. NAIC is a visitor-oriented national research center devoted to scientific investigations in radio and radar astronomy and atmospheric sciences. NAIC provides telescope users with a wide range of research and observing instrumentation, including receivers, transmitters, movable line feeds, and digital data acquisition and processing equipment. A major upgrade to the radio telescope and radar was recently completed. The FY 2002 Request includes $9.40 million for NAIC, $720,000 less than FY 2001, and emphasis will be on extending the high frequency capabilities of the upgraded telescope.

The National Optical Astronomy Observatories (NOAO) provide for research in ground-based optical and infrared astronomy. NOAO includes Kitt Peak National Observatory, outside Tucson, Arizona; Cerro Tololo Inter-American Observatory, in Chile; and the National Solar Observatory, in Arizona and New Mexico, and the U.S. Gemini Office which provides support for U.S. astronomers to use the Gemini Observatory. Large optical telescopes, observing equipment, and research support services are made available to qualified scientists. In FY 2002, the Global Oscillation Network Group (GONG) at NOAO will continue monitoring small-scale oscillations of the sun, permitting studies of the sun's interior structure. The instrumentation for the Synoptic Optical Long-term Investigation of the Sun (SOLIS) will continue refined studies of the Sun's atmosphere and surface, including determining conditions which give rise to solar flares. The FY 2002 Request includes $32.02 million for NOAO, $1.50 million over FY 2001.

The National Radio Astronomy Observatory (NRAO) is headquartered at Charlottesville, Virginia, and operates radio telescopes at sites in Arizona, New Mexico, and West Virginia. NRAO makes radio astronomy facilities available to qualified visiting scientists and provides staff support for use of the large radio antennas, receivers, and other equipment needed to detect, measure, and identify radio waves from astronomical objects. In FY 2001, the Green Bank Telescope in West Virginia will transition from commissioning to operations. Following a one-time increment in FY 2001 that enabled major improvements in facilities infrastructure and attention to deferred maintenance, the FY 2002 Request includes $40.13 million for NRAO operations, $5.30 million less than FY 2001.

The FY 2002 Request also includes an additional $9.0 million for the Atacama Large Millimeter Array (ALMA). Funding within the Major Research Equipment Account for Phase I of this project was completed in FY 2001. In FY 2002, funds provided through the Astronomy Subactivity will maintain the established infrastructure for this project while consideration of the Phase II construction project continues. This is a proposed international project being undertaken in partnership with the European, Canadian and possibly Japanese communities.

National Center for Atmospheric Research (NCAR)

NCAR facilities serve the entire atmospheric sciences research community and part of the ocean sciences community. Facilities available to university, NCAR, and other researchers include an advanced computational center providing resources and services well suited for the development and execution of large models and for the archiving and manipulation of large data sets. NCAR also provides research aircraft, which can be equipped with sensors to measure dynamic physical, and chemical states of the atmosphere. In addition, one airborne and one portable ground-based radar system are available for atmospheric research as well as other surface sensing systems. Roughly 30 percent of the funding for NCAR is provided by non-NSF sources. In FY 2002, more than 1,500 researchers and students will use the facilities and approximately 150 visiting scientists will stay for extended periods. NSF's FY 2002 support for NCAR totals $71.90 million, a decrease of $750,000, or 1.0 percent, from FY 2001.

National SMETE Digital Library

A National SMETE Digital Library (NSDL) responds to needs articulated by the NSF, the academic community, and corporate leaders for accelerating much needed improvements in science, mathematics, engineering, and technology education (SMETE). The NSDL, capitalizing on recent developments in digital libraries, will provide: a forum for the merit review and recognition of quality educational resources; a mechanism for electronic dissemination of information about high-quality educational materials, pedagogical practices, and implementation strategies; a centralized registry and archive for educational resources; and a resource for research in teaching and learning. In addition, the NSDL will provide an infrastructure to support and accelerate the impact of NSF programs. For example, developers of curricula and courses will benefit from awareness and knowledge of extant instructional materials, as well as information on their implementation. NSF support for the NSDL in FY 2002 will total $26.80 million, a decrease of $350,000, or 1.3 percent, from FY 2001.

Ocean Drilling Program Facilities

The Ocean Drilling Program is a multinational program of basic scientific research in the oceans which uses drilling and data from drill holes to improve fundamental understanding of the role of physical, chemical, and biological processes in the geological history, structure, and evolution of the oceanic portion of the Earth's crust. Operational support for this activity is shared by seven international partners, comprising 20 countries. NSF's FY 2002 support for Ocean Drilling Program facilities totals $31.0 million, an increase of $500,000, or 1.6 percent, over FY 2001.

Partnerships for Advanced Computational Infrastructure (PACI)

Partnerships for Advanced Computational Infrastructure provides access to, and support for, high-end computing for the national scientific and engineering community, and the development and application of the necessary software, tools and algorithms for use on scalable, widely distributed resources. The $70.71 million requested in FY 2002 will permit the PACI program, now in its fourth year, to continue the era of terascale computing. In FY 2002, emphasis will be on scaling additional applications' codes to be ready for transitions to the Terascale Computing Systems. Archiving and visualization of very

large data resources will continue to be crucial to support research in disciplinary areas. The education, outreach and training component of PACI will continue to broaden and accelerate the capability of the nation to utilize the advanced computational capabilities being developed.

Polar Science Operations and Logistics

NSF's FY 2002 support for Polar Science Operations and Logistics totals $197.31 million. Polar facilities make research possible in the remote and hazardous Antarctic continent, where all infrastructure must be provided. In accord with U.S. Antarctic policy, three year-round Antarctic research stations are operated and maintained — McMurdo Station on Ross Island, Palmer Station on Anvers Island, and Amundsen-Scott South Pole Station. In addition, necessary facilities include ski-equipped and fixed-wing aircraft, helicopters, research vessels (including a specially constructed ice-breaking research vessel), and an ice-strengthened supply and support ship. Logistical support for polar facilities is supplied in part by the Department of Defense. These facilities support research activities sponsored by NSF, NASA, DOI/USGS, DOC/NOAA, DOE and DOD.

Arctic facilities include camps and sites for studies of greenhouse gases, monitoring stations for research on ultra-violet radiation, ice coring sites for studies of global climate history, high latitude radar observatories and magnetometers for upper atmospheric research, use of the U.S. Coast Guard Cutter Healy, and the use of a vessel from the academic research fleet for oceanographic research in the Arctic Ocean.

Research Resources

Research Resources supports a range of activities throughout the Research and Related Activities account including: multi-user instrumentation; the development of instruments with new capabilities, improved resolution or sensitivity; upgrades to field stations and marine laboratories; support of living stock collections; facility-related instrument development and operation; and the support and development of databases and informatics tools and techniques. These various resources provide the essential platforms and tools for effective research in all areas of science and engineering. In FY 2002, funding for Research Resources decreases $3.35 million to a total of $121.56 million.

Other Tools

This category includes:

- Science resources studies are a vital tool for researchers and policymakers, providing them with data and information that is the basis for the making of informed decisions and policy formulation about the nation's science, engineering and technology enterprise. The primary statistical series produced by the Division of Science Resources Studies include the education and employment of scientists and engineers and the performance and financial support of research and development;

- Funding for the operations of the recently upgraded National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University;

- Continued support for the operation and maintenance of the newly upgraded Cornell Electron Storage Ring (CESR) at Cornell University;

- Support for the Science and Technology Policy Institute to provide analytical support to the Office of Science and Technology Policy (OSTP) to identify near-term and long-term objectives for research and development, and identify options for achieving those objectives;

- An increment of $3.50 million to strengthen support for user programs and facilities at the National High Magnetic Field Laboratory (NHMFL), enabling the NHMFL to properly maintain and upgrade a unique set of continuous and pulsed-field magnets for users across a wide range of disciplines; and

- Continued support for the National Nanofabrication Users Network (NNUN), an integrated network of nanofabrication user facilities at Cornell University, Stanford University, Howard University, Pennsylvania State University, and University of California at Santa Barbara.

Other items within this category include facilities for physics, materials research, ocean sciences, atmospheric sciences, and earth sciences, and the National High Field FT-ICR Mass Spectrometry Center.

FY 2002 GPRA Performance Goals for Tools

Strategic Outcomes	No.	Annual Performance Goals[1] for Strategic Outcomes	FY 2002 Areas of Emphasis
TOOLS **Outcome Goal:** **To provide "broadly accessible, state-of-the-art information-bases and shared research and education tools."**	**III-3**	***NSF's performance for the Tools Strategic Outcome is successful when, in the aggregate, results reported in the period demonstrate significant achievement in the majority (4 of 6) of the following indicators:*** • Provision of facilities, databases or other infrastructure that enable discoveries or enhance productivity of NSF research or education communities; • Provision of broadly accessible facilities, databases or other infrastructure that are widely shared by NSF research or education communities; • Partnerships with other federal agencies, national laboratories, or other nations to support and enable development of large infrastructure projects; • Use of the Internet to make SMET information available to NSF research or education communities; • Development, management, or utilization of very large data sets and information-bases; and • Development of information and policy analyses that contribute to the effective use of science and engineering resources.	• Investments in Major Research Equipment (MRE) • Continued Investments in: ◦ Major Research Instrumentation (MRI) Program ◦ Science & Engineering information, reports, and databases ◦ Scientific databases and tools for using them ◦ National SMETE Digital Library

[1] These performance goals are stated in the alternate form provided for in GPRA legislation.

FY 2002 GPRA Performance Goals for Tools

Performance Area	No.	Annual Performance Goals for Successful Management
Construction and Upgrade of Facilities	**IV-9a**	For 90 percent of facilities, keep construction and upgrades within annual expenditure plan, not to exceed 110 percent of estimates.
	IV-9b	Ninety percent of facilities will meet all major annual schedule milestones by end of the reporting period.
	IV-9c	For all construction and upgrade projects initiated after 1996, when current planning processes were put in place, keep total cost within 110 percent of estimates made at the initiation of construction.
Operations and Management of Facilities	**IV-10**	For 90 percent of facilities, keep operating time lost due to unscheduled downtime to less than 10 percent of the total scheduled operating time.

Highlights (Tools)

High Technology Microscopes: NSF support of advances in microscope-related technology has resulted in the development of the confocal microscope and more recently, the development of both the "two-photon" and "near-field scanning optical" microscopes. Two-photon confocal microscopy has now become a standard component of laboratory instrumentation in the area of cell biology, and has resulted in a better understanding of the basic biological processes in both plants and animals. Moreover, the movement of confocal and two-photon microscopy from an experimental tool to commercial production has resulted in net gains for the U.S economy, as the market for high technology products is a worldwide market.

National Science, Mathematics, Engineering, and Technology Education Digital Library (NSDL): Substantial progress is being made in laying the groundwork for the NSDL. Key user services and supporting technical standards are being developed at the University of Missouri and the National Center for Atmospheric Research. A demonstration project at the University of California-Berkeley is integrating NSDL collections and services, and intellectual property rights management models are under development at Columbia University. Advanced user tools to map, visualize, and analyze collected data sets are being developed at Cornell University, and management tools for video content are being developed at Carnegie Mellon University. The teacherLIB project at Eastern Michigan University and the Virtual Teacher Resource Center at Ohio State are providing the information infrastructure and content for seamless access to high quality learning materials for pre- and in-service teachers.

National Nanofabrication Users Network (NNUN). The NNUN, established in 1994, is a national integrated network of nanofabrication user facilities at Cornell, Stanford, Howard, Pennsylvania State, and the University of California, Santa Barbara. This investment supports the national infrastructure and education needs for the burgeoning nanoscience and technology research field by providing access, on-site and electronically via the Internet, to advanced nano- and micro-fabrication capabilities for researchers in diverse disciplines in academe, industry and government. The NNUN facilities provide capabilities for advanced lithographic, etching, deposition and growth processes in a variety of materials, together with the expertise needed to fabricate nanometer-scale structures, custom devices, and circuits. Since its establishment, users from 29 states, 7 foreign countries, and over 50 start-up companies have used the facilities. The number of unique users has reached over 1,400, an increase of about 30% from the previous year. Significant growth has occurred in the external academic user base in emerging areas of biology and chemistry through outreach efforts to these communities.

Brain Image Database: Brain scans are an important tool for medical science, basic research and education, but this expensive technology is often out of reach for many institutions. A multidisciplinary team of cognitive neuroscientists, computer scientists, psychologists, and mathematicians has developed a repository for images of human brain scans that is available free to researchers and educators worldwide. The National Functional Magnetic Resonance Imaging (fMRI) Data Center has been established with a 5-year grant from NSF. The brain images come from fMRI results published in peer-reviewed journals. Once the data are received, all traces of personal identity information are removed and the image files are converted into a standard format. "Computational tools were essential to the triumph of the human genome project, and we want to bring this power into brain research," says Michael Gazzaniga, director of Dartmouth's Center for Cognitive Neuroscience. Researchers and educators with modest budgets will now have access to recent fMRI data.

Auto-Nowcaster. The Auto-Nowcaster system, jointly sponsored by the Federal Aviation Administration, the Department of the Army, the National Weather Service, and NSF under the U.S. Weather Research Program, provides one-hour nowcasts of thunderstorms and strong winds. The Sterling Virginia National Weather Forecast Office's severe storm warnings for 1998 were far moreaccurate than any previous year, and they give partial credit to the Auto-Nowcaster system for the improvement.

Partnerships for Advanced Computational Infrastructure (PACI): PACI researchers are creating innovative ways to harness computing power to solve heretofore unsolvable problems. Scientists at the National Computational Science Alliance (NCSA) located at the University of Illinois, along with scientists at the University of Iowa and Argonne National Laboratory, have demonstrated the power of combining computers at multiple locations. By linking over 1,000 computers from around the world-computers from five different vendors operating together as a single parallel computer-they solved a quadratic assignment that has been unsolved for over 30 years: to find the lowest cost assignment of facilities to locations that will minimize the cost of moving material flows. Quadratic assignment problems arise in such varied applications as locating factories, hospital layouts and designing computer chips.

Ultraviolet (UV) Monitoring Network. The National Science Foundation Ultraviolet (UV) Monitoring Network was established in 1987 by the NSF Office of Polar Programs in response to serious ozone depletion reported in Antarctica. The first instruments were installed in 1988 and the network has operated since then. The network was the first automated, high-resolution UV scanning spectroradiometer network in the world. It has been successfully operated in the harshest environments on Earth (Antarctica and the Arctic) and is currently providing data to researchers studying the effects of ozone depletion on terrestrial and marine biological systems. Network data is also used to develop and verify models of atmospheric light transmission and ozone depletion impacts. Data is available at no cost to all interested parties via CD-ROM or the Internet.

NSF's **Science Resources Studies** (SRS) responsible for the collection, dissemination and analysis of information on the nation's scientific and technical resources. SRS' primary statistical series include the education and employment of scientists and engineers and the performance and financial support of research and development. Users traditionally had obtained SRS information through publications and general-purpose databases. Recently, however, SRS' web site has become the main interface. These data provide a vital tool for researchers and policymakers. For example, the databases and website recently were utilized to inform the policy debate on H-1B visas for high-tech workers. The web site provides complete access to SRS publications, related reports and databases. The SRS databases are WebCaspar, an integrated database of statistical data dealing with science and engineering at U.S. academic institutions and SESTAT, an integrated system covering the employment of scientists and engineers in the nation.

Quieter Solid State Laser Patented Following LIGO Supported Development. The Laser Interferometer Gravitational-Wave Observatory (LIGO) provides 10W of single frequency light to measure the disturbance of LIGO's arm cavities caused by the passage of gravitational waves. LIGO's requirement for solid-state infrared lasers as ultra-stable light sources for each of its interferometers required teaming university laser scientists with industry. That teaming has now led to a new commercial product, the Lightwave 6000 laser (http://www.lightwaveelectronics.com/solutions/model_6000.htm) and a patent for a new laser stabilization technique by a LIGO industrial partner, Lightwave Electronics of Mountain View, California. The partnership has continued to develop improvements. One of the requirements of the project, the stringent amplitude (brightness) stability, led Lightwave to develop a new optical technique that uses a nonlinear optical parametric oscillator. This oscillator, for which Lightwave has a patent pending, offers a broadband suppression of amplitude noise. This development, which will help the next generation of LIGO detectors to meet their ever-tightening sensitivity goals, is expected to be of interest in industrial applications requiring quiet laser interferometry. For example, the oil industry uses low-noise laser-fiber interferometers to sense the presence of oil though variations in the propagation of induced seismic disturbances.