Tools

"To provide broadly accessible, state-of-the-art and shared research and education 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 allow researchers access to essential state-of-the-art facilities. Support for these unique national facilities is necessary to advance U.S. capabilities required for world-class research. NSF investments include 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 2001 Actual	FY 2002 Estimate	FY 2003 Estimate
Academic Research Fleet	59	60	62
Advanced Networking Infrastructure	45	48	47
Gemini Observatories	9	12	13
Incorporated Research Institutions for Seismology	13	13	13
Laser Interferometer Gravitational Wave Observatory	19	26	30
Major Research Equipment and Facilities Construction	119	139	126
Major Research Instrumentation	75	76	54
National Astronomy Centers	86	87	84
National Center for Atmospheric Research	73	78	75
National STEM Education Digital Library	28	28	28
Ocean Drilling Program Facilities	31	31	30
Partnerships for Advanced Computational Infrastructure	71	74	71
Polar Science, Operations and Logistics	210	219	223
Research Resources	104	106	106
Other Tools[1]	115	148	160
Total, Tools	$1,055	$1,145	$1,122

Totals may not add due to rounding.

[1] Includes computational sciences, physics, materials research, ocean sciences, atmospheric sciences, and earth sciences facilities, Cornell Electron Storage Ring (CESR), the National High Field Mass Spectrometry Center, the MSU Cyclotron, the National High Magnetic Field Laboratory (NHMFL), the Science and Technology Policy Institute (STPI), Science Resources Statistics (SRS), and the National Nanofabrication Users Network (NNUN).

The FY 2003 request for Tools totals $1,122 million, a $23.0 million decrease from FY 2002. 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 and Facilities Construction (MREFC) 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 2003 support for the Academic Research Fleet totals $62.0 million, a $2.10 million increase over FY 2002, to provide the resources necessary for enhanced research in fields related to biocomplexity and planetary dynamics.

Advanced Networking Infrastructure (ANI)

Advanced Networking Infrastructure (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 2003 support for ANI facilities is $46.62 million, a decrease of $980,000 from FY 2002.

Gemini Observatories

The two Gemini Telescopes, developed and operated through an international partnership with Chile, Canada, the United Kingdom, Brazil, Argentina and Australia, offer world-class capabilities and unique opportunities to the scientific community. In particular, these telescopes are optimized for operation in the infrared region and are able to use adaptive optics, which at these wavelengths 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. Science operations commenced at the Chilean site in FY 2001. The FY 2003 Budget Request includes $12.60 million for the Gemini Observatories, an increase of $340,000 over FY 2002, with an emphasis on support for operations at the two sites.

Incorporated Research Institutions for Seismology (IRIS)

Incorporated Research Institutions for Seismology (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 2003 support for IRIS remains at the FY 2002 level of $13.10 million.

Laser Interferometer Gravitational-Wave Observatory (LIGO)

The Laser Interferometer Gravitational Wave Observatory (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, many other institutions are also involved. LIGO consists of identical but widely separated detectors, one in Hanford, Washington, and the other in Livingston, Louisiana, that are used for fundamental physics experiments to directly detect gravitational waves and gather data on their sources. In FY 2003, $29.50 million is requested, an increase of $3.55 million over FY 2002, in accordance with the funding schedule for LIGO operations.

Major Research Equipment and Facilities Construction (MREFC)

(Millions of Dollars)

PROJECTS	FY 2001 Actual	FY 2002 Plan	FY 2003 Request
Atacama Large Millimeter Array (ALMA) Construction (Phase II)		12.50	30.00
Atacama Large Millimeter Array (ALMA) R&D (Phase I)	5.99		
EarthScope: USArray, SAFOD, PBO			35.00
High-Performance Instrumented Airborne Platform for Environmental Research (HIAPER)	12.47	35.00	
IceCube Neutrino Detector		15.00	
Large Hadron Collider (LHC)	16.36	16.90	9.72
Network for Earthquake Engineering Simulation (NEES)	28.14	24.40	13.56
National Ecological Observatory Network (NEON)[1]			12.00
South Pole Station	11.38		6.00
Terascale Computing Systems[1]	44.90	35.00	20.00
Total, Major Research Equipment and Facilities Construction (MREFC)	$119.24	$138.80	$126.28

Totals may not add due to rounding.
[1] An additional $3 million for NEON operations, and $7.0 million for Terascale operations, is funded through the R&RA Account in FY 2003.

A total of $126.28 million is requested through the MREFC Account to initiate two new projects and to support five ongoing projects. Requested funds total $47.0 million for the two new projects:

- EarthScope is planned as a distributed, multi-purpose geophysical instrument array that will make major advances in our knowledge and understanding of the structure and dynamics of the North American continent. The three components of the project are the USArray, the San Andreas Fault Observatory at Depth (SAFOD), and the Plate Boundary Observatory (PBO). Initial funding of $35.0 million is requested for this project.

- National Ecological Observatory Network (NEON) will be a continental scale research instrument consisting of 10 geographically distributed observatories, networked via state-of-the-art communications, for integrated studies to obtain a predictive understanding of the nation's environments. In addition, NEON will serve as a biological early detection system that will provide an

- invaluable resource and a front line of homeland defense - both for its scientific potential and for enabling rapid detection of chemical and biological terrorist threats. Initial funding of $12.0 million is requested for this project for proof of concept prototyping, and will support the initiation of construction and networking of two initial sites.

A total of $79.28 million is requested for the five ongoing projects:

- Atacama Large Millimeter Array (ALMA) Construction (Phase II) is the construction phase of the Atacama Large Millimeter Array project, supported in partnership through NSF; NRC (Canada); European Southern Observatory and CNRS (France), PPARC (UK), MPG (Germany), NFR(Sweden), NfRA (Netherlands); with the possible addition of Japan. ALMA is planned as a millimeter wave interferometer made up of 64 12-meter antennas and will be an aperture-synthesis radio telescope operating in the wavelength range from 3 to 0.4 mm. The research and development phase of this project will be completed in FY 2002 and construction initiated. Funding of $30.0 million is requested in FY 2003 to continue construction.

- Large Hadron Collider (LHC) is planned to be the world's highest energy accelerator facility. Funded in partnership with CERN (the European Organization for Nuclear Research) and DOE, 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), through cooperative agreements and subawards to over 50 U.S. universities. Continued funding of $9.72 million is requested in FY 2003.

- 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 $13.56 million is requested in FY 2003.

- South Pole Station will be expanded to provide support infrastructure and utilities for 150 people, versus the original capacity for 110. This will accommodate increased interest in science at the South Pole. Requested funding of $6.0 million in FY 2003 also includes revised estimates due to increased fuel costs and weather-related schedule delays of cargo shipments.

- 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 $20.0 million in FY 2003.

NSF is not requesting additional funds in FY 2003 for two projects: the High-performance Instrumented Airborne Platform for Environmental Research (HIAPER) and the IceCube Neutrino Detector. Initial operations support for NEON is funded through the R&RA account. Funding for the Polar Support Aircraft Upgrades is completed. Additional information can be found in the MREFC section.

In addition to funding requested through the MREFC Account, funds are being spent for early planning, design, research and development of potential future MREFC projects. Typically these early planning investments are funded within the Research and Related Activities Account. Whether these projects ever become formal candidates for the MREFC Account will be determined by a systematic planning and review process to determine their scientific merit, feasibility, and readiness. When possible, these projects are identified and discussed in the Tools section of each subactivity. Planned and incurred costs are identified through FY 2003. Since these projects are only in the early planning and development stages, they have not been prioritized.

Once a project has been submitted for MREFC funding, it must undergo a multi-phase review and approval process. The process begins with a review by the MREFC Panel, which makes recommendations to the NSF Director with attention to criteria such as scientific merit, importance, readiness and cost-benefit. The Director then selects candidates for National Science Board (NSB) consideration. The NSB then approves, or not, projects for inclusion in future budget requests.

The Director selects from the group of NSB-approved projects those appropriate for inclusion in a budget request to OMB, and after discussion with OMB, to the Congress. Hence, in addition to the seven MREFC projects for which funding is requested, there are several NSB approved projects for which NSF is not requesting additional funds in FY 2003. These are: the High-performance Instrumented Airborne Platform for Environmental Research (HIAPER), the IceCube Neutrino Detector, Rare Symmetry Violating Processes (RSVP), Ocean Observatories, and Scientific Ocean Drilling. These projects, including their costs, are further discussed in the MREFC section or in the Tools section of the cognizant activity.

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 foster the integration of research and education by providing instrumentation for research-intensive learning environments. In FY 2003, NSF requests $54.0 million, a decrease of $21.90 million from FY 2002, 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 2003 Request totals $96.93 million (including support for the U.S. share of operations for the International Gemini Observatory):

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 2003 request includes $9.0 million for NAIC, $400,000 less than FY 2002, with emphasis 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; the National Solar Observatory, in Arizona and New Mexico, and the U.S. Gemini Office that 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. Activities in FY 2003 include continued design planning for the Advanced Technology Solar Telescope (ATST), an instrument that will use new techniques such as adaptive optics, to investigate a wide range of questions in solar physics. The FY 2003 request includes $31.70 million for NOAO base funding, plus $4.0 million for the Telescope Systems Instrumentation Program (TSIP) through NOAO, an overall decrease of $1.0 million from FY 2002.

The National Radio Astronomy Observatory (NRAO) is headquartered in 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 2003, the Robert C. Byrd Green Bank Telescope will enter full science operations and the Very Large Array will continue to be improved with its planned program of enhancements and expansion. The FY 2003 request includes $39.63 million for NRAO operations, $800,000 less than FY 2002.

National Center for Atmospheric Research (NCAR)

National Center for Atmospheric Research (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 2003, more than 1,500 researchers and students will use the facilities and approximately 150 visiting scientists will stay for extended periods. NSF's FY 2003 support for NCAR totals $74.87 million, a decrease of $3.02 million from FY 2002.

National STEM Education Digital Library

A National STEM Education Digital Library (NSDL) responds to needs articulated by the NSF, the academic community, and corporate leaders for accelerating improvements in science, technology, engineering and mathematics (STEM) education. 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 2003 totals $27.50 million, a decrease of $960,000 from FY 2002.

Ocean Drilling Program Facilities

The Ocean Drilling Program is a multinational program of basic scientific research in the oceans that 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. Seven international partners, comprising 20 countries, share operational support for this activity. NSF's FY 2003 support for Ocean Drilling Program facilities totals $30.0 million, a decrease of $1.0 million from FY 2002.

Partnerships for Advanced Computational Infrastructure (PACI)

The Partnerships for Advanced Computational Infrastructure program 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. Funding for FY 2003 is requested at $71.49 million, a decrease of $2.42 million from FY 2002. In FY 2003, 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 2003 support for Polar Science, Operations and Logistics totals $222.77 million, an increase of $4.15 million over FY 2002. 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 2003, funding for Research Resources increases by $70,000, to a total of $106.36 million.

Other Tools

This category includes:

- Funding for Science Resources Statistics, a vital tool for researchers and policymakers, providing them with data and information that is the basis for making informed decisions and formulating policy about the nation's science, engineering and technology enterprise. The primary statistical series produced by the Science Resources Statistics Subactivity include the education and employment of scientists and engineers and the performance and financial support of research and development. NSF is requesting an additional $8.50 million for implementation of the extensive redesign and data collection of its samples and surveys, a decadal process necessary to reflect the results of the Decennial Census;

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

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

- Funding for the Science and Technology Policy Institute (STPI) 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 to identify options for achieving those objectives;

- Continued 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 computational sciences, physics, materials research, ocean sciences, atmospheric sciences, and earth sciences, the National High-Field FT-ICR Mass Spectrometry Center, and operations and maintenance of the Terascale Computing Centers.

FY 2003 GPRA PERFORMANCE GOALS (TOOLS)

Strategic Outcomes	No.	Annual Performance Goals for Strategic Outcomes[1] (Continued)	FY 2003 Areas of Emphasis	
			For investment in emerging opportunities:	For GPRA reporting, as relevant:
TOOLS **Outcome Goal: Providing "broadly accessible, state-of-the-art and shared research and education tools."**	III-3	***NSF's performance[2] for the Tools Strategic Outcome is successful when, in the aggregate, results reported in the period demonstrate significant achievement in the majority of the following indicators:*** Development or provision of tools[5] that enables discoveries or enhances productivity of NSF research or education communities; Partnerships with local, state or federal agencies, national laboratories, industry or other nations to support and enable development of large facilities or other infrastructure; Development or implementation of other notable approaches or new paradigms[6] that promote progress toward the TOOLS outcome goal.	Major Research Equipment and Facilities Construction (new investments): NEON, EarthScope, ALMA II Science Resources Statistics (SRS) Survey Redesign National STEM Education digital library	Major Research Equipment and Facilities Construction (current and former): e.g., ALMA I, LIGO, Gemini, LHC, NEES, SPSM, Terascale Computing Major Research Instrumentation (MRI) Program Science and Engineering policy analyses, information, reports and databases Scientific databases and tools for using them, including the National STEM Education digital library

1 These performance goals are stated in the alternate form provided for in GPRA legislation.
2 For individual programs, performance assessment in practice refers to a majority of relevant indicators only.
5 For example, includes research and education infrastructure such as large centralized facilities, or integrated systems of leading-edge instruments, or databases, or widely utilized, innovative computational models or algorithms, or information that provides the basis for a shared-use networked facility.
6 For example, broad-based, program-wide results that demonstrate success related to management/utilization of large data sets/information bases, or development of information and policy analyses, or use of the Internet to make STEM information available to NSF research or education communities, or exceptional examples of broadly accessible tools shared by NSF research and education communities.

Highlights of Recent Accomplishments (Tools)

Providing widely-accessible, state-of-the-art science and engineering infrastructure is an essential part of NSF's mission. Support for these unique national facilities is necessary to advance U. S. capabilities required for world-class research.

Partnerships for Advanced Computational Infrastructure (PACI): PACI researchers are creating a powerful new tool for using resources on the national "grid" of high-performance research networks. The Web-based portal grid will help computer scientists, and other scientists and engineers by simplifying and consolidating access to advanced computing systems supported by NSF. Representatives from the National Partnerships for Advanced Computational Infrastructure (NPACI), the National Computational Science Alliance (NCSA), the Pittsburgh Supercomputing Center, and NASA have conducted a series of workshops targeting specific technologies and resources to include in the effort. The portal will integrate these and additional new technologies, such as the Network Weather Service and the San Diego Supercomputing Center Storage Resource Broker. NPACI unites 46 universities and research institutions to build the computational environment for tomorrow's scientific discovery. PACI also provides support to NCSA, which is developing a prototype for an advanced computational infrastructure for the 21st Century. NCSA includes more than 50 academic, government and industry research partners from across the United States.

National Science, Technology, Engineering, and Mathematics Education Digital Library (NSDL): A collaborative project is being conducted by the University Corporation for Atmospheric Research (UCAR), Cornell University and Columbia University to develop the essential technical and organizational infrastructure to support the coordination and management of the digital library's distributed collections, as well as the design and implementation of core services. Overall project management and key community building and outreach efforts are being conducted through UCAR. Team members at Cornell have primary responsibility for development of the software and networking infrastructure, and team members at Columbia are responsible for sustainability plans and intellectual property and digital rights management issues. At the second annual NSDL All-Projects meeting in December 2001, a technical architecture was presented that supports a "spectrum of interoperability" across diverse collections and services, as well as an organizational basis for engaging the educational community in the building of the digital library. All projects of NSDL will be working toward an initial "launch" of the digital library in late Fall 2002.

Refurbishment of ALVIN with Plans for Replacement: The manned deep-sea research submersible operated by Wood's Hole Oceanographic Institute's National Deep Sea Submergence Facility underwent a major overhaul and recertification in 2001. The ALVIN, which began operating in 1964, has been an extraordinary tool for exploring the deep ocean. A design study for an ALVIN replacement with greater depth capabilities also was funded this year.

Advances in Nanotechnology: Scientists at Pennsylvania State University have developed a precise method for making nanoscale, closely-spaced metal wires. The process could speed miniaturization of electronic devices used for circuits, high-density data storage and sensors. The new process fabricated wires that range from 15-70 nanometers wide and a few micrometers long and are spaced 10 to 40 nanometers apart. Using organic molecules as "molecular rulers," scientists expanded the molecules into nano-scale structures with precise amounts of spacing between them, and then used those spaces as miniature molds for gold wires. The ability to create such precisely sized, parallel nano-wires is expected to be useful in the development of molecular electronics, in which molecules connected by such wires will serve as transistors, switches and other electronic devices. NSF, the Army Research Office (ARO), the Defense Advanced Research Projects Agency (DARPA), and the Office of Naval Research (ONR) funded this research. It was conducted at one of NSF's National Nanofabrication Users Network (NNUN)

facilities. NNUN provides research and industrial communities with infrastructure and equipment to make nanoscale devices in small quantities. NNUN focuses research on control of properties at the atomic-molecular level, their assembly into nanostructured materials, and the utilization of the improved materials as building blocks for engineering applications, such as thin films and coatings, advanced chemical catalysts, artificial biomaterials, and novel optoelectronic devices.

Scientists at Harvard University have pioneered an entirely new technique for manipulating matter at the nanoscale. The Harvard group uses a low-energy beam of ions (charged atoms) to poke tiny holes in thin films and membranes, producing structures that in turn may be used to make solid-state devices with a variety of applications ranging from nano-electronics to medicine. They call the technique "ion-beam sculpture" and have used it, for example, to fabricate a robust electronic detector capable of registering single DNA molecules in aqueous solution. Such detectors may find use in rapid sequencing of DNA for medical diagnostics and rapid drug design for large populations.

Researchers at Northwestern University have made a significant development in the use of nanotubes in fabricating a flat panel screen display. The prototype screen uses hundreds of thousands of stationary nanotubes, which emit electrons to light up pixels on the screen. Unlike a standard Cathode Ray Tube (CRT) screen, in which one electron beam emitted from a hot filament moves rapidly back and forth to light the pixels, each pixel is lit by its own electron beam. The screen can be slim, the emission steady. And the resolution is extremely high. Once nanotubes can be manufactured in bulk, large screens could be fabricated very cheaply without expensive lithographic techniques.

New Instrumentation for Antarctic Borehole Research: Several new instruments have been developed for glaciology: hot water ice-drilling equipment, ice-coring equipment, and borehole video equipment and methodology. The ice borehole video probe, built by the Jet Propulsion Laboratory, is an instrument that enables visual observation of ice rock material at depth in glaciers and ice sheets, accessed in water-filled boreholes drilled by the hot-water-jet ice drilling method. Borehole video will probably be of much importance in the exploration of Lake Vostok. Data recovered from these instruments has improved understanding of mechanisms of ice stream formation, implications for possible collapse of the West Antarctic ice sheet, and potential effects on sea level.

Icebreaker *Healy* Steams to Arctic on First Science Cruise to Study Crust Formation: Researchers funded by NSF sailed on the maiden scientific voyage of the U.S. Coast Guard's newest icebreaker to study one of the world's slowest growing oceanic ridges, with an eye to understanding how the Earth's crust forms. The USCGC *Healy*, outfitted as a scientific research vessel with input from NSF and the University-National Oceanographic Laboratory System (UNOLS), carried out the Arctic Mid-Ocean Ridge Expedition (AMORE) from late June until early October 2001. The *Healy* later sailed with the German research vessel Polarstearn to sample and study the Gakkel Ridge, a little known geological feature in the Atlantic Ocean. Among the important discoveries on this expedition were the recovery of fresh sulfides indicating hydrothermal vent presence in the Arctic Ocean, and an as yet unexplained "discontinuity" of volcanic activity along the Gakkel Ridge.

Internet Advancement through Network Middleware: Current networked applications are managed at the "endpoints" – all the functionality of applications is custom-built into applications that run over the simple services provided by the "best-effort" Internet. Middleware is a new software level for developing distributed applications; it will provide more convenient, high level services for networked applications such as network storage, authentication, or auctions. These services, in turn, will reduce the cost of software while increasing functionality and reliability. Futuristic applications will be enabled, such as requests for a later flight made on a wireless device, which then brokers for best times and prices, arranges payment for a new ticket and refund for the unused ticket, and downloads an e-ticket into the user's hands. NSF is funding awards for middleware test beds for development and deployment.

Third-Generation Virtual Reality Devices under Development: Researchers at the Electronic Visualization Laboratory (EVL) at the University of Illinois, Chicago are pioneers in virtual reality (VR) research focusing on developing tools, techniques and hardware to support real-time, highly interactive visualization. Current efforts, funded through NSF's Major Research Instrumentation program, continue through the development of VR devices, software libraries/toolkits and applications for collaborative exploration of data over national and global high-speed networks – often called "tele-immersion." After building first and second-generation VR devices (CAVE in 1991 and the ImmersaDesk in 1995) to support tele-immersion applications, EVL is now conducting research in third-generation VR devices to construct variable resolution and desktop-office-sized displays. They continue to develop and refine a robust and VR-device-independent software library, as well as the software tools for building tele-immersion applications. This software infrastructure supports collaboration in design, training, scientific visualization, and computational steering in VR. Through advanced networking techniques, researchers can access distributed computing, storage and display resources more efficiently than ever.

Creation of the National Historical Geographic Information System (NHGIS): A major infrastructure project funded by NSF at the University of Minnesota - Twin Cities has established the National Historical Geographic Information System (NHGIS) to upgrade and enhance U. S. Census databases from 1790 to the present. This includes the digitization of all census geography so that place-specific information can be readily used in geographic information systems. The NHGIS consists of three major components:

- Data and Documentation will gather all extant machine-readable census summary data, perform data verification through paper census tabulations, harmonize formats and documentation of all files, and produce standardized documentation per the recently developed Data Documentation Initiative (DDI);
- Mapping will create consistent historical electronic boundary files for tracts, towns and boroughs, counties and larger geographical units; and
- Data-Access will create a powerful but user-friendly, Web-based browser and extraction system based on the new DDI metadata standard.

The completed system will provide public access free of charge to both documentation and data, with results in the form of tables or maps. Through these activities, the NHGIS will become a resource that can be used widely for social science training, by the media, for policy research at state and local levels, by the private sector, and in secondary education.

Bow-Shock Observed Near Galactic Center: The Gemini Observatories, newest of the large facilities available to the US astronomical community, passed from commissioning and construction into early science operations in this fiscal year. With both telescopes obtaining data, astronomers have full sky coverage with identical 8-meter-class telescopes for the first time ever. Results from Gemini North are already appearing in the press, with the first demonstration data of the galactic center having been released to the public. Using an adaptive optics system that was funded by NSF and built by the University of Hawaii, these images represent the sharpest images ever obtained over such a large area of our Galaxy's center. The images clearly reveal the morphology of a previously unresolved object called IRS-8 as a 'bow-shock' from a star moving rapidly relative to a gas cloud.