## MAJOR MULTI-USER RESEARCH FACILITIES $1,153,820,000

The FY 2008 Request includes $1,153.82 million for major multi-user research facilities, a $64.28 million increase, or 5.9 percent, over the FY 2007 request of $1,089.54 million. All operations and maintenance of multi-user facilities and research resources are funded through the Research and Related Activities (R&RA) account, and most major construction projects are funded through the Major Research Equipment and Facilities Construction (MREFC) account.

NSF investments provide state-of-the-art tools for research and education, such as multi-user research facilities, distributed instrumentation networks and arrays, accelerators, telescopes, research vessels, aircraft, and earthquake simulators. In addition, investments in internet-based and distributed user facilities are increasing as a result of rapid advances in computer, information, and communication technologies. NSF's investments are coordinated with those of other organizations, agencies, and countries to ensure complementarity and integration.

**NSF Funding for Major Multi-User Research Facilities**
(Dollars in Millions)

| | FY 2006 Actual | FY 2007 Request | FY 2008 Request | Change Over FY 2007 Amount | Change Over FY 2007 Percent |
|---|---|---|---|---|---|
| Facilities | 828.78 | 899.74 | 954.88 | 55.14 | 6.1% |
| Federally Funded R&D Centers | 184.31 | 189.80 | 198.94 | 9.14 | 4.8% |
| Total, Major Multi-User Research Facilities | $1,013.09 | $1,089.54 | $1,153.82 | $64.28 | 5.9% |

This chapter provides descriptions of each major multi-user research facility supported through the R&RA account and provides funding information by life cycle phase for each facility. The information presented for each facility follows the overall framework established by NSF for large facility projects.

The Large Facilities Manual, to be released in FY 2007, will provide guidance on the policies, procedures, and requirements related to planning, construction, management, and oversight of a large facility project throughout its life cycle.

For more information on the construction projects funded through NSF's MREFC account, please see the MREFC chapter.

## Major Multi-User Research Facility Funding

(Dollars in Millions

| | FY 2006 Actual | FY 2007 Request | FY 2008 Request | Change Over FY 2007 Amount | Change Over FY 2007 Percent |
|---|---|---|---|---|---|
| **Facilities** | **$828.78** | **$899.74** | **$954.88** | **55.14** | **6.1%** |
| Academic Research Fleet | $62.21 | $77.50 | $80.60 | $3.10 | 4.0% |
| Advanced Modular Incoherent Scatter Radar[1] | $7.50 | - | - | - | - |
| Cornell Electron Storage Ring | $14.62 | $14.71 | $14.71 | - | - |
| Gemini Observatory | $18.18 | $20.00 | $20.50 | $0.50 | 2.5% |
| Incorporated Research Institutes for Seismology | $11.41 | $12.90 | $11.40 | -$1.50 | -11.6% |
| Integrated Ocean Drilling Program[2] | $32.19 | $6.50 | $4.64 | -$1.86 | -28.6% |
| Large Hadron Collider | $13.36 | $18.00 | $18.00 | - | - |
| Laser Interferometer Gravitational Wave Observatory | $31.68 | $33.00 | $28.20 | -$4.80 | -14.5% |
| MREFC Projects[3] | $250.75 | $294.10 | $335.25 | $41.15 | 14.0% |
| National High Magnetic Field Laboratory | $25.74 | $26.50 | $29.00 | $2.50 | 9.4% |
| National Nanofabrication Infrastructure Network | $14.43 | $13.89 | $13.89 | - | - |
| National Superconducting Cyclotron Laboratory | $17.34 | $17.60 | $19.50 | $1.90 | 10.8% |
| Network for Earthquake Engineering Simulation | $21.03 | $21.27 | $22.17 | $0.90 | 4.2% |
| Other Facilities[4] | $14.09 | $13.26 | $15.76 | $2.50 | 18.9% |
| Polar Facilities & Logistics | $294.25 | $330.51 | $341.26 | $10.75 | 3.3% |
| **Federally Funded R&D Centers[5]** | **$184.31** | **$189.80** | **$198.94** | **$9.14** | **4.8%** |
| National Astronomy and Ionosphere Center | $12.15 | $12.16 | $12.15 | -$0.01 | -0.1% |
| National Center for Atmospheric Research | $84.51 | $86.85 | $90.87 | $4.02 | 4.6% |
| National Optical Astronomy Observatory | $36.91 | $40.05 | $43.18 | $3.13 | 7.8% |
| National Radio Astronomy Observatory | $50.74 | $50.74 | $52.74 | $2.00 | 3.9% |
| **Grand Total** | **$1,013.09** | **$1,089.54** | **$1,153.82** | **$64.28** | **5.9%** |

[1]Final construction funding for the Advanced Modular Incoherent Scatter Radar (AMISR) facility was provided in FY 2006. Funding for the operations and maintenance of AMISR, estimated to be approximately $3.0 million annually, is provided through Research Resources, a category not reported on this table.
[2]FY 2006-07 support for IODP includes funding for the continued phase out of program and contract activities for the Ocean Drilling Program, predecessor to the IODP.
[3]Funding levels for MREFC projects in this table include support for concept and development associated with these projects, initial support for operations and maintenance, both provided through the R&RA account, and implementation support provided through the MREFC account.
[4]Other Facilities includes support for other physics and materials research facilities.
[5]Federally Funded R&D Centers does not include the Science and Technology Policy Institute, which is an FFRDC but not a research platform.

**Academic Research Fleet**

Project Description: The Academic Research Fleet consists of 24 vessels in the University-National Oceanographic Laboratory System (UNOLS). These vessels range in size, endurance, and capabilities, enabling NSF and other federally funded scientists with the means to conduct ocean science research with a diverse fleet capable of operating in coastal and open ocean waters. Funding provides for the Academic Research Fleet includes investments in ship operations;, shipboard scientific support equipment; oceanographic instrumentation and technical services; ship acquisition and upgrade; and submersible support.

Principal Scientific Goals: The Academic Research Fleet serves as the main platform for the collection of data and testing of hypotheses about the structure and dynamics of the oceans. Scientists contribute to advances made in areas such as climate variability, marine ecosystems, fisheries, and ocean-related natural hazards such as tsunamis through use of these facilities.

Principal Education Goals: Vessels in the Academic Research Fleet permit shipboard training of future oceanographers. Participating graduate and undergraduate students interact with scientists and marine technicians, enabling them to gain first-hand exposure to ocean science field research. Recent technological innovations allow research conducted at sea to be transmitted via satellite back to the classroom, broadening the educational impact of the vessels to a wider audience, including K-12 students.

Partnerships and Connections to Industry: The Academic Research Fleet is supported through an interagency partnership, principally with the National Oceanic and Atmospheric Administration (NOAA) and the Office of Naval Research (ONR) via a Memorandum of Understanding (MOU). The operating funds for the Fleet are divided proportionally among the vessel users; NSF's portion is approximately 70 percent of the total. NSF also coordinates with ship-operating and ship-user academic institutions through its connection with and support of UNOLS.

Management and Oversight: NSF provides oversight to the Academic Research Fleet through cooperative agreements with each ship-operating institution and the UNOLS Office. In addition, NSF oversees the fleet through external review of proposals, site visits, ship inspections, and participation at UNOLS Council and Subcommittee meetings by Program Managers. Several Program Managers within the Division of Ocean Sciences (OCE) at NSF, at NOAA, and at ONR are involved in the activities and overall oversight of the Academic Research Fleet.

Management of an individual institution's ship-operating facilities varies with the scale of the operation, but the core responsibility typically resides with the Director of the Institution, the Marine Superintendent (for all aspects of the facility), and the Ship's Captain (for at-sea operations). For larger multi-ship-operating institutions, a chief of marine technicians, schedulers, and finance administrators may also be involved in facility management.

Current Project Status: Based on projected science requirements identified in recent reports and workshops, a fleet of vessels supporting ocean science research will be needed far into the future. In coordination with the other federal agencies with ocean research investments and UNOLS, the International Working Group for Facilities (IWG-F) is currently revising the 2001 report on long-range plans for renewal of the federal and academic oceanographic research and survey fleet, which will be published this year. In addition, several activities are requested or underway to support the upgrade of the U.S. Academic Research Fleet.

FY 2008 will see continued development and construction of a new deep submergence capability to replace the pioneering submersible human occupied vehicle (HOV) ALVIN. This project, begun in FY 2004, will take a total of six years and cost approximately $22.0 million; an increase over previous estimates due to rise in titanium costs. The FY 2008 support for this effort is $3.0 million. A second project currently underway is the design and potential construction of a series of up to three Regional Class Research Vessels (RCRVs), utilizing the experience in ship building and contracting of the Naval Sea Systems Command (NAVSEA). These ships will be built sequentially over a period of years starting in FY 2007. FY 2008 support for this activity is planned for $14.0 million. A design competition was completed and two U.S. shipyard/design agent consortia were selected to each produce a design and bid on construction by summer 2007. These investments will open significant expanses of the deepest ocean to exploration, enhance coastal research activities and bring greatly enhanced capability to map structures under the sea floor to U.S. researchers.

Funding Profile: All funding for the Academic Research Fleet to date has been provided through the R&RA Account.

**Academic Research Fleet Funding Profile**
(Dollars in Millions)

| | Implementation | | | | Operations & Maintenance | **Total, NSF** |
|---|---|---|---|---|---|---|
| | HOV | Langseth | RCRVs | Other | | |
| FY 2004 | 3.00 | 6.24 | 0.30 | 0.46 | 72.50 | $82.50 |
| FY 2005 | 2.23 | 8.00 | 2.00 | | 70.97 | $83.20 |
| FY 2006 | 8.63 | 1.74 | 3.63 | | 62.21 | $76.21 |
| FY 2007 Request | 5.10 | | 15.10 | | 77.50 | $97.70 |
| FY 2008 Request | 3.00 | | 14.00 | | 80.60 | $97.60 |
| FY 2009 Estimate | | | 10.00 | | 89.00 | $99.00 |
| FY 2010 Estimate | | | 12.00 | | 95.00 | $107.00 |
| FY 2011 Estimate | | | 14.00 | | 101.00 | $115.00 |
| FY 2012 Estimate | | | 16.00 | | 108.00 | $124.00 |
| FY 2013 Estimate | | | 18.00 | | 115.00 | $133.00 |

NOTE: Operations estimates for FY 2009 and beyond have been developed based on current cost profiles and are not intended to reflect actual budget requirements. They will be updated as new information becomes available.

Information pertaining to the data in the table is included below.

- Implementation: From time to time, vessels require conversions or upgrades that go beyond the normal maintenance supported by operating costs. Funding decisions for conversions and upgrades are based on strong evidence of scientific need. In past years, the funding has provided for the conversion or upgrade of ships already in service whose age, configuration, or operating costs have impaired their usefulness. More recently, planning has included the replacement of ships that have reached the end of their useful life and replacing the capability for studies in the deep ocean as the aging ALVIN submersible reaches the end of its useful life. In December 2001, the Federal Oceanographic Facilities Committee (FOFC) prepared a report titled "Charting the Future for the National Academic Research Fleet," which defined a federal interagency renewal strategy for the national Academic Research Fleet. The report is currently being revised by the IWG-F, which subsumed the FOFC; however, significant changes for renewal of the academic fleet are not anticipated. Major upgrade expenditures indicated in implementation requests for FY 2007 and out-

years are for continuation of development of a new deep submergence vehicle and replacement of Regional Class ships. The reconfiguration of a recently acquired seismic research vessel will be completed in FY 2006. All implementation activities for the Academic Research Fleet have been funded through the R&RA account.

- Operations and Maintenance: This amount includes funds for operating and maintaining the fleet, shipboard scientific support equipment, oceanographic instrumentation and technical services, and submersible support.

Renewal or Termination: Participation of each ship in the research fleet through a cooperative agreement is governed by the existence of an efficient schedule of scientific research cruises for that ship, assessments of the continued fitness of the ship to conduct research at sea, and the ability of the operating institution to maintain cost effective operations.

Associated Research and Education Activities: NSF-funded researchers utilizing the fleet are supported through NSF's research programs and are subjected to NSF's standard merit review process. The fleet supports approximately 2,600 users per year, which is based on the total number of individual researchers, postdoctoral associates, graduate and undergraduate students, teachers, K-12 students and observers who have participated in cruises.

Science Support: The existing interagency MOU enables the efficient operation of the academic fleet; NSF pays only for ship time used by NSF-funded awards.

**Advanced Modular Incoherent Scatter Radar (AMISR)**

Project Description: The Advanced Modular Incoherent Scatter Radar is a phased-array incoherent scatter radar with unique features that allow efficient and cost-effective dismantling, shipping, and re-assembly. The radar comprises three identical antenna faces, each with sensitivity comparable to the radar currently operating in Sondre Stromfjord, Greenland. Each of the three fixed antenna faces is 35 meters square with 3,000 to 4,000 radiating elements. In addition to being relocatable, AMISR will provide the means for unique scientific observations via two significant features that have not been technically feasible in the past and will greatly enhance the way observations and experimental campaigns are conducted. First, the phased-array concept will allow pulse-to-pulse beam steering, thus enabling three-dimensional "imaging" of electron density features in high signal-to-noise environments. Second, an incoherent scatter radar with a solid-state transmitter and no moving parts will permit both extended operating periods and true remote internet operation with virtual "control rooms" at universities world-wide.

Principal Scientific Goals: Long-term measurements of atmospheric parameters will help us understand the processes influencing global change, and observations during solar storms will help us understand and predict space weather, the primary goal of the multi-agency National Space Weather Program. There will also be strong synergy between AMISR scientific activities and the Center for Integrated Space Weather Modeling (CISM), one of NSF's Science and Technology Centers. The AMISR systems at Poker Flat, Alaska, and Resolute Bay, Canada, will enable researchers to investigate fundamental issues of solar-terrestrial science including how the Earth is magnetically and electrically coupled to the Sun; what the structure and dynamics of the magnetosphere, ionosphere, and upper atmosphere are; and how the energy entering the upper atmosphere at the poles flows to the equator. The scientific goals will change in the future as AMISR is deployed at other locations.

Principal Education Goals: The design for the AMISR is at the forefront of current radar, electronics, and signal processing technology. It uses advanced solid-state amplifiers that can be computer-controlled for maximum flexibility and ease of use. It will provide outstanding opportunities for students, young scientists, and engineers to be involved with the development of the project and the operation of the instrument. The AMISR will be the first incoherent scatter radar designed for remote usage, allowing students and scientists to plan and configure experiments, and watch in real-time as the data is returned from remote sites. The web-based tools to be developed will make AMISR an excellent means to train the next generation of incoherent scatter radar specialists. The possibilities for new discoveries, combined with the ease of operation, will inspire hundreds of scientists from all over the globe to use the facility.

Partnerships and Connections to Industry: Manufacturing of the antenna element units (AEUs) is being done by Sanmina SCI, a global electronics manufacturing firm with headquarters in San Jose, CA. The solid-state power amplifiers for the first 4,000 units were manufactured by Comtech PST, a company based in Melville, New York. The construction of the AMISR support structure and the foundation work in Alaska was performed by VECO Corp., an Alaska-based company that specializes in management, engineering design, and construction for the oil and power industries. The support structure at Resolute Bay will be built by a Canadian company, ATCO Frontec using the VECO design.

Management and Oversight: Overall project management and oversight is the responsibility of the program manager for Upper Atmospheric Facilities within the Division of Atmospheric Sciences (in GEO). A Project Advisory Team (PAT) has been appointed, which includes the Deputy Director for Large Facility Projects and members from GEO, the Office of Polar Programs, the Office of Budget Finance and Award Management, and the Office of the General Counsel. As required in the cooperative

agreement for the AMISR construction, SRI has assembled a Technical Advisory Committee to provide technical oversight in the design and development of the AMISR system. SRI has also written a Project Execution Plan (PEP) that describes the AMISR work breakdown structure, management structure, project milestones, and final test and acceptance plan.

Current Project Status: The first 32 panels of the AMISR system at Poker Flat, Alaska, were installed in November 2005 and used for interference testing in partnership with Air Force personnel from Clear Air Force Station. No interference was observed and SRI received official certification to continue testing the 32 panels at Poker Flat. An additional 65 panels were assembled at SRI and shipped to Alaska in Fall 2006, completing the first AMISR face. January 2007 marks the start of operations for the 97-panel system at Poker Flat with two weeks of observations in conjunction with a NASA sounding rocket campaign. A second joint radar and rocket campaign will be conducted in February 2007. Construction materials for the two AMISR faces being deployed at Resolute Bay were shipped to the site in August 2006. Panels for the two AMISR faces at Resolute Bay will be manufactured, integrated, and tested at SRI in 2007 for shipment in August 2007. The Resolute Bay faces will be constructed and tested in the first half of 2008.

Milestones for the project are outlined below:

FY 2006 Milestones:
- Poker Flat Activities
  - Continued operation and testing of 32 panels
  - Integrated and tested remaining 65 panels at SRI
  - Shipped and installed remaining 65 panels at Poker Flat
  - Poker Flat system test complete and operational
- Resolute Bay Activities:
  - Support scaffolding and distribution shelters shipped to Resolute Bay via sealift

FY 2007 Milestones:
- Poker Flat Activities
  - Complete system testing of 97-panel radar
  - Scientific operations of 97-panel radar begin
- Resolute Bay Activities:
  - Manufacture Antenna Element Units (AEUs)
  - Integrate and test panels at SRI
  - Ship completed panels to Resolute Bay via sealift

FY 2008 Milestones:
- Poker Flat Activities
  - Continue operations
- Resolute Bay Activities
  - Construct support platforms
  - Install complete panels on two antenna faces
  - System testing of completed faces
  - Operations begin

Funding Profile: The implementation phase of AMISR began late in FY 2003 with an initial allocation of $14.0 million. The total cost to construct AMISR is $44.0 million, as illustrated below. NSF provided the final year of implementation funding in FY 2006.

**AMISR Funding Profile**
(Dollars in Millions)

| | Concept/ Development | Implementation | Operations & Maintenance | Total, NSF |
|---|---|---|---|---|
| FY 2001 & Earlier | 3.60 | | | $3.60 |
| FY 2002 | 3.40 | | | $3.40 |
| FY 2003 | | 14.00 | | $14.00 |
| FY 2004 | | 12.00 | 0.40 | $12.40 |
| FY 2005 | | 10.50 | 0.50 | $11.00 |
| FY 2006 | | 7.50 | 2.70 | $10.20 |
| FY 2007 Request | | | 3.00 | $3.00 |
| FY 2008 Request | | | 3.00 | $3.00 |
| FY 2009 Estimate | | | 3.07 | $3.07 |
| FY 2010 Estimate | | | 3.15 | $3.15 |
| FY 2011 Estimate | | | 3.22 | $3.22 |
| FY 2012 Estimate | | | 3.22 | $3.22 |
| FY 2013 Estimate | | | 3.30 | $3.30 |

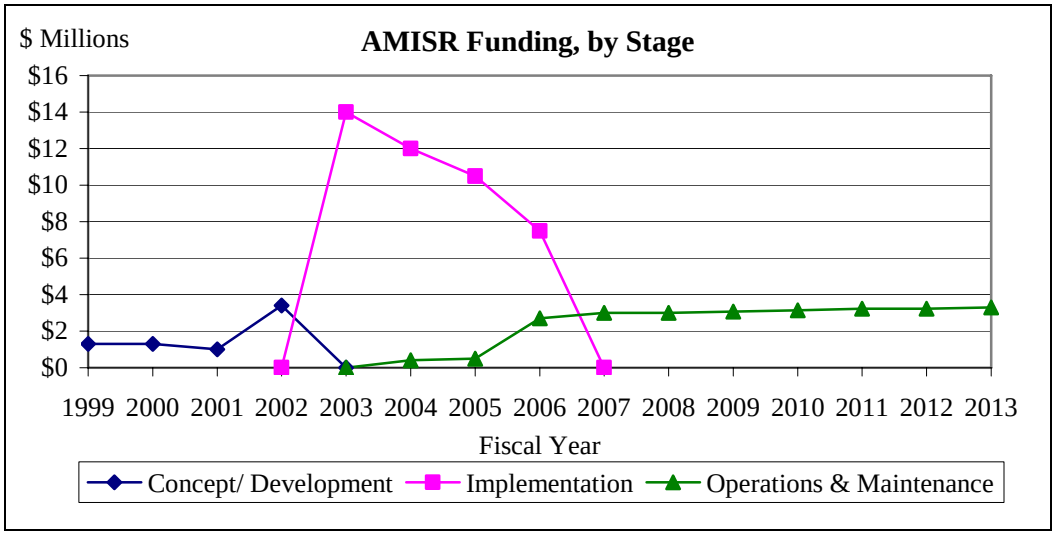
NOTE: A steady state of about $3 million in operations support is expected to occur in or about FY 2007. The expected operational lifespan of this project is 40 years, beginning in FY 2007. Operations estimates for FY 2009 and beyond have been developed based on current cost profiles and are not intended to reflect actual budget requirements. They will be updated as new information becomes available.

Information pertaining to the data in the table is included below.

- Concept/Development: Initial R&RA funding for AMISR began in FY 1999 with an award to SRI International to develop the design of the antenna element units. Subsequent funding was provided for building 32 engineering prototype units that were assembled into a panel for testing at the SRI field site near Stanford University and the U.S. Air Force antenna test facility in Ipswich, Massachusetts. The Concept/Development phase concluded with the competitive source selection of Sanmina SCI and two years of design for manufacturing activities involving close interaction between Sanmina and SRI engineers.

- Implementation: NSF provided final implementation funding for AMISR in FY 2006. The actual implementation phase will be complete, and the AMISR faces at Resolute Bay will be operational by spring 2008.

- Operations and Maintenance: SRI successfully competed for the initial operation and maintenance of the AMISR systems at Poker Flat and Resolute Bay. Funding began in FY 2006 under a five-year cooperative agreement; operation and maintenance of the face at Poker Flat will be accomplished in collaboration with personnel at the Geophysical Institute, University of Alaska. Other participating institutions include MIT, the University of Calgary, and the University of Saskatchewan. Additional instrumentation for the two facilities will be funded with R&RA funding through grants programs within ATM.




Associated Research and Education Activities: AMISR will be the first incoherent scatter radar designed for remote usage, allowing students and scientists to plan and configure experiments, and watch in real-time as the data are returned from remote sites. AMISR remote access will utilize a workbench concept consisting of several components, including databases, visualization software, web sites, and other tools. This will engage a new generation of students in the exciting research opportunities enabled by incoherent scatter observations. It will also provide a means for effective teaching of fundamental principles of radio science. Exposure to AMISR-related research will offer experience in basic atmospheric science, electrical engineering, radiowave communications, signal processing, computer design, and information technology. The possibilities for new discoveries, combined with the ease of operation, will inspire hundreds of young scientists from all over the globe.

Future Science Support: In addition to the operations support indicated above, AMISR research and education programs will be funded through the Aeronomy, Magnetospheric Physics, and Upper Atmospheric Facilities core programs within the Upper Atmospheric Research Section. The combined annual level of support for this research is estimated to be about $5 million.

**Cornell Electron Storage Ring (CESR)**

Project Description: The Cornell Electron Storage Ring (CESR) is a facility that supports research in elementary particle physics as well as research in accelerator physics and superconducting radio frequency (SRF) applications. CESR is an electron-positron collider that has provided important knowledge of the properties of the b-quark. Cornell University has modified CESR and the associated particle detector (CLEO) for operation over the energy range 1.5 GeV to 5.6 GeV per beam in order to address high-priority physics questions that relate to the c-quark and possible gluon states that cannot be addressed elsewhere. The transformed collider and detector are named CESR-c and CLEO-c respectively.

The CESR facility is also used by the materials research community at the Cornell High Energy Synchrotron Source (CHESS). CHESS is a high-intensity, high-energy X-ray source supported by NSF. It uses the synchrotron light given off by the charged particles, both electrons and positrons, as they circulate at nearly the speed of light around CESR. As a user facility, CHESS provides state-of-the-art synchrotron radiation facilities for research in physics, chemistry, biology, materials research, and environmental sciences.

Principal Scientific Goals: CESR-c and CLEO-c explore a large set of critical weak and strong interaction phenomena, knowledge of which is either lacking or fragmentary. These in turn drive theoretical advances that both extend and enable the full program of physics targeted by many new-generation detectors, such as those at the Stanford Linear Accelerator Center (SLAC), Fermilab, and the Large Hadron Collider (LHC), and lay the foundation for strong interaction theory to meet the requirements of future physics beyond the Standard Model.

Principal Education Goals: CESR's principle education goals are to support and enhance Ph.D. level graduate education, postdoctoral research experience, Research Experiences for Undergraduates (REUs), and research experiences for K-12 science teachers. Engendering excitement in science among young children will be a focus for K-12 engagements. An important program element is Teacher Professional Development through the dissemination of effective models and pedagogic approaches to science teaching and partnerships between researchers and educators.

Besides providing forefront research opportunities to women and under-represented minorities through base grants, broadening participation is one of key goals of the CESR REU Site Program, which is enriched substantially by major involvement on the part of physics faculty and students from Wayne State University, a major minority-serving institution.

Partnerships and Connections to Industry: CESR staff are transferring CESR SRF technology to industry. Two new industrially fabricated SRF cavity systems have been acquired in order to shorten the CESR bunch length with higher voltage. Through a license arrangement with Cornell, the ACCEL Corporation has manufactured two superconducting RF sources to power synchrotron light sources. They have been tested and installed in CESR to replace two older, lower gradient modules. Also, some of the CHESS users are from industry, including pharmaceutical corporations (Rib-x Pharmaceuticals) and the research arms of Eastman Kodak, Xerox, and General Motors. Some medical institutions also make use of CHESS (Dana Farber Cancer Institute, Boston Biomedical Research Institute, and Memorial Sloan-Kettering Institute).

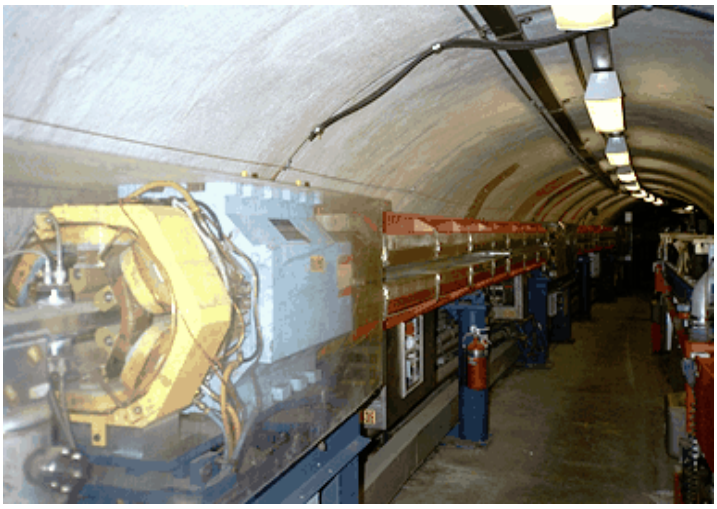
Management and Oversight: CESR-c is managed by the Director of the Laboratory for Elementary Particle Physics (LEPP) at Cornell with help from an Assistant Director and an Associate Director for Accelerator Physics. The CLEO-c experiment is the sole CESR-c experiment in particle physics, and this

collaboration consists of users from about 20 U.S. institutions. The CESR-c management interacts with the CLEO-c collaboration through the collaboration spokesperson and executive board as needed, and there are monthly meetings of the collaboration that include CESR-c management.

NSF oversight is provided through the Division of Physics (PHY) of the Directorate for Mathematical and Physical Sciences (MPS) and by periodic site visits by NSF staff. Technical review of the award involved panel evaluation of the CESR-c proposal, and a site visit by NSF staff and external reviewers. The oversight process includes annual financial reports and program reports to NSF, and an annual review by a Program Advisory Committee of outside physicists reporting to the Laboratory Director and NSF. A comprehensive review by NSF of the Laboratory and its programs was held at Cornell in April 2006, and involved an external panel of experts chaired by Professor Michael Witherell of UC Santa Barbara.

CHESS is supported through the Division of Materials Research (DMR) of MPS, the Directorate for Biological Sciences (BIO), and by the National Institutes of Health (NIH). Those organizations provide management oversight for CHESS through regular site visits. Pending the successful outcome of a renewal proposal, DMR will provide $3.9 million to CHESS in FY 2008; BIO will provide $900,000, and NIH will provide $600,000.

Current Project Status: CESR is reaching the final stages of the five-year cooperative agreement initiated in April 2003. Cornell University has modified the CESR colliding beam accelerator and the CLEO particle detector as mentioned above. In addition to the particle physics program, a vigorous program of accelerator science and technology development for accelerator concepts for the future will continue. CESR-c will also provide intense X-ray beams for the program in X-ray science at CHESS. The particle physics program and X-ray science program will now begin to use different accelerator energies, requiring the two programs to operate in different time periods. The FY 2008 Request for CESR totals $14.71 million. It is expected that the CESR-c and CLEO-c projects will cease during FY 2009.



The storage ring is on the left side; sextuple (yellow) and quadropole (blue) focusing magnets can be seen in the foreground, with solenoidal bending magnets behind. Part of the synchrotron is visible on the right, and the bending of the tunnel is easily seen. *Credit: Cornell University (www.lns.cornell.edu/public/lab-info/ring.html)*

Funding Profile: The FY 2003 – FY 2009 estimated funding for CESR-c and CLEO-c represents completion of the current program of operations and provides opportunity for the particle physics group and the CHESS facility to plan their future activities. All funding for CESR to date has been provided through the R&RA account.

**CESR Funding Profile[1]**
(Dollars in Millions)

| | Implementation | Operations & Maintenance | Total, NSF |
|---|---|---|---|
| FY 2001 | | 19.49 | $19.49 |
| FY 2002 | | 19.49 | $19.49 |
| FY 2003 | | 19.49 | $19.49 |
| FY 2004 | | 18.00 | $18.00 |
| FY 2005 | | 16.62 | $16.62 |
| FY 2006 | | 14.62 | $14.62 |
| FY 2007 Request | | 14.71 | $14.71 |
| FY 2008 Request | | 14.71 | $14.71 |
| FY 2009 Estimate | | 7.50 | $7.50 |
| FY 2010 Estimate | | - | - |

NOTE: Operations estimates for FY 2009 have been developed based on current cost profiles and are not intended to reflect actual budget requirements. They will be updated as new information becomes available. NSF support for CESR concludes in FY 2009.

[1]Includes funding for CESR only. No funding for CHESS is included in this table.

Information pertaining to the data in the table is included below.

- Management and Operations: The facility expects to operate about 5,000 hours per year for CLEO research and for accelerator physics and development. Maintenance is provided through a weekly eight-hour shift and through two or three three-week shut-downs for maintenance of the accelerator, superconducting RF, helium refrigerator, vacuum system, beam lines for CHESS, power systems, and other ancillary systems. Approximately 30 percent of the CESR funding is directed toward in-house research (both experimental elementary particle physics and accelerator physics) with the remainder used to operate and maintain the facility. The funding profile above includes minor detector and accelerator changes that are essential to completion of the scientific program before FY 2010.

Associated Research and Education Activities: Cornell continues to be active in outreach:

- Over 120 elementary and middle school students and 300 high school students were involved in activities hosted by the Laboratory for Elementary-Particle Physics. Over 500 people toured the Wilson Laboratory facility during this time frame;
- Over 60 undergraduate students participated in laboratory research or worked as technicians or in technical capacities such as computer operations; the laboratory is very active in mentoring programs for students and has hosted 30 REUs in collaboration with Wayne State University and George Mason University;
- The laboratory is very active in mentoring programs for teachers. Sixty-two high school physics teachers participated in several programs including Physics First workshops, Preparing Future Physics Teachers, and the Cornell Institute for Physics Teachers;
- Underrepresented populations are also engaged through EXPLORE! Bridge to Medicine Program and the New York City Region 3 Science Teacher Professional Development Day; and
- The laboratory trains graduate students in accelerator physics and has supported the development of superconducting radio frequency accelerating cavities.

Science Support: Approximately $3.0 million is provided annually by NSF in support of separate awards to external users of the CESR/CLEO facility. The Department of Energy (DOE) provides a similar

amount in support of awards to individual investigators and groups. In addition, $660,000 is provided in a separate award to Cornell in support of theoretical elementary particle physics research.

About 200 physicists from 22 universities have built and are operating the CLEO detector to study the products of the electron-positron collisions. CESR is a national user facility and the current CLEO-c collaboration includes more than 130 researchers from 25 U.S. and foreign institutions.

The CHESS facility serves a wide spectrum of experimental groups from universities, national laboratories, and industry and is used by the materials research community, with typically 600-700 users per year.

**Gemini Observatory**

Project Description: The Gemini Observatory consists of two 8-meter telescopes, one in the northern hemisphere, in Hawaii, and one in the southern hemisphere, in Chile. The Hawaiian telescope is optimized for infrared observations and is located on Mauna Kea at an altitude of 4,200 meters. The telescope in Chile is located on Cerro Pachon, an outstanding photometric site, at an altitude of 2,700 meters. This siting of the two telescopes assures complete coverage of the sky to complement the observations from space-based observatories, and provides access to the center of our own galaxy as well as the Magellanic Clouds, our nearest galactic neighbors. Both telescopes are designed to produce superb image quality, and both use sophisticated adaptive optics technology to compensate for the blurring effects of the Earth's atmosphere. The Observatory is an international collaboration with the United Kingdom, Canada, Australia, Chile, Argentina, and Brazil.

This image, taken at Gemini North (Mauna Kea, Hawaii) using adaptive optics, is of Jupiter and its two red spots (which apppear white because this is a near-infrared image; in visible light they appear reddish). In this color composite image, white indicates cloud features at relatively high altitudes; blue indicates lower cloud structures; and red represents still deeper cloud features. *Credit: Gemini Observatory/AURA*

Principal Scientific Goals: Astronomers need to resolve important questions about the age and rate of expansion of the universe, its overall topology, the epoch of galaxy formation, the evolution of galaxies once they are formed, and the formation of stars and planetary systems. The new generation of optical/infrared telescopes with significantly larger aperture (8-meter diameter) than previous instruments provides better sensitivity and spectral and spatial resolution. Technological advances in a number of key areas of telescope construction and design allow these instruments to take advantage of the best performance the atmosphere will allow.

Principal Education Goals: The Gemini telescopes play a central role in the education and training of U.S. astronomy and engineering students. An estimated 10 percent of the roughly 500 U.S. users per year are students. Gemini also provides a focus for public outreach and high school student training in all the partner countries, including the development of "sister city" arrangements between Hilo, Hawaii and La Serena, Chile involving students and teachers at high school and elementary school levels. In FY 2004, the Director of the Gemini Observatory was awarded Chile's Gabriela Mistral medal for the Observatory's great contributions to cultural exchange and knowledge of the universe by the Ministry of Education. This was the first time the medal had been awarded to a non-Chilean.

Partnerships and Connections to Industry: Gemini is an international partnership with the United Kingdom, Canada, Australia, Chile, Argentina, and Brazil. Construction of the telescopes and their instrumentation has involved a large number of industrial concerns in a number of partner and non-partner countries. These have involved firms in large and/or complex optical systems, aerospace industries, electronics and engineering firms, etc. Continued involvement of such industries is part of the instrumentation and facilities renewal activities included in the operating budget of the Gemini Observatory.

Management and Oversight: The Observatory is governed by the Gemini Board, established by the International Gemini Agreement signed by the participating agencies. NSF serves as the Executive Agency for the seven-nation partnership, carrying out the project on their behalf. Programmatic management is the responsibility of an assigned program manager for Gemini in the Division of Astronomical Sciences in MPS, assisted during construction by an internal Project Advisory Team (PAT)

with representation from the Office of the General Counsel, the Office of Legislative and Public Affairs, the Office of Budget, Finance and Award Management, and the Office of International Science and Engineering. An independent Visiting Committee, established by the Gemini Board, advises on the operation of the Observatory. Gemini is managed by Associated Universities for Research in Astronomy (AURA), Inc. on behalf of the partnership through a cooperative agreement with NSF. AURA conducts its own management reviews through standing oversight committees. All AST-funded facilities have established policies and practices designed to broaden the participation of individuals from groups under-represented in the scientific and technological workforce. Under the terms of the international agreement, the partnership, after a management review conducted in 2004, determined that it would not compete the management of the Observatory at that time. A proposal from AURA for operations during the period 2006 to 2010 was reviewed and an award to AURA for the next five years of operations was approved by the National Science Board. A new cooperative agreement for the period FY 2006-2010 has recently been put into place.

Current Project Status: Science operations are routine at both sites; over 90 percent of available time on Gemini North and over 80 percent of time on Gemini South is dedicated to scientific observing. Commissioning of facility instruments continues at both telescopes.

Funding Profile: The FY 2008 Request totals $20.50 million, an increase of $0.50 million over the FY 2007 Request of $20.0 million. Included in this total is enhanced operational and visitor support, as well as the continuation of funding of a new generation of advanced instrumentation.

**Gemini Funding Profile**

(Obligated Dollars and Estimates in Millions)

| | Concept/ Development | | Implementation | | Operations & Maintenance | | Totals | | Grand |
|---|---|---|---|---|---|---|---|---|---|
| | R&RA | MREFC | R&RA | MREFC | R&RA | MREFC | R&RA | MREFC | Total |
| FY 2004 & Earlier | 12.00 | | 47.00 | 45.00 | 13.27 | | 72.27 | 45.00 | $117.27 |
| FY 2005 | | | | | 15.48 | | 15.48 | - | $15.48 |
| FY 2006 | | | | | 18.18 | | 18.18 | - | $18.18 |
| FY 2007 Request | | | | | 20.00 | | 20.00 | - | $20.00 |
| FY 2008 Request | | | | | 20.50 | | 20.50 | - | $20.50 |
| FY 2009 Estimate | | | | | 25.07 | | 25.07 | - | $25.07 |
| FY 2010 Estimate | | | | | 25.46 | | 25.46 | - | $25.46 |
| FY 2011 Estimate | | | | | 26.50 | | 26.50 | - | $26.50 |
| FY 2012 Estimate | | | | | 26.10 | | 26.10 | - | $26.10 |
| FY 2013 Estimate | | | | | 27.16 | | 27.16 | - | $27.16 |
| Subtotal, R&RA | $24.00 | | $94.00 | | $283.65 | | $401.65 | | |
| Subtotal, MREFC | | - | | $90.00 | | - | | $90.00 | |
| **Total, Each Stage** | | $24.00 | | $184.00 | | $283.65 | | | $491.65 |

NOTE: Reporting of costs in the categories of implementation and operations and maintenance is as considered and reported by NSF in its response to OIG report 01-2001. FY 2005 - 2007 funding includes the cost of the Chilean capital return, consistent with the U.S. assumption of a portion of the Chilean share. FY 2005 funding includes one time costs of $0.55 million for improved internet connectivity and instrumentation. Funding under the current cooperative agreement ends in FY 2010. The figures for FY 2006-2011 reflect the anticipated growth of the operating budget and funds for second generation instrumentation being used by the Observatory and the Gemini Board for planning purposes. The anticipated lifetime of the Observatory is 25 years. A steady state of about $25 million annually (plus inflation) is anticipated for the U.S. share of operations and continued support of instrumentation development.

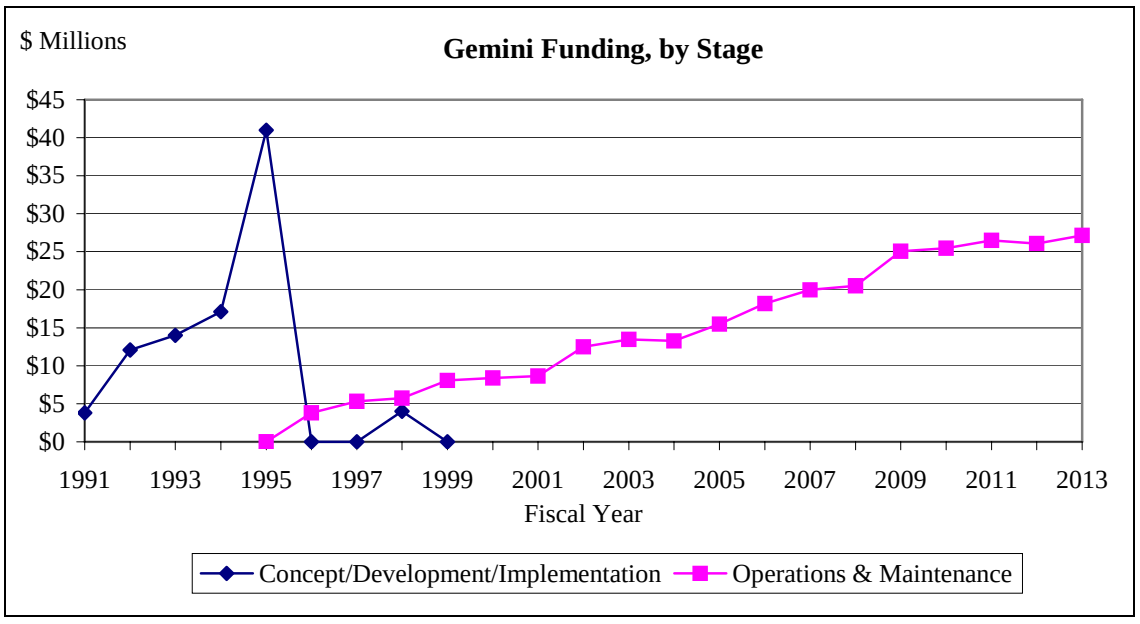
Information pertaining to the data in the table is included below.

Gemini North dome/enclosure with setting sun (to left) lighting up bottom half of telescope through thermal vents (fully open). The observing slit is partially open revealing the truss and top end of the telescope. *Credit: Neelon Crawford,Polar Fine Art; Gemini Observatory/AURA and NSF*

- Concept/Development: Funds represent estimated U.S. investments in the development of mirror technologies for a new generation of telescopes, as recommended by the National Academy Report "Astronomy and Astrophysics for the 1980s." Three different mirror technologies were explored. These investments in technology development contributed to the plans for Gemini, as well as to other new telescopes that advance research in astronomy.

- Implementation: Gemini construction was initiated in FY 1991, before establishment of the MREFC account in FY 1995. The $92.0 million obligated for Gemini construction is the U.S. share of the total cost ($184 million) for the two telescopes, with the balance provided by international partners.

- Management and Operations: Funding ramped up as the telescopes approached initial operations. Beginning in FY 2002, operations include the U.S. assumption of a portion of the Chilean share of operations costs, as agreed by the international partners. The funds provide additional observing time to the U.S. astronomy community while Chile maintains a share of observing time as host country. Under this adjustment, NSF supports just over 50 percent of management, operations and maintenance. In FY 2005-2007, costs reflect Chilean capital return, consistent with U.S. assumption of a portion of Chilean share.




Renewal or Termination: The cooperative agreement for the support of Gemini operations expired in FY 2006. Under the terms of the international agreement, the partnership determined that it did not wish to compete the management of the Observatory at this time. A proposal from AURA covering operations from 2006-2010 was reviewed and an award for the next five years of operations has been approved by

the National Science Board. A new cooperative agreement for the period FY2006-2010 has been put in place.

Associated Research and Educational Activities: The public information and outreach office at Gemini carries out local outreach to schools, teachers, and the general public. The office also coordinates and serves as a liaison for the outreach efforts of partner countries and provides media services and web-based resources. All facility educational and outreach activities seek to broaden participation by under-represented groups. The AST-supported facilities provide forefront research capability and opportunities for access that enable faculty and students from under-represented groups and at diverse institutions to develop and carry out competitive research programs.

Science Support: Peer-review telescope allocation committees provide merit-based telescope time but no financial support. NSF does not provide awards targeted specifically for use of Gemini. Most U.S. users are supported through NSF or NASA grants, or university research support to pursue scientific programs that require use of Gemini. More than 90 percent of the science time on the two telescopes is carried out in a 'queue' mode where the observations are scheduled by Gemini astronomers so as to best match the requirements of the scientific program to the observing conditions. Along with optimizing the productivity of the telescope time, this obviates the need for the scientists to travel to the remote sites, thereby reducing the cost to the researchers.

**Incorporated Research Institutes for Seismology (IRIS)**

Project Description: IRIS is a consortium of 104 U.S. universities and not-for-profit institutions with research and teaching programs in seismology. IRIS operates a distributed national facility for the development, deployment, and operational support of modern digital seismic instrumentation to serve national goals in basic research in the earth sciences, in earthquake research, and in nuclear test ban monitoring. IRIS is also leading the construction of the USArray component of the EarthScope MREFC project. IRIS is organized in four major program elements: (1) the Global Seismographic Network (GSN), which currently consists of a global deployment of 138 permanently installed digital seismic stations, most of which have real-time data access; (2) the Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL), which manages a pool of portable seismometers that are made available to the seismology research community for scheduled regional and local scale studies; (3) The IRIS Data Management System (DMS), which provides the national and international seismic research community with timely access to data from the GSN and PASSCAL (40 terabyte archive); and (4) The IRIS Education and Outreach (E&O) Program, which enables audiences beyond seismologists to access and use seismological data and research for educational purposes, including teacher workshops, student internships, museum exhibits, educational materials, and programs for under-resourced schools.

Principal Scientific Goals: The Earth's interior remains a major scientific frontier holding the key to understanding the origin of the planet. Recent developments in seismic sensor design, and the acquisition, transmission, and storage of data have resulted in dramatic improvements in the resolving power of seismic imaging of the interior. Earthquake research, including rapid and accurate location and characterization of the earthquake source, its magnitude and a better understanding of the physical process involved, has also benefited greatly from recent technical advances. The IRIS facility serves the research needs of the national and international seismology community by making available state-of-the-art designs in seismic sensors and data acquisition systems. In addition to its role in providing the observational data essential for basic research in geophysics and earthquake dynamics, IRIS plays a significant role in seismic monitoring of the Comprehensive Test Ban Treaty, and in bringing seismology to students and the public through the activities of its Education and Outreach program.

This is an image of the entrance to the Global Seismic Network's seismic vault on Tristan da Cunha in the South Atlantic. This station is part of a collaboration with the Comprehensive Test Ban Treaty Organization International Monitoring System and Geoscope. *Credit: Ted Kromer.*

Principal Education Goals: The IRIS E&O Program enables audiences beyond seismologists to access and use seismological data and research for educational purposes. E&O activities include teacher workshops, student field internships, museum exhibits, educational materials, the development of classroom seismic stations, and programs for under-resourced schools. E&O projects serve not only to advance public understanding of geoscience, but also to foster improved understanding of the scientific process and scientific data.

Partnerships: IRIS is heavily involved in partnership activities, many international in nature. Installation and operation of the GSN has put IRIS in contact with scientists as well as government and non-government organizations from around the world. Many international IRIS GSN stations are designated as the official stations for nuclear test ban monitoring in their host countries. International teams of

scientists organize most PASSCAL projects overseas. The IRIS facilities also are multi-use resources for other government agencies that have responsibilities for development of a nuclear test-ban monitoring capability and for monitoring global seismicity. For these purposes, agencies in partnership with NSF have provided substantial support to IRIS for accelerated development of the GSN (Department of Defense), shared operation and maintenance of the GSN (U.S. Geological Survey), and accelerated development of the PASSCAL instrument pool (Department of Energy).

Connections to Industry: The use of IRIS PASSCAL instruments for investigations of the shallow crust provides opportunities for collaboration with the petroleum exploration industry. Many students involved in these experiments receive training in techniques that prepare them for careers in the exploration industry. In a broader sense, IRIS continues to closely collaborate with industry in development of seismic instrumentation and software.

Management and Oversight: IRIS is incorporated as a non-profit consortium representing practically all U.S. university and non-profit organizations with research and teaching programs in seismology. Each member institution appoints a representative. However, all IRIS program and budget decisions are made by a nine-member Board of Directors. These decisions are made after consultation with the IRIS advisory committees (the four standing committees for each of the four IRIS programs and additional ad hoc working groups appointed for special tasks). The Board of Directors appoints a president of IRIS to a two-year term. The president is responsible for IRIS operations, all of which are managed through the IRIS Corporate Office.

The Division of Earth Sciences (in GEO), through its Instrumentation & Facilities Program (IF), provides IRIS with general oversight to help assure effective performance and administration. The program also facilitates coordination of IRIS programs and projects with other NSF-supported facilities and projects and with other Federal agencies and evaluates and reviews the scientific and administrative performance of IRIS.

Current Project Status: The IRIS consortium was founded in 1984 by 26 universities in response to recommendations in a report issued in 1983 by the Committee on Science, Engineering, and Public Policy (COSEPUP) of the National Academies. This report urged that "NSF act as overall coordinator and lead agency for funding a global digital seismic array and that the operation be planned and overseen by a university consortium." During the last twenty-two years, with support from the Foundation and federal partners, the IRIS consortium has grown to 104 full-member (voting) U.S. universities that operate core research facilities consisting of a GSN, PASSCAL, and a DMS. The FY 2008 Request for IRIS totals $11.40 million, a decrease of $1.50 million below the FY 2007 Request.

Funding Profile: All funding for IRIS to date has been provided through the R&RA Account

**IRIS Funding Profile**
(Dollars in Millions)

| | Implementation | Operations & Maintenance | Total, NSF |
|---|---|---|---|
| FY 2004 | 3.10 | 9.90 | $13.00 |
| FY 2005 | 2.85 | 9.05 | $11.90 |
| FY 2006 | 2.80 | 8.61 | $11.41 |
| FY 2007 Request | 3.40 | 9.50 | $12.90 |
| FY 2008 Request | 2.80 | 8.60 | $11.40 |
| FY 2009 Estimate | 2.90 | 8.70 | $11.60 |
| FY 2010 Estimate | 3.00 | 8.80 | $11.80 |
| FY 2011 Estimate | 3.10 | 8.90 | $12.00 |
| FY 2012 Estimate | 3.20 | 9.00 | $12.20 |
| FY 2013 Estimate | 3.30 | 9.20 | $12.50 |

NOTE: Operations estimates for FY 2009 and beyond have been developed based on current cost profiles and are not intended to reflect actual budget requirements. They will be updated as new information becomes available.

Information pertaining to the data in the table is included below.

- Implementation: Implementation includes funds for major equipment purchases (data recorders and seismometers) for the PASSCAL Instrument Center in Socorro, NM; the Global Seismographic Network (GSN); and the Data Management System in Seattle, WA.

- Operations and Maintenance: This category includes funds to support the IRIS corporate office in Washington, DC, including the Education & Outreach Program (E&O); the PASSCAL Instrument Center in Socorro, NM; the Data Management System (DMS) in Seattle, WA; and the Global Seismographic Network (GSN). IRIS conducts no "in-house research."

Renewal or Termination: Two reviews were stipulated in the last NSF cooperative agreement with IRIS: (1) an in-depth study by IRIS of the operation, personnel, and instrument costs, and support of the Global Seismographic Network (GSN), in collaboration with the USGS, representatives of the Federation of Digital Seismic Networks (FDSN), and GSN network operators by July 1, 2003; and (2) an NSF review of IRIS management in coordination with IRIS and its appropriate governance committees, to be completed by July 1, 2004. Both reviews have now been completed. The latter review provided more information for the basis of the decision to allow the submission of a renewal proposal rather than to recompete the operation of this facility. A new five-year cooperative agreement with the IRIS Consortium for the continued management of the IRIS facilities (2006-2011) was approved by the NSB in May 2006 and finalized in September 2006.

Associated Research and Education Activities: IRIS sponsors an active education and outreach program, which reaches a vast number of individuals annually. There are over 2,000 individuals on the IRIS mailing list, and over 120 K-12 schools and science centers are using seismographs provided by IRIS. The website visitors data in the table below indicate a yearly sum of unique visitors each month, and shows that the large increase in public interest after the Sumatra earthquake and tsunami has continued through the past year. The number of posters distributed has continued to increase, through the creation of "A Century of Great Earthquakes" poster in commemoration of the 1906 San Francisco earthquake centennial, the translation of the "Exploring the Earth" poster into Spanish, and a contribution to the American Geophysical Institute's Earth Science Week packet. Sixteen public Distinguished Lectures were given to audiences of up to 400 in FY 2006 in coordination with the Seismological Society of

America. IRIS holds a variety of professional development workshops each year for K-12 teachers and/or college faculty, varying in length from one hour to three days; in FY 2006, six such workshops of one day or more duration were held as well as four one-hour workshops. The teachers listed in the table only include one day or longer workshops. In addition, IRIS provided materials for 17 workshops organized by other groups. The K-12 students number assumes each teacher interacts with 80 students per year and continues to teach new students each year. The museum display visitors number is the total number of visitors to the museums that have an IRIS/USGS display.

| Year | K12 Students taught by IRIS trained teachers | Undergrad summer interns | Graduate students sponsored to attend annual IRIS workshop | K-12 Teachers trained in IRIS workshops | College faculty trained in 1-day workshops | Museum display visitors | Posters distributed | Website visitors |
|---|---|---|---|---|---|---|---|---|
| FY 1998 | 3,400 | 2 | 28 | 43 | | 500,000 | 2,000 | |
| FY 1999 | 5,300 | 6 | 22 | 23 | 35 | 2,000,000 | 5,000 | |
| FY 2000 | 6,900 | 2 | 30 | 20 | 20 | 9,000,000 | 4,000 | |
| FY 2001 | 12,000 | 3 | 33 | 65 | 25 | 9,000,000 | 3,000 | 250,000 |
| FY 2002 | 18,000 | 6 | 24 | 76 | 16 | 9,000,000 | 2,000 | 300,000 |
| FY 2003 | 27,000 | 9 | 25 | 117 | 25 | 9,000,000 | 4,000 | 450,000 |
| FY 2004 | 35,000 | 4 | 20 | 103 | 18 | 16,000,000 | 8,500 | 650,000 |
| FY 2005 | 43,000 | 9 | 20 | 110 | 0 | 15,500,000 | 20,000 | 1,400,000 |
| FY 2006 | 52,000 | 9 | 23 | 124 | 12 | 15,000,000 | 28,000 | 1,800,000 |

Science Support: The EAR/Geophysics and Continental Dynamics Programs, the OCE/Marine Geology and Geophysics Program, and the OPP/Antarctic Research Section (Geology and Geophysics and Glaciology Programs) provide most of the funds for NSF-sponsored research, totaling approximately $15.0 million per year. Funds permit deployment of PASSCAL instruments and use of GSN data stored at the DMS to solve major earth science problems.

**Integrated Ocean Drilling Program (IODP)**

Project Description: The Ocean Drilling Program (ODP) terminated in September 2003 with its final drilling programs in the North Atlantic. During the 18-year duration of the ODP, NSF provided 60% of the program's resources and all of the required facilities, with the remaining funding provided by international partners. Phase-out of program and contract activities is planned through FY 2007.

The Integrated Ocean Drilling Program (IODP), begun in FY 2004, is the successor program to the Ocean Drilling Program (ODP), and represents an expanded international partnership of scientists, research institutions, and funding agencies organized to explore the evolution and structure of Earth as recorded in the ocean basins. Ocean drilling is an essential capability in modern geoscience research and education and is used to examine processes ranging from changes in the Earth's climate to the rifting and drifting of continents. Over 600 ocean and earth scientists have completed an internationally coordinated planning effort to examine the scientific objectives for IODP, culminating in the *IODP Initial Science Plan: Earth, Oceans, and Life*. These objectives require a heavy vessel for drilling deep sedimentary and crustal holes; a lighter vessel to provide widely distributed arrays of high-resolution cores to address climate, environmental, and observatory objectives; and occasional use of drilling platforms for the Arctic and nearshore projects, which cannot be undertaken from the two primary IODP vessels.

The Ministry of Education, Culture, Sports, Science, and Technology (MEXT) of Japan has secured funding of at least $500 million and has completed construction of the heavy drillship *Chikyu* (Earth, in Japanese) to address deep drilling objectives in the new program. *Chikyu*, launched in January 2002, is undergoing testing and will be available for IODP operations in late 2007. NSF's contribution includes rebuilding the ODP drillship *JOIDES Resolution* to serve as the light drillship, the Scientific Ocean Drilling Vessel (SODV), using $115 million in MREFC funds in FY 2005 through FY 2007. An initial period of *JOIDES Resolution* operations extended from June 2004 to January 2006; MREFC SODV shipyard conversion began in Fall 2006. Delivery of the rebuilt *JOIDES Resolution* to IODP is expected in November 2007, and it is likely that the ship will be renamed to reflect its greatly enhanced capabilities. The European Consortium for Ocean Research Drilling (ECORD), composed of 16 European countries and Canada, is participating in IODP and providing short-term use of chartered drilling platforms for Arctic and near-shore objectives. The People's Republic of China and South Korea are additional IODP participants; Australia and several potential additional Asian countries may join as partners in the future.

IODP drilling operations provide sediment and rock samples (cores), shipboard and shore-based facilities for the study of these samples, downhole geophysical and geochemical measurements (logging), and opportunities for special experiments to determine in situ conditions beneath the seafloor. The IODP drilling platforms collect geologic samples from the floor of the deep ocean basins primarily through rotary coring and hydraulic piston coring. The logs and samples of the cores are made available to qualified scientists throughout the world for research projects.

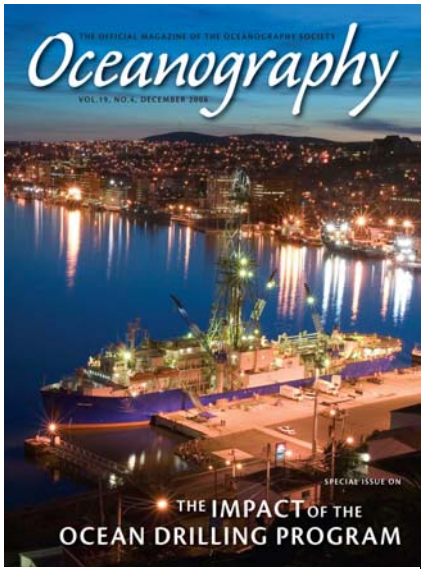
Principal Scientific Goals: The IODP scientific program is identified in the *IODP Initial Science Plan: Earth, Oceans and Life*, and includes emphasis on the following research themes:

- The Deep Biosphere and the Subseafloor Ocean: Drilling will concentrate on defining the architecture and dynamics of the vast subseafloor plumbing system, where flowing water alters rock, modifies the long-term chemistry of the oceans, lubricates seismically active faults, concentrates economic mineral deposits, and controls the distribution of the deep biosphere.

- The Processes and Effects of Environmental Change: Using a global array of sites, ocean sediment cores will be used to construct a detailed record of the causes, rates, and severity of changes in the earth's climate system, and their relation to major pulses in biologic evolution.

- Solid Earth Cycles and Geodynamics: Drilling will concentrate on sampling and monitoring regions of the seafloor that currently have the highest rates of energy and mass transfer, and comparing these results to older geologic settings. A crucial initial program of deep drilling will study the seismogenic zone responsible for large destructive earthquakes along active plate boundaries.

Principal Education Goals: Undergraduate and graduate students participate in drilling expeditions, working with some of the world's leading scientists and becoming part of the intellectual fabric essential for future advances in the earth sciences. To reach students that do not participate directly in IODP, investments are made in curriculum enrichment including interactive CD-ROMs, visiting lecture programs, museum displays, remote classroom broadcasts from the drillship, and having in service teachers sailing on drilling expeditions.




Evening falls on the Ocean Drillings Program's drillship *JOIDES Resolution* in St. Johns, Newfoundland, Canada. *Credit: Bill Crawford (Front cover of Oceanography Magazine, Vol. 19; No. 4, Dec. 2006)*

Partnerships: MEXT and NSF are equal partners in the IODP and contribute equally to program operation costs. A consortium of 16 European countries and Canada (ECORD), and the People's Republic of China, have officially joined IODP. In addition to its financial contribution, the European consortium supplies additional drilling facilities for IODP for short-term operations in shallow water and the Arctic. South Korea has joined as part of an emerging Asian Consortium, and negotiations for membership are underway with India and Australia.

Connections to Industry: As it did in ODP, NSF is contracting the services of the light drillship from a leading offshore drilling contractor. A commercial contractor provides downhole-logging services. In addition, scientists from industrial research laboratories participate in IODP cruises, are members of the program's scientific and technical advisory committees, and supply data for planning and interpretation of drilling results.

Management and Oversight: NSF and MEXT have signed a Memorandum of Cooperation, which identifies procedures for joint management of a contract to an IODP Central Management Office (CMO). The CMO coordinates and supports scientific planning, drilling platform activity, data and sample distribution, and publication and outreach activities through its management of commingled international science funds, collected and provided by NSF. A non-profit corporation founded by U.S. and Japanese institutions (IODP Management International, Inc.) has been contracted by NSF for the CMO activity. Drillship providers are responsible for platform operational management and costs. NSF provides the light drillship through contract with the U.S. System Integration Contractor (SIC), the Joint Oceanographic Institutions, Inc. (JOI) Alliance, a consortium of JOI, Texas A&M University, and Lamont-Doherty Earth Observatory. MEXT will manage its drillship through the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), while the British Geological Survey manages European drilling contributions.

Scientific advice and guidance for IODP is provided through the Scientific Advisory Structure (SAS). The SAS consists of the Science Advisory Structure Executive Committee (SASEC, the IODP executive

authority), and an advisory structure headed by the Science Planning Committee (SPC). The CMO, under the direction of the SPC Chair, is responsible for the coordination of the SAS committees and panels, and for integrating the advice from the panel structure in a manner suitable for providing drilling and operational guidance to the CMO. Membership in the SAS is proportional to IODP financial contribution.

The Division of Ocean Sciences (in GEO) manages the IODP for NSF under the NSF Ocean Drilling Program. NSF's Ocean Drilling Program is placed within the Marine Geosciences Section, with several program officers dedicated to its oversight. One of the program officers serves as the contracting officer's technical representative on the CMO and SIC contracts, and another oversees the MREFC SODV activity.

Current Program Status and Future Program Planning: IODP started in FY 2004. A first phase of light drillship drilling activity started in mid-FY 2004 and continued into early FY 2006. The NSF-supplied light SODV drillship, converted using MREFC funds for IODP needs, will begin drilling in late FY 2007. The heavy drillship *Chikyu* is expected to begin scientific drilling operations in late FY 2007. European-funded drilling expeditions have occurred in two places: the northern Arctic, where several icebreakers, one modified for drilling, were used in late FY 2004 and early FY 2005; and in shallow coral reefs around Tahiti in late FY 2005 and early FY 2006. Future European-funded drilling is expected off of New Jersey on the U.S. east coast margin.

Funding Profile: All funding for the operation of the ODP has been provided through the R&RA account. FY 2005 to FY 2007 MREFC account funding supports the acquisition and outfitting of a drillship for use in the program. For more information on this project, please see the SODV section of the MREFC chapter of this document.

**Ocean Drilling Funding Profile**
(Obligated Dollars and Estimates in Millions)

| | ODP Operations & Maintenance | SODV Operations & Maintenance | IODP Operational Support | Total, NSF |
|---|---|---|---|---|
| FY 2004 | - | | 35.75 | $35.75 |
| FY 2005 | 3.49 | | 36.70 | $40.19 |
| FY 2006 | 3.63 | | 28.56 | $32.19 |
| FY 2007 Request | 2.00 | 21.30 | 4.50 | $27.80 |
| FY 2008 Request | | 33.36 | 4.64 | $38.00 |
| FY 2009 Estimate | | 35.03 | 4.77 | $39.80 |
| FY 2010 Estimate | | 36.78 | 4.92 | $41.70 |
| FY 2011 Estimate | | 38.62 | 5.06 | $43.68 |
| FY 2012 Estimate | | 40.55 | 5.40 | $45.95 |
| FY 2013 Estimate | | 42.58 | 6.00 | $48.58 |

NOTE: Operations estimates for FY 2009 and beyond have been developed based on current cost profiles and are not intended to reflect actual budget requirements. They will be updated as new information becomes available.

Information pertaining to the data in the table is included below.

- Operations and Maintenance: The general contractor for the overall management and operation of the ODP is JOI, a consortium of major U.S. oceanographic institutions. Drilling operations and science support services (laboratory equipment, technical support, database maintenance, sample storage and

distribution) are managed by Texas A&M University. Lamont-Doherty Earth Observatory of Columbia University manages logging. Support for participation and drilling-related research performed by U.S. scientists is provided by NSF.

Renewal or Termination: IODP international agreements and contracts cover activities through FY 2013. Activities regarding IODP renewal are expected to commence in FY 2011.

Associated Research and Education Activities: Much of the support for Education and Outreach activities in ODP is through a cooperative agreement with JOI Inc., which has resulted in various educational products and services described here in brief. The "JOI Learning" program (Teaching for Science; Learning for Life) can be viewed at www.joilearning.org. Three educational CD-ROMs with teaching activities, interviews with scientists, and operational footage have been developed and widely distributed. An educational poster titled, "Blast from the Past," describing the meteorite impact that led to the demise of the dinosaurs was printed, and 64,000 copies have been distributed. An additional poster called "A Bolt from the Blue" shows several important aspects of methane hydrates that store methane gas in ocean sediments. A brochure of abstracts (text and figures) highlighting 17 of the Ocean Drilling Program's greatest scientific accomplishments was published and distributed. JOI also publishes a newsletter three times a year with a distribution of about 2,000. In addition, a display of ODP materials was produced and contributed to the Smithsonian Museum, in Washington DC, where it has been on permanent display since 1997. This display is viewed daily by thousands of museum visitors. (Numbers are not reflected in the table below.)

The services of the program are also listed here in brief.

- A Distinguished Lecturer Series, through which each year approximately 6 lecturers give a total of about 30 lectures at universities, colleges, and other institutions throughout the country.
- An Undergraduate Student Trainee Program enables undergraduates to sail on a research vessel as members of the scientific team. Mentors and scientific projects are an integral part of this program.
- An internship program at JOI was initiated several years ago as an attempt to introduce recent graduates to the career opportunities of science program management.
- A longstanding fellowship program provides graduate student fellowship awards to conduct ODP research.
- Each year JOI sponsors educational and promotional booths at national and international meetings where products and services are highlighted.
- The drillship *JOIDES Resolution* has visited U.S. ports approximately 10 times since 1994. At each visit, ship tours are given, and promotional and educational activities have been held at five of these port calls.
- JOI/ODP sponsors scientific research and planning workshops that commonly involve graduate students- many graduate students have sailed on the *JOIDES Resolution*.
- Finally, a highly successful "School of Rock" educator workshop was recently held aboard the *JOIDES Resolution* during a 16 day transit; participation by middle and high school teachers, museum educators and exhibit designers, and other educational professionals led to broadly-viewed daily webcasts as well as development of new curricular and museum outreach materials.

A breakdown of student and teacher participation by year and by category is reflected in the table below.

**ODP/IODP Participation**

| Year | K-12 | Undergrad | Graduate | Teachers |
|---|---|---|---|---|
| FY 1996 | 620 | 1,500 | 1,400 | 700 |
| FY 1997 | 2,620 | 6,210 | 4,900 | 1,800 |
| FY 1998 | 1,300 | 4,110 | 3,800 | 1,300 |
| FY 1999 | 2,600 | 5,740 | 5,900 | 2,200 |
| FY 2000 | 17,600 | 13,680 | 7,400 | 4,200 |
| FY 2001 | 5,600 | 9,750 | 9,400 | 9,700 |
| FY 2002 | 6,000 | 8,000 | 9,500 | 7,000 |
| FY 2003 | 6,500 | 8,500 | 9,500 | 7,500 |
| FY 2004 | 6,500 | 8,500 | 9,500 | 7,500 |
| FY 2005 | 6,500 | 8,500 | 9,500 | 7,500 |
| FY 2006 | 160,000 | 9000 | 9500 | 27000 |
| FY 2007 Estimate | 180,000 | 10,000 | 10,500 | 35,000 |

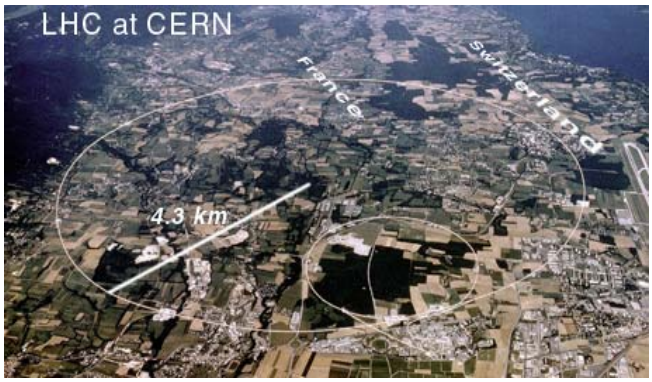
K-12 students is an estimate of students in classrooms with a teacher who was directly involved in IODP-supported education workshops or other activities targeted at K-12 educators.

Science Support: Over 2000 scientists from forty nations have participated on ODP and IODP cruises since 1985. About 900 of these have been U.S. scientists from over 150 universities, government agencies, and industrial research laboratories, with over 300 of them participating in more than one ODP cruise. Samples and data have been distributed to an additional 800 or more U.S. scientists. These more than 1,700 direct U.S. users of ODP materials approach 15 percent of the U.S. geoscience community as identified by the American Geological Institute.

NSF provides most of the support for the participation of U.S. scientists in the IODP. The majority of the funding comes from the Division of Ocean Sciences, with additional funding from the Office of Polar Programs related to Arctic and Antarctic drilling research. Total funding for U.S. participation and analysis of samples and data is expected to reach approximately $30-35 million annually.

**Large Hadron Collider (LHC)**

Project Description: The LHC will be the premier facility in the world for research in elementary particle physics. The facility will consist of a superconducting particle accelerator providing two, counter-rotating beams of protons, each beam having an energy up to 7 TeV ($1TeV=10^{12}$ electron volts). The U.S. is involved in the construction of two particle detectors, A Toroidal LHC Apparatus (ATLAS) and the Compact Muon Solenoid (CMS). They are being constructed to characterize the different reaction products produced in the very high-energy proton-proton collisions that will occur in intersection regions where the two beams are brought together.




The LHC is an underground particle accelerator that will accelerate tow counter-rotating beams of protons to 7,000 billion electron volts. The goal will be for protons from one beam collide with protons from the other. The accelerator is located on the border between France and Switzerland. *Credit: CERN* (www.atlas.ch/etours_accel/etours_accel03.html)

The LHC is an international project under construction at the CERN laboratory in Geneva, Switzerland. NSF awarded MREFC grants to Northeastern and Columbia Universities under cooperative agreements with subcontracts to over 50 U.S. universities. In FY 2003, the funding of LHC construction by NSF was completed. A total of 34 international funding agencies participate in the ATLAS detector project, and 31 in the CMS detector project. NSF and DOE are providing U.S. support. CERN is responsible for meeting the goals of the international LHC project. The ATLAS and CMS detectors are expected to take data approximately 200 days per year. The remaining time is to be used for maintenance and testing.

U.S. LHC maintenance and operations, software, and computing activities, funded through the R&RA account, are now ramping up with awards to UCLA (for CMS) and to Columbia University (for ATLAS). This includes some R&D for future detector upgrades.

The U.S. LHC collaboration has been a leader in the development of Grid-based computing. The Grid will enable the enhanced participation of U.S. universities, and thus the training of students, in both state of the art science and computational techniques, in a project that is centered overseas. The Grid is expected to have broad application throughout the scientific and engineering communities.

Principal Scientific Goals: The LHC will enable a search for the Higgs particle, the existence and properties of which will provide a deeper understanding of the origin of mass of known elementary particles. The LHC will also enable a search for particles predicted by a powerful theoretical framework known as supersymmetry, which will provide clues as to how the four known forces evolved from different aspects of the same 'unified' force in the early universe, and can investigate the possibility that there are extra dimensions in the structure of the universe.

Principal Education Goals: Through the participation of young investigators, graduate students, undergraduates, and minority institutions in this international project, LHC serves the goal of helping to produce a diverse, globally-oriented workforce of scientists and engineers. Further, innovative education and outreach activities, such as the QuarkNet project, allow high school teachers and students to participate in this project (see http://quarknet.fnal.gov). Many highly-trained students in high-energy physics move into industrial jobs.

LHC provides excellent opportunities for broadening participation of under-represented minorities in this energy frontier facility. In addition to students' participation on research grants, there are three noteworthy programs: (i) CHEPREO (Center for High Energy Physics Research and Education Outreach) lead by Florida International University, one of the largest Hispanic-serving U.S. institutions, creates a robust outreach activity based on CMS research, advanced networking, and LHC-related Grid computing infrastructure, creating pedagogic enhancements and teacher training; (ii) Center for the Study of the Origin and Structure of Matter, at Hampton University, an HBCU, which provides a strong graduate education program building upon Hampton's leadership role in U.S. LHC detector construction; and (iii) a large REU Site program at CERN with specific focus on involving African-American undergraduate students in the LHC research program.

Connections to Industry: Major procurements of components of both warm and superconducting magnets, as well as high-speed electronics, are performed through U.S. industries. Major developments in Grid computing are also valuable outcomes.

Management and Oversight: A program director in PHY (in MPS) is responsible for day-to-day project oversight. The NSF program director also participates in an internal PAT, including staff from BFA (including the DDLFP), OGC, OLPA, OISE, and the Office of the Assistant Director for MPS.

U.S. LHC program management is performed through a Joint Oversight Group (JOG), created by the NSF and DOE. The JOG has the responsibility to see that the U.S. LHC Program is effectively managed and executed to meet commitments made under the LHC International Agreement and its Protocols.

Current Project Status: CERN Project Management is making every effort to maintain the LHC extended schedule, which aims for first collisions in 2007, without significant delays. While both experiments may benefit from the extended LHC schedule by having additional time to optimize their installation plans, the U.S. collaborators continue on the original baseline schedule to avoid any increases in labor and costs. The entire U.S. LHC construction activity is being maintained within the funding cap set forth in the original U.S. funding guidance for the project.

FY 2007 Milestones: These focus on preparations for first collisions using both the ATLAS and CMS detectors.

US ATLAS
- Begin Trigger/DAQ support for operations with cosmic rays
- Receive ATLAS Approval of all U.S. ATLAS upgrade R&D tasks
- Release final version of software before first collisions
- Complete installation of muon system
- All U.S. ATLAS Detector Systems Operating
- Close ATLAS Beam Pipe
- Five Tier 2 Computing Facilities in Full Operation

US CMS
- Install DAQ from underground halls to surface
- Submit addenda to Physics Technical Design Report
- Complete Installation and cabling of tracker in underground hall
- Ensure CMS ready to close for beam
- Tier 0, 1, and 2 Computing Systems Operational (pilot run capacity)
- Receive pixel tracker at surface hall and ready for installation

FY 2008 Milestones: These focus on commissioning and data taking with both the ATLAS and CMS Detectors.

US ATLAS
- Complete first ATLAS Collisions at 0.9 TeV
- Finish installation of Trigger and Data Acquisition system
- Complete first ATLAS Collisions at 14.0 TeV

US CMS
- Complete first CMS Collisions at 0.9 TeV
- Complete installation of Pixel Tracker
- Operate Tier 0, 1, and 2 Computing Systems (low luminosity capacity)
- Complete first CMS Collisions at 14 TeV

Funding Profile: Funding for the overall LHC project, including the ATLAS and CMS detectors and the accelerator, is provided through an international partnership involving NSF, DOE, and the CERN member states, with CERN member states providing the major portion. Other countries that are not member states are also participating.

**LHC Funding Profile**
(Dollars in Millions)

| | Concept/ Development | | Implementation | | Operations & Maintenance | | Totals | | Grand |
|---|---|---|---|---|---|---|---|---|---|
| | R&RA | MREFC | R&RA | MREFC | R&RA | MREFC | R&RA | MREFC | Total |
| FY 2001& Earlier | 8.69 | | 0.15 | 54.26 | | | 8.84 | 54.26 | $63.10 |
| FY 2002 | 1.60 | | | 16.90 | | | 1.60 | 16.90 | $18.50 |
| FY 2003 | | | | 9.69 | 5.00 | | 5.00 | 9.69 | $14.69 |
| FY 2004 | | | | | 7.00 | | 7.00 | - | $7.00 |
| FY 2005 | | | | | 10.51 | | 10.51 | - | $10.51 |
| FY 2006 | | | | | 13.36 | | 13.36 | - | $13.36 |
| FY 2007 Request | | | | | 18.00 | | 18.00 | - | $18.00 |
| FY 2008 Request | | | | | 18.00 | | 18.00 | - | $18.00 |
| FY2009 Estimate | | | | | 18.00 | | 18.00 | - | $18.00 |
| FY 2010 Estimate | | | | | 18.00 | | 18.00 | - | $18.00 |
| FY 2011 Estimate | | | | | 18.00 | | 18.00 | - | $18.00 |
| FY 2012 Estimate | | | | | 18.00 | | 18.00 | - | $18.00 |
| FY 2013 Estimate | | | | | 18.00 | | 18.00 | - | $18.00 |
| Subtotal, R&RA | $10.29 | | $0.15 | | $161.87 | | $172.31 | | |
| Subtotal, MREFC | | - | | $80.85 | | - | | $80.85 | |
| **Total, Each Stage** | | $10.29 | | $81.00 | | $161.87 | | | $253.16 |

NOTE: The estimated operational lifespan of this project is approximately 20 years. NSF and DOE jointly provide the U.S. share of Operations and Maintenance funding for the LHC ATLAS and CMS detectors, as was done for construction. For FY 2002 and earlier, R&RA funds totaling $4.59 million for Concept/Development were listed under Operations and Maintenance in the Budget Requests for FY 2006 and earlier. This has been corrected in the present table. Operations and maintenance estimates for FY 2012 are for planning purposes only and may not reflect actual budget requirements.

The total U.S. contribution to the construction project was $531 million, with $450 million from DOE and $81 million from NSF. NSF and DOE jointly provided a total contribution of $331 million for the detector construction, while DOE provided the entire U.S. contribution ($200 million) for the accelerator

construction. There are two other major detectors being constructed, ALICE and LHC-B, in which the U.S. does not play a role in construction, although one NSF-supported group has recently joined the LHC-B experiment and is participating in monitoring and detector upgrade R&D.

Information pertaining to the data in the table is provided below.

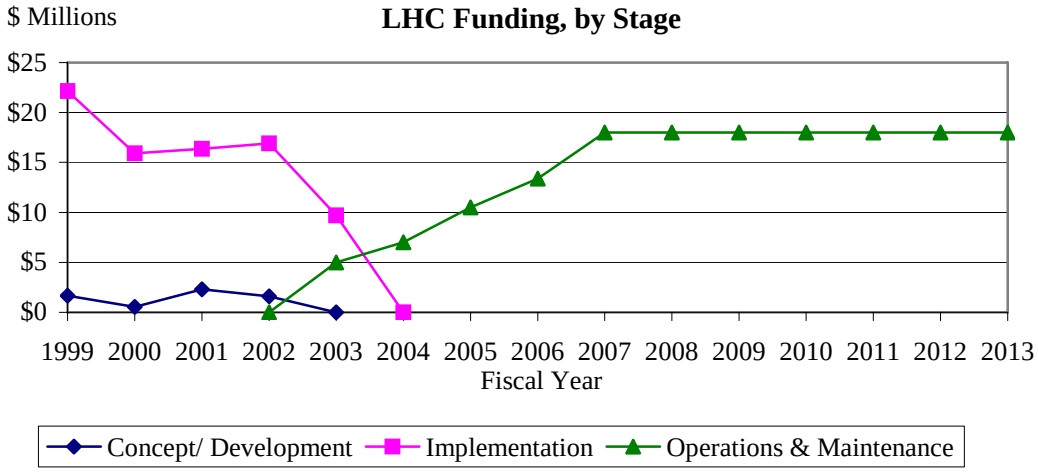
- Concept/Development: The LHC concept has been under discussion since FY 1989. NSF funding in FY 1996-99 supported technical design studies prior to the initiation of construction in FY 1999.

- Implementation: NSF components of the ATLAS and CMS detectors, constructed with funds provided FY 1999-2003, were originally anticipated to be completed, tested and ready to install by the end of FY 2005. The overall LHC project is now anticipated for completion at CERN in FY 2007. Final implementation funding was provided in FY 2003.

- Management & Operations: FY 1999-2008 funding primarily represents investments in university computing infrastructure and software development for remote access, which allows university scientists and students to participate in LHC research as well as other projects. Estimated funding for FY 2007 and beyond reflects NSF's share of operations as the ATLAS and CMS detectors approach and initiate operations. Components of these detectors, by far the largest ever constructed in particle physics, become inaccessible when additional components are installed, and all become inaccessible when data taking begins. To insure satisfactory performance, components must be operated, tested and repaired as soon as installed. Estimated funding during the same period also includes the development and maintenance of LHC grid software and computing (S&C). Detector operations costs and S&C costs are approximately equal. It is anticipated that over the lifetime of the LHC project, upgrades and new components to address emerging research questions will be considered. Funds for such activities are not included here.

This is the underground tunnel of the Large Hadron Collider (LHC) accelerator ring, where the proton beams are steered in a circle by magnets. The LHC is the accelerator facility (in France and Switzerland) which will contain the ATLAS and CMS detectors. *Credit: CERN* (www.atlas.ch/etours_accel/etours_accel01.html)

Software and Computing: Both US ATLAS and US CMS are active members in the US Grid activity that is providing computing resources to several sciences in addition to the LHC collaborations. In addition, both collaborations have now selected their initial set of "Tier-2 centers" which are primarily funded by NSF to provide data analysis capabilities for university researchers.




Science Support: Along with direct support for operations and maintenance for LHC, NSF will support science and engineering research performed at the facility, through ongoing research and education programs. The annual support for such activities is presently estimated to be about $5 million through awards to individuals once the facility reaches full operations. Both ATLAS and CMS have well-developed outreach activities (see Education Goals above).

**Laser Interferometer Gravitational Wave Observatory (LIGO)**

LIGO Livingston Observatory, Livingston Louisiana. *Credit: LIGO Laboratory.*

Project Description: Einstein's theory of general relativity predicts that cataclysmic processes involving extremely dense objects in the universe will produce gravitational radiation. Detection of these gravitational waves is of great importance, both for fundamental physics and for astrophysics. LIGO, the most sensitive gravitational wave detector ever built, comprises two main facilities, one in Livingston Parish, LA and one in Hanford, WA. At each facility, a large vacuum chamber, with two 4-km arms joined at right angles, houses one or more optical interferometers; Hanford has a second interferometer in the same housing. The interferometers are used to measure minute changes in the distances between test masses at the ends of the arms caused by a passing gravitational wave. The predicted distortion of space caused by a gravitational wave from a likely type of source is on the order of one part in $10^{21}$, meaning that the expected change in the apparent 4-km length is only on the order of $4 \times 10^{-18}$ or about 1/1000th the size of a proton. The 4-km length for LIGO, by far the largest for any optical interferometer, was chosen to make the expected signal as large as possible within terrestrial constraints. Looking for coincident signals in all the interferometers simultaneously increases the likelihood for gravitational wave detection. LIGO is currently operating at better than its design specifications. The Advanced LIGO (AdvLIGO) upgrade, designed to reach optimal sensitivity for an earth-based instrument, is requested to begin construction in FY 2008. For more information on AdvLIGO, see the MREFC chapter.

Principal Scientific Goals: Of the four known fundamental forces of nature (electromagnetic, weak, strong, and gravitational), the gravitational force is the most enigmatic. It is by far the weakest, yet it holds the universe together, ignites the fusion reaction in stars, and curves space in black holes so severely that light is trapped. Furthermore, even though the universe is believed to be filled with gravitational waves, not only from a host of cataclysmic cosmic phenomena but from the Big Bang itself, we have never detected a gravitational wave nor measured its waveform.

The principal scientific goals of LIGO are to detect gravitational waves for the first time and to develop this capability into a new window on the universe, a window through which we can observe phenomena such as the inspiral and coalescence of neutron stars in binary orbit, black hole collisions, unstable dynamics of newborn neutron stars, supernovae, stochastic background from the early universe, and a host of more exotic or unanticipated processes.

Principal Education Goals: LIGO has been a significant source of highly trained Ph.D. graduates for the country's workforce. The number of graduate students has grown from the beginning of LIGO's science runs in FY 2002 and will continue to do so. In addition, LIGO has a diverse set of educational activities at its different sites, activities that involve a large number of undergraduates (including those from minority-serving institutions), hands-on activities for K-12 classes, teachers at all levels, and informal education and outreach activities for the public. In FY 2004, LIGO received a large grant to build a Visitor Center at the Livingston, LA site that will be filled with Exploratorium exhibits and will be the focal point for augmenting teacher education at Southern University and other student-teacher activities state-wide through the Louisiana Systemic Initiative Program. Construction began on the center in early FY 2006, and it was dedicated in November FY 2007.

LIGO is committed to broadening participation. Both facilities are located near large populations of underrepresented minorities. Southern University, the largest HBCU, is heavily involved in LIGO research, with faculty and students able establish strong research programs; and LIGO has been able to partner with SU in their outreach program to reach to the larger African-American community. The LIGO Hanford facility is located in a region with large Hispanic and Native American population, and through laboratory outreach programs and visitor programs, has been able to interest students and teachers from K-12 schools and from local colleges and universities from those communities in the forefront science of LIGO and in science and mathematics generally.

Connections to Industry and to Other Federal Agencies: Substantial connections with industry have been required for the state-of-the-art construction and measurements involved in the LIGO projects. Some have led to new products. Areas of involvement include novel vacuum tube fabrication technology, seismic isolation techniques, ultrastable laser development (new product introduced), development of new ultra-fine optics polishing techniques, and optical inspection equipment (new product). LIGO has recently cooperated with the Defense Intelligence Agency on research on LIGO interferometers as impulse seismic event detectors.

Management and Oversight: LIGO is sponsored by NSF and managed by Caltech under a cooperative agreement. The management plan specifies significant involvement by the user community, represented by the LIGO Scientific Collaboration (LSC), and collaboration with the other major gravitational-wave detector activities in Japan, Europe, and Australia. External peer-review committees organized by the NSF help provide oversight through an annual review. NSF oversight is coordinated internally by the LIGO Program Director in PHY in MPS, who also participates in the Physics Division PAT, comprising staff from the OGC, OLPA, BFA (including the DDLFP), and OISE.

Current Project Status: All three LIGO interferometers were fully operational by the spring of 2002. Since then, activity has been divided between improving the sensitivity of the interferometers and collecting scientific data. Four science runs have been performed: S-1, in the period from August 23, 2002 to September 9, 2002, with a sensitivity of about a factor of 100 from the design goal; S-2 lasted 59 days from February 14, 2003 to April 14, 2003, with a sensitivity of about a factor of 10 from the design goal; S-3 in the period from October 31, 2003 to January 8, 2004, with a sensitivity of about a factor of 3.5 from the design goal; and S-4 from February 22, 2005 to March 23, 2005. The improvements achieved in S-4 were remarkable. The addition of the Hydraulic External Pre-Isolation (HEPI) system to the Livingston interferometer to eliminate interference from anthropogenic noise sources was totally successful, as indicated in the improvement of the Livingston duty cycle from 21.8 percent in S-3 to 74.5 percent in S-4 leading to more than a 50 percent triple coincidence operation during the run. In addition, during S-4 all three interferometers showed high sensitivity, achieving levels within a factor of two of design sensitivity. The LIGO facility in Livingston Parish, LA, suffered only very minor damage from Hurricane Katrina.

LIGO Hanford Observatory, Hanford, Washington. *Credit: LIGO Laboratory.*

The mission-defining S-5 science run, which began on November 4, 2005, and is expected to last for eighteen months, has already attained a sensitivity approximately 40 percent better than the design goal. The FY 2008 request for LIGO operations is $28.20 million. This funding level, which is less than the $33.0 million requested for FY 2007, assumes that the AdvLIGO construction project will start in FY 2008 and that some LIGO personnel will be diverted to that project.

Funding Profile: The history of the LIGO project dates back to early conceptual work in the mid-1970s, moving through pre-construction R&D in the late 1980s to the initiation of LIGO construction in FY 1992. LIGO pre-dates the establishment of the MREFC account in FY 1995.

**LIGO Funding Profile**
(Obligated Dollars and Estimates in Millions)

| | Concept/ Development (R&RA) | Implementation | | Operations & Maintenance (R&RA) | Totals | | Grand Total |
|---|---|---|---|---|---|---|---|
| | | R&RA | MREFC | | R&RA | MREFC | |
| FY 2004 & Earlier | 47.56 | 35.90 | 236.00 | 33.00 | 116.46 | 236.00 | $352.46 |
| FY 2005 | | | | 32.00 | 32.00 | - | $32.00 |
| FY 2006 Actual | | | | 31.68 | 31.68 | - | $31.68 |
| FY 2007 Request | | | | 33.00 | 33.00 | - | $33.00 |
| FY 2008 Request | | | | 28.20 | 28.20 | - | $28.20 |
| FY 2009 Estimate | | | | 27.60 | 27.60 | - | $27.60 |
| FY 2010 Estimate | | | | 27.80 | 27.80 | - | $27.80 |
| FY 2011 Estimate | | | | 29.20 | 29.20 | - | $29.20 |
| FY 2012 Estimate | | | | 32.20 | 32.20 | - | $32.20 |
| FY 2013 Estimate | | | | 36.00 | 36.00 | - | $36.00 |
| FY 2014 Estimate | | | | 42.90 | 42.90 | - | $42.90 |
| Subtotal, R&RA | $47.56 | $35.90 | | $353.58 | $437.04 | | |
| Subtotal, MREFC | | | $236.00 | | | $236.00 | |
| **Total, Each Stage** | $47.56 | | $271.90 | $353.58 | | | $625.48 |

NOTE: The expected operational lifespan of this project is about 20 years. The decreases beginning in FY 2008 reflect the initiation of construction of Advanced LIGO, scheduled to begin that year. LIGO activities will continue during the construction of AdvLIGO. These operations estimates were developed strictly for planning purposes. A recent cost and schedule baseline review may result in modifictions to these numbers, once the results have been through the standard NSF processes. For more information on future operations of the upgraded facility, please consult the MREFC chapter of this document.

Detailed information pertaining to the data in the table is included below.

- Concept/Development: Funds supported three phases of planning, design and development for LIGO: early conceptual R&D – $11.6.0 million (FY 1975-87); pre-construction R&D – $16.0 million (FY 1988-91); and ongoing R&D throughout construction – $20.0 million (FY 1992-98).

- Implementation: LIGO construction occurred between FY 1992-98, totaling $271.90 million. Prior to the start of the MREFC account, construction funding was provided through the R&RA account.

- Management and Operations: LIGO management and operations (M&O) costs began phasing-in in FY 1997. Commissioning costs are included in LIGO operations through FY 2001. M&O funding includes operation for science and engineering runs and R&D for advanced detectors. Note that the M&O figures for LIGO in FY 2008 through FY 2015 are the same as those shown for AdvLIGO in the MREFC section.

Renewal or Termination: NSF extended the cooperative agreement for the support of LIGO operations, which was to expire at the end of FY 2006, to continue operations, including the current extended science run, and to conduct research in preparation for Advanced LIGO.

Associated Research and Education Activities: Active outreach programs have been developed at both the Livingston and Hanford sites. Teams at both sites have provided visual displays, hands-on science exhibits, and fun activities for visiting students and members of the public. In the last three years an average of over 2,000 students per year at each site have taken advantage of this opportunity. More formal programs at the sites include participation in the Research Experiences for Teachers (RET) Program, a set of "scientist-teacher-student" research projects in support of LIGO, and participation in the Summer Undergraduates Research Fellowships/Research Experiences for Undergraduates (SURF/REU) programs for college students. In collaboration with RET participants and networks of local educators, both sites have developed Web-based resources for teachers that include information on research opportunities for schools and a set of standards-based classroom activities, lessons, and projects related to LIGO science. In FY 2004, NSF initiated a project to build a Science Education Center at the Livingston, LA site that will be filled with Exploratorium exhibits. The Center, which was dedicated in November 2006, is the focal point for augmenting teacher education at Southern University and hosts other student-teacher activities state-wide through the Louisiana Systemic Initiative Program. Outreach coordinators have been hired at each site to augment the existing activities.

Science Support: Along with direct operations and maintenance support for LIGO, NSF supports science and engineering research directly related to LIGO activities through ongoing research and education programs. The annual support for such activities is estimated to be about $5.5 million.

In 1997, LIGO founded the LIGO Scientific Collaboration (LSC) to organize the major international groups doing research that was supportive of LIGO. The LSC now has more than 40 collaborating institutions with over 500 participating scientists. An MOU between the LIGO Laboratory and each institution determines the role and membership responsibilities of each participating institution. The LSC plays a major role in many aspects of the LIGO effort including: R&D for detector improvements, R&D for Advanced LIGO, data analysis and validation of scientific results, and setting priorities for instrumental improvements at the LIGO facilities.

## Major Research Equipment and Facilities Construction Projects

The MREFC account supports the acquisition, construction and commissioning of major research facilities and equipment that provide unique capabilities at the frontiers of science and engineering. Projects supported by this account are intended to extend the boundaries of technology and open new avenues for discovery for the science and engineering community. Initial planning and design, and follow on operations and maintenance costs of the facilities are provided through the R&RA and Education and Human Resources (EHR) accounts.

NSF believes that the highest priority within the MREFC account must be the current projects. To that end, the highest priority in FY 2008 is to continue to fund the Alaska Region Research Vessel ($42.0 million), the Atacama Large Millimeter Array ($102.07 million), the IceCube Neutrino Observatory ($22.38 million), the National Ecological Observatories Network ($8.0 million), the Ocean Observatories Initiative ($30.99 million), and the South Pole Station Modernization project ($6.55 million).

NSF is requesting funding for one new start in FY 2008: Advanced LIGO ($32.75 million). For additional information on all projects funded through the MREFC account, please see the MREFC chapter of this document.

**National High Magnetic Field Laboratory (NHMFL)**

Project Description: The NHMFL develops and operates high magnetic field facilities that scientists use for research in physics, biology, bioengineering, chemistry, geochemistry, biochemistry, materials science, medicine, and engineering. It is the world's largest and highest-powered magnet laboratory, outfitted with a comprehensive assortment of high-performing magnet systems. Many of the unique facilities were designed, developed, and built by the magnet engineering and design team at the NHMFL in collaboration with industry. The NHMFL is committed to broaden the participation of the user base and make its facilities available to all qualified scientists and engineers through a peer-review proposal process.

Principal Scientific Goals: NHMFL scientific goals are to provide the highest magnetic fields, state-of-the-art instrumentation, and support services for scientific research conducted by users from a wide range of disciplines, including all areas of science and engineering.

Principal Education Goals: NHMFL promotes science education and assists in developing the next generation of scientists, engineers, and science education leaders with special emphasis on broadening the participation to include women and minorities currently underrepresented in science, mathematics, and engineering. A variety of programs, opportunities, and mentorship experiences are available for teachers and students at all academic levels – K-12 through post-graduate. The laboratory, with its distinguished faculty and world-class facilities, provides a unique interdisciplinary learning environment and has had a national impact in curriculum development. In FY 2005, its regional K-12 outreach efforts engaged over 6600 students from Florida and neighboring Georgia in hands-on science activities and tours of the laboratory.

Partnerships and Connections to Industry: The Magnet Science and Technology (MS&T) Division of the NHMFL has broad responsibility to develop high magnetic fields and materials for high field magnet wires in response to national needs, such as building advanced magnet systems for the NHMFL sites, working with industry to develop the technology to improve and address new opportunities in magnet-related technologies, and pushing the state-of-the-art beyond what is currently available in high field magnet systems through materials research and magnet technology development. To this purpose, MS&T has established leading capabilities in many aspects of magnet system engineering and assessment. In addition, MS&T cooperates with industry and other international magnet laboratories on a variety of technology projects such as the advancement of conducting materials for magnets, including high quality Copper-Niobium micro-composite wires with outstanding characteristics (strength, conductivity, and resistive ratio) that are now available for the construction of high field coils. These technology projects cover the range of analysis, design, materials, component development and testing, coil fabrication, cryogenics, and system integration and testing.

According to the NHMFL's web site, www.magnet.fsu.edu/collaborations/, the Laboratory is collaborating with the "U.S. Navy, FSU, the FAMU-FSU College of Engineering, and numerous private sector partners to develop advanced power systems that will support the Navy's all-electric ship program. This R&D effort for the next-generation of ship propulsion is expected to have broad applications in aerospace, commercial industry, and electric utilities."

Management and Oversight: The NHMFL is operated for the NSF by a consortium of institutions comprised of Florida State University (FSU), the University of Florida (UF), and Los Alamos National Laboratory (LANL) under a cooperative agreement that sets forth the goals and objectives of the NHMFL. NSF established the NHMFL in 1990 and the facility was dedicated and opened to users in October 1994. FSU, as the signatory of the cooperative agreement, has the responsibility for establishing

and maintaining appropriate administrative and financial oversight and for ensuring that the operations of the laboratory are of high quality and consistent with the broad objectives of the cooperative agreement.

**The 900 MHz Ultra-Wide Bore Magnet**

The 900 MHz Ultra-Wide Bore Magnet, one of the most powerful superconducting magnets on the planet, capable of creating a magnetic field of 21 tesla (about .5 million times the strength of the Earth's magnetic field). *Credit: NHMFL*

The principal investigator serves as the director of the NHMFL. Four senior faculty members serve as co-principal investigators. The laboratory is organized into three functional activities: User Programs, Magnet Science and Technology Programs, and Research Programs. In addition, the NHMFL has an Office of Government and Public Affairs that oversees corporate outreach activities, including interactions with private industry, federal agencies and institutions, and international organizations. The NHMFL also operates a Center for Integrating Research and Learning (CIRL) that manages educational outreach at all levels. Through the organizational network, the director receives guidance and recommendations from the NHMFL Executive Committee, staff, participating institutions, and user communities. Two external committees meet regularly to provide the laboratory with critical advice on important user, management, and operational issues. The Users' Committee, elected by the user community, represents the broad range of users of all of the NHMFL facilities and provides guidance on the development and use of NHMFL facilities and services in support of users. The External Advisory Committee is comprised of representatives from academic, government, and industrial organizations, and from the user community and reports directly to the President of Florida State University. It provides advice and guidance on matters critical to the success of the management of the NHMFL.

The National Facilities Program Director in NSF's Division of Materials Research (in MPS) has primary responsibility for NSF administration and oversight of the NHMFL with guidance from an *ad hoc* working group with representatives from the Division of Chemistry (MPS), the Directorate for Engineering, and the Directorate for Biological Sciences. Site visit reviews are conducted annually. Representatives from other federal agencies including DOE and NIH are invited to participate as observers at the site visit reviews.

The Laboratory has a diversity plan that is part of the cooperative agreement. The plan is updated and reviewed annually. As part of the plan the NHMFL has increased the diversity of its advisory committee. In addition, a newly established Diversity Advisory Committee reports directly to the Laboratory Director.

Current Project Status: When first established in 1990, the primary emphasis of the NHMFL was magnet technology and development in order to provide high magnetic fields for users. An extensive suite of instrumentation for high-field research is now in place. Major projects completed include a continuous-field 45 Tesla hybrid magnet in operation since 2003 and a 900 Megahertz (MHz) ultra-wide-bore nuclear magnetic resonance (NMR) magnet open for use since July 2005. The NHMFL has now entered a new phase with emphasis on service to users in combination with in-house and collaborative research and an extensive set of educational programs. The magnet technology activity has moved towards the development of new energy efficient magnets and to making high magnetic fields available at the nation's premier neutron and photon sources.

NSF renewed support for the NHMFL in 1996 and again in 2001 following comprehensive external reviews. The current cooperative agreement for the support of NHMFL operations was extended for 2 years with NSB approval, and will end in December 2007. Based on the recommendation of an external advisory panel, further support for the Laboratory will depend on the evaluation of a renewal proposal submitted to NSF in FY 2007.

The NSF FY 2007 Request for the NHMFL totals $26.50 million, including support for the National High Field Mass Spectrometry Facility from the Division of Chemistry. An additional $2.50 million in annual support is currently planned beginning in FY 2008; final support levels for FY 2008 and beyond will depend on the outcome of the review of the renewal proposal.

Funding Profile: All NSF funding for the NHMFL to date has been provided through the R&RA account.

**NHMFL Funding Profile**
(Dollars in Millions)

| | Implementation | Operations & Maintenance | Total, NSF |
|---|---|---|---|
| FY 2001 | 6.20 | 13.80 | $20.00 |
| FY 2002 | 7.97 | 17.00 | $24.97 |
| FY 2003 | 6.50 | 17.43 | $23.93 |
| FY 2004 | 3.44 | 21.06 | $24.50 |
| FY 2005 | 3.83 | 21.67 | $25.50 |
| FY 2006 | 3.90 | 21.84 | $25.74 |
| FY 2007 Request | 4.00 | 22.50 | $26.50 |
| FY 2008 Request | 4.00 | 25.00 | $29.00 |
| FY 2009 Estimate | 4.00 | 25.00 | $29.00 |
| FY 2010 Estimate | 4.00 | 25.00 | $29.00 |
| FY 2011 Estimate | 4.00 | 25.00 | $29.00 |
| FY 2012 Estimate | 4.00 | 25.00 | $29.00 |

The data are presented as being either implementation (permanent equipment) or operations and maintenance (including non-permanent equipment). Estimates for FY 2008 and beyond are dependent on the outcome of a 5 year renewal request to be reviewed in FY 2007.

Information pertaining to the data in the table is included below.

- Implementation: The NHMFL supports a wide range of state-of-the-art magnets and instrumentation that are continuously upgraded for the user community. Capacitor driven magnets are the backbone of user programs at the Pulsed Field Facility at Los Alamos. Magnet Science and Technology has aggressively pursued several major magnet projects that are part of the NHMFL core mission to develop world-class magnet systems for high field research. The Ultra-Wide Bore 900 MHz NMR magnet is currently available to users through a competitive peer review process. Contingent on merit review, NSF plans to support the construction of the Series-Connected Hybrid (SCH). SCH will provide combined high DC field with high stability and high homogeneity at much lower power than current magnets. At the NHMFL/LANL, construction continued steadily on the NSF-DOE funded 100 T Multi-Shot Magnet. In FY 2006 DMR made a Conceptual Design Award to Johns Hopkins University for a high-field magnet for neutron scattering experiments at the Spallation Neutron Source.

The NHMFL's Ion Cyclotron Resonance (ICR) Program supports a 14.5 Tesla Fourier Transform-Ion Cyclotron Resonance (FT-ICR) mass spectrometer to address a broad range of biological, drug discovery, and petrochemical problems that require ultrahigh resolution and extremely accurate mass. A 7 T FT-ICR mass spectrometer is dedicated to analysis of volatile mixtures (e.g., low boiling fractions of crude oil) and FT-ICR instrumentation development.

- Operations and Maintenance: These funds support the operation of the NHMFL, including magnet technology and development, support for user programs, in-house research, routine maintenance, instrumentation and technical services, and education and outreach programs. The increased level of maintenance and operations support that began in FY 2002 and continues through 2007 has enabled the NHMFL to strengthen its programs for user support, equipment and facility maintenance, educational outreach and partnerships, and in-house research, and to meet increased costs for internal facilities and administration including electricity demand charges to operate high-field magnets. Research in the DC general-purpose facility is supported by eight scientists and an engineer whose specialties cover the kinds of measurements needed for most of the science done at the NHMFL and who work directly with users. In addition, the DC facility is supported by eight magnet plant and cryogenic system operators and mechanical, electronic, and computer engineers and technicians.

Associated Research and Education Activities: The NHMFL base award currently includes support of Research Experiences for Undergraduates (REU), and a wide variety of pre-college educational outreach and partnership activities with additional funding from the State of Florida. The REU program hosted 15 females, 6 Hispanics and 6 African-Americans among the 37 REU students in the 2005 and 2006 programs. In FY 2006 NHMFL was awarded $122,057 to continue a Research Experiences for Teachers (RET) activity in FY 2006. The Laboratory's diversity plan anticipates increased accessibility for minorities to the REU/RET programs. In addition, ongoing partnerships with HBCUs and other minority institutions will be strengthened.

In FY 2005, educators at the Center for Integrating Research and Learning (an integral part of the NHMFL) provided in-class educational experiences for over 6600 students from 31 schools in nine counties and two states. The Center provided professional development opportunities for over 100 teachers through summer institutes, workshops, and conferences. In addition, tours of the NHMFL were provided to 970 members of the general public with 840 contact hours led by over 60 different guides. This gives rise to a total of more than 7,000 students, teachers, and general public coming in contact with some facet of the NHMFL's educational programs.

**Participation in NHMFL Education Programs**

| Year | K-12 | Undergrad[1] | Graduate[2] | Teachers[3] |
|---|---|---|---|---|
| FY 1994 | 1,200 | 8 | N/A | 3 |
| FY 1995 | 1,515 | 10 | N/A | 9 |
| FY 1996 | 3,990 | 16 | N/A | 30 |
| FY 1997 | 4,075 | 18 | 19 | 255 |
| FY 1998 | 4,080 | 18 | 15 | 547 |
| FY 1999 | 7,100[a] | 20 | 16 | 385 |
| FY 2000 | 4,266 | 21 | 22 | 1,875[b] |
| FY 2001 | 3,959 | 17 | 20 | 1117 |
| FY 2002 | 3,500 | 15 | 22 | 1319 |
| FY 2003 | 6,841 | 21 | 19 | 226[c] |
| FY 2004 | 6,252 | 20 | 16 | 189 |
| FY 2005 | 7,000 | 20 | 22 | 200 |
| FY 2006[d] | 7,000 | 17 | 3 | 200 |

[1]Undergraduates participating in the Summer Minority Program and/or REU

[2]NHMFL-affiliated graduate students earning Ph.D.'s

[3]Reflects teachers participating in workshops, Ambassador Program, and Research Experiences for Teachers.

[a]Statewide implementation of curriculum project in 1999.

[b]Teacher workshops extended to Connecticut and Illinois in 2000.

[c]State of Florida eliminated funding for "Science, Tobacco and You" Program in 2003.

[d]The FY 2006 number of students receiving PhDs data is incomplete

In addition to the individuals included in the table above, the NHMFL also integrates undergraduate and graduate students and postdoctoral fellows into its ongoing research activities on a regular basis. For example, during 2006, the NHMFL at FSU supported an average of 97 graduate students, 33 postdoctoral research associates, and 25 undergraduates through awards outside the NSF-NHMFL core funding, e.g. individual investigator grants, state funding, and external sources. The NHMFL is actively preparing and recruiting the next generation of high-field magnet scientists, engineers, and users.

Science Support: Users are supported by NSF, other Federal, state and local agencies, and the private sector. User projects and time are allocated by merit on a competitive basis. NSF does not track the level of user support from non-NSF sources. The laboratory serves more than 2,000 individual users annually.

**National Nanofabrication Infrastructure Network (NNIN)**

Project Description: The NationaleNanotechnology Infrastructure Network (NNIN) comprises 13 university sites that form an integrated national network of user facilities supporting research and education in nanoscale science, engineering, and technology. The NNIN provides users across the nation with access, both on-site and remotely, to leading-edge tools, instrumentation, and capabilities for fabrication, synthesis, characterization, design, simulation, and integration. The broad scope of NNIN coverage includes areas of physics, chemistry, materials, mechanical systems, geosciences, biology, life sciences, electronics, optics, molecular synthesis, and molecular scale devices, among others.

Principal Scientific Goals: The NNIN's broad-based national user facilities enable the nation's researchers from academia, small and large industry, and government to pursue new discoveries and applications and help stimulate technological innovation in diverse domains of nanoscale science and engineering. The network also develops the infrastructure and intellectual capacity needed to examine and address societal and ethical implications of nanotechnology, including issues of environment, health, and safety.

Principal Educational and Outreach Goals: The NNIN undertakes on a national scale a broad spectrum of innovative activities in education, human resource development, knowledge transfer, and outreach with special emphasis on non-traditional users and under-represented groups, including women and minorities.

Partnerships and Connections to Industry: The NNIN seeks to leverage its capabilities through connections and collaborations with national and industrial laboratories, and with foreign institutions. Through such partnerships, joint meetings, and workshops, the network will share expertise and perspectives, provide specialized training opportunities, coordinate access to unique instrumentation, and transfer newly developed technologies.

Management and Oversight: The NNIN is managed as a cohesive and flexible network partnership through a Network Executive Committee derived from individual Site Directors and Education/Outreach and Society/Ethics Coordinators. The Network Director provides intellectual leadership for the network; is responsible, in cooperation with the Network Executive Committee, for developing strategies, operational plans, and coordination of the activities of the network; and serves as the principal contact on behalf of the network with NSF. An external Network Advisory Board meets at least annually, and provides independent advice and guidance to the Network Director and Executive Committee concerning the network's programs, activities, vision, funding allocations, and new directions. The Advisory Board shares its major recommendations with NSF. The Site Directors are responsible for local management functions of individual user facilities; for interfacing with other facilities and with the management team for the overall network; and for connections with the outside communities.

NSF provides oversight to the NNIN under a cooperative agreement, which requires annual site reviews held at one of the network sites. In addition, a semi-annual review is held at NSF attended by the Network Director, Site Directors, and area coordinators. The program officer for the NNIN activity resides in the Division of Electrical, Communications, and Cyber Systems (ECCS) in ENG. The program officer coordinates NNIN oversight with other Division and Directorate members of the NNIN working group. The working group consists of representatives from all NSF Directorates.

Current Project Status: The NNIN began operation under its award on March 1, 2004. The first comprehensive annual review of the NNIN was held following an initial nine months of operation at the Georgia Institute of Technology node in December 2004. The second annual review was held at the University of Texas, Austin node in February 2006. Due to continuity provided by the five sites in the

previous National Nanofabrication Users Network (NNUN), and to the credit of the NNIN management team, the network displays many of the attributes promised in the original vision from the proposal: a broad area of accessible micro- and nano- fabrication and characterization resources; a solid base of users with a significant representation from outside the host institutions including industrial and educational users; a strong research portfolio generated by the user community; continued improved performance at new sites with good plans in place to make them fully functioning nodes with solid user bases, including external users; and impressive network-wide efforts on educational outreach and societal and ethical implications of nanotechnology.

Funding Profile: The first three years of funding were $13.80 million in FY 2004 and FY 2005 and $14.43 million in FY 2006. The FY 2008 Request is $13.89 million, equal to the FY 2007 Request of $13.89 million. Primary funding for NNIN is provided by ENG; additional funding is provided by all the Directorates in the R&RA account. The Directorate for Education and Human Resources provides support for NNIN through the Advanced Technology Education program.

**NNIN Funding Profile**
(Dollars in Millions)

| | Implementation | Operations & Maintenance | Total, NSF |
|---|---|---|---|
| FY 2004 | | 13.80 | $13.80 |
| FY 2005 | | 13.80 | $13.80 |
| FY 2006 | | 14.43 | $14.43 |
| FY 2007 Request | | 13.89 | $13.89 |
| FY 2008 Request | | 13.89 | $13.89 |
| FY 2009 Estimate | | 13.90 | $13.90 |
| FY 2010 Estimate | | 14.00 | $14.00 |
| FY 2011 Estimate | | 14.10 | $14.10 |
| FY 2012 Estimate | | 14.20 | $14.20 |
| FY 2013 Estimate | | 14.30 | $14.30 |

NOTE: Data in FY 2004-2008 does not include support provided through the Advanced Technological Education program in the Directorate for Education and Human Resources. Estimates for FY 2009 and beyond are developed strictly for planning purposes and are based on current usage and cost profiles. They will be updated as new information becomes available.

Information pertaining to the data in the table is included below.

- Operations and Maintenance: The major portion of NSF funds provides for operation and staffing of the user facilities and associated network activities. They also provide for acquisition and for in-house development of appropriate instrumentation, tools, and processes to serve the user needs. NSF may provide up to a 15 percent annual increase in budget beginning in FY 2008 should there be a need to cover anticipated growth in the user base, with related increased education, training and staffing costs; and enhanced instrumentation. NNIN has provided cumulative user data for the latest annual reporting period, extrapolated over the last three months, to cover March 2006-February 2007. The cumulative number of users for all 13 NNIN sites is 4,625, a 12% increase over the previous reporting year. This includes 3,473 academic users, 448 small company users, and 222 large company users. Academic users includes undergraduates, graduates, postdoctoral associates, and faculty, but is primarily graduate students. Approximately 1,000 graduate students earning PhD awards each year depend on NNIN facilities to conduct an important part of their research. Over

1,700 scholarly publications have resulted and over $400 million in research investment nationwide is leveraged by use of NNIN facilities.

Renewal or Termination: The current award expires at the end of FY 2008. It may be renewed once without re-competition for an additional five years, subject to satisfactory review of performance and availability of funds. The maximum duration of the award is for ten years.

Associated Research and Education Activities: The institutions comprising the NNIN have strong underlying internal research programs that provide critical research mass and knowledge base in developing new processes, methodologies, and instrumentation. Planned and ongoing NNIN educational contributions include a hyperlinked open textbook on nanotechnology for undergraduate and graduate students, a science magazine designed to stimulate and challenge 6-10 years olds to explore the physical sciences, a web-based multimedia suite encompassing training and courses for various disciplines in nanoscale science and engineering, and a network-wide Research Experience for Undergraduates (REU) program. In FY 2005, 81 undergraduate students participated in the REU program primarily with use of NSF supplemental REU site funds and other agency resources. In FY 2006, due to lack of these supplemental resources and the need to rely on NNIN site funds, the number of REU students was reduced to 64.

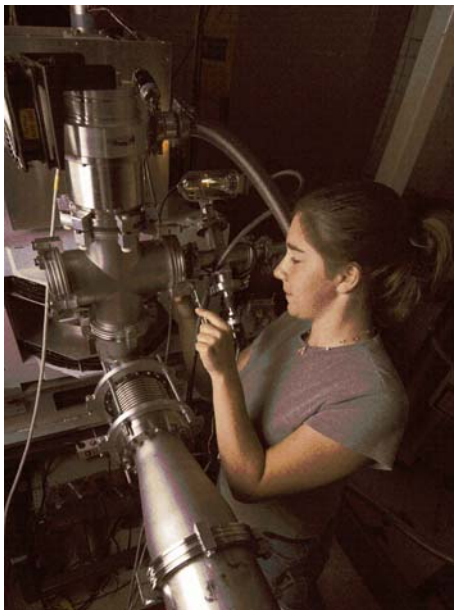
Science Support: NSF and other agencies independently award research grants to principal investigators who may use the NNIN facilities to carry out some aspects of their research projects.

**National Superconducting Cyclotron Laboratory (NSCL)**

Project Description: This project supports the operation of the NSCL at Michigan State University (MSU) as a national user facility and also supports the MSU research program. The NSCL is the leading rare isotope research facility in the U.S. NSCL scientists and researchers employ a wide range of tools for conducting advanced research in fundamental nuclear science, nuclear astrophysics, and accelerator physics. Important applications of the research conducted at the NSCL benefit society in numerous areas, including new tools for radiation treatments of cancer patients and the assessment of health risks to astronauts. The NSCL began operations of the coupled cyclotron radioactive beam facility in FY 2002, providing users with unique access to beams of unstable nuclei. The NSCL is among the world leaders in heavy ion nuclear physics and nuclear physics with radioactive beams.

The NSCL operates two superconducting cyclotrons. The K500 was the first cyclotron to use superconducting magnets, and the K1200 is the highest-energy continuous beam accelerator in the world. These and other related devices have enabled researchers to learn more about the origins of the elements in the cosmos. Through the recently completed Coupled Cyclotron Facility (CCF), heavy ions are accelerated by the K500 and then injected into the K1200, enabling the production of rare unstable isotopes at much higher intensities.

Principal Scientific Goals: Scientists at the NSCL work at the forefront of rare isotope research. They make and study atomic nuclei that cannot be found on earth and perform experimental research using beams of unstable isotopes to extend our knowledge of new types of nuclei, many of which are important to an understanding of stellar processes. Research activities include a broad program in nuclear astrophysics studies, the studies of nuclei far from stability using radioactive ion beams, and studies of the nuclear equation of state. In addition, research is carried out in accelerator physics.



A graduate student prepares the beta-Nuclear Magnetic Resonance apparatus for an experiment with rare isotopes. While the general methods employed in beta-NMR are the same as used today in medical applications of Magnetic Resonance Imaging, experiments with rare isotopes are up to 14 orders of magnitude more sensitive by detecting the emitted beta particle, when the rare isotope decays. *Credit: NSCL at Michigan State University*

Principal Education Goals: NSCL supports and enhances Ph.D. level graduate education and post-doctoral research experience. In addition, the site provides research experiences for undergraduate students, as well as training for K-12 teachers.

Partnerships and Connections to Industry: NSCL occasionally enters into license agreements with industry for cyclotron technology or nuclear electronics. A specific license agreement with Accel Corporation exists for compact cyclotrons based on superconducting technology.

Management and Oversight: The NSCL is managed by the Laboratory Director and three Associate Directors: one for Nuclear Science, one for Accelerator Research, and one for Operations. The NSCL research program is guided by a Program Advisory Committee consisting of external experts as well as an in-house expert, and includes the chairperson of the full NSCL User Group. The procedure for users includes writing and submitting proposals to the NSCL Director and oral presentations. There are two opportunities for proposal submission each year. Approximately 5,000 beam hours for experiments are provided each year. There is generally at least a one-year backlog

for experiments. NSF oversight is provided through annual site visits by the cognizant program officer of the Physics Division (MPS) and other staff, accompanied by external experts. During the NSCL upgrade, NSF convened several technical panels to review cost, schedule, technical progress, and management of the project to monitor progress and maintain oversight.

About 50 undergraduate students are presently also involved in research, 16 of whom are women. Since 2002, there have been a total of 103 graduate students, of whom 17 are women and three are African American. The laboratory has also recently launched additional efforts to broaden participation by under-represented groups at all levels, beginning with the appointment of an external advisory panel for diversity matters, and leading to the development of a formal diversity plan.

Current Project Status: An experimental program using the coupled cyclotron facility is now underway. The FY 2008 Request for the NSCL totals $19.50 million, a $1.90 million increase over the FY 2007 Request of $17.60 million. This will support operations and research at this unique radioactive ion beam facility.

Funding Profile: All funding for NSCL to date has been provided through the R&RA account.

**NSCL Funding Profile**
(Dollars in Millions)

| | Implementation | Operations & Maintenance | Total, NSF |
|---|---|---|---|
| FY 2001 | 1.00 | 11.40 | $12.40 |
| FY 2002 | 0.40 | 14.41 | $14.81 |
| FY 2003 | | 15.65 | $15.65 |
| FY 2004 | | 15.65 | $15.65 |
| FY 2005 | | 17.50 | $17.50 |
| FY 2006 | | 17.34 | $17.34 |
| FY 2007 Request | | 17.60 | $17.60 |
| FY 2008 Request | | 19.50 | $19.50 |
| FY 2009 Estimate | | 20.50 | $20.50 |
| FY 2010 Estimate | | 21.00 | $21.00 |
| FY 2011 Estimate | | 21.50 | $21.50 |
| FY 2012 Estimate | | 21.50 | $21.50 |
| FY 2013 Estimate | | 21.50 | $21.50 |

Operations numbers for FY 2008-2011 reflect the results of the review process and NSB-approved NSF recommendations for a new Cooperative Agreement. Numbers for FY 2012-2013 will be determined at a later date.

Information pertaining to the data in the table is included below.

- Implementation: The facility was upgraded between 1996 and 2001 to couple two superconducting cyclotrons and to upgrade the fragment separator to produce intense beams of unstable isotopes providing a facility unique in the world. This recent upgrade of the NSCL to the coupled cyclotron facility was accomplished using $12.0 million in incremental funding from the NSF and over $6.0 million from MSU. In addition, $4.0 million was provided to upgrade the cryogenic plant.

- Operations and Maintenance: Funding within this category supports the operation of the facility. Activities include routine preventive maintenance of the two coupled NSCL cyclotrons carried out each quarter, including vacuum systems, RF power systems, beam transport systems, the helium

refrigerator used to supply coolant for the superconducting cyclotrons, and miscellaneous subsystems. Approximately 25 percent of the funding is directed toward in-house research (both experimental nuclear science and accelerator research and development) with the remainder used to operate and maintain the facility. The facility serves several hundred active users.

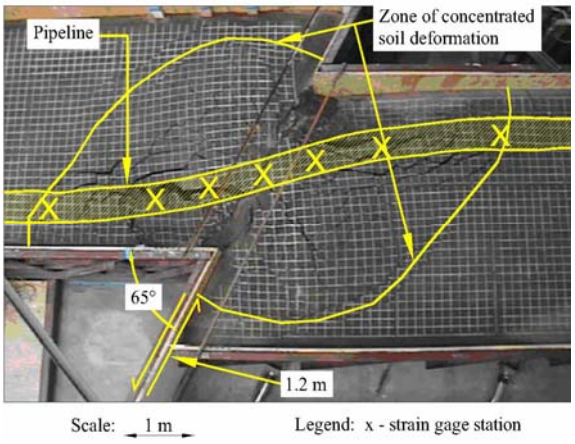
Renewal or Termination: On the basis of ad-hoc and site reviews, NSF staff have implemented a new Cooperative Agreement that was recently approved by the National Science Board.

Associated Research and Education Activities: The NSCL faculty has an excellent reputation for high quality instruction and innovation in the classroom. Several NSCL faculty members have received Michigan State University's prestigious Teacher Scholar Award. NSCL faculty members make effective use of technology to enhance active learning in large lecture courses commonly found at large research universities. They pioneered the CAPA (Computer-Assisted Personalized Assignment) program and developed it further into the Learning Online Network with CAPA (LON-CAPA), an open-source software system, free of licensing fees, which provides a shared pool of over 60,000 granular learning resources within the framework of a full-featured course management system. Faculty at over 30 colleges and universities worldwide participate in the creation and sharing of problems as well as of other educational resources. In addition, online learning materials from seven major science textbook publishers are available in connection with the adoption of their printed materials, and K-12 teachers from over 20 schools use LON-CAPA for their students. NSCL faculty have also pioneered the use of multimedia "virtual university" teaching technologies and offer several courses for long-distance learners over interactive websites.

Science Support: Theoretical nuclear physics research at the NSCL is separately supported by NSF grants totaling approximately $500,000 annually. Additionally, in several recent years NSF has also awarded several Major Research Instrumentation grants to the NSCL which have permitted construction of detectors and other equipment important to the operation of the laboratory as a user facility.

**NEES: The George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)**

Project Description: NEES is a national, networked simulation resource of 15 advanced, geographically distributed, shared use earthquake engineering research experimental facilities with teleobservation and teleoperation capabilities. NEES provides a national infrastructure to advance earthquake engineering research and education through collaborative and integrated experimentation, computation, theory, databases, and model-based simulation to improve the seismic design and performance of U.S. civil infrastructure systems. Experimental facilities include shake tables, geotechnical centrifuges, a tsunami wave basin, large-scale laboratory experimentation systems, and mobile and permanently installed field equipment. NEES facilities are located at academic institutions (or at off-campus field sites) throughout the United States, networked together through a high performance Internet2 cyberinfrastructure system. NEES completed construction on September 30, 2004, and opened for user research and education projects on October 1, 2004. NEES is currently operated by the non-profit corporation NEES Consortium, Inc. (NEESinc), headquartered in Davis, California. Through an initial five-year cooperative agreement with NSF (FY 2005 – FY 2009), NEESinc operates the 15 experimental facilities; the NEES cyberinfrastructure center; coordinates education, outreach, and training; and develops national and international partnerships.




Researchers at Cornell University, using the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), conducted the largest laboratory experiments ever performed of ground rupture effects on underground pipelines and duplicated what would happen to real pipelines at active, moving faults. This image shows an overhead view of a large-scale ground rupture test on a 400-mm-diameter plastic pipeline composed of high density polyethylene (HDPE). *Credit: N. Olson, Cornell University*

Principal Scientific Goals: NEES's broad-based national research facilities and cyberinfrastructure enables new discovery and knowledge through capabilities to test more comprehensive, complete, and accurate models of how civil infrastructure systems respond to earthquake loading (site response, soil-foundation-structure interaction, tsunami effects, and structural and nonstructural response). This enables the design of new methodologies, modeling techniques, and technologies for earthquake hazard mitigation.

Principal Education Goals: NEES engages engineering, science, and other students in earthquake engineering discovery through on-site use of experimental facilities, telepresence technology, archival experimental and analytical data, and computational resources with the aim of integrating research and education. NEESinc has developed an education, outreach, and training strategic plan to develop a broad spectrum of education and human resource development activities with special emphasis on non-traditional users and underrepresented groups.

Partnerships and Connections to Industry: The Congressionally mandated National Earthquake Hazards Reduction Program (NEHRP), the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), NSF, and the U.S. Geological Survey (USGS) support research related to earthquake hazard mitigation and are sources of federal partnerships. Connections to industry include private engineering consultants, and engineering firms engaging in NEES research or using data and models developed through NEES. NEES is leveraging and complementing its capabilities through connections and collaborations with large testing facilities at foreign earthquake-related centers, laboratories, and institutions. NSF and NEESinc have recently developed partnerships to utilize the NEES infrastructure with the 3-D Full-Scale Earthquake Testing Shake Table Facility (E-Defense), built

by the Japanese National Research Institute for Earth Science and Disaster Prevention (NIED) and operational in 2005. To facilitate NEES/E-Defense collaboration, in August 2005, NEESinc and NIED signed an MOU, and in September 2005, NSF and the Japanese Ministry of Education, Culture, Sports, Science, and Technology signed the Memorandum Concerning Cooperation in the Area of Disaster Prevention Research. In March 2006, researchers from 19 countries convened in San Francisco, CA, for the first World Forum to discuss sharing expertise and coordination in earthquake engineering testing and cyberinfrastructure.

Management and Oversight: NEESinc operates the 15 experimental facilities and the NEES cyberinfrastructure center; coordinates education, outreach, and training; and develops national and international partnerships. As a non-profit corporation, NEESinc operates under its own governance structure and is overseen by a Board of Directors elected from its membership in accordance with its by-laws. Day-to-day operations of NEESinc are overseen by its headquarters staff that is led by an Executive Director. Each experimental facility has an on-site director responsible for local day-to-day equipment management, operations, and interface with NEESinc, other NEES facilities, users, and the NEES cyberinfrastructure center for network coordination. The NEES cyberinfrastructure center maintains the telepresence, data, collaborative, simulation, and other related services for the entire NEES network.

NSF provides oversight to NEES operations through a cooperative agreement with NEESinc. NEES operations are reviewed through annual site visits. The NSF program manager for NEES is located in the Civil, Mechanical, and Manufacturing Innovation (CMMI) Division in the Directorate for Engineering (ENG).

Current Project Status: NEES completed its primary construction activities at the end of FY 2004. About $2.7 million in remaining FY 2004 MREFC funds was used to fund construction of deferred capabilities for NEES, which included four new capabilities for system integration (cyberinfrastructure), completed in September 2005, and new capabilities at 13 experimental facilities, which were completed in FY 2006.

Through three annual program solicitations and Small Grants for Exploratory Research, CMMI has funded 33 research projects to utilize the NEES facilities. In FY 2008, $15.0 million will be used to support basic research in multi-hazard engineering involving experimental and theoretical simulations at the NEES facilities, addressing important challenges in earthquake and tsunami engineering research.

Funding Profile: NSF received $7.70 million in FY 2000 to initiate construction of NEES. Total MREFC funding for this project was $81.76 million during FY 2000-04, with an additional $1.10 million provided to the project through the Experimental Program to Stimulate Competitive Research (EPSCoR) through the Education and Human Resources (EHR) account. NSF plans to provide $22.17 million to NEES for operations and maintenance in FY 2008.

**NEES Funding Profile**
(Dollars in Millions)

| | Concept/ Development | | Implementation | | | Operations & Maintenance | | Totals | | | **Grand** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | R&RA | MREFC | R&RA | MREFC | EHR | R&RA | MREFC | R&RA | MREFC | EHR | **Total** |
| FY 1998 & Earlier | 0.26 | | | | | | | $0.26 | - | - | **$0.26** |
| FY 1999 | | | | | | | | - | - | - | **-** |
| FY 2000 | | 0.36 | | 7.34 | | | | - | $7.70 | - | **$7.70** |
| FY 2001 | 0.44 | 0.03 | | 28.11 | 1.10 | | | $0.44 | $28.14 | $1.10 | **$29.68** |
| FY 2002 | | | | 24.40 | | | | - | $24.40 | - | **$24.40** |
| FY 2003 | | | | 13.47 | | | | - | $13.47 | - | **$13.47** |
| FY 2004 | | | | 8.05 | | | | - | $8.05 | - | **$8.05** |
| FY 2005 | | | | | | 17.94 | | $17.94 | - | - | **$17.94** |
| FY 2006 | | | | | | 21.03 | | $21.03 | - | - | **$21.03** |
| FY 2007 Request | | | | | | 21.27 | | $21.27 | - | - | **$21.27** |
| FY 2008 Request | | | | | | 22.17 | | $22.17 | - | - | **$22.17** |
| FY 2009 Estimate | | | | | | 23.02 | | $23.02 | - | - | **$23.02** |
| FY 2010 Estimate | | | | | | 23.57 | | $23.57 | - | - | **$23.57** |
| FY 2011 Estimate | | | | | | 23.57 | | $23.57 | - | - | **$23.57** |
| FY 2012 Estimate | | | | | | 23.60 | | $23.60 | - | - | **$23.60** |
| FY 2013 Estimate | | | | | | 24.19 | | $24.19 | - | - | **$24.19** |
| Subtotal, R&RA | $0.70 | | $0.00 | | | $200.36 | | $201.06 | | | |
| Subtotal, MREFC | | $0.39 | | $81.37 | | | $0.00 | | $81.76 | | |
| Subtotal, EHR | | | | | $1.10 | | | | | $1.10 | |
| **Total, Each Stage** | | **$1.09** | | | **$82.47** | | **$200.36** | | | | **$283.92** |

NOTE: The expected operational lifespan of this project is 10 years, from FY 2005 to FY 2014. NEES operations for FY 2005 – FY 2009 was approved by the National Science Board in May 2004 for up to $106.52 million total; approximately $21.3 million annually. Operations estimates for FY 2010 and beyond are developed strictly for planning purposes and are based on current cost profiles. They will be updated as new information becomes available.

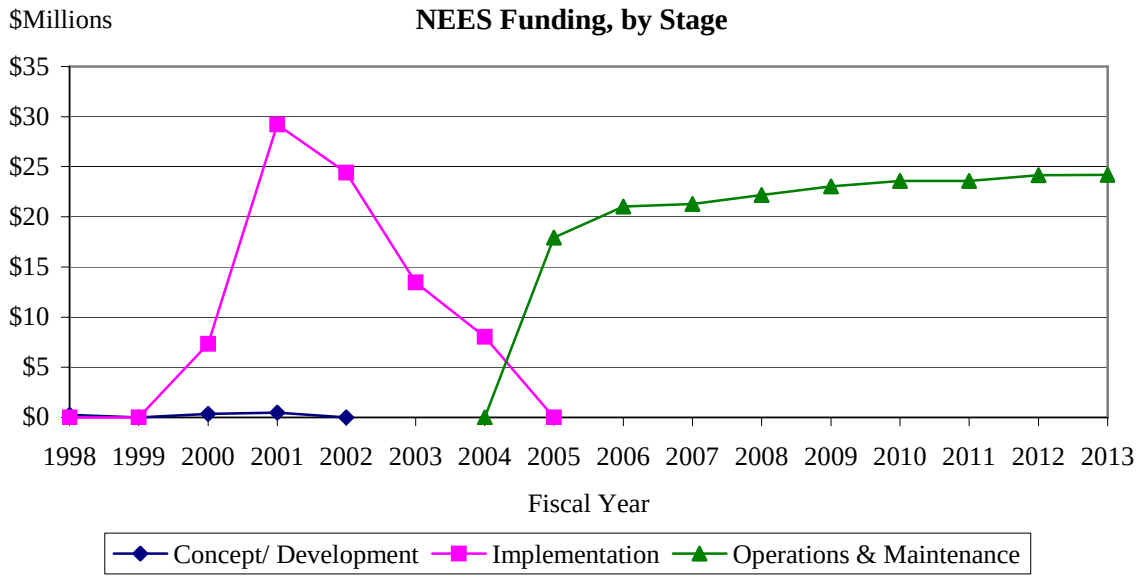
Information pertaining to the data in the table is provided below.

- Concept/Development: R&RA support for planning, design, and development included early workshops on experimental needs of the earthquake engineering community and on refinement of ideas for experimental systems in FY 1995 and FY 1998. During this period, the community also developed an action plan at NSF's invitation. Additional R&RA support funded an international workshop to foster long term working relationships for experimental earthquake engineering research and national workshops and studies to develop long-term NEES research concepts and plans (FY 2001). MREFC funds supported planning, design, and development specifically for a scoping study of the NEES network system (user and system architecture requirements), including a community workshop for broader input on user requirements prior to the full system integration award being made by NSF.

- Implementation: MREFC funds during this phase supported a range of equipment acquisition, as well as system integration and consortium development. To encourage the broadest participation for establishment of geographically distributed NEES experimental facilities, the FY 2000 competitive program solicitation for NEES research equipment specifically encouraged participation from EPSCoR states. As a result of the merit review process, one award was made to an institution from

an EPSCoR state for which the EPSCoR program provided partial funding through the EHR account in FY 2001.

- Operations and Maintenance: With completion of the major construction period in FY 2004, NEES entered its 10-year operational period through FY 2014. NEESinc provides the leadership, management, and coordination for operations of all the NEES shared use resources and establishes a broad and integrated partnership that includes participation of the earthquake engineering community, both within the U.S. and abroad. During FY 2006, NEESinc maintained 93% of its planned functional facility days at the 15 experimental facilities. As an internet-based resource, access to the NEES network is 24/7 to anyone with internet capabilities. The NEES experimental facilities are utilized annually for research by the broad earthquake engineering community as well as by personnel at the host institutions of the 15 NEES facilities.




Renewal or Termination: The initial five-year NEES operations award may be renewed once for an additional five years, subject to satisfactory review of performance and availability of funds. The maximum duration of this award is ten years.

Science Support: Along with direct operations and maintenance support for NEES, NSF provides support for research conducted at NEES experimental facilities through ongoing research and education programs. The NEES cyberinfrastructure also provides a platform for the earthquake engineering community as well as other communities to develop new tools for shared cyberinfrastructure. In addition, NSF has initiated grand challenge, small group, individual investigator, and payload research projects that utilize the NEES experimental facilities, data, and computational resources to comprehensively address major research questions in earthquake engineering and seismic hazard mitigation. The annual support for such activities is estimated to be $15.0 million in FY 2008.

## POLAR FACILITIES AND LOGISTICS

### Polar Facilities

Project Description: The Operations and Science Support program within the Division of Antarctic Infrastructure and Logistics provides support for all U.S. research conducted in Antarctica, including that funded by U.S. mission agencies, for year-round work at three U.S. stations, two research ships, and a variety of remote field camps. All life support is provided by NSF, including transportation, facilities, communications, utilities (water and power), and health and safety infrastructure. The U.S. Antarctic Program (USAP) also provides environmental stewardship and maintains the U.S. presence in Antarctica in accordance with U.S. policy.

Partnerships and Connections to Industry: There are many separate subcontractors for supplies and technical services. The Office of Polar Programs contracts with a prime support contractor for science support, operations, and maintenance of the Antarctic stations and related infrastructure in New Zealand and Chile, and leasing of research vessels. The contractor is selected through a competitive bidding process. The current Antarctic support contract was recompeted and awarded to Raytheon Polar Services Corporation (RPSC) in FY 2000. After a five-month phase-in period, RPSC assumed responsibility for operations in March 2000. The contract's ten-year performance period is segregated into a five-year initial period and a five-year optional period. NSF has exercised its option to extend the performance period through 2010.

South Pole residents walk near the cargo buildings at Amundsen-Scott South Pole Station in late March, the day before the annual sunset. The temperature on this particular day was minus 60 degrees Fahrenheit. As Austral Winter approaches, the Sun remains below the horizon for longer and longer periods of time until winter officially sets in. The next sunrise won't occur until September 21. During the six months of darkness that is the austral winter, temperatures will drop to minus 100 degrees Fahrenheit. *Credit: Brien Barnett, NSF*

Rotary- and fixed-wing aircraft used in support of research are provided through additional competitively awarded contracts. Other agencies and contractors also provide technical support in areas of expertise such as engineering, construction, and communications.

Management and Oversight: OPP has overall management responsibility for Operations and Science Support. OPP evaluates the performance of RPSC every year via a Performance Evaluation Committee and an Award Fee Board that includes representatives from OPP and the Office of Budget, Finance, and Award Management (BFA). The Operations and Science Support program in the Division of Antarctic Infrastructure and Logistics also provides oversight and direction of the South Pole Station Modernization (SPSM) project, an activity funded out of the Major Research Equipment and Facilities Construction (MREFC) account since FY 1998. Since FY 2006, NSF has been responsible for funding the operation and maintenance of the U.S. Coast Guard's (USCG) three polar icebreakers. The agencies cooperate under a Memorandum of Agreement that includes guidance for planning and scheduling. It sets forth the terms and conditions for reimbursement to the USCG from NSF. NSF and the USCG work together to formulate operations and maintenance plans and associated funding requirements. NSF is responsible for ascertaining the needs of other federal agencies and for securing USCG program plans for

accommodating them, on a reimbursable funding basis. OPP's performance is reviewed externally by Committees of Visitors and the OPP Advisory Committee (OPPAC).

Current Project Status: All facilities (stations, research vessels and field camps) are currently operating normally. The poor condition of the USCG polar icebreakers, the Polar Star and the Polar Sea, and the uncertainty regarding their future prompted OPP and the OPPAC to identify and study options for reducing demands on the ship-based logistics system. OPP and the OPPAC are in the process of developing contingency plans for dealing with a possible failure of that system.

Funding Profile: NSF is requesting $230.14 million in FY 2008 for Polar Facilities to provide infrastructure critical to supporting International Polar Year (IPY) activities as well as continued support for research projects in the Antarctic. All funding for polar facilities, excluding support for the SPSM MREFC project, is provided through the R&RA account. Support for SPSM is discussed in the MREFC chapter.

**Polar Facilities**
(Dollars in Millions)

| | Antarctic Operations & Science Support | | |
|---|---|---|---|
| | Implementation | Operations & Maintenance | Total, NSF |
| FY 2001 | | 117.96 | $117.96 |
| FY 2002 | | 126.15 | $126.15 |
| FY 2003 | | 141.43 | $141.43 |
| FY 2004 | | 147.04 | $147.04 |
| FY 2005 | | 155.73 | $155.73 |
| FY 2006 Actual | | 196.45 | $196.45 |
| FY 2007 Request | | 218.09 | $218.09 |
| FY 2008 Request | | 230.14 | $230.14 |
| FY 2009 Estimate | | 235.89 | $235.89 |
| FY 2010 Estimate | | 241.79 | $241.79 |
| FY 2011 Estimate | | 247.84 | $247.84 |
| FY 2012 Estimate | | 254.03 | $254.03 |
| FY 2013 Estimate | | 260.38 | $260.38 |

NOTE: Estimates for FY 2009 and beyond are developed strictly for planning purposes and are based on current cost profiles. They will be updated as new information becomes available. Beginning in FY 2006, Antarctic Operations & Science Support includes estimates for NSF to assume the responsibility, from the U.S. Coast Guard, for funding the costs of icebreakers needed for the support of scientific research in polar regions.

Renewal or Termination: NSF will not terminate support for the facilities themselves, such as McMurdo station or South Pole Station. U.S. policy directs NSF to maintain an active and influential presence in Antarctica, including year-round occupation of South Pole Station and two coastal stations.

## Polar Logistics

Project Description: Polar Logistics consists of two activities: the U.S. Antarctic Logistical Support Activities program within the Division of Antarctic Infrastructure and Logistics, and the Research Support and Logistics program within the Arctic Sciences Division.

Partnerships and Connections to Industry: There are many separate subcontractors for supplies and technical services.

A worker at Admundsen-Scott South Pole station waves goodbye to an LC-130 military aircraft as it departs the station with approximately 35 employees who had "wintered over" (spent the winter) at the bottom of the world. The flight was the first of several to transport groups of residents home from the Antarctic. *Credit: USAP/NSF; Photo by Mark Buckley, RPSC (2001)*

The U.S. Antarctic Logistical Support Activities program funds support provided by the U.S. Department of Defense (DoD). The DoD operates as a primary logistical support provider on a cost-reimbursable basis. Major funding elements of DoD support include: military personnel, LC-130 flight operations, maintenance, and facilities support of the 109th Airlift Wing (AW) of the New York Air National Guard in Scotia, New York and Antarctica; transportation and training of military personnel supporting the U.S. Antarctic Program; support for air traffic control, weather forecasting, and electronic equipment maintenance; the charter of Air Mobility Command Airlift and Military Sealift Command ships for the re-supply of McMurdo Station; bulk fuel purchased from the Defense Logistics Agency; and reimbursement for use of DoD satellites for communications.

The Research Support and Logistics program in the Arctic Sciences Division is driven by and responds to science supported by the Division. Funding is provided directly to grantees or to key organizations that provide or manage Arctic research support and logistics. The current contract with VECO USA to provide research support and logistics services for NSF-sponsored activities in the Arctic was recompeted and awarded in January 2005. The contract has an initial term of four years and three one-year extensions excercised on the basis of performance. Additional major support components include: access to U.S. Coast Guard and other icebreakers, University-National Oceanographic Laboratory (UNOLS) vessels and coastal boats; access to fixed and rotary-wing airlift support; upgrades at Toolik Field Station, University of Alaska, Fairbanks' field station for ecological research on Alaska's North Slope; safety training for field researchers and funding for field safety experts; global satellite telephones for emergency response and improved logistics coordination; and development of a network of strategically placed U.S. Long-Term Ecological Research Observatories linked to similar efforts in Europe and Canada.

Management and Oversight: OPP has overall management responsibility for U.S. Antarctic Logistical Support Activities and Arctic Research Support & Logistics. OPP's performance is externally reviewed by Committees of Visitors and the OPP Advisory Committee.

Current Project Status: All facilities (stations, research vessels and field camps) are currently operating as normal.

Funding Profile: All funding is provided through the R&RA account. Support provided by DoD for the U.S. Antarctic Logistical Support Activities program remains at $67.52 million in FY 2008. NSF is requesting $43.60 million for Arctic Research Support and Logistics in FY 2008 to provide infrastructure critical to supporting IPY activities as well as continuing support for research projects throughout the Arctic.

**Polar Logistics**
(Dollars in Millions)

| | U.S. Antarctic Logistical Support Activities | | Arctic Research Support & Logistics | | |
|---|---|---|---|---|---|
| | Implementation | Operations and Maintenance | Implementation | Operations and Maintenance | Total, NSF |
| FY 2001 | | 68.16 | | 25.40 | $93.56 |
| FY 2002 | | 70.27 | | 27.58 | $97.85 |
| FY 2003 | | 68.55 | | 30.29 | $98.84 |
| FY 2004 | | 67.54 | | 37.39 | $104.93 |
| FY 2005 | | 70.26 | | 35.06 | $105.32 |
| FY 2006 Actual | | 66.66 | | 31.15 | $97.81 |
| FY 2007 Request | | 67.52 | | 44.90 | $112.42 |
| FY 2008 Request | | 67.52 | | 43.60 | $111.12 |
| FY 2009 Estimate | | 67.52 | | 44.69 | $112.21 |
| FY 2010 Estimate | | 67.52 | | 45.81 | $113.33 |
| FY 2011 Estimate | | 67.52 | | 46.95 | $114.47 |
| FY 2012 Estimate | | 67.52 | | 48.13 | $115.65 |
| FY 2013 Estimate | | 67.52 | | 49.33 | $116.85 |

NOTE: Estimates for FY 2009 and beyond are developed strictly for planning purposes and are based on current cost profiles. They will be updated as new information becomes available.

Renewal or Termination: NSF will not terminate support for the facilities themselves.

## FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTERS

### National Astronomy and Ionosphere Center (NAIC)

Project Description: The NAIC is a visitor-oriented national research center, supported by NSF and focusing on radio and radar astronomy and atmospheric sciences. Its principal observing facility is the world's largest radio/radar telescope, a 305m-diameter spheroid constructed within a karst depression in western Puerto Rico near the town of Arecibo. The facility itself is called the Arecibo Observatory. The NAIC is operated by Cornell University for NSF under a cooperative agreement. NAIC provides telescope users with a wide range of research and observing instrumentation and serves over 250 users annually. The center has a permanent staff of scientists, engineers, and technicians who are available to help visiting investigators with their observation programs.

The gregorian dome and its suspension structure over the main deflector of the Arecibo radio telescope, at night. *Credit: Arecibo Observatory/NSF*

Principal Scientific Goals: The NAIC was founded to advance the study of basic research in Radio Astronomy, Solar System Radar Astronomy, and Ionospheric Physics.

Principal Education Goals: NAIC's primary education goal is to support and enhance the education of graduate and undergraduate student researchers. Arecibo was one of NSF's first sites for the Research Experiences for Undergraduates (REU) program. At Arecibo, graduate students receive training through use of the facility for Ph.D. research. NAIC also sponsors a major outreach program in Puerto Rico via a modern Visitor's Center, a new Learning Center, and summer workshops for K-12 teachers. In addition NAIC holds, in collaboration with NRAO, a summer school on single-dish radio astronomy techniques. This is a continuing bi-yearly school alternating between NRAO sites and Arecibo.

Partnerships and Connections to Industry: NAIC currently has partnerships with NRAO, Penn State and other universities, and the Angel Ramos Foundation of Puerto Rico (a private organization).

Management and Oversight: Management is through a cooperative agreement with Cornell University. Oversight is through detailed annual program plans and long range plans for NAIC, plus bi-weekly teleconferences with the NAIC director and annual reports that are submitted to NSF. NSF conducts periodic reviews of Cornell management by external committees. Ongoing oversight and evaluation is by an assigned NSF program director in the Division of Astronomical Sciences (AST) in the Directorate for Mathematical and Physical Sciences (MPS) and in consultation with community representatives. Arecibo Visiting Committee meetings (commissioned by Cornell) are attended by the NSF program manager, and committee reports are made available to NSF. All AST-funded facilities have established policies and practices designed to broaden the participation of individuals from under-represented groups among their scientific and technical workforce.

Current Project Status: A solicitation for the management of NAIC was issued in November 2003. Two proposals were received. The proposal from Cornell was deemed to be superior and was approved for funding by the NSB at its March 2005 meeting. A new cooperative agreement is now in effect until March 31, 2010.

Funding Profile: All funding for NAIC to date has been provided through the R&RA account. Funding amounts for FY 2008 and beyond include consideration of the implementation of the recommendations of the Senior Review of the Astronomy Division (AST) portfolio. The FY 2008 Request for NAIC totals $12.15 million, with $10.45 million from AST and $1.70 million from the Division of Atmospheric Sciences (ATM) in the Directorate for Geosciences.

**NAIC Funding Profile**
(Dollars in Millions)

| | Implementation | Operations & Maintenance | Total, NSF[1] |
|---|---|---|---|
| FY 2002 | | 11.06 | $11.06 |
| FY 2003 | | 12.73 | $12.73 |
| FY 2004 | | 12.33 | $12.33 |
| FY 2005 | | 12.22 | $12.22 |
| FY 2006 | | 12.15 | $12.15 |
| FY 2007 Request | | 12.16 | $12.16 |
| FY 2008 Request | | 12.15 | $12.15 |
| FY 2009 Estimate | | 11.27 | $11.27 |
| FY 2010 Estimate | | 9.67 | $9.67 |
| FY 2011 Estimate | | 5.67 | $5.67 |
| FY 2012 Estimate | | 5.67 | $5.67 |

[1]Total budget includes funding from both MPS/AST and GEO/ATM. In FY 2008, $10.45 million is planned from AST and $1.70 million from ATM. See narrative below for discussion of FY 2008 and outyear projected budgets.

Information pertaining to the data in the table is included below.

- Budget Explanation: Funding levels for FY 2008-2010 reflect a staged reduction in AST funding from $10.46 million in FY 2007 to $8.0 million in FY 2010 as recommended by the Senior Review of the AST facilities portfolio, with an assumption of constant ATM funds of $1.70 million per year. Funding to paint a part of the telescope, estimated at $3.2 million, is included in these estimates.

  The Senior Review recommendation calls for the observatory to reduce its scientific scope and operational complexity by focusing primarily on survey operations with a new multi-feed receiver, with suspension of all new instrumentation development. The concomitant reductions in staffing levels for both engineering and scientific support provide the recommended cost savings. Budgets for 2011 and 2012 incorporate a further reduction to $4 million per year from AST as recommended by the Senior Review; additional funding, with sources yet to be determined, will be required in order to provide adequate support for the facility.

- Implementation: All construction and commissioning occurred before this reporting period. Construction of the Arecibo Observatory by the Air Force was completed in 1963. NSF took over funding for operations in 1970. A $25 million upgrade, jointly funded by NSF and NASA, was completed in 1997 and included a Gregorian feed system to enhance telescope efficiency and increase usable bandwidth.

- Operations and Maintenance: Funding for management, operations and maintenance primarily maintains and utilizes existing facilities and develops new instrumentation in support of research by the national astronomical community. In-house research accounts for about 6 percent of the total operations budget of NAIC. Most of this research concerns traditional radio-astronomical

observations (interstellar gas, galaxies, pulsars) and radar astronomy of solar system objects (asteroids, planetary surfaces and moons). The planetary radar program was funded by NASA until FY 2005 and is now incorporated in the base NAIC budget.

Renewal or Termination: On October 1, 2005, a new 54-month cooperative agreement with Cornell University went into effect. A mid-term management review will be held in March of 2007. A decision on termination of the facility will be undertaken in the 2010 timeframe.

Associated Research and Education Activities: Teacher training is conducted in intensive workshops, held in the past at the Visitor's Center, and as of 2002 in the Learning Center (both built with funding from the Angel Ramos Foundation of Puerto Rico). Arecibo attracts roughly 120,000 visitors per year, with many K-12 school groups visiting from across the island. Many graduate students use NAIC for dissertation research and Research Experiences for Undergraduates (REU) students also use the telescope as part of their summer research experience. All facility educational and outreach activities seek to broaden participation by under-represented groups. The AST-supported facilities provide forefront research capability and opportunities for access that enable faculty and students from under-represented groups and at diverse institutions to develop and carry out competitive research programs.

Science Support: In addition to the funds listed above, approximately $70,000 per year is provided for the REU activities from the Program for Education and Special Programs in the Division of Astronomical Sciences (in MPS) and the Division of Atmospheric Sciences (in GEO). A peer-review telescope allocation committee provides merit-based telescope time but no financial support. NSF does not provide individual investigator awards targeted specifically for use of NAIC. Many users are supported through NSF or NASA grants which pursue scientific programs that require use of NAIC.

**National Center for Atmospheric Research (NCAR)**

Project Description: The National Center for Atmospheric Research is a federally funded research and development center (FFRDC) serving a broad research community, including atmospheric scientists and researchers in complementary areas of the environmental and geosciences. Facilities available to university, NCAR, and other researchers include world-class supercomputing services well suited for the development, validation, and execution of large computational models in the atmospheric, oceanic, and related sciences. NCAR is also responsible for the curation, archiving, and manipulation of large data sets; NCAR's aviation infrastructure provides research aircraft, which can be equipped with sensors to measure dynamic physical and chemical states of atmospheric phenomena at local, regional, and global scales. In addition, airborne and portable ground-based radar systems, atmospheric sounding, and other surface sensing systems are available for atmospheric research. NCAR operates several facilities of the High Altitude Observatory (HAO) that are dedicated to the study of the Sun, solar phenomena, space weather, and the responses of the upper atmosphere to the Sun's output. As an NSF sponsored facility, NCAR is committed to the dissemination of newly discovered knowledge in all the above areas.

Principal Scientific Goals: As an internationally-recognized center of excellence, NCAR operates scientific research programs that include the following areas: studies of large-scale atmospheric and ocean dynamics that contribute to an understanding of the past and present climate processes and global climate change; global and regional atmospheric chemistry, including atmospheric connections to geochemical and biogeochemical cycles; the variable nature of the Sun and the physics of the corona and their interaction with the Earth's magnetic field; the physics of clouds, thunderstorms, precipitation formation, and their interactions and effects on larger-scale weather; and the examination of human society's impact on and response to global environmental change. In addition, NCAR further supports the scientific community by providing fellowships, internships, workshops, and colloquia for students and visiting scientists.

Principal Education Goals: NCAR disseminates knowledge of the geosciences to the general public, K-12 schools, teachers and students, undergraduate and graduate institutions, postdoctoral and career scientists and researchers, as well as to policy and decisions makers. One way this is achieved is via educational tours and exhibits reaching tens of thousands of people every year. Professional training courses, innovative and award-winning science education websites, as well as the directed activities of NCAR's Office of Education and Outreach are further examples of how NSF's goal of integrating research and education is attained through NCAR activities.

Partnerships: Research collaborations among NCAR staff and university colleagues are integral to its success as an institution, and serve as a focus and meeting point for the broader atmospheric and related sciences community. NCAR fosters and strongly supports these interactions through many approaches devised and refined over the course of 47 years. Notable examples include the joint development of community models and extensive collaboration with university partners and non-academic scientists nationally and internationally.

Connections to Industry: NCAR works to develop new collaborations and partnerships with the private sector through directed research and technology transfer. These activities span improved capabilities for detecting, warning, and forecasting mesoscale weather phenomena of economic and social importance to the private and public sectors to longer term economic consideration of climate change issues.

Management and Oversight: NCAR is managed by the University Corporation for Atmospheric Research (UCAR), a university-governed and university-serving organization comprised of over 70 Ph.D. granting academic institutions. UCAR works in partnership with NSF, the university community, and its other

research sponsors such as NASA, NOAA, DOE, DOD, EPA, and the FAA whenever such research collaboration enhances NCAR's basic NSF-supported research goals or facilities missions. NSF's Division of Atmospheric Sciences (in GEO) along with the Division of Acquisitions and Cooperative Support (DACS), provide oversight of NCAR and the cooperative agreement with UCAR for its management.

NSF's Gulfstream V jet, operated by NCAR, made its first flight during the Terrain-Induced Rotor Experiment (T-Rex). Scientists aboard will collect data at the tops of storms and lower edge of the stratosphere, altitudes out of reach of most research aircraft. The aircraft's range will enable scientists to survey remote ocean regions in a single flight to learn more about interactions between the oceans and atmosphere. *Credit: UCAR*

Current Project Status: The NCAR strategic plan, "NCAR as Integrator, Innovator and Community Builder," was completed in FY 2006. The plan sets outs the mission, core values and strategic goals that guide NCAR science. In working towards these goals, NCAR will seek to support the scientific community in explaining how the Earth system functions and accurately predicting how it is likely to evolve, providing robust, accessible, and well-integrated information services and tools for research, analysis, and education. By connecting strategic goals, plans, and accomplishments, the NCAR annual report (http://www.nar.ucar.edu/) provides a summary of the full life-cycle of the research, facilities, and educational activities that have taken place in FY 2006.

In addition, NCAR has managed the acquisition, modification and instrumentation of the the High-Performance Instrumented Airborne Platform for Environmental Research (HIAPER) through the MREFC account, which is now also operated and maintained by NCAR. A highly modified and FAA certified Gulfstream G-V aircraft, HIAPER began full scientific operations research during the first quarter of calendar year 2006. Operation of HIAPER is estimated at approximately $5.0 million annually; and it enables, in any given year, approximately $20 million in NSF funded science proposals.

NCAR Funding Profile: All funds for NCAR during this time frame, excluding construction funding for HIAPER, have been provided through the Research and Related Activities (R&RA) Account.

**NCAR Funding Profile**
(Dollars in Millions)

| | Implementation | Operations & Maintenance | Total, NSF |
|---|---|---|---|
| FY 2004 | 4.61 | 78.31 | $82.92 |
| FY 2005 | 4.73 | 75.31 | $80.04 |
| FY 2006 | 4.85 | 79.66 | $84.51 |
| FY 2007 Request | 4.97 | 81.88 | $86.85 |
| FY 2008 Request | 5.00 | 85.87 | $90.87 |
| FY 2009 Estimate | 5.10 | 86.00 | $91.10 |
| FY 2010 Estimate | 5.10 | 87.00 | $92.10 |
| FY 2011 Estimate | 5.22 | 89.00 | $94.22 |
| FY 2012 Estimate | 5.23 | 91.00 | $96.23 |
| FY 2013 Estimate | 5.23 | 91.00 | $96.23 |

NOTE: MPS contributions for statistics and modeling are included. Operations estimates for FY 2009 and beyond have been developed based on current cost profiles and are not intended to reflect actual budget requirements. They will be updated as new information becomes available.

Information pertaining to the data in the table is included below.

- Implementation: These costs represent expenditures for major equipment purchases and activities which go beyond simple maintenance and involve significant refurbishment or renovation of assets such as buildings and office space. Since FY 1999, a project to refurbish the Mesa Lab building located in Boulder, CO, has been the single largest component of this category. In 2007 and 2008, refurbishment of the taxi way and access routes at the Jefferson County Airport (where NSF houses it's aircraft) to improve safety and functionality will be undertaken. Estimates beyond FY 2008 are based on historical funding needs.

- Operations and Maintenance: This funding supports the operation of the NCAR facilities, including supercomputers, instrumented research aircraft and associated flight costs, and ground-based portable observing systems. Routine maintenance costs of the aircraft and facilities are also covered under this category. In addition, approximately half of the operations, and maintenance amount is used to support science conducted by NCAR scientists.

Renewal or Termination: The cooperative agreement for the management of NCAR is currently being competed. The next agreement will be for the five years beginning FY 2009. Proposals will be subject to NSF's standard merit review procedures, with expert reviewers who are preeminent researchers and managers. In addition, a mid-award review of management of NCAR took place in March 2006, that produced favorable comments from the review panel and a set of constructive recommendations; funding levels beyond FY 2007 will be dependent on the implementation of the review panel's recommendations and on the continuous oversight provided by NSF.

Associated Research and Education Activities: NCAR employs a large number of scientists who pursue research objectives individually and in groups, and numerous external researchers use NCAR facilities to further their research objectives. NCAR has also recently created an expanded and updated visitor area with various hands-on displays for schoolchildren or citizens visiting the Mesa Laboratory. Lectures and demonstrations are provided for visiting students and teachers. In addition, UCAR's education and outreach (EO) program maintains a website, Windows to the Universe (www.windows.ucar.edu), a bi-lingual English/Spanish website), and other EO websites which have K-12 as their primary audience.

These sites touch many students, with over 14.6 million user sessions in FY 2006 involving 125.4 million pages served.

The table below lists K-12 teachers and students coming to NCAR to attend workshops or learn about atmospheric sciences, and undergraduate and graduate students who arrive at NCAR for a temporary stay to do specific research that typically lasts three months to a year.

**Direct Impact of NCAR's Participation in Education Activities**

| Year | K-12 | Undergraduate | Graduate | Teachers |
|---|---|---|---|---|
| 1997 | 7,067 | *25* | *67* | 32 |
| 1998 | 7,063 | *26* | *68* | 264 |
| 1999 | 9,569 | *24* | *69* | 90 |
| 2000 | 9,894 | *24* | *69* | 92 |
| 2001 | 8,995 | *23* | *63* | 101 |
| 2002 | 9,424 | *67* | *57* | 865 [a] |
| 2003 | 7,295 [b] | *85* | *109* | 815 [b] |
| 2004 | 8,505 | *81* | *125* | 1,381 |
| 2005 | 13,723 [c] | *92* | *189* | 1,510 |
| 2006 | 15,215 [c] | *54* | *200* | *1,200* |

NOTE: Numbers in italics are estimates.

a The increased number of teachers in FY 2002 includes participants at a series of

b The decreased number in FY 2003 reflects partial closure of Mesa Lab facilities

c Includes public visits to Mesa Lab throughout year and special events: Super Science Saturday and 2 Wild Bear Science Saturdays, Earth Day: (4,500 attendance in FY 2006)

Science Support: NSF-supported researchers with grants totaling approximately $28 million per year used the aircraft and observational facilities operated by NCAR in FY 2006. This support comes from programs within the Atmospheric Sciences Division (in GEO) for proposals submitted for use of the NCAR aircraft during field campaigns. Additional use of NCAR observational facilities by other NSF funded activities such as oceanography and polar programs, along with cross-directorate environmental research and education programs also contribute to this support. NSF-supported researchers with grants totaling approximately $30 million per year used the computational resources of NCAR for a wide range of modeling, simulation, and data assimilation tasks. Many principal investigators additionally request computing time at the NCAR facility to accomplish analyses required to evaluate results from their completed field and observational work.

**National Optical Astronomy Observatories (NOAO) and the National Solar Observatory (NSO)**

Project Description: NOAO was established in 1982 by uniting the operations of the Kitt Peak National Observatory in Arizona and the Cerro Tololo Inter-American Observatory in Chile. NOAO is a federally funded research and development center (FFRDC) for research in ground-based, nighttime, optical and infrared astronomy. NOAO also is the gateway for the U.S. astronomical community to the International Gemini Observatory. The National Solar Observatory (NSO), once administratively part of NOAO but now with an independent management structure, makes available to qualified scientists the world's largest collection of optical and infrared solar telescopes and auxiliary instrumentation for observation of the solar photosphere, chromosphere, and corona. In addition, NSO provides routine synoptic solar data used by many researchers and other agencies. The NSO operates facilities in Sunspot, New Mexico and Tucson, Arizona as well as a coordinated worldwide network of six telescopes (GONG) specifically designed to study solar oscillations. As national facilities, NOAO and NSO telescopes are open to all astronomers regardless of institutional affiliation on the basis of peer-reviewed observing proposals and serve over 1,000 users annually.

Principal Scientific Goals: NOAO and NSO support basic research in astronomy and solar physics by providing access to modern, ground-based, astronomical telescopes and instrumentation to the nation's astronomers and solar physicists, promoting public understanding and support of science, and advancing all aspects of U.S. ground-based astronomical research.

The Cerro Tololo Inter-American Observatory 4-meter telescope dome in June of 2006. *Credit: M. Urzúa Zuñiga/Gemini Observatory/NSF*

Principal Education Goals: NOAO promotes and enhances the education of undergraduate and graduate student researchers and outreach training and curriculum development for K-12 teachers. Approximately 15 percent of all NOAO and NSO users are graduate students. Some recent examples of outreach activities include: (1) Project ASTRO, which matches astronomers with 4th to 9th grade teachers and community educators in the Tucson and Sunspot areas who want to enrich their astronomy and science teaching; (2) the Teacher Leaders in Research-Based Science Education, a summer workshop for middle and high school teachers; and (3) Astronomy from the Ground Up, a program for professional development of informal science educators from small- and moderate-size science centers nationwide.

Partnerships and Connections to Industry: Thirty-two U.S. member institutions and seven international affiliate members comprise the Member Institutions of the Association of Universities for Research in Astronomy (AURA), Inc., the management organization for NOAO and NSO. Other partners include the USAF Office of Scientific Research, NASA, and industrial vendors. Development of new telescopes, instrumentation, and sensor techniques is done in partnership with relevant industry, through subawards to various large and small aerospace, optical fabrication, and IT companies.

Management and Oversight: Management is through a cooperative agreement with AURA. Separate directors for NOAO and NSO report to the president of AURA. Oversight is through detailed annual program plans and long range plans for NOAO and NSO, plus quarterly and annual reports that are submitted to NSF. All AST-funded facilities have established policies and practices designed to broaden the participation of individuals from under-represented groups among their scientific and technical workforce. NSF conducts periodic reviews of AURA management by external committees. The most recent management review took place in August 2006; the panel endorsed AURA's performance as excellent. Ongoing oversight and evaluation is by an assigned NSF program director in the Division of

Astronomical Sciences (AST) in the Directorate for Mathematical and Physical Sciences (MPS) and in consultation with community representatives.

Current Project Status: Cooperative agreements for continuing management and operations are for terms of five years; a new agreement was competed and awarded to AURA October 1, 2002. A management review was carried out in August 2006. In response to the favorable management review, AST will extend the current Cooperative Agreement with AURA for management of NOAO and NSO for one year, which will be through FY 2008. The additional year will provide time for NSF and AURA to incorporate the recommendations of the Senior Review into management of NOAO and NSO. The FY 2008 Request for base operations for NOAO is $26.88 million and for NSO is $11.30 million, for a total of $38.18 million, an increase of $3.63 million over the FY 2007 Request. This increase represents the net response to the recommendations of the AST Senior Review, which included (i) a one-time reinvestment in the infrastructure at Kitt Peak and Cerro Tololo, and (ii) reductions in several targeted programs

NSO is nearing the completion of the design and development phase for the Advanced Technology Solar Telescope (ATST), which entered the 'readiness' phase for MREFC funding in late FY 2005. Detailed reviews to assess its status with regard to inclusion in a future budget will be held in FY 2007. NOAO is also actively participating in the development of potential future infrastructure projects or funding opportunities such as the Giant Segmented Mirror Telescope and the Large Synoptic Survey Telescope, both of which are high priority recommendations of the Decadal Survey conducted by the National Research Council's Astronomy and Astrophysics Survey Committee and other high-level studies.

Funding Profile: All funding for NOAO to date has been provided through the R&RA account.

**NOAO and NSO Funding Profile**
(Dollars in Millions)

| | TSIP | AODP | NOAO and NSO Base Operations and Maintenance | Total, NSF |
|---|---|---|---|---|
| FY 2001 | | | 31.20 | $31.20 |
| FY 2002 | 4.00 | | 32.82 | $36.82 |
| FY 2003 | 4.00 | 3.00 | 32.64 | $39.64 |
| FY 2004 | 4.00 | 3.00 | 34.35 | $41.35 |
| FY 2005 | 2.00 | 1.20 | 34.74 | $37.94 |
| FY 2006 | 2.00 | 0.36 | 34.55 | $36.91 |
| FY 2007 Request | 4.00 | 1.50 | 34.55 | $40.05 |
| FY 2008 Request | 5.00 | 0.00 | 38.18 | $43.18 |
| FY 2009 Estimate | 5.00 | 0.00 | 38.18 | $43.18 |
| FY 2010 Estimate | 5.00 | 0.00 | 38.18 | $43.18 |
| FY 2011 Estimate | 5.00 | 0.00 | 38.18 | $43.18 |
| FY 2012 Estimate | 5.00 | 0.00 | 38.18 | $43.18 |
| FY 2013 Estimate | 5.00 | 0.00 | 38.18 | $43.18 |

NOTE: The current cooperative agreement expires in FY 2007. Funding for FY 2008 reflects initial implementation of the recommendations of the AST Senior Review. Estimated budgets for FY2009 and beyond are indicative only. Actual annual requests will be formulated based on results of detailed cost reviews and implementation plans currently being developed for recommendations of the Senior Review.

Information pertaining to the data in the table is included below.

- TSIP and AODP: The funding for the Telescope System Instrumentation Program (TSIP), a community instrumentation program developed to foster the system of large US public and private telescopes, is provided by NSF and administered through NOAO. TSIP funds instrument development and construction at the private observatories in return for observing time on those facilities which is in turn allocated to the astronomical community at large on the basis of peer-reviewed observing proposals. TSIP funding totals $5.0 million in the FY 2008 Request, an increase of $1 million over the FY 2007 Request. Funding for the projects in the Adaptive Optics Development Program, a similar community instrumentation program, will be complete in FY 2007. Future development in adaptive optics will be funded from AST's Advanced Technologies and Instrumentation program.

- Operations and Maintenance: The management and operations budget primarily maintains and utilizes existing facilities and develops new instrumentation for existing telescopes in support of research by the national astronomical community. Basic research by in-house scientific staff accounts for approximately 9 percent of the total budget.

Renewal or Termination: The current cooperative agreement expires at the end of FY 2007. A management review was carried out in August 2006, on the basis of which NSF has decided to renew the program. Funding amounts for FY 2008 include initial consideration of the recommendations of the Senior Review of the AST portfolio. Funding levels for future years will be based on results of detailed costs reviews and implementation plans currently being developed for recommendations of the Senior Review.

Associated Research and Educational Activities: Teacher training includes participation of more than 160 teachers in Project ASTRO, which directly impacts nearly 6000 students in the Tucson area; intensive (multi-week) training of about 25 teachers per year through Teacher Learning through Research Based Science Education; and Research Experiences for Teachers. K-12 numbers are not tracked but it is estimated that school groups make up about 10 percent of the roughly 85,000 visitors per year to public visitor centers at NOAO and NSO. Instructional materials are developed in collaboration with the Lawrence Hall of Science Great Explorations in Science and Math (GEMS) program. The "Hands on Optics" program, aimed at middle school students, is being developed by NOAO in collaboration with the Optical Society of America and the International Society for Optical Engineering. NOAO hosts the "Astronomy Education Review," a refereed, on-line journal (http://aer.noao.edu) that disseminates information about astronomy and space science education. Observational facilities are also used by approximately 200 graduate students each year and by undergraduate students participating in the Research Experiences for Undergraduate (REU) program, university-sponsored research, and the Practicas de Investigacion de Astronomia program (Chile). All facility educational and outreach activities seek to broaden participation by under-represented groups. The AST-supported facilities provide forefront research capability and opportunities for access that enable faculty and students from under-represented groups and at diverse institutions to develop and carry out competitive research programs.

Science Support: In addition to the funds listed above, approximately $270,000 per year is provided in total from the Program for Education and Special Programs in the Astronomy Division (REU and teacher enhancement) (MPS), and the Office of International Science and Engineering (REU). For all NOAO and NSO telescopes, peer-review telescope allocation committees provide merit-based telescope time but no financial support. NSF does not provide awards targeted specifically for use of NOAO and NSO. Most users are supported through NSF or NASA grants to pursue scientific programs that require use of NOAO and NSO.

**National Radio Astronomy Observatory (NRAO)**

Project Description: NRAO provides state-of-the-art radio telescope facilities for use by the scientific community. NRAO conceives, designs, builds, operates and maintains radio telescopes used by scientists from around the world to study virtually all types of astronomical objects known, from planets and comets in our own Solar System to quasars and galaxies billions of light-years away. It operates major radio telescopes at Green Bank, West Virginia, at Socorro, New Mexico, and at ten telescope array sites spanning the U.S. from the Virgin Islands to Hawaii. NRAO's headquarters are in Charlottesville, Virginia. NRAO is also the North American executing organization for the international Atacama Large Millimeter Array (ALMA) project. These federally funded, ground-based observing facilities for radio astronomy are available to any qualified astronomer, regardless of affiliation or nationality, on the basis of scientific peer-reviewed proposals, and annually serve over 1,500 users worldwide.

Principal Scientific Goals: NRAO supports and advances basic research in the astronomical sciences, including understanding the geometry and the matter content of the universe, the formation of galaxies, stars and planets, and the nature of black holes.

Principal Education Goals: NRAO supports and enhances the education of undergraduate and graduate student researchers and training for K-12 teachers. The primary educational goal is to support the development of a scientifically and technically literate society through a comprehensive outreach program in which information about radio astronomy is made available to the public through the world-wide web and news media. NRAO sites support visitor/education centers and educational programs are developed in partnership with other institutions. NRAO also supports undergraduate, graduate and post-doctoral students in radio-astronomy scientific research, as well as the design, construction, test and implementation of innovative scientific instruments and telescopes for radio astronomy and of software tools for scientific data analysis and for the interpretation of radio-astronomical data.

The Green Bank Telescope (GBT) in West Virginia is the world's largest, fully steerable radio telescope. Described as a 100-meter telescope, the actual dimensions of the surface are 100 by 110 meters. The overall structure of the GBT is a wheel-and-track design that allows the telescope to view the entire sky above 5 degrees elevation. The track is level to within a few thousandths of an inch in order to provide precise pointing of the structure while bearing 7,300 metric tons of moving weight. *Credit: NRAO/AUI/NSF*

Partnerships and Connections to Industry: Numerous U.S. universities, NASA, foreign scientific and technical institutes and industrial vendors are partners. The development of new telescopes, instrumentation, and sensor techniques is completed in partnership with relevant industry, through competitive subawards to various large and small aerospace companies, radio antenna manufacturing firms, and specialized electronics and computer software companies.

Management and Oversight: Management is through a cooperative agreement with Associated Universities Incorporated (AUI). The NRAO director reports to the president of AUI. Oversight is through detailed annual program plans and long range plans for NRAO, plus monthly, quarterly, and annual reports submitted to NSF. All AST-funded facilities have established policies and practices designed to broaden the participation of individuals from under-represented groups among their scientific and technical workforce. NSF conducts periodic reviews of AUI management using external committees. Ongoing oversight and evaluation is by an assigned NSF program director in the Division of Astronomical Sciences (in MPS) and in consultation with community representatives.

Current Project Status: Cooperative agreements for continuing management and operations are for terms of five years. The present cooperative agreement was extended through the end of FY 2009 by action of the National Science Board in December 2005. The VLA is undergoing an upgrade of its electronics and communications systems to significantly enhance its capabilities. The upgrade, referred to as Phase I of the Expanded Very Large Array (EVLA), is being carried out with NRAO funding. The NRAO is also engaged in construction of ALMA, a millimeter/submillimeter interferometer, which was approved as a Major Research Equipment and Facilities Construction (MREFC) project by the National Science Board in winter 2001. NRAO is the U.S. implementing organization of the ALMA project.

Funding Profile: The FY 2008 Request for NRAO totals $52.74 million. The FY 2008 request includes an increase over the FY 2007 Request of $2.0 million, including a total of $8.22 million for early ALMA operations. All funding for NRAO to date, excluding construction funding for ALMA, has been provided through the R&RA account.

**NRAO Funding Profile**
(Dollars in Millions)

| | Implementation | Operations & Maintenance | Total, NSF |
|---|---|---|---|
| FY 2001 | 5.00 | 47.10 | $52.10 |
| FY 2002 | 5.00 | 35.43 | $40.43 |
| FY 2003 | 5.00 | 40.33 | $45.33 |
| FY 2004 | 9.34 | 45.64 | $54.98 |
| FY 2005 | 5.43 | 41.60 | $47.03 |
| FY 2006 | 5.44 | 45.30 | $50.74 |
| FY 2007 Request | 5.84 | 44.90 | $50.74 |
| FY 2008 Request | 4.32 | 48.42 | $52.74 |
| FY 2009 Estimate | 4.32 | 50.93 | $55.25 |
| FY 2010 Estimate | 4.32 | 51.11 | $55.43 |
| FY 2011 Estimate | 1.00 | 54.43 | $55.43 |
| FY 2012 Estimate | - | 55.43 | $55.43 |
| FY 2013 Estimate | - | 55.43 | $55.43 |

The current cooperative agreement expires in FY 2009. Estimated budgets for FY2009 and beyond are indicative only. Actual annual requests will be formulated based on results of detailed cost reviews and implementation plans currently being developed for recommendations of the Senior Review.

Information pertaining to the data in the table is included below.

- Implementation: All construction and commissioning of NRAO telescopes occurred before this reporting period. The Observatory is now engaged in an upgrade to the 25-year-old Very Large Array (VLA) radio telescope located in New Mexico that will enhance the capabilities of the current VLA. This upgrade is referred to as Phase I of the Expanded Very Large Array (EVLA).

- Operations and Maintenance: Funding for management, operations and maintenance primarily maintains and utilizes existing facilities and develops new instrumentation for existing telescopes in support of research by the astronomical community. Basic research by in-house staff is less than 5 percent of the total budget. The budgets estimated for FY 2009 and beyond are indicative only. Budget levels will be formulated based on results of detailed cost reviews and implementation plans currently being developed for recommendations of the AST Senior Review.

- ALMA operations: While ALMA construction is funded through the MREFC account, as elements of the facility take form, operations and maintenance must begin. The funding profile for the ALMA activity includes early operations funding beginning in FY 2005 at $1.0 million and increasing to $8.22 million in FY 2008.

Renewal or Termination: The present cooperative agreement was extended to the end of FY 2009 with approval by the NSB in December 2005. A management review was carried out in early FY 2007, on the basis of which NSF will decide whether to renew or recompete the program.

The Very Large Array (VLA), supported by NRAO and one of the world's premier astronomical radio observatories, consists of 27 radio antennas in a Y-shaped configuration on the Plains of San Agustin fifty miles west of Socorro, New Mexico. Each antenna is 25 meters in diameter. The data from the antennas is combined electronically to give the resolution of an antenna 36km across, with the sensitivity of a dish 130 meters. *Credit: NRAO/AUI/NSF.*

Associated Research and Education Activities: NRAO conducts an active educational and public outreach program. The observatories host a combined total of approximately 50,000 visitors each year to the Green Bank and VLA facilities, including school field trips for K-12 students. The Green Bank observatory recently completed the construction of a bunkhouse to house student groups on overnight trips. Observatory professional scientific and engineering staff also visit classrooms regularly to provide special instruction in the astronomical and radio sciences. Observational facilities are used by graduate students carrying out dissertation research and those on work experience programs and by undergraduate students participating in the Research Experiences for Undergraduates (REU) program. All facility educational and outreach activities seek to broaden participation by under-represented groups. The AST-supported facilities provide forefront research capability and opportunities for access that enable faculty and students from under-represented groups and at diverse institutions to develop and carry out competitive research programs.

Science Support: In addition to the funding listed above, approximately $500,000 per year is provided in total from the Directorate for Education and Human Resources and the Program for Education and Special Programs in the Astronomy Division. A peer-review telescope allocation committee provides merit-based telescope time but no financial support. NSF does not provide individual investigator awards targeted specifically for use of NRAO facilities. Many users are supported through NSF or NASA grants to pursue scientific programs that require use of NRAO.

**Recent Highlights**

Adjusting LIGO's Optical Beams. *Credit: LIGO Laboratory*

► **LIGO Comes of Age**: The Laser Interferometer Gravitational-Wave Observatory (LIGO) has met and exceeded its sensitivity design goal. One of the most advanced scientific instruments ever built, LIGO began its first run at better than its design sensitivity on November 4, 2005 and will collect data through April 2007. Gravitational waves are distortions in the fabric of space-time produced by the rapid motion of massive objects. Although predicted by Einstein's general theory of relativity, they have never been directly observed. They can pass unhindered through dust and gas that would block the passage of radio, light, and X-ray radiation. Because of this, their exotic origin, and their nature as traveling ripples in space-time, they will open a new window on phenomena occurring in the universe. In addition to revealing many previously unseen phenomena, LIGO's observations can lead to refinements in the theory of relativity and assist scientists in choosing among theories of the universe.

All three IODP drilling platforms will be operational in FY 2008. From left and clockwise, the light drill ship (U.S.), the heavy drill ship (Japan), and an example of a mission specific platform (Europe) used for Arctic drilling. *Credit: JOI*

► **The Integrated Ocean Drilling Program** (IODP), an international effort for which NSF is a lead agency, has recorded numerous scientific achievements in its initial phase (FY2004-2007). For example:

- IODP showed that the Arctic had a subtropical climate 55 million years ago, a fact with far-reaching implications for Earth's climate system.
- Drilling off the Cascades uncovered valuable new clues about how methane hydrates, rich in greenhouse gas and a potential source of energy, are linked to subseafloor life.
- Deep drilling into Pacific ocean crust recovered, for the first time, a coarse-grained rock called gabbro, confirming the idea that ocean crust forms from the cooling of molten magma at mid-ocean ridges.

IODP officials expect more fundamental accomplishments in FY 2008 when all three of the program's drilling platforms will be in operation. The Japanese drillship Chikyu, which started testing in December 2005, will begin scientific exploration deep into the Earth's crust, focusing on how large, tsunami-generating earthquakes are formed. Meanwhile, NSF will rebuild the "light" IODP drillship, dramatically improving the program's ability to study seafloor life, analyze recovered core from drilling operations, and link characteristics of core samples to Earth's past climate and internal processes. The ship will be lengthened by 32 feet, which will increase lab space by 50 percent; quadruple its ability to support temporary laboratories; and increase its stability to provide better coring capability in inclement weather.

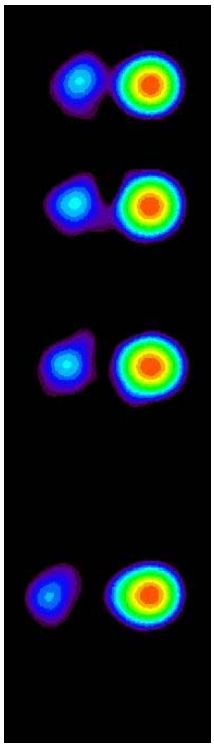
► **A Magnet for Education and Learning:** While the National High Magnetic Field Laboratory in Tallahassee, Florida, is known throughout the world for research involving high magnetic fields, the lab also supports a rich variety of educational activities for students, teachers, and the general public. In summer 2005, 20 undergraduate students and 11 teachers participated in research experiences for undergraduates and teachers programs, 40 local teachers attended a four-day summer institute on scientific literacy, two summer Teachers in Residence created and then presented a teachers' workshop for the American Geophysical Union, and college bound high school students participated in the Regional Institutes for Math and Science research experience. Each year, NHMFL staff members conduct outreach activities with more than 7,000 K-12 students. The annual Open House regularly attracts more than 4,200 members of the general public, who come from neighboring states for the annual event. Collaborations are ongoing through local science museums and outreach centers, high school "externships" and high school science laboratory support.

Whether Magnet Lab staff takes the science to them or they come to the lab, thousands of elementary, middle and high-school students are touched by the lab's educational activities each year. *Credit: NHMFL*

► **South Pole Proof of Concept: Traverse** On January 14, 2006, an NSF convoy returned to the U.S. base at McMurdo Station after a two-month, 2,056-mile overland journey to the South Pole and back. The successful traverse, the first over that route since the 1950's, was the culmination of a four-year effort to prove that NSF can resupply its Amundsen-Scott South Pole Station by ground as well as by air. This overland transport capability will remove two major engineering and logistical constraints—cargo size and weight—that have limited the design of large scientific instruments and infrastructure at the Pole. Until now, the only way in or out of the station was aboard an LC-130 transport aircraft. Everything from the large polar telescopes to the new South Pole station itself has had to be designed in individual sections that could be transported in an LC-130's cargo bay and then reassembled on site.

The Antarctic traverse arrived at the South Pole on Dec. 23, 2005. From left to right: Russ Magsig, lead heavy equipment mechanic; Greg Feleppa, equipment operator; Judy Goldsberry, heavy equipment operator; Richard "Stretch" Vaitonis, (holding flag) heavy equipment operator; John Wright (holding flag), project manager; Brad Johnson, heavy equipment operator; Tom Lyman, field safety, radar operator; John Van Vlack, heavy equipment mechanic. *Credit: Scott Jackson, NSF*

In the quest for a better way, traverses have set out in each of the past three years to cover steadily increasing distances between McMurdo and the Pole, encountering such difficulties as crevasse fields and enormous areas of soft snow that delayed their passage. This year, a crew of seven men and one woman guided their convoy of tracked vehicles out of McMurdo on Nov. 11, 2005, towing sleds of cargo, fuel and life-support modules. Six weeks later, after crossing numerous crevasse fields and ascending more than 9,300 feet from sea level to the top of the Polar Plateau, they arrived at the South Pole on Dec. 23, 2005, to deliver nearly 110 tons of cargo. The payload, which included two tractors, is equivalent to 11 loads of equipment and supplies aboard an LC-130.



► **Blazar Jets Push Closer to Cosmic Speed Limit** Astronomers using the National Science Foundation's Very Long Baseline Array (VLBA) have discovered jets of plasma blasted from the cores of distant galaxies at speeds within one-tenth of one percent of the speed of light, placing these plasma jets among the fastest objects yet seen in the Universe. "This tells us that the physical processes at the cores of these galaxies, called blazars, are extremely energetic and are capable of propelling matter very close to the absolute cosmic speed limit," said Glenn Piner of Whittier College in Whittier, California. Piner worked on the project with student Dipesh Bhattari, also of Whittier College, Philip Edwards of the Japan Aerospace Exploration Agency, and Dayton Jones of NASA's Jet Propulsion Laboratory.

According to Einstein's Special Theory of Relativity, no object with mass can be accelerated to the speed of light. To get even close to the speed of light requires enormous amounts of energy. "For example, to accelerate a bowling ball to the speed newly measured in these blazars would require all the energy produced in the world for an entire week," Piner said, "and the blobs of plasma in these jets are at least as massive as a large planet."

Very Long Baseline Array (VLBA) sequence of blazar 0827+243. This sequence shows plasma moving away from the blazar's core. The core is the bright red dot at right; the plasma is the blue object to the left. The VLBA images show the plasma's motion over about 8.4 months. Credit: Piner et al., NRAO/AUI/NSF

► **Bringing the House Down.** Using two of the largest indoor shake tables in the world, researchers at the University at Buffalo, SUNY, subjected a full-size, wood-frame townhouse to the shaking of the 1994 Northridge, Calif., earthquake. The simulation was the first to subject a full-scale, finished home to the reproduced forces of an earthquake.

The two-story, three-bedroom townhouse was completely furnished and equipped, complete with a car in the attached garage, two water heaters—one anchored, according to earthquake protection measures, and one not—and dishes on the dining room table. For the first time, researchers observed a rocking motion during the largest shaking, a phenomenon that appeared to reduce the seismic forces and prevented the house's collapse.


Full-size, two-story townhouse astride the NEES dual shake tables at the University at Buffalo, SUNY. *Credit: Credit: John W. van de Lindt and the project web site* *http://www.engr.colostate.edu/NEESWood*

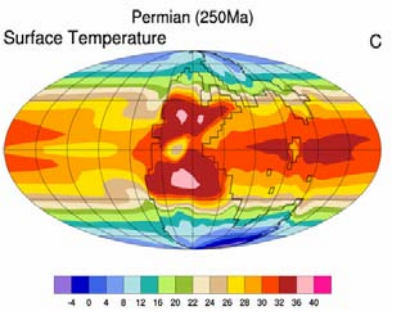
More than 80 percent of U.S. housing is wood frame construction. The results provide new insights for improving design and construction of wood frame structures, eventually enabling the construction of larger, taller wood structures in seismic regions.

The Buffalo facility is just one component of NSF's multi-institution George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). The Nov. 2006 test was part of a larger collaboration involving researchers in the United States and Japan. In 2009, a six-story wood frame structure pre-fabricated in the United States will be shipped to Miki City, Japan to be tested on the world's largest shake table..

► **CMS Turns On**: On July 26, 2006, scientists announced that the giant Compact Muon Solenoid (CMS) detector at CERN, the European Organization for Nuclear Research, in Geneva, Switzerland, had been sealed and switched on to collect data for an important series of tests using cosmic ray particles.

The Central Yoke of the CMS Detector. *Credit: CERN*

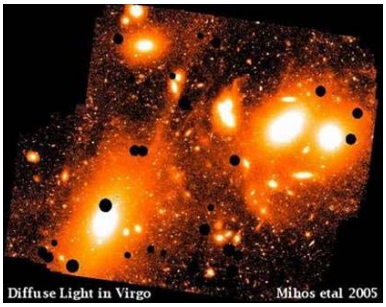
The test data is being used to calibrate and align the CMS, which is receiving joint U.S. funding from the Department of Energy (DOE) and NSF. Next year, when CERN's Large Hadron Collider (LHC) is scheduled to begin operations as the world's largest particle accelerator, CMS will be one of four major detectors used to observe the products of collisions of high energy protons at the LHC. The detector will thus help answer questions such as what gives matter its mass, what composes the invisible 96 percent of the universe, why nature prefers matter to antimatter and how matter evolved from the first instants of the universe's existence. U.S. scientists collaborate on all four experiments.




► **Climate Models Give Clue to Greatest Mass Extinction in Earth's History:** Scientists at the National Center for Atmospheric Research have used a computer model to simulate the Earth's climate at the time of the Permian Extinction, when 90 to 95 percent of all marine species and 70 percent of terrestrial species became extinct. The researchers used the Community Climate System Model (CCSM), which integrates changes in atmospheric temperatures with ocean temperatures and currents. The work supports the theory that an abrupt and dramatic rise in atmospheric carbon dioxide triggered the extinction 251 million years ago.

This large pulse of carbon dioxide seems to have come from an equally large burst of volcanic activity that played out over the relatively short span of some 700,000 years. According to the model, the resulting rise in carbon dioxide levels raised the temperature of the atmosphere, which in turn raised the temperature of the oceans' surface waters. Once this warming of the oceans reached a depth of 4,000 meters, it interfered with the seas' normal circulation process and kept oxygen from moving into the deep ocean. This lack of oxygen then killed the marine organisms that normally would have removed carbon dioxide from the atmosphere. The result: an even faster rise in carbon dioxide levels, thereby increasing the temperatures on land and in the ocean even further.

► **A Vast Stellar Web Spun by Colliding Galaxies:** Case Western Reserve University astronomers have captured the deepest, wide-field image ever obtained of the nearby Virgo cluster of galaxies. The image reveals for the first time that the space between the cluster galaxies is filled with a vast, complex web of "intracluster starlight" nearly 1,000 times fainter than the dark night sky. The streamers, plumes and cocoons that make up this extremely faint starlight are made of stars ripped out of galaxies as they collide with one another inside the cluster, and act as an "archaeological record" of their violent lives. The Virgo image was captured through Case's newly refurbished 24-inch Burrell Schmidt telescope, located at the Kitt Peak National Observatory in Arizona.




The deep, wide-field image of the Virgo Cluster, revealing its complex web of diffuse intracluster light. *Credit: Chris Mihos, Paul Harding, John Feldmeier, Heather Morrison (Case Western Reserve University)*