MAJOR MULTI-USER RESEARCH FACILITIES $1,085,560,000
-$8,320,000 / -0.8%

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

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
Facilities	$840.02	$876.76	$526.93	$865.47	-$11.29	-1.3%
Federally Funded R&D Centers	191.37	217.12	28.70	220.09	2.97	1.4%
Total, Major Multi-User Research Facilities	$1,031.39	$1,093.88	$555.63	$1,085.56	-$8.32	-0.8%

Totals may not add due to rounding.

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. All operations and maintenance of multi-user facilities 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.

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. Information on the construction projects funded through NSF's MREFC account is provided in the MREFC chapter.

NSF is investing $555.63 million of ARRA funds in major research facilities and infrastructure. $400.0 million of these funds are provided through the MREFC account for construction and acquisition activities associated with three MREFC projects: the Alaska Region Research Vessel (ARRV); the Advanced Technology Solar Telescope (ATST); and the Ocean Observatories Initiative (OOI). An additional $3.10 million of ARRA funding is provided through the R&RA account to the ATST for late-stage design and development. The balance of ARRA funding provided through the R&RA account, totaling $152.53 million, supports major facilities and infrastructure needs across the NSF portfolio.

Major Multi-User Research Facilities Funding

(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Request
Academic Research Fleet	$75.28	$98.68	$18.00	$87.58	-$11.10	-11.2%
Cornell Electron Storage Ring	14.11	10.50	7.80	6.60	-3.90	-37.1%
Cornell High Energy Synchrotron Source	5.60	2.51	7.20	6.67	4.16	165.7%
EarthScope[1]	19.21	24.31	4.00	25.05	0.74	3.0%
Gemini Observatory	18.69	18.71	-	19.10	0.39	2.1%
Incorporated Research Institutes for Seismology	11.75	12.00	2.33	12.36	0.36	3.0%
Integrated Ocean Drilling Program[2]	37.41	43.41	25.00	43.41	-	-
Large Hadron Collider	18.00	18.00	-	18.00	-	-
Laser Interferometer Gravitational Wave Observatory	29.50	30.30	-	28.50	-1.80	-5.9%
National High Magnetic Field Laboratory	27.75	26.50	20.00	31.95	5.45	20.6%
National Nanotechnology Infrastructure Network	14.13	16.26	10.00	16.26	-	-
National Superconducting Cyclotron Laboratory	19.25	20.50	2.00	21.00	0.50	2.4%
Network for Earthquake Engineering Simulation	19.38	21.82	-	22.00	0.18	0.8%
Other Facilities[3]	8.45	6.30	5.00	6.65	0.35	5.6%
Polar Facilities and Logistics[4]	328.60	342.18	22.50	374.35	32.17	9.4%
MREFC Projects[5]	192.91	184.78	403.10	145.99	-38.79	-21.0%
Federally Funded R&D Centers[6]						
National Astronomy and Ionosphere Center	12.75	11.60	3.10	11.40	-0.20	-1.7%
National Center for Atmospheric Research	89.07	106.92	13.20	100.00	-6.92	-6.5%
National Optical Astronomy Observatory and the National Solar Observatory	36.81	37.81	7.00	41.60	3.79	10.0%
National Radio Astronomy Observatory[7]	52.73	60.79	5.40	67.09	6.30	10.4%
Grand Total	$1,031.38	$1,093.88	$555.63	$1,085.56	-$8.32	-0.8%

Totals may not add due to rounding.

[1]EarthScope funding includes support provided through the R&RA account for operations and maintenance of the facility. Support provided through the MREFC account for the construction of the project, totaling $4.21 million in FY 2008, is included in the MREFC Projects line.

[2]Funding for the Integrated Ocean Drilling Program (IODP) includes support for the continued phase out of program and contract activities for the Ocean Drilling Program, predecessor to the IODP. This line also includes support for the operations and maintenance of the Scientific Ocean Drilling Vessel. Final MREFC support for the SODV, totaling $24,000 in FY 2008, is included on the MREFC projects line.

[3]"Other Facilities" includes support for other physics and materials research facilities.

[4]Polar Facilities and Logistics funding includes support for the operations and maintenance of the South Pole Station Modernization (SPSM) project. Funds provided through the MREFC account for SPSM, totaling $7.57 million in FY 2008, are included on the MREFC Projects line.

[5]Funding levels for MREFC Projects in this table include support for concept and development associated with these projects provided through the R&RA account, specifically for NEON, OOI and ATST, initial support for operations and maintenance provided through the R&RA account, and implementation support provided through the MREFC account. Final MREFC support for EarthScope, SODV and SPSM is also included in this line.

[6]"Federally Funded R&D Centers" does not include support for the Science and Technology Policy Institute, which is an FFRDC but not a research platform.

[7]Funding for the National Radio Astronomy Observatory includes operations and maintenance support for the Atacama Large Millimeter Array (ALMA). Construction funding for ALMA is included in the MREFC Projects line above.

Academic Research Fleet

$87,580,000
-$11,100,000 / -11.2%

Academic Research Fleet
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
Academic Research Fleet	$75.28	$98.68	$18.00	$87.58	-$11.10	-11.2%

The Academic Research Fleet consists of 22 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 for the Academic Research Fleet includes investments in ship operations; shipboard scientific support equipment; oceanographic instrumentation and technical services; and submersible support. Funding levels reported here reflect investments by the Division of Ocean Sciences (OCE) and the Division of Innovative and Collaborative Education and Research (ICER), and the FY 2008 Actual includes $2.0 million in supplemental appropriations. In addition to operations, OCE has undertaken selected construction projects based on an inter-agency fleet renewal status plan.

Total Obligations for the Academic Research Fleet
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Operations and Maintenance	$73.68	$98.58	$15.00	$80.58	$81.00	$82.00	$84.00	$86.00	$88.00
Fleet Renewal:									
Human Occupied Vehicle	-		3.00	5.00	2.00	-			
R/V Langseth (Seismic Ship)	1.60	-							
Regional Class Research Vessel		0.10		2.00	2.00	20.00	20.00	20.00	20.00
Total, Academic Research Fleet	$75.28	$98.68	$18.00	$87.58	$85.00	$102.00	$104.00	$106.00	$108.00

Totals may not add due to rounding.

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. 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.

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 costs for the Fleet are divided proportionally

among the vessel users based on usage; NSF supports approximately 70 percent of the total. NSF also coordinates with ship-operating and ship-user academic institutions through UNOLS.

Support for scientists using the fleet is provided by both NSF and other state and federal agencies. Within NSF, science is supported via competitive peer-reviewed proposals, most typically funded within OCE and through selected programs in the Divisions of Earth Sciences (EAR) and the Division of Atmospheric and Geospace Sciences (AGS), and also through the Office of Polar Programs (OPP) and the Directorate for Biological Sciences (BIO). Approximately 30 percent of the GEO proposals request ship time; GEO-funded shipboard science has ranged from about $35 million to $45 million per year over the last 5 years. Not reflected in this number is the science that utilizes samples or data collected on prior cruises, scientists piggy-backing on scheduled cruises to accomplish additional science, international scientists sailing with the U.S. fleet, and science funded by other agencies.

The significant temporary increase in funding for support of ship operations in FY 2009 reflects the large number of awards that NSF anticipates will require ship support, for which NSF will provide funding through ARRA. This temporary increase reflects approximately 600 additional ship days. The FY 2010 Request of $80.58 million will support approximately 2,400 ship days.

Project Report:

Management and Oversight:

- Fleet Operations:

  - NSF provides oversight to the Academic Research Fleet through cooperative agreements with each ship-operating institution and through a separate cooperative agreement with the UNOLS Office. In addition, NSF oversees the fleet through the Large Facilities Office via the Business Systems Review of selected operating institutions, site visits, ship inspections, and participation at UNOLS Council and Subcommittee meetings by program managers. Several program managers within OCE at NSF, at NOAA, and at ONR are involved in the activities and overall oversight of the Academic Research Fleet. NSF has recently reviewed two large Academic Research Fleet operating institutions through the Large Facilities office via the Business Systems Review in CY 2008.
  - 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.

- Fleet Renewal:

  - The NSF coordinator is the program director for Ship Acquisitions and Upgrades, within the Integrative Programs Section (IPS) in OCE, with additional IPS staff providing project management assistance.
  - External Structure: NSF and the Navy's Program Executive Office Ships (PEO Ships) are ending a MOU for the acquisition of the Regional Class Research Vessels (RCRVs). The design competition produced two designs by late 2008 and the process was halted before a down-select to a single design was completed because funds to commence with ship construction in 2009 could not be identified.

- Reviews: 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 Interagency Working Group for Facilities (IWG-F) published a Federal Oceanographic Fleet Status Report in December 2007 describing plans for renewal of the federal and academic oceanographic research and survey fleet. In addition, several activities are underway to support the upgrade of the U.S. Academic Research Fleet. Ship operations and technical activities are internally reviewed yearly on the basis of detailed annual reports provided by the operating institutions. Ship operations proposals are exempt from external review by peers. Detailed annual reports, in the form of the ship operations proposals, are reviewed and budgets are negotiated yearly and are dependent on the number of days at sea in support of NSF funded research programs. Technical services awards are reviewed every three years and negotiated annually.

Fleet Renewal:

- Ongoing activity in FY 2009 and key FY 2010 milestones:

  - Development and construction of a deep submergence capability to replace the submersible human occupied vehicle (HOV) *ALVIN* continues in FY 2010. This project, begun in FY 2004, includes a Preliminary Design Review (PDR) in July 2009 and a Final Design Review (FDR) in December 2009. Integration of a new titanium 6,500 meter-capable personnel sphere with existing *ALVIN* vehicle components is planned during FY 2010. Initial Phase I operations are anticipated in 2011 with a depth capability of 4,500 meters, the limit of the current *ALVIN* and the infrastructure components to be shared across both platforms. Upgrades to permit operations at a depth of 6,500 meters could follow in 3 to 5 years. The anticipated total NSF cost for Phase I is $32.90 million, which includes $22.90 million from prior years and $10.0 million from FY 2009 through FY 2011. Funding in FY 2009 represents the $3.0 million provided through ARRA for final Phase I design of the *ALVIN* upgrade and limited development activities. An increase of $10.0 million in NSF funds over previous estimates are due to delays in schedule, increases in labor costs and levels of effort, and a rise in titanium costs. Additional increases will be shared by the awardee.
  - NSF is awaiting the results of two NRC studies on Ocean Infrastructure needed in the near and longer term before moving ahead with construction of the Regional Class Research Vessel (RCRV's). Funds in FY 2009 allow finalization of the design work for construction of vessels; those in FY 2010 will allow any needed design refresh to comply with any regulation changes and, potentially, the issue of a shipyard RFP.
  - The Research Vessel (R/V) *Marcus G. Langseth* started seismic operations in 2008, and scientific outfitting continues to ready the ship for general oceanographic research. To date, the quality and quantity of data collected has been remarkable, and the ship is recognized world-wide by the science community as the premier ship for geophysical studies.
  - Maintenance and upgrade projects are on-going on all of the 22 ships in the Academic Research Fleet. $15.0 million in ARRA funding will be used to upgrade specific ship management control systems, replace aged science mission equipment, and accomplish deferred maintenance on many of the ships in the fleet.

Cornell Electron Storage Ring and Cornell High Energy Synchrotron Source

$13,270,000
+$260,000 / 2.0%

Cornell Electron Storage Ring-Cornell High Energy Synchrotron Source
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
Cornell Electron Storage Ring	$14.11	$10.50	$7.80	$6.60	-$3.90	-37.1%
Cornell High Energy Synchrotron Source	5.60	2.51	12.40	6.67	4.16	165.7%
Combined CHESS/CESR*	$19.71	$13.01	$20.20	$13.27	$0.26	2.0%

Totals may not add due to rounding.

* Starting in FY 2009

The Cornell Electron Storage Ring (CESR) was originally constructed to support research in elementary particle physics as well as accelerator physics and superconducting radio frequency applications. CESR funding for these purposes concluded with final phase-out support from the Division of Physics in the Directorate for Mathematical and Physical Sciences in FY 2009. Concomitant with this phase-out, a larger fraction of CESR operations was dedicated to providing electrons for the Cornell High Energy Synchrotron Source (CHESS) beginning in FY 2009. As of FY 2010, this will be CESR's primary function.

CHESS is a high-intensity, high-energy X-ray source supported by NSF, with partial co-support from the National Institutes of Health (NIH). It uses synchrotron light given off by 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 facilities for X-ray light research in physics, chemistry, biology, materials, and environmental sciences. Areas of user emphasis include soft matter and thin film studies, solution scattering, structured nanomaterials, high-pressure science, structural biology, time-resolved materials science, and x-ray studies of items of art and archaeology.

Total Obligations for CESR-CHESS
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
CESR-Ops & Maintenance	$14.11	$10.50	$6.50	$6.60	$11.03	$11.90	$12.96	$13.65	$14.44
CHESS-Ops & Maintenance	5.60	2.51	7.20	6.67	7.90	8.38	8.47	8.89	9.41
CESR-R&D	-	-	1.30	-	-	-	-	-	-
CHESS-R&D	-	-	5.20	-	-	-	-	-	-
Combined CHESS/CESR	$19.71	$13.01	$20.20	$13.27	$18.93	$20.28	$21.43	$22.54	$23.85

Totals may not add due to rounding.

Note: Estimated support beyond FY 2010 is contingent upon satisfactory performance review.

Starting in FY 2010, CESR/CHESS facilities are transitioning to DMR stewardship. $13.27 million will allow for continued operation of the facilities in support of synchrotron light users as well as in support of research and development on coherent light sources. Funding beyond FY 2010 is contingent upon the successful outcome of a performance review expected to conclude in late FY 2009-early 2010.

CESR/CHESS staff assist in transferring Superconducting Radio Frequency (SRF) technology to industry. Through a license arrangement with Cornell University, 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 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).

CESR/CHESS supports and enhances Ph.D. level graduate education, postdoctoral research, research experiences for undergraduates, and research experiences for K-12 science teachers. Engendering excitement in science among children is a focus for strengthening K-12 engagements. An important component of that effort is the participation of graduate students in pre-college science classrooms.

Project Report:

Management and Oversight:

- NSF Structure: Through FY 2008, NSF oversight of CESR was 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 continuation proposal, and a site visit by NSF staff and external reviewers. The oversight process included 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. As CESR transitions from supporting elementary particle physics research to a dedicated source of electrons for CHESS, oversight and funding of CESR will shift from PHY to the Division of Materials Research (DMR) in 2010. (For more information, see the PHY and DMR narratives within the MPS chapter).

  CHESS is supported through the Division of Materials Research (DMR) in MPS and by NIH. These organizations provide management oversight for CHESS through regular site visits.

- External structure: Both CESR and CHESS are administratively part of the Cornell Laboratory of Accelerator-based Sciences and Education (CLASSE) reporting to Cornell's Vice-Provost for Research. CESR and CHESS are operated by Cornell University in accordance with the respective cooperative agreements with NSF that set goals and objectives of the facilities.

- CHESS is a national user facility providing access to users on the basis of competitive proposal review. The primary function of facility staff is to maintain and operate the facility and to assist users in use of the facility. A Users Committee, appointed by the users of CHESS, provides advice to the Director of CHESS on policies related to the use and development of CHESS facilities and equipment for user experiments. An annual users meeting with several workshops help to disseminate results of facility users and of CHESS and MacCHESS (the component supported by NIH) staff. As of FY 2010 the CESR storage ring is dedicated to supporting the CHESS operation.

- Reviews:
  - Recent reviews conducted (CESR):
    - Comprehensive site review with panel of external experts, FY 2006
    - Review for phase-out of facility particle physics operations, FY 2008
  - Recent reviews conducted (CHESS):
    - Proposal review including site visit review with panel of external experts, FY 2008

- Upcoming reviews:
  - Review of combined CESR/CHESS (planned) FY 2009

Renewal/Recompetition/Termination:

CESR is currently funded through a five-year cooperative agreement initiated in 2003. Use of CESR as a facility for particle physics concluded with final phase-out over FY 2008 and FY 2009. As of FY 2010, CESR is dedicated entirely to support the CHESS operation. CHESS is currently funded through a cooperative agreement also initiated in 2003. NSF expects to consider the continued operation of CESR/CHESS in support of X-ray photon science past FY 2010 pending satisfactory performance review.

EarthScope

$25,050,000
+$740,000 / 3.0%

EarthScope
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
EarthScope	$19.21	$24.31	$4.00	$25.05	$0.74	3.0%

The EarthScope facility is a distributed, multi-purpose geophysical instrument array that is making major advances in our knowledge and understanding of the structure and dynamics of the North American continent. EarthScope instrumentation is expected to be located in nearly every county within the U.S. over the 10 year life span of the program. Construction of EarthScope was completed September 30, 2008, on-time and on-budget. FY 2009 is the first year of operation of the full EarthScope.

Total Obligations for EarthScope
(Dollars in Millions)

	Prior Years	FY 2008 Actual	FY 2009 Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
R&RA Obligations:									
Concept & Development	$9.36								
Management and Operations	11.63	19.21	24.31	25.05	26.00	26.65	27.25	28.05	28.86
ARRA Estimate			4.00						
Subtotal, R&RA Obligations	$20.99	$19.21	$28.31	$25.05	$26.00	$26.65	$27.25	$28.05	$28.86
MREFC Obligations:									
Implementation	195.97	4.21	-	-					
Subtotal, MREFC Obligations	$195.97	$4.21	-	-	-	-	-	-	-
Total, EarthScope	**$216.95**	**$23.42**	**$28.31**	**$25.05**	**$26.00**	**$26.65**	**$27.25**	**$28.05**	**$28.86**

Totals may not add due to rounding.

EarthScope seeks to enhance our understanding of the structure and evolution of the North American continent, including earthquakes and seismic hazards, magmatic systems and volcanic hazards, lithospheric dynamics, regional tectonics, continental structure and evolution, fluids in the crust, and associated educational aspects. Science and non-science students will be engaged in geosciences discovery through the use of technology in real time or retrospectively with the aim of integrating research and education.

The U.S. Geological Survey (USGS), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the International Continental Scientific Drilling Programme are partners with NSF in EarthScope. Project partners also include state and local governments, geological and engineering firms, and Canadian and Mexican agencies. Over 3,000 earth scientists and students are expected to use the facility annually. Geotechnical and engineering firms directly use data and models, which are enabled by EarthScope. Instrumentation firms are collaborating on development for state-of-the-art seismic systems, down-hole instrumentation, and high-precision GPS antenna designs.

Along with direct operations and maintenance support for EarthScope, NSF will support research performed utilizing the facility through ongoing research and education programs. The annual support for such activities is estimated to be about $6.20 million in FY 2010.

Project Report:

Management and Oversight:

- NSF Structure: The EarthScope Program Director, located in the Division of Earth Sciences (EAR) in the Directorate for Geosciences (GEO), provides NSF oversight. The Deep Earth Processes Section Head in EAR and a Project Advisory Team, including the staff from GEO, the Office of the General Counsel (OGC) and staff from the Office of Budget, Finance and Award Management (BFA), including the Deputy Director for Large Facility Projects, provide other internal oversight.

- External Structure: The external management structure includes a community-based EarthScope National Office, currently located at Oregon State University, an independent Steering Committee consisting of scientists from the EarthScope community including two subcommittees, one devoted to Education and Outreach and one devoted to Cyberinfrastructure; and external management oversight committees for each of the EarthScope facility components.

- Reviews: Each year, NSF convenes a panel of external experts to review project management, cost, schedule, and technical status of the EarthScope facilities and provide advice for the EarthScope managers and NSF.

Current Project Status:

EarthScope completed its construction phase on-time and on-budget on September 30, 2008 and is now fully operational. The USArray component of EarthScope is a continental-scale seismic and magnetotelluric observatory designed to provide a foundation for integrated studies of continental lithosphere and deep Earth structure over a wide range of scales. USArray consists of four major components: (1) a Reference Network of permanent seismic stations, (2) a Transportable Array of ~400 seismic stations, (3) a Flexible Array pool of seismic instruments for use in specific experiments, and (4) a Magnetotelluric Array with permanent and transportable instruments. The Plate Boundary Observatory (PBO) component of EarthScope is a geodetic observatory designed to study the three-dimensional strain field resulting from deformation across the active boundary zone between the Pacific and North American plates in the western United States. PBO includes 1200 geodetic and 79 strain meter/seismic stations. The San Andreas Fault Observatory at Depth (SAFOD) is a 3-kilometer deep hole drilled directly into the San Andreas Fault midway between San Francisco and Los Angeles, near Parkfield, CA. Located in an area that has ruptured six times since 1857, the hole is providing the first opportunity to observe directly the conditions under which earthquakes occur, to collect rocks and fluids from the fault zone for laboratory study, and to continuously monitor the physical condition within an active earthquake nucleation zone. Up-time of EarthScope seismic and geodetic instruments is consistently greater than 90 percent.

Although it became fully operational only last year, EarthScope has already led to a number of important scientific advances. EarthScope is aiding in the development of predictive models for earthquakes by unraveling the dynamic processes along faults, from stress build-up to catastrophic rock failure. While the unique SAFOD core from the San Andreas Fault is just beginning to be analyzed, early mineralogical analysis has already answered key questions about why sections of the fault exhibit slip in the form of

creep. The combined use of PBO geodetic and strain data, and USArray seismic data, has documented a wide range of seismic and aseismic signals associated with different modes of fault slip along the Cascadia subduction zone and provided unique new insight into spatial and temporal relationships between earthquakes (large and small), tremor, and slow slip. These exciting new results may have important implications for assessing seismic risk along a plate boundary that is capable of a magnitude 9+ earthquake similar to the great Sumatra earthquake and tsunami of December 2005. PBO's regional scale geodetic network has also provided surprising new information on the Pacific-North American plate boundary, showing for example that extension in the Basin and Range province is not uniform as was once widely believed, but instead focused near its western and eastern edges. New advances are also being made in joint modeling of EarthScope seismic and strain data with other data types such as geochemistry and structural geology. Finally, EarthScope data has been used to develop a revolutionary new tomographic technique for imaging crust and upper mantle structure in western North America that utilizes seismic signals previously considered to be noise.

The EarthScope project has been represented at several dozen professional meetings and conferences through an exhibit booth, presentations, and well-attended scientific sessions. Scientific results utilizing data collected by the EarthScope facility have already been presented at national meetings and in professional publications. The third biennial EarthScope National Meeting will be held in Idaho in the Spring of 2009.

Operations costs

Annual operational costs for EarthScope are anticipated to remain approximately steady at about $25.0 million, with annual adjustments for inflation. EarthScope is receiving $4.0 million in ARRA funds in FY 2009 to cover a budget shortfall caused by smaller than anticipated growth of the EarthScope operations budget in 2008. The ARRA funds will allow the full EarthScope facility to operate throughout 2009, avoiding a potential reduction in operations staff and loss of scientific data.

Gemini Observatory

$19,100,000
+$390,000 / 2.1%

Gemini Observatory
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
Gemini Observatory	$18.69	$18.71	-	$19.10	$0.39	2.1%

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, Gemini North, is optimized for infrared observations and is located on Mauna Kea at an altitude of 4,200 meters. The telescope in Chile, Gemini South, is located on Cerro Pachon, also an outstanding photometric site, at an altitude of 2,700 meters. This siting of the two telescopes assures complete coverage of the sky and complements the observations from space-based observatories. It 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.

Total Obligations for the Gemini Observatory
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Operations and Maintenance	$18.69	$18.71	$19.10	$19.58	$20.07	$20.57	$21.08	$21.61

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, including our own once they are formed, and the formation of stars and planetary systems. The current 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 optimize the telescopes' imaging capabilities and infrared performance, and compensate for the blurring effects of the Earth's atmosphere.

The Gemini telescopes help educate and train U.S. astronomy and engineering students. An estimated 10 percent of the roughly 500 U.S. users per year are students. Gemini is also providing a focus for public outreach and high school student training in all the partner countries, including "sister city" arrangements between Hilo, Hawaii and La Serena, Chile involving students and teachers at high school and elementary school levels. Gemini staff also provides guidance and support to the Imiloa Science Center, a public astronomy and cultural center in Hilo.

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 entities in a number of partner and non-partner countries. These have involved firms specializing in large and/or complex optical systems, aerospace industries, electronics, and engineering, etc. Continued involvement of such industries is part of the instrumentation and facilities renewal activities included in the operating budget of the Gemini Observatory.

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. Many U.S. users are supported through separate NSF or NASA grants to pursue scientific programs that require use of Gemini.

Laser guide star systems, which greatly improve the telescopes' ability to correct for atmospheric blurring, are being developed for both telescopes with the laser on Gemini North in routine operation and integration of the system on Gemini South underway. An advanced 'multi-conjugate' adaptive optics system, which will yield crisp images over a larger field of view, is in development on Gemini South and will start scientific operation in FY 2009. Several new instruments are in various states of development, including: (1) an improved infrared spectrometer, to be delivered in FY 2009; (2) the construction of the Gemini Planet Imager, a camera designed to directly detect planets around nearby stars; and (3) design studies for a very wide-field optical spectrometer that will collect data from thousands of objects simultaneously.

The Gemini North telescope photographed while propagating its guide star laser. The laser excites neutral sodium atoms at a height of about 90 km in the Earth's atmosphere, which produces an artificial guide star which is used by the adaptive optics system to correct for the blurring of the atmosphere. *Credit: Gemini Observatory.*

Budget projections for FY 2011 and beyond are based on a 2.5 percent annual ramp approved by the Gemini Board and NSF.

Facility Report

Management and Oversight:

- NSF Structure: NSF has one seat on the Gemini Board and provides the Executive Secretary to the Board. Programmatic management is the responsibility of an assigned NSF program manager for Gemini in the Division of Astronomical Sciences in the Directorate for Mathematical and Physical Science. The program manager approves funding actions, reports, and contracts, and conducts reviews on behalf of the Gemini partnership.

- External Structure: 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. An independent Visiting Committee, established by the Gemini Board, advises on the operation of the Observatory and meets bi-annually. 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.

- Reviews: In addition to a review held mid-way through the cooperative agreement, NSF conducts periodic reviews of AURA management and observatory programs as requested by the Gemini

Board. The mid-term management review was held in Hilo on September 23-26, 2008. In addition, NSF conducted a Business System Review of the observatory in March 2009.

Renewal/Recompetition/Termination:

The current International Gemini Agreement will expire in 2012. The Gemini Board has begun discussing the process and schedule for renegotiation of the agreement. A decision point has been established by the Board for November 2009, at which time the partners must express their intention (or not) to remain in the partnership following 2012. It is anticipated that there will be changes in the partnership including possible rebalancing of the partners' shares. Negotiations for the international agreement and the Gemini management scheme may require a number of years to complete, thus requiring extensions of the current agreements.

The current NSF cooperative agreement is for FY 2006-2010. On the basis of the mid-term management review of AURA's performance as the Gemini managing organization in November 2008, the Gemini Board recommended not to compete the management of the observatory when the current cooperative agreement expires. The new cooperative agreement, expected to start in 2011, may be subject to amendment as details of the renewal International Gemini Agreement are finalized in the 2012-2013 timeframe. Discussions with AURA are underway to provide stable ongoing operations and management through the negotiations with the Gemini partners on their future involvement in the partnership.

Incorporated Research Institutions for Seismology

$12,360,000
+$360,000 / 3.0%

Incorporated Research Institutes for Seismology
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
Incorporated Research Institutes for Seismology	$11.75	$12.00	$2.33	$12.36	$0.36	3.0%

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, global real-time earthquake monitoring, and in nuclear test ban verification. It is managed via a consortium of 109 U.S. universities and non-profit institutions with research and teaching programs in seismology. IRIS led the construction of the USArray component of the EarthScope project and it is now operating USArray as part of the EarthScope Facility.

Total Obligations for IRIS
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Operations and Maintenance	$11.75	$12.00	$12.36	$12.71	$13.09	$13.48	$13.89	$14.31
ARRA Estimate		2.33						
Total, IRIS	$11.75	$14.33	$12.36	$12.71	$13.09	$13.48	$13.89	$14.31

Totals may not add due to rounding.

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. To serve the research needs of the broad national and international seismology community, IRIS is organized in four major core program elements:

1. The Global Seismographic Network (GSN), which currently consists of a global deployment of over 150 permanently installed broadband 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 (70 terabyte archive);
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.

In addition, IRIS operates the USArray component of EarthScope. The USArray is a continental-scale seismic and magnetotelluric observatory designed to provide a foundation for integrated studies of continental lithosphere and deep Earth structure over a wide range of scales. The $2.33 million provided

to IRIS through the American Recovery and Reinvestment Act of 2009 (ARRA) will be used to augment the Reference Network of USArray in the Pacific Northwest in order to facilitate the study of a wide spectrum of earthquake fault behavior and crustal deformation along this active plate boundary, including the newly discovered phenomena of episodic tremor and slip.

Besides its role in providing the observational data essential for basic research in geophysics and earthquake dynamics, IRIS also plays a significant role providing real-time seismic data to the U.S. Geological Survey and the National Oceanic and Atmospheric Administration for global earthquake and tsunami monitoring, 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.*

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. 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).

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 collaborate closely with industry in development of seismic instrumentation and software.

The Geophysics, Tectonics, and Continental Dynamics Programs in the Division of Earth Sciences (EAR); the Marine Geology and Geophysics Program in the Division of Ocean Sciences (OCE); and the Geology and Geophysics and Glaciology Programs in the Antarctic Research Section of the Office of Polar Programs (OPP) provide most of the funds for NSF-sponsored research making use of the IRIS facilities, totaling approximately $15 million per year. Funds permit deployment of PASSCAL instruments and use of GSN data stored at the DMS to solve major earth science problems.

Facility Report:

<u>Management and Oversight:</u>

- NSF Structure: EAR, 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.

- External Structure: 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.

Reviews & Renewal:

A new five-year cooperative agreement with the IRIS Consortium for the continued management of the IRIS core facilities (2006-2011) was approved by the NSB in May 2006 and finalized in September 2006. All major ongoing geoscience facilities routinely undergo mid-award reviews of their management in addition to peer review of proposals for new or continued support. A management review of IRIS took place in April 2009. Although a number of specific recommendations were made by the review committee, overall the committee found that IRIS is an extremely well-managed and effective organization that has, through its commitment to the collection and open dissemination of the highest quality seismological data, transformed the discipline of seismology.

The Integrated Ocean Drilling Program and the Scientific Ocean Drilling Vessel

$43,410,000
+$0.0 / 0.0%

The Integrated Ocean Drilling Program
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
Integrated Ocean Drilling Program	$37.41	$43.41	$25.00	$43.41	-	-

The Integrated Ocean Drilling Program (IODP), which began in FY 2004, is an expanded successor program to the Ocean Drilling Program (ODP) and represents an international partnership of more than 20 national funding organizations, scientists, and research institutions organized to explore the evolution and structure of Earth as recorded in the ocean basins. The IODP is co-led by NSF and the Ministry of Education, Culture, Sport, Science and Technology (MEXT) of Japan. IODP platforms provide sediment and rock samples (cores), in-situ monitoring, sampling, and measurement from borehole observatories, shipboard and shorebased descriptive and analytical facilities, downhole geophysical and geochemical measurements (logging), and opportunities to conduct experiments to determine in-situ conditions beneath the seafloor.

SODV Underway for Initial Science Expedition, March 10, 2009. *Credit: NSF*

Total Obligations for IODP
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
SODV Operations and Maintenance	$37.41	$43.41	$43.41	$43.41	$44.41	$44.41	$45.00	$46.00
ARRA Estimate		25.00						
Total, IODP	$37.41	$68.41	$43.41	$43.41	$44.41	$44.41	$45.00	$46.00

Totals may not add due to rounding.

NOTE: The IODP program officially ends in 2013 but may be renewed. NSF activities regarding IODP renewal, including overall program review, are expected to commence in FY 2011. IODP scientific community planning efforts for a post- FY 2013 science program commenced in FY 2009. Funding for FY 2014 and FY 2015 is estimated assuming renewal of the program.

Annual operations and maintenance support for IODP includes the costs of operating the platform itself, providing technical scientific support, maintaining databases and preparing scientific publications emerging from IODP expeditions, and management of the international program. In addition, NSF will support research enabled by the facility through ongoing research and education programs. The annual costs for such associated science support, not included in the table above, are estimated to be about $11.0 million. Operations and maintenance costs are based on NSF experience in management of the ODP and the contract with the SODV operator. Funding in FY 2009, including $25.0 million provided through the American Recovery and Reinvestment Act of 2009 (ARRA), will enable a 30 percent increase in the operating schedule of the Scientific Ocean Drilling Vessel (SODV). This increase allows for full time operation of the vessel.

The IODP Scientific program includes emphasis on the following research themes:

- Deep Biosphere and the Sub-seafloor Ocean.
- Processes and Effects of Environmental Change.
- Solid Earth Cycles and Geodynamics, including study of tsunami-producing seismogenic zones and other geohazards.

Undergraduate and graduate students participate in drilling expeditions, working with leading scientists to help become future leaders themselves. Other students and the public are engaged in geoscience discovery through distance learning initiatives (including remote broadcasts from the drillship), classroom teaching modules on IODP research initiatives, outreach displays for museums and educational/teaching institutions, and lecture programs. In FY 2007, an estimated 180,000 K-12, 10,000 undergraduate and 10,500 graduate students engaged in or were supported by IODP education and outreach efforts, as were 35,000 teachers.

MEXT and NSF are equal partners in IODP and contribute equally to program operation costs. The European Consortium for Ocean Research Drilling (ECORD) – representing 16 European countries and Canada – the People's Republic of China and Korea have officially joined IODP and provide financial contributions. India and Australia have also announced their intention to join the partnership. IODP partners, including NSF, support IODP integrative activities including science planning, review, data management, drilling science-related engineering development, core and sample archiving, publishing, and international outreach.

Over 2,000 scientists from 40 nations have participated on ODP and IODP expeditions since 1985, including about 900 U.S. scientists from over 150 universities, government agencies, and industrial research laboratories. Samples and data have been distributed to more than 800 additional U.S. scientists.

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 propose and participate in IODP cruises, are members of the program's scientific and technical advisory committees, and supply data for planning expeditions and interpretation of drilling results.

Facility Report:

Management and Oversight:

- NSF Structure: The Division of Ocean Sciences in the Directorate for Geosciences (GEO) manages the SODV and the IODP under the NSF Ocean Drilling Program. NSF's Ocean Drilling Program is located 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 for the Central Management Office (CMO) contract and the System Integration Contractor (SIC) contract.

- External Structure: NSF and MEXT have signed a Memorandum of Cooperation, which identifies procedures for joint management of a contract to an IODP CMO. A non-profit corporation of U.S., Japanese, and other international institutions (IODP Management International, Inc.) has been contracted by NSF for the CMO activity. 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. Drillship providers are responsible for platform operational management and costs. NSF provides the light drillship through contract with the U.S. SIC, an alliance formed by the Consortium for Ocean Leadership, Inc. (COL) together with subcontractors Texas A&M University and Lamont-Doherty Earth Observatory, Columbia University. MEXT manages its drillship through the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), while the British Geological Survey manages ECORD drilling contributions.

Scientific advice and guidance for IODP is provided through the science advisory structure (SAS). The SAS consists of a Science Advisory Structure Executive Committee (SASEC) and a series of committees, panels, and groups headed by the Science Planning Committee (SPC). The CMO, under the direction of the SPC Chair, is responsible for coordinating the SAS committees, panels, and groups, and for integrating the advice from the SAS into drilling and operational guidance for IODP. Representation in the SAS is proportional to IODP member's financial contribution.

- Reviews: Both the CMO and SIC contracts call for management reviews every three years by independent, external panels. Both the SIC and CMO contracts will undergo external review in FY 2010. Reviews for each expedition are carried out on a regular basis to evaluate operational and scientific performance, with review of scientific progress in broader thematic areas conducted by independent panel every several years.

Renewal/Recompetition/Termination:

IODP international agreements and contracts cover activities through FY 2013. NSF activities regarding IODP renewal, including overall program review, are expected to commence in FY 2011. IODP scientific community planning efforts for a post- FY 2013 science program commenced in FY 2009.

Scientific Ocean Drilling Vessel (SODV)

The SODV project was funded through the Major Research Equipment and Facilities Construction (MREFC) account and supported the contracting, conversion, outfitting and acceptance trials of a deep-sea drilling vessel for long-term use in the IODP. The total NSF cost of the project was $115 million appropriated through the MREFC account over three years, with FY 2007 representing the final year of appropriations. The ship operator, Overseas Drilling Limited (ODL), is covering certain construction costs in exchange for a higher day rate charge during the operations phase. Construction activities have been completed and the ship is scheduled to commence international scientific operations on May 10, 2009. The outfitted drillship is capable of operating in nearly all ocean environments (subject to limitations regarding minimum water depth and surface ice coverage), and accommodates a scientific and technical staff of up to 60 persons.

Project Report:

Management and Oversight:

- NSF Structure: The project was overseen by a program director in the OCE in GEO with advice and oversight support from a NSF Project Advisory Team, including representatives from GEO, the Office of Polar Programs, the Office of Budget, Finance and Award Management (BFA), and the

Office of General Counsel. The BFA Deputy Director for Large Facility Projects participated as a member of the PAT, providing advice and assistance.

- External Structure: A SODV Independent Oversight Committee provided technical, financial and scheduling recommendations and advice for the SODV project to top-level management. A Program Advisory Committee (PAC), comprised of members of the science and drilling communities, provided ongoing assessment of the design plans for the on-board science and drilling capabilities, to assure that the converted vessel reflects the needs of the scientific communities.

- Reviews:
  - A two-phase independent readiness assessment of the SODV science systems was completed in February and March 2009 by a group of ocean drilling veteran scientists: the first phase included a land-based assessment of a new integrated database for IODP measurements, and the second phase included an underway assessment of the functionality of analytical instruments and their integration with the database software.
  - A final acceptance review process is being performed by the System Integration Contractor and NSF and is due in late 2009.

Current Project Status:

Shipyard conversion of the vessel was completed in early January 2009. Initial load-out and shakedown activities were conducted and the SODV is scheduled to commence IODP scientific operations on May 10, 2009.

Cost and Schedule:

Refitting of the ship is completed. Due to the enormous worldwide demand for shipyard services during the SODV refit period, actual shipyard work lagged planned progress, resulting in significant delay in return of the vessel to science operations. Various project costs are still under review but current indications are that the NSF portion of the SODV refit has been completed within the MREFC project funding profile established in early FY 2005.

Risks:

The remaining project risks include successful and timely resolution of final “punch list” items requiring vendor repairs and science system software issues identified during the independent readiness assessment.

Future Operations Costs:

Future operations costs are described in the obligations table above.

Large Hadron Collider

$18,000,000
$0.0 / 0.0%

Large Hadron Collider
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
Large Hadron Collider	$18.00	$18.00	-	$18.00	-	-

The Large Hadron Collider (LHC), an international project under construction at the CERN laboratory in Geneva, Switzerland, 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 maintenance and operation of two particle detectors, a Toroidal LHC Apparatus (ATLAS) and the Compact Muon Solenoid (CMS). These have been built 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. A total of 34 international funding agencies participate in the ATLAS detector project and 31 in the CMS detector project. NSF and the Department of Energy (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.

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.

Total Obligations for the LHC
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Operations and Maintenance	$18.00	$18.00	$18.00	$18.00	$18.00	$18.00	$18.00	$18.00

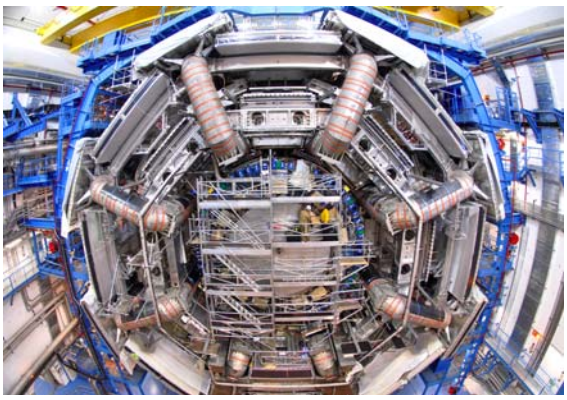
The current cooperative agreement ends in FY 2011. Outyear funding estimates are for planning purposes only and do not reflect policy decisions.

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 may 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. 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).

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. In the construction phase, approximately $45.0 million was devoted to materials procurements from industry. In FY 2010 the estimate for material procurements is approximately $3.80 million, which is included within the $18.0 million operating costs.

The U.S. LHC Collaboration is in the final stages of installation of detector components in the experimental areas and has been actively engaged in the integration of these components with the rest of the detectors and the commissioning of the detectors using cosmic rays. This effort is proceeding on schedule and budget. However, the accelerator start-up schedule has been delayed due to failure in September 2008 of a high current line that caused arching and destructive failure of a liquid helium cryogenic system. First beams are now expected in late FY 2009, after which detector commissioning will proceed using the particle beams and will continue into FY 2010. Data-taking is expected to begin in FY 2010 when the beam performance stabilizes.



The ATLAS detector in February 2007. *Credit: CERN.*

Facility Report:

Management and Oversight:

- NSF Structure: A program director in the Division of Physics (PHY) is responsible for day-to-day project oversight. The NSF program director participates in an internal Project Advisory Team, including staff from the NSF Offices of Budget Finance and Award Management, General Counsel, Legislative and Public Affairs, Office of International Science and Engineering, and Office of the Assistant Director for MPS.

- External Structure: 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.

- Reviews: There is one major management/technical review each year with a panel of external, international experts as well as one review by NSF/DOE program directors to monitor progress on issues raised at panel reviews. Two JOG review meetings per year monitor overall program management.

Renewal/Recompetition/Termination:

The LHC project is expected to continue at least through to the end of the next decade. Since the present award goes through FY 2011, it will require a renewal. The U.S. LHC collaboration is part of an international collaboration where the U.S. contribution to the detector construction and operations is intimately connected to that of its international collaborators. Under these circumstances it would be difficult, if not unrealistic, to consider recompeting the U.S. role in the international collaboration when the present award ends.

Laser Interferometer Gravitational-Wave Observatory

$28,500,000
-$1,800,000 / -5.9%

Laser Interferometer Gravitational-Wave Observatory
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
Laser Interferometer Gravitational-Wave Observatory	$29.50	$30.30	-	$28.50	-$1.80	-5.9%

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 for both fundamental physics and astrophysics. The Laser Interferometer Gravitational Wave Observatory (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 2-km 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 4×10^{-18} or about 1/1000th the diameter of a proton. The 4-km length for LIGO, 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's current and projected operations and maintenance requests for FYs 2009-2013 are less than the FY 2014 and later requests since some employees and resources will be diverted to the Advanced LIGO (AdvLIGO) project funded through the Major Research Equipment and Facilities Construction (MREFC) account, which began in FY 2008. LIGO operations will, however, continue to analyze data taken during the current and earlier runs and will also plan for, conduct, and analyze future scientific runs scheduled from FY 2009 until a temporary shutdown of the detectors in FY 2011.

Total Obligations for LIGO
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Operations and Maintenance	$29.50	$30.30	$28.50	$30.30	$30.40	$30.50	$36.00	$39.00

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 and teachers at all levels, and informal education and outreach activities for the public. A Visitors' Center at the Livingston, LA site, dedicated in November, 2006, is filled with Exploratorium exhibits and is the focal point for augmenting teacher education at Southern University and other student-teacher activities state-wide through the Louisiana Systemic Initiative Program, originally funded by NSF.

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. Involvement includes novel techniques for fabrication of LIGO's vacuum system, seismic isolation techniques, ultrastable laser development (new product), development of new ultra-fine optics polishing techniques, optical inspection equipment (new product). LIGO has recently cooperated with the Defense Intelligence Agency on research on LIGO interferometers as impulse seismic event detectors.

The intersection of the 4-kilometer arms of the Livingston, LA LIGO interferometer. *Credit: Courtesy of the LIGO Laboratory.*

In 1997 LIGO founded the LIGO Scientific Collaboration (LSC), an open collaboration that organizes the major international groups doing research supportive of LIGO. The LSC now has more than 60 collaborating institutions with over 650 participating scientists. A Memorandum of Understanding 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 AdvLIGO, data analysis and validation of scientific results, and setting priorities for instrumental improvements at the LIGO facilities. Annual NSF support for science and engineering research directly related to LIGO activities through ongoing research and education programs is about $5.50 million.

LIGO concluded its mission-defining scientific run (S5), in which a year's accumulation of data was taken at its design sensitivity with all three interferometers operating in coincidence, in October, 2007. These data were taken at a detector sensitivity in excess of the defined goal sensitivity outlined in the design specifications. Science runs planned to begin in 2009 will test technologies that will become part of AdvLIGO; the detector sensitivity will be at least twice that during the previous S5 run.

LIGO's operations during the AdvLIGO construction era will concentrate on:

- Planning for and operation of "enhanced" LIGO and the corresponding science run at a sensitivity about twice that of initial LIGO in FYs 2009–2011
- Research and development to reduce risk for the AdvLIGO project, to enhance performance post-construction and to enable future enhancements
- Data analysis and other science activities by staff of the LIGO Laboratory
- Education and Outreach activities
- Ramp-up of AdvLIGO commissioning activities

For more information on AdvLIGO, see the MREFC chapter.

Facility Report:

Management and Oversight:

- NSF Structure: NSF oversight is coordinated internally by the LIGO Program Director in the Division of Physics (PHY), who also participates in the PHY AdvLIGO Project Advisory Team, comprising staff from the Office of General Counsel, the Office of Legislative and Public Affairs, the

Office of Budget, Finance and Award Management, including the Deputy Director for Large Facility Projects, and the Office of International Science and Engineering.

- External Structure: 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 Asia, Europe, and Australia. External peer-review committees organized by the NSF help provide oversight through an annual review.

- Reviews:
  - Advanced LIGO Baseline Review, May-June 2006
  - LIGO Annual Review, November 2006
  - Advanced LIGO Baseline Update Review, June 2007
  - LIGO Annual Review and LIGO FY 2009-2013 Operations Proposal Review, November 2007
  - LIGO Annual Review, November 2008
  - Advanced LIGO Annual Review, April 2009

Renewal/Recompetition/Termination:

LIGO began operating under a new five-year cooperative agreement at the beginning of FY 2009. As a condition of approval of this award (and a possible future award), the National Science Board stipulated that the operation of LIGO be recompeted no later than 2018. The projected lifetime of the LIGO facility is 20 years.

Major Research Equipment and Facilities Construction Account 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 Research and Related Activities (R&RA) and Education and Human Resources (EHR) accounts.

For information on projects funded through this account, please see the MREFC chapter in this document.

National High Magnetic Field Laboratory

$31,950,000
+$5,450,000 / 20.6%

National High Magnetic Field Laboratory
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
National High Magnetic Field Laboratory	$27.75	$26.50	$5.00	$31.95	$5.45	20.6%

The National High Magnetic Field Laboratory (NHMFL) is operated by Florida State University (FSU), the University of Florida (UF), and Los Alamos National Laboratory (LANL). The Laboratory develops and operates high magnetic field facilities that scientists and engineers use for research in physics, biology, bioengineering, chemistry, geochemistry, biochemistry, materials science, medicine, and engineering. It is the world's premier high magnetic field laboratory with a comprehensive assortment of high-performing magnet systems. Many of the unique magnet systems were designed, developed, and built by the magnet engineering and design team at the NHMFL in collaboration with industry. The facilities are available to all qualified scientists and engineers through a peer-review proposal process. The additional funding requested in FY 2010 will support magnet development, new instrumentation, planned facility upgrades, and support of in-house high impact research and development.

Total Obligations for NHMFL
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Operations and Maintenance	$27.75	$26.50	$31.95	$34.00	$34.00	$37.50	$38.50	$39.50
ARRA Estimate	-	5.00	-	-	-	-	-	-
Total, NHMFL	$27.75	$31.50	$31.95	$34.00	$34.00	$37.50	$38.50	$39.50

Totals may not add due to rounding.

An increase of $5.45 million in FY 2010 will allow the facility to strengthen user support and in-house research, education, and training. Funding will also help meet operations needs, such as electricity and cryogenics cost increases, critical parts for replacement of aging equipment, completion of the planned split-magnet development, and support of technical staff and education and training efforts.

The principal scientific goals of NHMFL are to provide the highest magnetic fields, state-of-the-art instrumentation, and support services for scientific research conducted by users from a range of science and engineering disciplines. In addition, the lab is an internationally recognized leader in magnet design, development, and construction. The Magnet Science and Technology (MS&T) Division of NHMFL has broad responsibility to develop high field magnets and conducting and superconducting materials for future generation magnet wires in response to national needs. MS&T works with industry and other international magnet laboratories on a variety of technology projects. These include analysis, design, component development and testing, coil fabrication, cryogenics, system integration and testing.

Current magnet development at NHMFL is focusing on design and construction of high field magnets for the Nation's premier neutron and light sources. The lab has collaborated with more than 60 private sector companies, including American Magnetics, Exxon Mobil, and Oxford Instruments, and national laboratories and federal centers, including those supported by the Department of Energy (DOE) such as

the Spallation Neutron Source and the Advanced Photon Source. International collaboration includes magnet development with the Hahn-Meitner Institute in Berlin and the Korea Basic Science Institute.

With its distinguished faculty and world-class facilities, NHMFL provides a unique interdisciplinary learning environment. Its annual K-12 outreach engages over 7,000 students from Florida and Georgia in hands-on activities and tours of the lab. In addition NHMFL conducts a College Outreach-Workforce Initiative Program to increase diversity in lab programs. This has included outreach to approximately 200 undergraduates at Historically Black Colleges and Universities. NHMFL hosts an annual one-day Open House (over 5,000 attendees in 2009) as well as tours (e.g., about 10,000 students per year).

Facility Report

Management and Oversight:

- NSF Structure: NHMFL is supported by the Division of Materials Research (DMR) and Division of Chemistry (CHE) in the Directorate for Mathematical and Physical Sciences (MPS). Primary responsibility for NSF oversight is with the National Facilities Program Director in DMR, with guidance from an ad hoc working group with members from CHE and the Directorates for Engineering and for Biological Sciences. Site visit reviews are conducted annually. Representatives from other federal agencies such as DOE and the National Institutes of Health (NIH) are invited to observe.

- External Structure: NHMFL is operated by a FSU, UF, and LANL consortium under a cooperative agreement. FSU, as the signatory of the agreement, has the responsibility for appropriate administrative and financial oversight and for ensuring that operations of the laboratory are of high quality and consistent with the objectives of the cooperative agreement. The principal investigator serves as the NHMFL director. Fur senior faculty members are co-principal investigators. The NHMFL director receives guidance and recommendations from an External Advisory Committee, the NHMFL Executive Committee, NHMFL staff, participating institutions, and the Users' Committee.

- Reviews: NSF conducts annual reviews using external reviewers, which assess user programs, in-house research, long-term plans to contribute significant research developments both nationally and internationally, and operations, maintenance, and new facility development. Annual reviews also assess the status of education training and outreach, operations and management efficiency, and diversity plans. Recent reviews include:
  - Renewal Review, January 9-11, 2007
  - Annual Review by external panel, December 2008
  - Total Business Systems review planned, Spring 2009
  - Annual Reviews by external panel planned, late 2009, and 2010

Renewal/Recompetition/Termination:

A comprehensive renewal review was conducted in FY 2007. On August 8, 2007 the National Science Board approved NSF's recommendation for a 5-year renewal award not to exceed $162.0 million for FY 2008-2012. This award allows NHMFL to increase its user program, continue development of new magnet systems, and support the strongest aspects of its in-house research efforts. The award ensures that the laboratory will remain the international leader in magnet research operations and development. In FY 2011 NSF will examine options to recompete or renew the award in FY 2012.

National Nanotechnology Infrastructure Network

$17,000,000
+$0.0 / 0.0%

The National Nanotechnology Infrastructure Network
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
The National Nanotechnology Infrastructure Network	$13.83	$17.00	$10.00	$17.00	-	-

The National Nanotechnology Infrastructure Network (NNIN) has been renewed for a final five-year period from FY2009-2013. In the renewal period, NNIN now comprises 14 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.

Total Obligations for NNIN
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Operations and Maintenance	$13.83	$17.00	$17.00	$17.00	$17.00	$17.00	$17.00	$17.00
ARRA Estimate	-	10.00						
Total, NNIN	$13.83	$27.00	$17.00	$17.00	$17.00	$17.00	$17.00	$17.00

Totals may not add due to rounding.

NNIN's broad-based national user facilities enable the Nation's researchers from academia, small and large industry, and government to pursue transformative research, to seek new discoveries and applications in a broad range of domains of nanoscale science and engineering, and to stimulate technological innovation. The network also develops the infrastructure and intellectual and institutional capacity needed to examine and address societal and ethical implications of nanotechnology, including issues of environment, health, and safety.

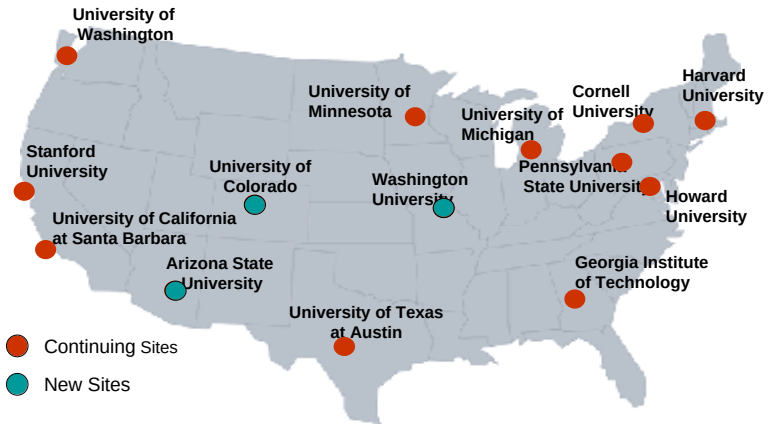
NNIN undertakes on a national scale a broad spectrum of innovative activities in education, human resource development, knowledge transfer, and outreach to the science, engineering, and technological communities. Special emphasis is placed on education and training of a diverse science and engineering workforce that involves non-traditional users and under-represented groups, including women and minorities.

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 shares expertise and perspectives, provides specialized training opportunities, coordinates access to unique instrumentation, and transfers newly developed technologies.

NNIN leverages research strengths of the university to bring them to the external community. The institutions comprising the NNIN have strong underlying internal research programs that provide the

knowledge base for developing new processes, methodologies, and instrumentation, as well as much of the capital infrastructure. NSF and other agencies independently award research grants to principal investigators who use the NNIN facilities to carry out some aspects of their research projects.

During the renewal award period, three new institutions have joined the network, and each brings new capabilities: the University of Colorado, which will focus on research in energy-related problems and in precision sciences, which includes measurements, standards, and systems; Arizona State University, which will focus on organic/inorganic interfaces in electronics, biodesign, implantable devices, flexible electronics, sensors., and outreach to underrepresented communities in the Southwest; and Washington University in St. Louis, a leading medical and public health institution, whose research focus will be on nanomaterials and nanosciences for environment, health, and safety.



NNIN continues to maintain a strong network-wide Research Experience for Undergraduates (REU) program, with a focus on the diversity of its participants. The renewal award provides substantial support for the REU program. NNIN held its first International Winter School for Graduate Students (iWSG) at IIT Kanpur, India in late 2008. It was attended by 12 U.S. graduate students who were competitively selected from across the country and several NNIN faculty members. The program provided an international learning experience in a nascent research area of organic electronics and optoelectronics with strong society and ethics components aimed at exposing U.S. graduate students to nanotechnology issues and research challenges in the context of developing country environments.

In its fifth year of operation, user data collected during the initial ten-month period showed that NNIN served 4,739 unique users, of whom 3,906 were academic users, 758 industrial users, 32 from US State and Federal laboratories, and 34 from foreign institutions. More than 1,600 new users were trained during the ten-month period. Over a period of a year, NNIN has enabled in excess of 1,000 PhD awards, activities of 250 small and large companies, and leveraged over $400 million dollars in research investments through use of its facilities.

Facility Report:

Management and oversight:

- NSF structure: NSF provides oversight of the NNIN under a cooperative agreement. The program officer for the NNIN activity resides in the Division of Electrical, Communications and Cyber Systems (ECCS) in the Directorate for Engineering (ENG). The program officer coordinates NNIN oversight with the NNIN working group comprised of representatives from all NSF research and

education directorates. NNIN is reviewed annually through site reviews held at one of the network sites. These reviews involve an external team of experts selected by NSF staff. In addition to the annual site reviews, semi-annual briefings of NSF staff are held at the NSF attended by the NNIN network director, site directors, and area coordinators.

- External structure: NNIN is managed as a cohesive and flexible network partnership through a Network Executive Committee derived from the individual Site Directors, and the Education/Outreach and Society/Ethics Coordinators. The Network Director, is from the lead institution, Cornell University, and 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 the 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 the NSF. The Site Directors are responsible for local management functions of the individual user facilities, for interfacing with other facilities and with the management team for the overall network, and for connections with the outside communities.

- Reviews:
  - The first comprehensive annual review of the NNIN was held following an initial 9 months of operation at the Georgia Institute of Technology site in December 2004. The second annual review was held at the University of Texas-Austin site in February 2006. The third annual review was held at the University of Michigan site in May 2007. The fourth annual review was held at Stanford University in May 2008. This review also served to evaluate the NNIN renewal proposal for the five-year period FY 2009-2113.
  - Upcoming reviews: A fifth annual review will be held in Spring 2010.

NNIN will be provided $10,000,000 in ARRA funds to acquire advanced nanofabrication and characterization instrumentation and tools at several of its network sites that will enable users to accomplish state-of-the-art research projects. Availability of these funds will address the challenges the network has faced in maintaining its capital equipment base through acquisition of new instrumentation and replacement of old or high-demand equipment.

Renewal/Recompetition/Termination:

Consistent with the program solicitation under which NNIN was competed, the NNIN award could be renewed once, without recompetition, for an additional five years. In early 2008, NNIN submitted a renewal proposal, which was reviewed both by *ad hoc* mail review and by on-site panel review in May 2008. The site review panel report strongly recommended that NSF renew NNIN for an additional five years. The National Science Board approved NSF's recommendation and authorized renewal of the NNIN award for a final five-year period from FY 2009-2013. In the third year of this final award period, NSF plans to convene a panel of recognized national experts to evaluate the needs of, and appropriate future investments in, the national infrastructure for nanotechnology.

National Superconducting Cyclotron Laboratory

$21,000,000
+$500,000 / 2.4%

National Superconducting Cyclotron Laboratory
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
National Superconducting Cyclotron Laboratory	$19.25	$20.50	$2.00	$21.00	$0.50	2.4%

The National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) is a national user facility. With two superconducting cyclotrons, K500 and K1200, it is the leading rare isotope research facility in the U.S. and is among the world leaders in heavy ion nuclear physics and nuclear physics with radioactive beams. Funding for NSCL also supports the MSU research program.

Total Obligations for the NSCL
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Operations & Maintenance	$19.25	$20.50	$21.00	$21.50	$21.50	$21.50	$21.50	$21.50
ARRA Estimate	-	2.00	-	-	-	-	-	-
Total, NSCL	$19.25	$22.50	$21.00	$21.50	$21.50	$21.50	$21.50	$21.50

Totals may not add due to rounding.

The current cooperative agreement expires in FY 2011. Outyear funding estimates are for planning purposes only and do not reflect policy decisions.

NSCL scientists employ a range of tools for conducting advanced research in fundamental nuclear science, nuclear astrophysics, and accelerator physics. 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 K500 was the first cyclotron to use superconducting magnets, and the K1200 is the highest-energy continuous beam accelerator in the world. 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.

Scientists at 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.

NSCL supports and enhances doctorate graduate education and post-doctoral research experiences. About 10 percent of all doctorates granted in nuclear physics in the U.S. are based on research at NSCL. Also, the site provides research experiences for undergraduate students as well as K-12 teacher training.

NSCL occasionally enters into license agreements for cyclotron technology or nuclear electronics. An agreement with Accel Corporation exists for compact cyclotrons based on superconducting technology.

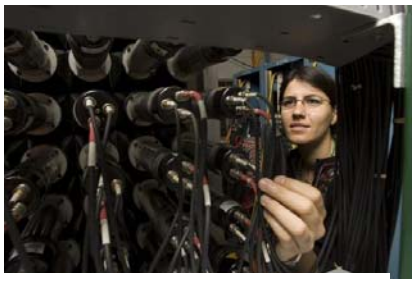
An experimental program using the coupled cyclotron facility is also underway. This effort is determined by beam use proposals. A Program Advisory Committee (external membership) selects the best proposals at a typical success rate of about 50 percent. The science output of NSCL is driven by these experiments – many per year, with most running one to three days. The FY 2010 funding level is part of an overall 5-year plan in response to recommendations from an external operations review committee in 2006. That committee recommended ramping up support (above the 2006 level and beyond a nominal rate of inflation) such that NSCL runs at close to optimal operation, which is defined as the maximum amount of added beam time per extra dollar spent.

Facility Report:

Management and Oversight:

- NSF Structure: MSU operates NSCL under a cooperative agreement with NSF. The laboratory director is the key officer, who has the authority to appoint associate directors and designate responsibilities, notifying NSF of changes. NSF oversight is provided through annual site visits by the cognizant program officer of the Physics Division and other staff, accompanied by external experts.

- External Structure: NSCL is managed by the laboratory director and four associate directors for research, education, operations, and new initiatives. NSCL's research program is guided by a Program Advisory Committee of external experts as well as an in-house experts, 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. About 5,000 beam hours are provided for experiments each year, with a backlog of at least a year.



A NSCL research associate adjusts cabling on a detector. *Credit: NSCL.*

- Reviews:
  - Latest Review: An annual review in FY 2008 covered results and achievements related to intellectual merit and broader impacts.
  - Next Review: Annual reviews are planned for FY 2009 and each year thereafter. Review topics include science and operations, with emphasis (and choice of external experts) to be determined.

Renewal/Recompetition/Termination:

NSCL is funded through a cooperative agreement that was renewed in FY 2007 and will expire in FY 2011. NSF anticipates that MSU will submit a renewal proposal in FY 2011. NSF will decide at that time whether to recompete the award, or whether to proceed with merit review of the proposal. Funding for FY 2012 and beyond will be determined by the outcome of that process.

Network for Earthquake Engineering Simulation

$22,000,000
+$18,000 / 0.8%

Network for Earthquake Engineering Simulation
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
Network for Earthquake Engineering Simulation	$19.38	$21.82	-	$22.00	$0.18	0.8%

NEES is a national, networked simulation resource of advanced, geographically distributed, shared use earthquake engineering research experimental facilities with telepresence 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 U.S., 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 a five-year cooperative agreement with NSF (FY 2005–FY 2009), NEESinc operates the NEES experimental facilities and the NEES cyberinfrastructure center; coordinates education, outreach, and training; and develops national and international partnerships. During FY 2008–FY 2009, NSF is recompeting NEES operations for a second five-year period.

Total Obligations for NEES
(Dollars in Millions)

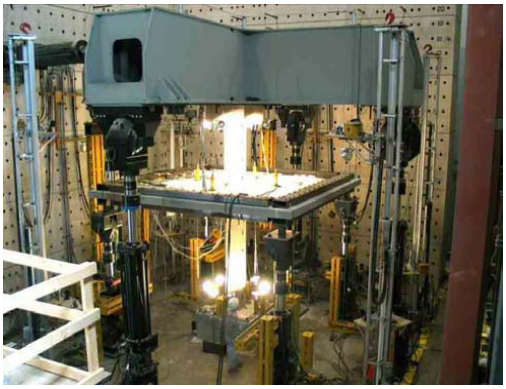
	FY 2008 Actual	FY 2009 Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Operations and Maintenance	$19.38	$21.82	$22.00	$22.00	$22.00	$22.00	$22.50	$22.50

NEES' 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 and tsunamis. This enables the design of new methodologies, modeling techniques, and technologies for earthquake and tsunami hazard mitigation. NEES engages 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 through its Research Experiences for Undergraduates (REU) program. NEESinc also organizes the NEES Annual Meeting for NEES users/researchers and facility operators.

Through the National Earthquake Hazards Reduction Program (NEHRP), the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), the U.S. Geological Survey (USGS), and the NSF support research related to earthquake hazard mitigation. 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 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 a Memorandum of Understanding (MOU), and in September 2005, NSF and the Japanese Ministry of Education, Culture, Sports, Science, and Technology signed a Memorandum Concerning Cooperation in the Area of Disaster Prevention Research. A planning meeting was held at NSF in January 2009 to explore research topics for a second five years of NEES/E-Defense collaboration.

Along with direct operations and maintenance support for NEES, NSF separately provides support for research to be conducted at the NEES experimental facilities through ongoing research and education programs. The NEES cyberinfrastructure also provides a platform for the earthquake engineering and tsunami communities, as well as other communities, to develop new tools for shared cyberinfrastructure. The annual support for such activities, funded through annual NEES research program solicitations, is estimated to be up to $12.0 million in FY 2009 and $12.50 million in FY 2010. These awards 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.



Slab-column subassembly being tested as part of a NSF-supported NEES research award at the NEES Multi-Axial Subassemblage Testing (MAST) Laboratory at the University of Minnesota. *Courtesy of the MAST Laboratory at the University of Minnesota.*

Facility Report:

Management and oversight:

- NSF structure: NSF provides oversight to NEES operations through a cooperative agreement with NEESinc during FY 2005-FY 2009. NEES operations are reviewed through annual site visits and through periodic site visits to the individual NEES equipment sites. The NSF Program Manager for NEES is located in the Division of Civil, Mechanical and Manufacturing Innovation (CMMI). The Deputy Director for Large Facility Projects in the Office of Budget, Finance and Award Management (BFA) provides advice and assistance.

- External structure: NEESinc, located in Davis, CA, operates the NEES 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 led by a Chief Executive Officer. Each of the experimental facilities 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 telepresence, data, collaborative, simulation, and other related services for the entire NEES network.

- Reviews:
  - Management reviews: NSF BFA Business Systems Review - May 2006
  - Mid-award operations reviews: NSF Annual Merit Reviews - June 2005, April 2006, July 2007
  - Experimental facility reviews: NSF Periodic Merit Reviews - FY 2006 - FY 2008

Renewal/Recompetition/Termination:

NEESinc currently operates under a five-year cooperative agreement during FY 2005 – FY 2009, with annual funding based upon satisfactory progress and availability of funding. In FY 2008, NSF made the decision to recompete NEES operations for a second five-year period from FY 2010 – FY 2014. During FY 2010, the incumbent awardee (NEESinc) will be supported by NSF to provide continuity of operations, help transition software, documents, and other inventory to the new awardee and to complete award close-out. In FY 2010, NSF will fund an assessment of the NEES experimental facilities and cyberinfrastructure and multi-hazard experimental facilities available worldwide. This assessment is expected to be completed by early FY 2012 and will form the basis for determination by NSF of whether to renew the cooperative agreement for an additional period, recompete NEES operations, or terminate NEES operations at the end of FY 2014.

Polar Facilities And Logistics **$374,350,000**
and the South Pole Station Modernization Project **+$32,170,000 / 9.4%**

Polar Facilities and Logistics
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
Polar Facilities	$217.73	$233.35	$15.50	$260.08	$26.73	11.5%
Polar Logistics	111.21	108.83	7.00	114.27	5.44	5.0%
Total, Polar Facilities and Logistics	$328.94	$342.18	$22.50	$374.35	$32.17	9.4%

Totals may not add due to rounding.

Polar Facilities:

The Office of Polar Programs (OPP) within NSF provides the infrastructure needed to support 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/OPP, including transportation, facilities, communications, utilities (water and power), and health and safety infrastructure. NSF management of the U.S. Antarctic Program (USAP) also provides environmental stewardship and maintains the U.S. presence in Antarctica in accordance with U.S. policy.

Total Obligations for Polar Facilities
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Antarctic Infrastructure & Logistics	$166.84	$179.35	$15.50	$206.08	$209.58	$213.78	$218.26	$222.85	$227.53
South Pole Station Modernization Project	*15.38*	*15.76*	-	*15.93*	*16.20*	*16.53*	*16.88*	*17.23*	*17.59*
U.S. Coast Guard Icebreaker Support	50.89	54.00	-	54.00	54.00	54.00	54.00	54.00	54.00
Total, Polar Facilities	$217.73	$233.35	$15.50	$260.08	$263.58	$267.78	$272.26	$276.85	$281.53

Totals may not add due to rounding.

NOTE: Funding for the South Pole Station Modernization (SPSM) Project in this table is for the operation of the South Pole Station and is included in the amounts shown for Antarctic Infrastructure and Logistics.

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

Facility Report:

Management and Oversight:

- NSF Structure: OPP has overall management responsibility for Operations and Science Support. From FY 2006 through 2008, NSF also funded the operation and maintenance of the U.S. Coast Guard's (USCG) three polar icebreakers, the *Polar Star*, the *Healy*, and the *Polar Sea*. Beginning in FY 2009, it was decided that NSF would fund operation and maintenance for only the *Polar Sea* and the *Healy* because NSF does not envision current or future use of the *Polar Star* in support of its mission. 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 by 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.

- External Structure: The current Antarctic support contract was recompeted and awarded to Raytheon Polar Services Company (RPSC) in FY 2000. There are many separate subcontractors for supplies and technical services.

- Reviews: 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). In addition, OPP's performance is reviewed externally by Committees of Visitors and the OPP Advisory Committee (OPP AC).

Helicopters provide support to field parties in the McMurdo Dry Valleys in southern Victoria Land and at remote field camps. *Credit: Kristan Hutchison, RPSC.*

Current Status:

- All facilities (stations, research vessels, and field camps) are currently operating normally. The relatively poor condition of the USCG polar icebreaker *Polar Sea*, due to its age and the uncertainty regarding its future availability, prompted OPP and the OPP AC to identify and study options for reducing demands on the ship-based logistics system. OPP is implementing several projects as contingencies against a possible failure of that system.

Evolution:

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. However, the research emphases at the three stations changes as the scientific forefronts addressed there evolve with time, as does the infrastructure needed to support it.

Recompetition:

NSF is currently engaged in an effort to recompete the Antarctic support contract. The most recent Antarctic support contract was recompeted and awarded to Raytheon Polar Services Company (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 option period. NSF exercised its option to extend the performance period through March 31, 2010. An award for the new support contract is expected to be made in FY 2010.

Polar Logistics:

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

Total Obligations for Polar Logistics
(Dollars in Millions)

		FY 2009	FY 2009						
	FY 2008	Current	ARRA	FY 2010	**ESTIMATES**				
	Actual	Plan	Estimate	Request	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
U.S. Antarctic Logistical Support	$67.63	$67.52	-	$67.52	$67.52	$67.52	$67.52	$67.52	$67.52
Research Support and Logistics	43.59	41.31	7.00	46.75	47.54	48.50	49.51	50.55	51.62
Total, Polar Logistics	$111.21	$108.83	$7.00	$114.27	$115.06	$116.02	$117.03	$118.07	$119.14

Totals may not add due to rounding.

The U.S. Antarctic Logistical Support 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 ground 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 CH2M HILL (previously, 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 the possibility of three one-year extensions exercised 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.

Facility Report:

Management and Oversight:

- NSF Structure: OPP has overall management responsibility for U.S. Antarctic Logistical Support and Arctic Research Support & Logistics. DoD operates as a primary logistical support provider on a cost-reimbursable basis. The agencies cooperate under a Memorandum of Agreement that includes guidance for planning and scheduling and sets forth the terms and conditions for reimbursement to DoD by NSF.

- External Structure: There are many separate subcontractors for supplies and technical services.

- Reviews: OPP's performance is externally reviewed by Committees of Visitors and the OPP AC.

Current Status:

- All facilities (stations, research vessels, and field camps) are currently operating as normal.

Renewal/Recompetition/Termination:

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. However, as discussed above, the research emphases at the three stations and at Arctic research sites changes as the scientific forefronts addressed there evolve with time, as does the logistics support for these activities. Support contracts are recompeted as noted earlier.

South Pole Station Modernization (SPSM)

The SPSM project was funded through the MREFC Account and supported the procurement, construction, and commissioning. SPSM provides a new station to replace the previous U.S. station at the South Pole, built 30 years ago and inadequate in terms of capacity, efficiency, and safety. The new station is an elevated complex with two connected buildings, supporting 150 people in the summer and 50 people in the winter. The completed South Pole Station will provide a platform for the conduct of science at the South Pole and fulfills NSF's mandate to maintain a continuous U.S. presence at the South Pole in accordance with U.S. policy. FY 2008 represented the final year of appropriations for SPSM; no funds are requested in FY 2010. Construction continues through FY 2010.

The prime contractor for the U.S. Antarctic Program is responsible for constructing the South Pole Station. In addition, there are approximately 385 separate subcontractors for supplies and technical services.

NSF will also support education associated with the research projects at the South Pole. Along with direct operations and maintenance support for South Pole Station, NSF will support science and engineering research through ongoing programs. The annual support for such activities is currently estimated to be approximately $9.50 million.

Total Obligations for SPSM
(Dollars in Millions)

	Prior Years	FY 2008 Actual	FY 2009 Current Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
R&RA Obligations									
Concept & Development	$16.40								
Management & Operations		15.38	15.76	15.93	16.20	16.53	16.88	17.23	17.59
Subtotal, R&RA Obligations	$16.40	$15.38	$15.76	$15.93	$16.20	$16.53	$16.88	$17.23	$17.59
MREFC Obligations									
Implementation	139.66	7.57	2.06	-					
Subtotal, MREFC Obligations	$139.66	$7.57	$2.06	-	-	-	-	-	-
Total, SPSM Obligations	**$156.06**	**$22.95**	**$17.82**	**$15.93**	**$16.20**	**$16.53**	**$16.88**	**$17.23**	**$17.59**

Totals may not add due to rounding.

NOTE: Funding for the operation of South Pole Station is provided through Antarctic Infrastructure and Logistics.

Project Report:

Management and Oversight:

- NSF Structure: OPP has the overall oversight responsibility for SPSM, including development of the basic requirements, design, procurement, and construction. The project status, including cost expenditures and cost projections, is monitored closely by the OPP Facilities Engineer and other OPP staff, and on a periodic basis by the project's Project Advisory Team, a group of experts drawn from all relevant NSF Directorates and Offices.

- External Structure: NSF has contracted for procurement and construction management for all phases of the project, including design reviews of all drawings and specifications; conformance of the designs and procurements with established standardization criteria; assistance in establishing functional interfaces; transition from the existing to the new facilities; and systems integration. Naval Facilities Engineering Command, Pacific Division (PACDIV) selects, monitors, and manages architectural and engineering firms for design, post-construction services, and construction inspection for the project.

- Reviews: Design, development, planning, and closely related activities in support of this project included preparation of more than 40 engineering studies and reports. The documents ranged widely in subject matter including subjects such as snowdrift minimization modeling, detailed analysis of power and heating requirements, preparation of a draft Environmental Impact Statement, energy conservation measures, efficiency and maintainability of diesel generators, fuel storage support system evaluation, design code criteria matrix, concept for signal/communication systems, gray-water system evaluation, minimization of ventilation requirements, control of diesel engine exhaust emissions, and jacking plan and concept.

  The OPP Facilities Engineer, other OPP and NSF staff, and subject matter experts attend quarterly reviews at the contractor's facility for the purpose of reviewing all aspects of the project including cost, schedule, and plans. In September 2006, an external panel of experts reviewed the scope, cost, schedule, and effectiveness of management processes to complete the final 10 percent of the project.

As a result, the project's baseline was increased to $149.29 million. A review of the cost and schedule for the final year of the project is planned for early FY 2010.

Current Project Status:

- Tasking Completed in FY 2009:
  - Conditional Occupancy of the Logistics Facility and the Aircraft Fueling Module, the last major technical milestones

Cost and Schedule:

SPSM scope is nearly 95 percent complete, with the elevated station and all science facilities in full use. Project cost performance index (CPI) and schedule performance index (SPI) are presently ranked green, indicating variances are within 10 percent, and current forecasts show the project completing on schedule. The project is just over budget and behind schedule, with a cost performance index of 98.18 percent and a schedule performance index of 98.63 percent as of February 2009 financial data. Available contingency is approximately 2 percent of remaining costs

- Tasking Scheduled/Completed for FY 2009:
  - Conditional Occupancy of Logistics/Warehousing Facility
  - Completion of Siding Pod A
  - Begin Dome Demolition
  - Aircraft Fueling Module

- Tasking Scheduled for FY 2010:
  - Complete Dome Demolition
  - Retrograde Demolition Materials
  - Install Logistics Facility Racks
  - Complete Siding of the Elevated Station
  - Complete Punch List Items

Risks:

Project performance could be affected if a full construction crew cannot be maintained for the remaining scope. Additional high impact risk elements to project completion include equipment failure, damaged materials, unforeseen downtime from power failures, inclement weather, and widespread illness – all of which have occurred to varying degrees. Risk management is ongoing and has produced multiple sets of back-up strategies to employ in the face of identified concerns.

Future Operations Costs:

Operational costs of the modernized station are expected to be higher than operational costs of the previous station due to increased station size and increases in science support and information systems. A steady state of operational support is anticipated at $15.0 million, excluding inflation. The expected lifetime of the modernized station is 25 years, through FY 2031.

FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTERS

National Astronomy and Ionosphere Center — $11,400,000
-$200,000 / -1.7%

National Astronomy and Ionosphere Center
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
National Astronomy and Ionosphere Center	$12.75	$11.60	$3.10	$11.40	-$0.20	-1.7%

The National Astronomy and Ionosphere Center (NAIC) is a national research center focusing on radio and radar astronomy and atmospheric sciences. The center's principal observing facility is the world's largest single-dish radio/radar telescope, a 305-meter diameter reflector in western Puerto Rico. Located near the town of Arecibo on 120 acres of U.S. Government-owned land, the facility is known as Arecibo Observatory. NAIC is Federally Funded Research and Development Center (FFRDC), operated and managed by Cornell University under a cooperative agreement with NSF. NAIC provides telescope users with a wide range of research and observing instrumentation and serves over 250 users annually.

NAIC has a staff of about 120 positions, including those who support the Angel Ramos Visitor Center and Learning Center. A permanent staff of 17 scientists and 36 engineers/technicians are available to help visiting investigators with their observation programs. The remainder includes 25 administrative and clerical positions, 37 maintenance staff, and several postdoctoral scholars and graduate students.

Total Obligations for NAIC
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Operations and Maintenance	$12.75	$11.60	$11.40	$7.00	$7.42	$7.87	$8.34	$8.84
Astronomical Sciences (MPS)	*10.72*	*9.60*	*8.40*	*4.00*	*4.24*	*4.49*	*4.76*	*5.05*
Atmospheric & Geospace Sciences (GEO)	*2.02*	*2.00*	*3.00*	*3.00*	*3.18*	*3.37*	*3.57*	*3.79*
ARRA Estimate (MPS)	-	3.10	-	-	-	-	-	-
Total, NAIC	$12.75	$14.70	$11.40	$7.00	$7.42	$7.87	$8.34	$8.84

Totals may not add due to rounding.

NOTE: The Division of Astronomical Sciences (AST) Senior Review recommended that sufficient external financial or personnel contributions be found to operate NAIC with competitive scientific productivity after 2011 with an AST contribution not to exceed half of the expected costs, estimated at $8.0 million in FY 2006. FY 2011-2015 amounts are extrapolations based on current levels only. The program solicitation for management and operation of NAIC will identify five-year budget guidance at a significantly reduced level relative to current operations. AST support for FY 2011–2015 will be based upon the Senior Review recommendation, guidance from a third-party cost review of AST facilities, and a third-party estimate of NAIC's non-scientific costs.

NAIC is jointly supported by the Division of Astronomical Sciences (AST) in the Directorate for Mathematical and Physical Sciences (MPS) and the Division of Atmospheric and Geospace Sciences (AGS) in the Directorate for Geosciences (GEO). AGS funds currently support incremental science programs in Space and Atmospheric Sciences. The AST Senior Review recommended an emphasis on observations in support of large astronomical surveys and a reduction in AST funding to $8.0 million (FY 2006 dollars) for NAIC by 2010. In response, the managing organization, Cornell University, has

modified the operating mode for astronomy observations and limited the observing time for astronomy projects. These changes also resulted in a reduction in force of 30 FTEs in FY 2007. In addition, availability of the S-band planetary radar system was reduced in FY 2008. The FY 2010 Budget Request reflects the planned ramp down to meet Senior Review recommendations.

Partnerships and Other Funding Sources: NAIC leverages NSF support with funding from other federal and non-federal sources. In FY 2008, NAIC received $942,000 from other federal agencies such as the Defense University Research Instrumentation program at the Air Force Office of Scientific Research (AFOSR/DURIP) and the Office of Naval Research (ONR), and approximately $100,000 from the Joint Institute for Very Long Baseline Interferometry (VLBI) in Europe and other non-federal and private sources. Cornell has also contracted for $2.35 million with the Puerto Rico Department of Education to provide student enhancement and teacher professional development programs at Arecibo through the site's Angel Ramos Foundation Visitor and Learning Center.

A peer-review telescope allocation committee provides merit-based telescope time but no financial support. NSF does not provide awards targeted specifically for use of Arecibo. Many users are supported through NSF or NASA grants to pursue scientific programs that require use of NAIC.

An image of the Arecibo Radio Telescope in Puerto Rico. The gregorian dome, which houses the main suite of research instruments, and its suspension structure are visible over the main reflector below. *Credit: Arecibo Observatory/NSF.*

Education and Public Outreach: NAIC's primary education goal is to support and enhance the experiences of student researchers. Arecibo hosts a Research Experiences for Undergraduates (REU) site, and Ph.D. students receive training through use of the facility. In collaboration with the National Radio Astronomy Observatory, NAIC holds a summer school on single-dish radio astronomy techniques. NAIC also sponsors a major outreach program in Puerto Rico via the modern Visitor Center and Learning Center, as well as summer workshops for K-12 teachers. The Visitor Center attracts roughly 100,000 visitors each year, and with new funds from the Puerto Rico Department of Education, NAIC will host up to 50,000 school children each year for science enrichment programs. Continued operation and enhancement of these programs are anticipated to generate additional revenue that may contribute to Observatory operations.

Operations and Maintenance, $11.40 million ($200,000 below the FY 2009 Current Plan level of $11.60 million): NAIC administers observing time to the astronomy and aeronomy communities via competitive observing proposals and conducts educational and public outreach programs at all levels. Observing hours among science programs are based on the quality of observing proposals; the current average oversubscription rate of the telescope is approximately three to four. This metric accounts for the number of current astronomical surveys requesting time for a given area of sky, plus the time request in the Program Year for small radio astronomy projects, solar system observations, and atmospheric sciences programs.

- Division of Astronomical Sciences, $8.40 million ($1.20 million below the FY 2009 Current Plan level of $9.60 million): AST funds basic operations costs and science programs in passive radio astronomy and solar system radar astronomy. Radio astronomers and planetary scientists use the

Arecibo facility to study diverse areas such as interstellar gas, galactic structure formation and evolution, pulsars and fundamental physics, the dynamic variations in Earth's ionosphere, and topics in solar system astronomy, such as the physical properties of asteroids, planetary surfaces and moons and the post-discovery characterization and orbital refinement of near-Earth asteroids. Funding for the Astronomy program decreases by $1.20 million from FY 2009 to FY 2010 following the recommendations of the AST senior review.

- Starting in 2006 approximately 80 percent of the astronomy observing time was dedicated to three large survey programs that use the Arecibo L-band Feed Array (ALFA) receiver that was commissioned in 2005–2006. About 75 percent of astronomy users conduct their observing programs remotely via networked control software, while radar observations typically employ on-site users.

- Division of Atmospheric and Geospace Sciences, $3.0 million (+$1.0 million over FY 2009 Current Plan level of $2.0 million): AGS primarily funds a research staff in the Space and Atmospheric Sciences program and has historically contributed only incrementally for basic operations costs. As AST has ramped down support for NAIC in response to the Senior Review, AGS has provided modest increases that may be directed towards basic operations. Funding for the Space and Atmospheric Sciences program increases by $1.0 million from FY 2009 to FY 2010.

Facility Report:

Management and Oversight:

- NSF Structure: Ongoing oversight is by an assigned NSF program director in AST and in consultation with community representatives. The program director makes use of detailed annual program plans, long range plans, quarterly technical and financial reports, and annual reports submitted to NSF by Cornell as well as attending Cornell governance committee meetings. To address issues as they arise, AST program managers work closely with other offices at NSF, particularly the Division of Acquisition and Cooperative Support, the Office of General Counsel, and the Large Facilities Project Office. The NSF Program Officer conducts site periodic visits.

- External Structure: Management is via a cooperative agreement with Cornell University. Cornell provides management and oversight through its own advisory and visiting committees. The NAIC Director is resident at Cornell and reports to the Vice Provost for Research in Physical Sciences and Engineering. The Arecibo Observatory Site Director reports to the NAIC Director.

- Reviews: Management reviews by external review panels are held midway into each 5-year cooperative agreement. The last management review was held in March 2007; a follow up assessment of Cornell's response to the Astronomy Senior Review recommendations was completed in March 2008. NAIC underwent a NSF Business Systems Review in FY 2005. In addition, in response to recommendations from the Senior Review, AST conducted a review of administrative and operational costs at all its facilities.

Renewal/Recompetition/Termination:

The current cooperative agreement with Cornell for the management of Arecibo is in effect through March 31, 2010. Consistent with NSB policy, NSF will solicit proposals for a new, five-year cooperative agreement for the management and operation of NAIC through a competitive process. The program solicitation is under development with publication anticipated in 2009.

The Astronomy Senior Review report recommended that sufficient external financial or personnel contributions be found to operate NAIC with competitive scientific productivity after 2011 with an AST contribution not to exceed half of the expected function costs. In response, AGS plans to increase support post-2010 to $3.0 million, including a $1.50 million contribution to basic operations.

The program solicitation for the management and operation of NAIC will identify five-year budget guidance at a significantly reduced level relative to current operations. AST support for FY 2011–2015 will be based upon the Senior Review recommendations, guidance from a third-party cost review of AST facilities, and a third-party estimate of NAIC's nonscientific function costs. Potential managing organizations will be encouraged to consider novel models of operations and governance, revisions to programmatic scope, and/or sources of additional funding that would sustain NAIC as a competitive scientific and educational facility that is responsive to its stakeholders in the scientific community and the Commonwealth of Puerto Rico.

National Center For Atmospheric Research

$100,000,000
-$6,920,000 / -6.5%

National Center for Atmospheric Research
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
National Center for Atmospheric Research	$89.07	$106.92	$13.20	$100.00	-$6.92	-6.5%

The National Center for Atmospheric Research (NCAR) 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. NCAR is managed under a cooperative agreement with NSF by the University Corporation for Atmospheric Research (UCAR), a university-governed and university-serving organization comprising 73 Ph.D. granting academic institutions.

The Mesa Laboratory, designed by architect I. M. Pei, in Boulder, CO. *Credit: NCAR*

As of January 2009, there are a total of 756 FTEs in NCAR of which 357 are funded under the NSF primary award to UCAR.

Number of FTEs Supported at NCAR

FTEs	Primary Award[1]	All Funding
Career Scientists	98	130
Scientific Support[2]	233	507
Other Staff[3]	26	119
Total	357	756

[1]The primary award supports substantial facility infrastructure that does not include staff costs.

[2]Scientific Support includes Associate Scientists, Project Scientists, Post Docs, Software Engineers, Engineers, System Support and Technicians.

[3]Other Staff includes Administrative positions, Managers, Paid Visitors, Pilots and Mechanics.

NCAR provides facilities to university, NCAR, and other atmospheric researchers including world-class supercomputing services, research aircraft, airborne and portable ground-based radar systems, atmospheric sounding, and other surface sensing systems for atmospheric research. In addition, NCAR operates several facilities 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.

Total Obligations for NCAR
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Aircraft Support[1]	$7.58	$9.30	$10.70	$9.30	$9.77	$10.25	$10.77	$11.30	$11.87
Computational Infrastructure[2]	18.61	25.00	2.50	22.00	23.10	24.26	25.47	26.74	28.08
Other Facility Support	23.02	27.62	-	25.70	26.99	28.33	29.75	31.24	32.80
Research & Education Support	39.86	45.00	-	43.00	45.15	47.41	49.78	52.27	54.88
Total, NCAR	$89.07	$106.92	$13.20	$100.00	$105.00	$110.25	$115.76	$121.55	$127.63

Totals may not add due to rounding.

[1]Includes about $150,000 for scientific research in areas such as biogeosciences and aerosols.

[2]Does not contain research funds

Partnerships and Other Funding Sources: NCAR leverages NSF support with funding provided by other federal agencies and non-federal sources. In FY 2008, NCAR received approximately $40.0 million in support from other federal agencies such as the National Oceanographic and Atmospheric Administration (NOAA) and the Office of Naval Research (ONR), and $23.0 million from non-federal sources.

Major Investments in FY 2010: In FY 2010, investments at NCAR will focus on issues of societal importance in the areas of atmospheric chemistry, climate, including climate models, cloud physics and storms weather models, weather hazards to aviation, and interactions between the sun and earth. In all of these areas, NCAR scientists will work with their university colleagues to look closely at the role of humans in both creating climate change and responding to severe weather occurrences. Example investments are an increased emphasis on preparing input for the next Intergovernmental Panel on Climate Change (IPCC) assessment and research into significantly enhancing our ability to understand and predict changes in hurricane intensity. In addition, UCAR will continue to invest NSF funds to refurbish NSF-owned infrastructure such as replacing the underground power cable to the laboratory, which is forty years old, and beyond its designed life expectancy.

Aircraft Support: NCAR operates a C-130 and a Gulfstream V (also know as the High Altitude Instrumented Airborne Platform for Experimental Research, or HIAPER), both of which are highly modified to enable the support of complex research measurements. The two aircraft will support several community-originated projects deemed by peer review to be of exceptional scientific merit. In 2010, aircraft support totals $9.30 million.

Scheduled projects in FY 2009:

- The continuation of a project investigating shorter-range dynamics and forecast problems over eastern Asia and the western North Pacific to better understand medium range dynamics and forecast problems of regions downstream (e.g., North America). This is a multi-aircraft experiment conducted primarily in late FY 2008 and continuing into FY 2009 and located in Hawaii, Guam, and Japan.
- The VOCALS Research Experiment, which seeks to understand the physical and chemical processes central to the climate of the Southeast Pacific, including the interactions of clouds, aerosols, marine boundary layer and upper ocean dynamics. This experiment is primarily located in Chile and includes aircraft from several countries and US agencies. Logistical support for the experiment totaled $1.91 million, which includes $1.54 million for C-130 support and operation costs.

- The HIAPER Pole to Pole Observations (HIPPO) experiment, which measures cross sections of atmospherics concentrations of carbon cycle and greenhouse gases from the north to the south polar areas four different times over a two year period. This experiment provides a comprehensive global survey of atmospheric trace gases covering the full troposphere in all seasons and multiple years. Location: It is primarily located in Colorado, Alaska, Hawaii, American Samoa, New Zealand, Tahiti, Easter Island, and Costa Rica, and totals $2.96 million to support all HIAPER-related costs.
- The Profiling of Winter Storms (PLOWS) Main Study total $2.22 million, which includes $1.55 million for the C-130. PLOWS is an experiment to learn more about the profile of storms in the central U.S.
- A study of Airborne Detector for Energetic Lightning Emissions (ADELE). Specific costs associated with deployment of the G-V are approximately $359,000.
- An examination of the Sprite Spectra. Specific costs for deployment of the G-V are approximately $393,000.

Projects scheduled or under consideration for FY 2010:

- The PRE-Depression Investigation of Cloud-systems in the Tropics (PREDICT) is a scheduled field experiment designed to improve our understanding of the dynamics of tropical cyclone formation and to dramatically improve the spatial and temporal sampling of tropical disturbances prior to, and during, genesis. The project will be located in St. Croix and totals about $3.0 million, including $1.76 million to support costs associated with HIAPER. Aircraft from other agencies will also be utilized.
- The HIAPER Equipment Flight Test for FY 2009 (HEFT-09) is a scheduled experiment to test the performance of new research instruments on the G-V aircraft, totaling $250,000.
- The Global Climate Change and Antarctic Peninsula (GLIMPSE) project is a proposed experiment to examine in detail the atmospheric response to external forcing in the Weddell Sea sector of Antarctica. The Antarctic peninsula is a barrier to stable air flow from both the east and west and is an effective climatic divide between the Weddell Seas on the east and the Bellingshausen Sea to the west. The proposed cost of the project is $2.37 million, which includes $1.94 million for G-V support costs; however, the project has not yet been approved.

Computational Infrastructure: NCAR's computational facility is recognized as world-class. The latest addition to the facility, BlueFire, installed in November 2008, was ranked as the 43rd most powerful computer in the world by the top 500 Supercomputer Centers project.

Computational Infrastructure by Subcategory, FY 2010
(Dollars in Millions)

Operations Staff and Staff Related Costs	$13.54
IT and Facility Infrastructure, Utilities, Data Analysis, Mass Storage Equipment	4.46
Supercomputing Capital Equipment	4.00
Total	$22.00

BlueFire supports the Community Climate Simulation Model (CCSM) which uses mathematical formulas to recreate the chemical and physical processes that drive Earth's climate, and was used by the Intergovernmental Panel on Climate Change (IPCC) to forecast future climate under a number of scenarios.

In FY 2010, planning efforts will continue for a new computational facility. These activities received $2.5 million in ARRA funding in FY 2009. This activity is currently in the development phase and the total preliminary project cost is currently estimated between $60 million and $62 million. For this effort, NCAR is working with the University of Wyoming and other partners in the state. The Wyoming partners are providing the land, $20 million for the construction of the facility, and will also contribute $1 million annually for maintenance. The building and computational resources would be available to the community in 2012 according to a preliminary proposal. This 3-year effort would provide the physical infrastructure needed to expand NCAR's computational capability. Planning activities currently underway include a project development plan, an architectural and engineering study, an environmental assessment study, and a thorough external review of the proposed enhancement to NCAR facilities.

Other Facility Support: In addition to the C-130 and G-V, NCAR also provides support for a number of other atmospheric observing platforms through its Earth Observing Laboratory (EOL), including mobile Doppler radars, upper atmosphere observing capabilities, and other experimental systems. These facilities are used by both NCAR and community researchers to undertake cutting edge research projects. Funding for other facilities at NCAR totals $25.70 million in FY 2010.

Other Facility Support by Subcategory, FY 2010
(Dollars in Millions)

Observing Platforms and Technology	
EOL Infrastructure (including Equipment)	$2.77
Field Proj. and Data Management	0.94
Design and Fabrication Services	1.19
CDS Systems Infrastructure	1.88
Dropsonde/Driftsonde	1.16
SPOL	2.03
Technology Developments	1.02
ISFS	1.22
ELDORA	0.68
ISS/GAUS	1.14
Subtotal, Observing Platforms and Technology	$14.03
Community Models	
Community Climate System Model	$7.28
Weather Research and Forecasting model	1.60
Whole Atmosphere Community Climate Model	0.60
Subtotal, Community Models	$9.48
Other Infrastructure	
Upper atmospheric observing facilities	$1.39
Chemistry instrumentation (ACD)	0.80
Subtotal, Other Infrastructure	$2.19
Grand Total, Other Facility Support	**$25.70**

Totals may not add due to rounding.

Research and Education Support: Funding for research and education support at NCAR totals $43.0 million in FY 2010. 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.

Management at NCAR uses the NSF merit review criteria to allocate resources within NCAR. These allocations are subject to review and approval by the Division of Atmospheric and Geospace Sciences.

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. Further, 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. This research is preformed in the Research Application Laboratory and currently receives $1.40 million in support.

Educational activities at NCAR are recognized as outstanding in their field, in particular the SOARS (Significant Opportunities in Atmospheric Research and Science) program is an undergraduate-to-graduate bridge program designed to broaden participation in the atmospheric and related sciences, which integrates research, education, and mentoring into an effective program.

In addition, NCAR further supports the scientific community by providing fellowships, internships, workshops, and colloquia for students and visiting scientists, and 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 decision makers. 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. Total support for Educational and Outreach is $2.80 million which includes the Advanced Study Program.

Facility Report:

Management and Oversight:

- NSF Structure: 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 the University Corporation for Atmospheric Research (UCAR) for NCAR's management. The present Cooperative Agreement between UCAR and NSF encourages interactions between NCAR scientists and ATM staff and ensures close coordination between ATM and UCAR management. There are specific activities under the agreement that delineate requirements necessary for ATM's oversight of the NCAR program and UCAR management activities that affect NCAR. These include a requirement that UCAR submit an annual program plan for ATM approval that provides details on how resources will be used in that fiscal year. In addition, NCAR summarizes its

past year's accomplishments in an annual scientific report. Annual strategic planning sessions between ATM, UCAR and NCAR are held to ensure that scientific and facility priorities remain consistent with those of NSF. Previous COV reports offered positive and constructive comments on NSF's oversight of UCAR/NCAR. Nearly all the recommendations of the previous COV have been addressed. A COV of the oversight section for UCAR/NCAR will take place in 2009.

- External Structure: UCAR works in partnership with NSF, and the university community to ensure the effective implementation of the strategic mission of NCAR to the benefit of the research community. In addition, other research sponsors such as NASA, NOAA, DOE, DOD, EPA, and the FAA support research collaboration wherever it enhances NCAR's basic NSF-supported research goals or facilities missions

- Reviews:
  - Management review: March, 2006.
  - Complete science and management review leading to the 2008 award to UCAR
  - Approximately mid-way through the current award comprehensive reviews of science, facilities, and management will be conducted.

Renewal/Recompetition/Termination Issues:

In May 2008, UCAR competed successfully for the management and operation of NCAR. The term of the award is for a period of 60 months allowing for an additional 60 months after appropriate and successful review.

National Optical Astronomy Observatory and National Solar Observatory

$41,600,000
+$2,020,000 / 5.1%

National Optical Astronomy Observatory and National Solar Observatory
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
National Optical Astronomy Observatory[1]	$28.60	$29.58	$5.60	$32.50	$2.92	9.9%
National Solar Observatory[2]	9.95	10.00	4.50	9.10	-0.90	-9.0%
Total	$38.55	$39.58	$10.10	$41.60	$2.02	5.1%

Totals may not add due to rounding.

[1] Includes the Telescope System Instrumentation Program (TSIP)

[2] Includes $3.10 million in ARRA funding for ATST late stage design and development.

The National Optical Astronomy Observatory (NOAO) was established in 1982 by uniting operations of the Kitt Peak National Observatory (KPNO) in Arizona and the Cerro Tololo Inter-American Observatory (CTIO) 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 and to several non-federal observatories through the Telescope System Instrumentation Program (TSIP). NOAO manages national community involvement in the development of potential future infrastructure projects such as the Giant Segmented Mirror Telescope and the Large Synoptic Survey Telescope, both of which are high priority recommendations of the 2000 Decadal Survey conducted by the National Research Council's Astronomy and Astrophysics Survey Committee.

The National Solar Observatory (NSO) operates facilities in New Mexico (Sacramento Peak Observatory, SPO) and Arizona (at KPNO) as well as a coordinated worldwide network of six telescopes (GONG) specifically designed to study solar oscillations. NSO leads the community in design and development of the Advanced Technology Solar Telescope (ATST). (More information on this project can be found in the Major Research Equipment and Facilities Construction chapter). NSO 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. NSO provides routine, synoptic solar data used by many researchers and other agencies through its online archive.

The Cerro Tololo Inter-American Observatory 4-meter telescope dome. *Credit: M. Urzua Zuniga/Gemini Observatory.*

NOAO and NSO telescopes are open to all astronomers regardless of institutional affiliation on the basis of peer-reviewed observing proposals. They serve over 1,000 scientists annually. In FY 2009 NOAO employed about 47 support scientists, 10 postdoctoral fellows, 59 engineers and technical staff, and 130 other personnel, a decrease of 24 FTEs below FY 2008. In FY 2009 NSO employed approximately 17 support scientists, 29 technical staff and 43 other personnel within the operating budget. In FY 2010,

NOAO will replace approximately half the FTEs lost in FY 2009 and NSO will reduce staff by approximately three FTEs.

Total Obligations for NOAO and NSO
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
NOAO-Operations	$17.62	$18.14	$5.60	$19.00	$19.73	$20.40	$21.00	$21.65	$22.25
NOAO-Development	5.59	7.02	-	8.00	8.10	8.22	8.50	8.75	9.03
NOAO-Research & Ed.	1.39	0.42	-	0.50	0.50	0.55	0.55	0.55	0.60
TSIP	4.00	4.00	-	5.00	5.00	5.00	5.00	5.00	5.00
NSO-Operations	7.53	7.11	1.40	7.25	7.47	7.70	7.90	8.10	8.35
NSO-Development	2.10	2.56	-	1.50	1.55	1.60	1.65	1.75	1.75
NSO-Research & Ed.	0.32	0.33	-	0.35	0.35	0.35	0.39	0.39	0.45
ATST Design/Develop.	-	-	3.10	-	-	-	-	-	-
Total, NOAO and NSO	$38.55	$39.58	$10.10	$41.60	$42.70	$43.82	$44.99	$46.19	$47.43

Totals may not add due to rounding.

Funding displayed for FY 2011 through FY 2015 are planning estimates only.

TSIP is the Telescope System Instrumentation Program.

Partnerships and Other Funding Sources: Thirty-four U.S. member institutions and seven international affiliate members comprise the Association of Universities for Research in Astronomy, Inc. (AURA), the management organization for NOAO and NSO. Other partners include the U.S. Air Force Office of Scientific Research, U.S. Air Force Weather Agency, NASA, and industrial vendors. A large number of U.S. universities support their own astronomical facilities at KPNO and CTIO with reimbursed services provided by NOAO. Many universities and institutes collaborate with NSO on solar instrumentation development and on the design and development of ATST. Development of new telescopes, instrumentation, and sensor techniques is done in partnership with industry through subawards to aerospace, optical fabrication, and information technology companies. NOAO and NSO leverage NSF support with funding from other federal agencies and non-federal sources. In FY 2008, NOAO and NSO received about $2.49 million from other federal agencies and $1.94 million from non-federal and industrial sources. For all NOAO and NSO telescopes, peer-review telescope allocation committees provide merit-based telescope time but no financial support.

Education and Public Outreach: Both NOAO and NSO support U.S. education goals by promoting public understanding and support of science and by providing education and training at all levels. Typically, twenty-five percent of doctorates awarded annually in astronomy involve use of NOAO/NSO facilities. The observatories introduce undergraduate students to scientific research by providing stimulating environments where they are exposed to basic astronomical research and related technologies through NSF's Research Experiences for Undergraduate Students (REU) program. NOAO and NSO have diverse education programs, visitor centers, and web-based information portals, including www.noao.edu and www.nso.edu.

NOAO-Operations, $19.0 million (+$860,000 over FY 2009 level of $18.14 million): NOAO-Operations covers the operation of facilities at KPNO, CTIO, and the headquarters in Tucson. An increase of $860,000 will support the observatories' limited funding in early FY 2009. The majority of these funds will allow the hiring of technical support personnel for user support.

NOAO-Development, $8.0 million (+$980,000 over FY 2009 level of $7.02 million): Development support covers NOAO's share of the design and development of the Large Synoptic Survey Telescope (LSST) and the development of new instrumentation for telescopes at KPNO and CTIO. The Senior Review recommended that the instrumentation at KPNO and CTIO urgently be modernized. In FY 2010 NOAO will begin a multi-year effort to introduce new capabilities to the U.S. community through investment in new instrumentation at KPNO and CTIO using in part the $980,000 increase. Ongoing design and development for the LSST will continue.

NOAO-Research & Education, $500,000 (+$80,000 over FY 2009 level of $420,000): NOAO links the research conducted at its facilities to the education of the public through its Education and Public Outreach office in Tucson. An increase of $80,000 is requested to provide science community outreach, news and public information, and educational activities for K-12.

Telescope System Instrumentation Program, $5.0 million (+$1.0 million over FY 2009 level of $4.0 million): This program supports the development and fabrication of instrumentation at non-federal observatories in return for competitively reviewed observing time for the national community. A recommendation of the 2000 Decadal Survey in astronomy, TSIP has proved extremely effective in gaining access for the national community of researchers to non-federal observatories. NOAO manages the program on behalf of NSF. An increase of $1.0 million will add access to the national community for up to 20 nights of telescope time on 8-10 meter class telescopes.

NSO-Operations, $7.25 million (+$140,000 over FY 2009 level of $7.11 million): NSO-Operations includes facility operations at KPNO, SPO, and the world-wide Global Oscillations Network Group.

NSO-Development, $1.50 million (-$1.06 million below FY 2009 level of $2.56 million): This funding for NSO covers design and development of ATST and development of new instrumentation for telescopes at KPNO and SPO. The reduction of $1.06 million in FY 2010 acknowledges the end of the design and development phase of the ATST and the commencement of construction with funding from the Major Research Equipment and Facilities Construction account

NSO-Research & Education, $350,000 (+$20,000 over FY 2009 level of $330,000): NSO supports education of the public in solar physics through its Education and Public Outreach office at Sacramento Peak Observatory. This office provides science community outreach, a visitors' center, and news and public information with a modest increase of $20,000 in FY 2010.

Facility Report:

Management and Oversight:

- NSF Structure: An NSF program director in the Division of Astronomical Sciences (AST) provides ongoing oversight, including consultation with an annual NSF Program Review Panel. The program director makes use of detailed annual program plans, annual long range plans, quarterly technical and financial reports, and annual reports submitted by NOAO and by NSO as well as attending AURA governance committee meetings. These governance committees are formed from the national astronomical community and provide additional windows into community priorities and concerns. AST program managers work closely with other offices at NSF, particularly the Division of Acquisition and Cooperative Support, the Office of General Counsel, and the Large Facilities Project Office.

- External Structure: AURA is the managing organization for both NOAO and NSO. Separate NOAO and NSO directors report to the president of AURA who is the principal investigator on the two FY 2010 NSF cooperative agreements. AURA receives management advice from an Observatory Council for each observatory composed of members of its scientific and management communities. NOAO and NSO each employ separate Visiting and Users Committees for the purposes of self-evaluation and prioritization. The Visiting Committees, composed of nationally prominent individuals in science, management, and broadening participation, review for AURA all aspects of the management and operations of the observatories. The User Committees, composed of scientists with considerable experience with the observatories, review for the Directors all aspects of the observatories that affect the experiences of the users of that observatory.

- Reviews: In addition to reviews held mid-way through all cooperative agreements, NSF conducts both periodic and ad hoc reviews of AURA management as needed by external committees. In response to recommendations from the 2006 Senior Review, AST carried out a review of administrative and operational costs at all its facilities using a outside contractor. That review concluded that NOAO and NSO are operated in a very cost effective manner and also recommended several cost-savings changes that AST now has under review.

Renewal/Recompetition/Termination:

A management review of AURA's performance was carried out in August 2006. In response to the favorable review, the National Science Board extended the current cooperative agreement with AURA for eighteen months, through September 30, 2009. A proposal for renewal of the cooperative agreement was received from AURA in December 2007 and underwent review in 2008. The National Science Board authorized two new cooperative agreements with AURA, one for management and operation of NOAO and one for management and operation of NSO, for the period October 1, 2009, though March 31, 2014.

National Radio Astronomy Observatory

$67,090,000
+6,300,000 / 10.4%

National Radio Astronomy Observatory
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over FY 2009 Plan Amount	Change over FY 2009 Plan Percent
National Radio Astronomy Observatory	$52.73	$60.79	$5.40	$67.09	$6.30	10.4%

The National Radio Astronomy Observatory (NRAO) provides state-of-the-art radio telescope facilities for scientific users. 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.

As a Federally Funded Research and Development Center (FFRDC), NRAO operates major radio telescopes in Green Bank, West Virginia, near Socorro, New Mexico, and at ten telescope array sites spanning the U.S. from the Virgin Islands to Hawaii. NRAO's headquarters is in Charlottesville, Virginia. NRAO is also the North American implementing 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. The Observatory allocates telescope time on the basis of merit but provides 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 the facility.

NRAO staff include 405 FTEs in the operations and maintenance component of the Observatory: 61 in Observatory Management, 300 in Observatory Operations, 31 in Science & Academic Affairs and Education and Public Outreach (EPO), and 13 in the Central Development Laboratory.

Total Obligations for NRAO
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2010 Request	ESTIMATES FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Operations & Maintenance	$39.08	$43.60	$43.14	$43.24	$42.89	$44.33	$46.95	$49.25
Observatory Management	*5.71*	*7.30*	*7.10*	*7.10*	*7.10*	*7.25*	*7.30*	*7.40*
Observatory Operations	*27.85*	*30.35*	*30.30*	*30.39*	*30.04*	*30.93*	*33.15*	*35.00*
Science, Academic Affairs, EPO	*3.96*	*4.26*	*4.19*	*4.25*	*4.25*	*4.40*	*4.50*	*4.60*
Central Development Lab	*1.56*	*1.69*	*1.55*	*1.50*	*1.50*	*1.75*	*2.00*	*2.25*
ARRA Estimate	-	*5.40*	-	-	-	-	-	-
Implementation of EVLA	6.01	6.19	6.38	1.13	-	-	-	-
ALMA Operations	7.64	11.00	17.57	23.50	30.65	33.92	36.41	39.17
Total, NRAO	$52.73	$66.19	$67.09	$67.87	$73.54	$78.25	$83.36	$88.42

Totals may not add due to rounding.

Funding displayed under Operations and Maintenance subareas in FY 2010 to FY 2015 are planning estimates only.

Partnerships and Other Funding Sources: NRAO supplements Division of Astronomical Sciences (AST) support with funding provided by other NSF sources, other federal agencies, and non-federal sources. In FY 2008, NRAO received approximately $1.0 million from non-AST sources at NSF and $250,000 from other federal agencies such as NASA, and about $300,000 from U.S. universities, foreign scientific and technical institutes, and other non-federal and industrial sources. The development of new telescopes, instrumentation, and sensor techniques is completed in partnership with relevant industries through competitive subawards to various large and small aerospace companies, radio antenna manufacturing firms, and specialized electronics and computer hardware and software companies.

In FY 2010, increased investments at NRAO will provide for the continued ramp up of ALMA operations. A consequence of the increase for ALMA will be a $460,000 decrease in the base operations and maintenance account of the Observatory.

Education and Public Outreach: NRAO's primary education 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 (see www.nrao.edu/index.php/learn). Observational facilities are used by graduate students carrying out dissertation research and on work experience programs and by undergraduate students participating in the Research Experiences for Undergraduates (REU) program. Typically over 150 students use NRAO facilities annually. NRAO sites also support visitor/education centers and conduct an active educational and public outreach program.

NRAO has centralized its outreach activities into an Office of Education and Public Outreach. The new Green Bank Science Center is in full operation, and the VLA Visitor Center was redesigned. Approximately 68,000 public visitors pass through the Green Bank Science Center and the VLA Visitor Center each year.

The Very Large Array (VLA) telescope, located about 80 km west of Socorro, NM, is composed of 27 individual antennas arranged in a "Y" pattern. In their closest configuration (about 1 km wide), the VLA is able to image large portions of the sky. In its largest configuration (about 36 km wide) the VLA is able to home in on the fine details of astronomical objects. *Credit: NRAO/AUI and Kelly Gatlin, Patricia Smiley.*

Observatory Management, $7.10 million ($200,000 below the FY 2009 Current Plan level of $7.30 million): Funding is shifted to partially accommodate the ramp up in ALMA operations. Observatory Management includes the Director's office, administrative services, the end-to-end data management initiative, and the New Initiatives Office.

Observatory Operations, $30.30 million ($50,000 below the FY 2009 Current Plan level of $30.35 million): Funding is shifted to partially accommodate the ramp up in ALMA operations. The Observatory Operations programmatic area includes the support for operating facilities at Green Bank, West Virginia and in New Mexico, and the computer and information services that support the facilities.

Science & Academic Affairs and EPO, $4.19 million ($70,000 below the FY 2009 Current Plan level of $4.26 million): Funding is shifted to partially accommodate the ramp up in ALMA operations. This area includes staff research, science training and education, science centers, the library, science community outreach, and news and public information.

Central Development Laboratory (CDL), $1.55 million ($140,000 below the FY 2009 Current Plan level of $1.69 million): Funding is shifted to partially accommodate the ramp up in ALMA operations. The CDL is developing next generation electronics and detectors for radio astronomy, making fundamental contributions to materials science, the physics of quantum detectors, electromagnetics, photonics, and radio propagation.

Implementation of EVLA, $6.38 million ($190,000 over the FY 2009 Current Plan level of $6.19 million): FY 2010 funding allows for a long planned increase. The Very Large Array (VLA) is undergoing an upgrade of electronics and communications systems, referred to as the Expanded Very Large Array (EVLA), to significantly enhance capabilities. Total project cost is $87 million. Construction of the EVLA began in FY 2001 and is proceeding on budget and on schedule for a 2012 completion. The EVLA will provide a factor of ten improvement in capability in several areas over the VLA. More than half of the VLA antennas have been converted to EVLA standards and all remaining antennas will be retrofitted by the end of 2010. Canada is responsible for the correlator for processing EVLA data, and the first sections of the correlator arrived in the third quarter of 2008. Shared risk scientific observing will begin in 2009/2010, with full science operations by 2013. The transformation of the VLA into the EVLA has proceeded with little interruption to the regular VLA observing schedule.

ALMA Operations, $17.57 million (+$6.57 million over the FY 2009 Current Plan level of $11.0 million): NRAO is also engaged in construction of the international ALMA, which in FY 2010 will be entering the 9th year of its eleven year construction phase, funded through the Major Research Equipment and Facilities Construction (MREFC) account. Early operations funding for ALMA began in FY 2005 and ramps up sharply in FY 2008 to FY 2015. A funding profile through FY 2011 was authorized by the National Science Board in December 2007. The operations estimates for FY 2012 and beyond are based on current cost projections. Additional information on the ALMA project is available in the MREFC chapter.

In 2006 NRAO created the North American ALMA Science Center (NAASC) to support the broad user community in fully realizing the scientific capabilities of ALMA. The NAASC is ramping up its activity level in conjunction with the ramp up in ALMA operations. The NAASC serves two key functions: supporting basic ALMA operations as the North American ALMA Regional Center (ARC) by providing day-to-day support for ALMA operations carried out in Chile; and providing ease of access and strong support for the broad astronomical community in using ALMA. The NAASC is organizing schools, workshops, and courses in the techniques of millimeter and submillimeter astronomy.

Facility Report:

Management and Oversight:

- NSF Structure: Ongoing oversight and assessment is carried out in AST and in consultation with community representatives making use of detailed annual program plans, long range plans, quarterly technical and financial reports, and annual reports submitted to NSF by NRAO as well as by attendance at governance committee meetings of the managing organization, Associated Universities, Inc., (AUI). AST works closely with other NSF offices NSF, such as the Division of Acquisition and Cooperative Support, Office of General Counsel, and Large Facilities Project Office to address issues as they arise.

- External Structure: Management is through a cooperative agreement with AUI. AUI manages the observatory through its own community-based oversight and users' committees. The NRAO director reports to the president of AUI.

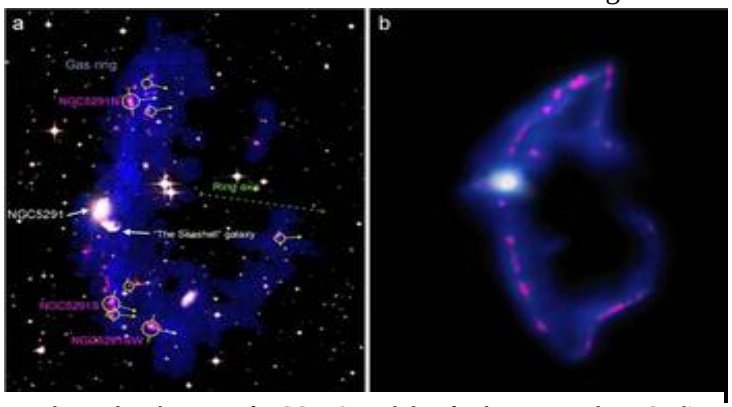
- Reviews: In addition to reviews held mid-way through all cooperative agreements, NSF conducts periodic reviews of AUI/NRAO management by external committees on an ad hoc basis. In addition, in response to recommendations from the Senior Review, AST carried out a review of administrative and operational costs at all its facilities in 2008. That review concluded that NRAO is operated in a cost effective manner and recommended several possible cost savings that AST has under review.

Renewal/Recompetition/Termination:

The present cooperative agreement expires at the end of FY 2009. AUI has submitted a renewal proposal for the operation and management of NRAO for the period FY 2010-2015, which is currently being reviewed.

Recent Research Highlights

► **Big Dwarf Galaxies May Contain Missing Mass:** When galaxies collide, smaller "dwarf" galaxies form from the debris. An international team of astronomers studying these dwarf galaxies found them to be much more massive than expected. The researchers believe the additional material is "missing mass" that theorists said should not be present in this kind of dwarf galaxy. The scientists used NSF's Very Large Array radio telescope to study a galaxy called NGC 5291, which is 200 million light years from Earth. This galaxy collided with another 360 million years ago, and the collision shot streams of gas and stars outward. Later, the dwarf galaxies formed from the ejected debris. This research is a significant development in our understanding of the way galaxies form and the resulting evolution of galactic collisions.



Multiwavelength image of NGC 5291 and dwarf galaxies around it. *Credit: Pierre-Alain Duc, CEA-CNRS/NRAO/AUI/NSF/NASA.*

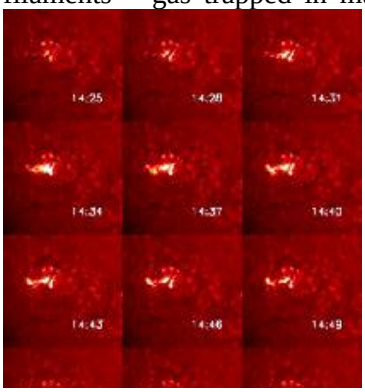
► **First Array Antennas Arrive in Chile:** Several antennas from North America and Japan have arrived at the mid-altitude, 2,800 meter site in Northern Chile for assembly and verification. The site serves as a base for the Atacama Large Millimeter Array (ALMA) of antennas. After testing, the staff will integrate them with receiver packages and test their ability to function as an interferometric pair before transporting each completed antenna to the high-altitude (5,000 meters) operational site. The array is a partnership between North America and Europe to each construct 25 antennas, 12-meters in diameter. Japan will provide an added four antennas, 12 meters in diameter, and 12 antennas, 7 meters in diameter. Processing the signal from each antenna with that measured by every other antenna allows a radio image of the sky to be constructed with a resolution equivalent to a single dish the size of the entire array.

The first of several Atacama Large Millimeter Array antennas at the mid-level site in Chile undergoing initial testing. *Credit: Image courtesy NRAO/AUI.*

► **A Peek Inside a Blue Compact Dwarf Galaxy:** An undergraduate researcher from Bryn Mawr College used data obtained from NSF's Very Large Array radio telescope in Socorro, New Mexico, to learn important information about "VIIZw403," a blue compact dwarf galaxy with an unresolved (no visible structure) X-ray source. Although this galaxy had been observed by astronomers, the researcher uncovered the previously unresolved structure in the atomic hydrogen around the X-ray point source and other regions of the galaxy. This work may ultimately shed light on how blue compact dwarf galaxies undergo bursts of star formation without an obvious instigator. The researcher carried out her work as a summer student in a program led by the Florida Institute of Technology.

NSF-funded Very Large Array Radio Observatory, located in Socorro, New Mexico. *Credit: NRAO.*

► **Unraveling erupting filaments on the Sun:** A middle-school teacher tracked and analyzed erupting filaments – gas trapped in magnetic field loops – on the surface of the Sun through an NSF-funded summer school at the National Solar Observatory's facilities in New Mexico.

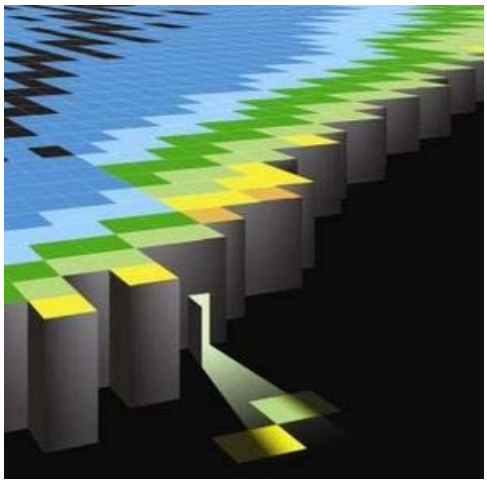


Archival data used in the analysis of erupting filaments on the Sun. These images, taken on June 20, 2004, with a hydrogen alpha emission imaging system, show the development of the filament over time. *Credit: Kathy Allshouse and & OSPAN/AFRL.*

Her analysis of the intensity and Doppler signatures of the erupting filaments showed there is expansion and unspiraling of filament structures as they erupt. The teacher is taking her research experience back into the classroom where she will be add new material to the astronomy section of the Earth Science curriculum at her middle school. She plans to include topics such as the Doppler effect, optics, telescopes, and the electromagnetic spectrum.

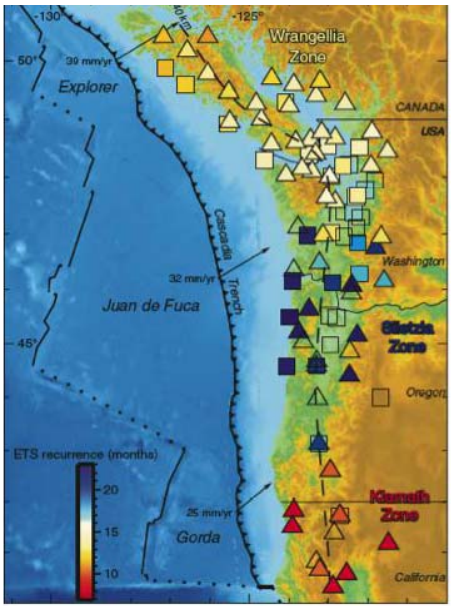
The National Solar Observatory's 2007 Research Experiences for Undergraduates and Researcher Experiences for Teachers & Summer Research Assistantship Program participants. Kathy Allshouse, the middle-school teacher featured in this highlight, is on the far left. *Credit: NSO/AURA/NSF.*

► **New Isotopes Push the Neutron "Dripline" for Magnesium and Aluminum:** How many neutrons can an atomic nucleus hold? Possibly a lot more than current scientific models predict. That's the conclusion a team of physicists from Michigan State University reached after creating one new ultra-heavy isotope of magnesium and two new ultra-heavy types of aluminum. According to one of the leading theoretical models, one of the aluminum isotopes – aluminum-42 – should not exist. That it does exist suggests the outer limit for neutron stuffing, called "the dripline" by nuclear physicists, includes more novel, neutron-rich isotopes than previously thought. Right now, scientists only know the dripline limit for the eight lightest elements, hydrogen to oxygen. The researchers used a dual-filtering process that detected and measured isotopes so rare they represent only one in every billion million particles that passed by the detectors. This experiment marks one of the first uses of two-stage separation in the world.



Michigan State University researchers created never-before-seen isotopes of magnesium and aluminum – represented by the two colored squares floating in blackness. Research results suggest that variants of everyday elements might exist which are heavier than current scientific models predict. The extra weight refers to the additional neutrons stuffed into the nucleus by a dual filtering process. *Credit: Alex Paisons, Michigan State University.*

► **Earth's Shifting Plates Provide Clues to Earthquakes and Volcanoes:** Subduction occurs when two of Earth's tectonic plates move towards each other and one plate is thrust beneath the other. Subduction also generates scraping between the plates and chemical changes within the submerging plate that can lead to earthquakes and volcanoes. A researcher from Miami University and his co-researcher from the University of California at Berkeley took an in-depth look at the Cascadia subduction zone that stretches from Vancouver Island to Northern California. Using seismic and GPS data, the researchers determined intervals between the "episodic tremor and slip" episodes – the slow release of accumulated strain along the interface of the two plates – negatively correlates with the topography of the overriding plate. Conversely, there was not a discernible relationship with characteristics of the downgoing oceanic plate. This intriguing result suggests the geology of the overriding plate may play a more important role in tremor and slip episodes and earthquake behavior than previously thought.



"Map illustrating patterns in episodic tremor and slip (ETS) along the entire Cascadia subduction zone. Colored base map shows topography and bathymetry. Dashed line onshore marks 40 km depth contour of the subduction interface. Arrows and associated annotations show directions and speeds of subduction relative to North America. Locations of continuous global positioning system stations (squares) and broadband seismometers (triangles) that exhibit ETS are shown, with colors indicating the recurrence interval when multiple ETS events were observed. Recurrence intervals establish three zones that are labeled based on the continental terrane block with which they are associated." from Geology, Oct 2007, v. 35, no, 10, p. 907. *Credit: Geology, October 2007; v.35; no. 10; p. 907-910.*