

MAJOR MULTI-USER RESEARCH FACILITIES

Major Multi-user Research Facilities Funding

(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change Over FY 2014 Estimate	
				Amount	Percent
Total Research and Related Activities	\$900.18	\$955.79	\$978.26	\$22.47	2.4%
Operations and Maintenance of Existing Facilities	654.76	674.38	672.39	-1.99	-0.3%
Federally Funded Research and Development Centers	195.17	198.11	203.87	5.76	2.9%
Operations and Maintenance of Facilities under Construction	40.01	75.80	100.00	24.20	31.9%
R&RA Planning and Concept Development	10.24	7.50	2.00	-5.50	-73.3%
Major Research Equipment and Facilities Construction	\$196.49	\$200.00	\$200.76	\$0.77	0.4%
Total, Major Multi-User Research Facilities	\$1,096.67	\$1,155.79	\$1,179.02	\$23.24	2.0%

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. Planning, 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 projects under construction funded through NSF's MREFC account is provided in the MREFC chapter.

Major Multi-User Research Facilities

Major Multi-User Research Facilities Funding

(Dollars in Millions)

	FY 2013	FY 2014	FY 2015	Change over	
	Actual	Estimate	Request	FY 2014 Estimate Amount	Percent
Operations and Maintenance of Existing Facilities	\$654.76	\$674.38	\$672.39	-\$1.99	-0.3%
Engineering					
National Nanotechnology Infrastructure Network (NNIN)	16.07	15.46	15.46	-	-
Network for Earthquake Engineering Simulation (NEES)	21.82	20.00	12.00	-8.00	-40.0%
Geosciences					
Academic Research Fleet ¹	81.40	83.00	85.00	2.00	2.4%
Geodetic Facilities for the Advancement of Geoscience and EarthScope (GAGE)	9.28	11.58	11.58	-	-
International Ocean Discovery Program (IODP)	47.70	50.00	48.00	-2.00	-4.0%
Polar Facilities and Logistics	288.51	295.91	296.23	0.32	0.1%
Seismological Facilities for the Advancement of Geosciences and EarthScope (SAGE)	24.35	24.35	24.35	-	-
Mathematical and Physical Sciences					
Arecibo Observatory	8.30	8.00	8.00	-	-
Cornell High Energy Synchrotron Source (CHESS)	20.00	20.00	20.00	-	-
Gemini Observatory	18.15	19.59	20.61	1.02	5.2%
IceCube	6.90	6.90	6.90	-	-
Large Hadron Collider (LHC)	18.00	17.37	18.00	0.63	3.6%
Laser Interferometer Gravitational-Wave Observatory (LIGO)	30.50	36.43	39.43	3.00	8.2%
National High Magnetic Field Laboratory (NHMFL)	31.62	32.63	33.67	1.04	3.2%
National Solar Observatory (NSO) ²	8.00	8.00	8.00	-	-
National Superconducting Cyclotron Laboratory (NSCL)	21.50	22.50	22.50	-	-
Other Facilities ³	2.66	2.66	2.66	-	-
Federally-Funded Research and Development Centers⁴	\$195.17	\$198.11	\$203.87	\$5.76	2.9%
National Center for Atmospheric Research (NCAR)	95.75	95.20	98.20	3.00	3.2%
National Optical Astronomy Observatory (NOAO)	25.50	25.50	25.50	-	-
National Radio Astronomy Observatory (NRAO) ⁵	73.92	77.41	80.17	2.76	3.6%
Operations and Maintenance of Facilities under Construction	\$40.01	\$75.80	\$100.00	\$24.20	31.9%
Daniel K. Inouye Solar Telescope (DKIST) ⁶	2.00	2.00	7.00	5.00	250.0%
National Ecological Observatory Network (NEON)	1.21	21.00	38.00	17.00	81.0%
Ocean Observatories Initiative (OOI)	36.80	52.80	55.00	2.20	4.2%
R&RA Planning and Concept Development	\$10.24	\$7.50	\$2.00	-\$5.50	-73.3%
Pre-construction Planning ⁷	10.24	7.50	2.00	-5.50	-73.3%
Concept and Development for MREFC Projects	-	-	-	-	-
Major Research Equipment and Facilities Construction	\$196.49	\$200.00	\$200.76	\$0.76	0.4%
Total, Major Multi-User Research Facilities	\$1,096.67	\$1,155.79	\$1,179.02	\$23.23	2.0%

Totals may not add due to rounding.

¹ An additional \$2.74 million in FY 2013, \$1.0 million in FY 2014, and \$2.0 million in FY 2015 for Research Class Regional Vessels is included in pre-construction planning.

² The NSO total presented in FY 2015 does not include \$5.0 million for operations and maintenance support for the DKIST facility construction project. That funding is captured within the total presented on the DKIST line below. For more information, see the NSO narrative.

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

⁴ Federally-Funded R&D Centers do not include support for the Office of Science and Technology Policy Institute (STPI), which is an FFRDC but not a multi-user research facility.

⁵ Operations and maintenance of ALMA are included in NRAO.

⁶ Of the total DKIST funding presented, in FY 2015, \$5.0 million is for operations and maintenance support provided through the National Solar Observatory, and for all years, \$2.0 million is for cultural mitigation activities as agreed to during the environmental compliance process. For more information, see the DKIST narrative in the MREFC chapter.

⁷ Pre-construction planning includes R&RA funding for potential next-generation major multi-user facilities.

NSF’s Facilities Investments in FY 2015

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ACADEMIC RESEARCH FLEET**\$87,000,000**
+\$3,000,000 / 3.6%**Academic Research Fleet**

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over	
			FY 2014 Estimate Amount	Percent
\$84.14	\$84.00	\$87.00	\$3.00	3.6%

The Academic Research Fleet consists of 20 vessels in the University-National Oceanographic Laboratory System (UNOLS) in calendar year 2014, and 19 vessels in calendar year 2015. 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 Fleet includes investments in ship operations; shipboard scientific support equipment; oceanographic instrumentation and technical services; and submersible support. Funding levels reported here reflect investments in the Directorate of Geosciences (GEO) by the Division of Ocean Sciences (OCE). In addition to operations, OCE has undertaken selected construction projects based on inter-agency planning and coordination as discussed in the *Federal Oceanographic Fleet Status Report* published in May 2013.

Total Obligations for the Academic Research Fleet

(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	ESTIMATES ¹				
				FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$81.40	\$83.00	\$85.00	\$85.00	\$85.00	\$85.00	\$85.00	\$85.00
RV <i>SIKULIAQ</i> O&M ²		\$4.17	\$8.34	\$8.50	\$8.50	\$8.50	\$8.50	\$8.50
Fleet Renewal								
Regional Class Research Vessel	2.74	1.00	2.00	2.00	-	-	-	-
Total, Academic Research Fleet	\$84.14	\$84.00	\$87.00	\$87.00	\$85.00	\$85.00	\$85.00	\$85.00

Totals may not add due to rounding.

¹ Outyear funding estimates are for planning purposes only.

² As discussed in the R/V *SIKULIAQ* narrative section, operations and maintenance for the RV *SIKULIAQ* are now included in Fleet Operations and Maintenance. Because the Academic Fleet is operated as a shared multi-agency resource where agencies pay for time they use on vessels, the annual OCE operating budget for any single vessel may vary significantly from year to year. Thus, estimates for the RV *SIKULIAQ* for FY 2015 and beyond are provided as a rough guide of likely costs.

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 ocean. Scientists contribute to advances in many areas including climate variability, marine ecosystems, fisheries, and ocean-related natural hazards, such as tsunamis through use of these facilities. Participating graduate and undergraduate students interact with scientists and marine technicians, enabling them to gain first-hand exposure to ocean science field research. Increasingly, technological innovations allow research conducted at sea to be transmitted via satellite back to the classroom, broadening the educational impact of the vessels.

The Fleet is supported through an interagency partnership, principally with the Office of Naval Research (ONR) and the National Oceanic and Atmospheric Administration (NOAA). The operating costs for the Fleet are divided proportionally among the vessel users based on usage; NSF supports approximately 63 percent of the total, which includes the Ocean Observatories Initiative's use of the Fleet. 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 federal and state agencies. Within NSF, science is funded through competitive peer-reviewed proposals, most typically funded within OCE and through selected programs in the Division of Earth Sciences (EAR), the Division of Atmospheric and Geospace Sciences (AGS), the Division of Polar Programs (PLR), and the Directorate for Biological Sciences (BIO). Approximately 25 percent of OCE proposals request ship time. 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. Academic Research Fleet, and science funded by other agencies.

The FY 2015 Request of \$85.0 million will support approximately 2,100 ship operating days.

Fleet Operations

- Oversight: 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 site visits, ship inspections, and participation at UNOLS Council and Committee meetings by NSF program directors. Several program directors within OCE at NSF, at NOAA, and at ONR are involved in the activities and oversight of the Academic Research Fleet. NSF conducted a Business Systems Review (BSR) of Columbia University/Lamont Doherty Earth Observatory as the operator of the R/V *LANGSETH*, and issued a final report in September 2010. No BSRs of Academic Research Fleet operating institutions are currently scheduled for 2014 or 2015.
- Management: Management of an 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.
- 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. Recent documents supporting this need include the *National Ocean Policy* and the *Final Recommendations of the Interagency Ocean Policy Task Force* of July 19, 2010. Two applicable reports by the National Research Council (NRC) include *Science at Sea: Meeting Future Oceanographic Goals with a Robust Academic Research Fleet* published in 2009, and *Critical Infrastructure for Ocean Research and Societal Needs in 2030* published in 2011. In coordination with UNOLS and the other federal agencies which invest in ocean research, the Interagency Working Group on Facilities (IWG-F), which has been renamed as the Interagency Working Group on Facilities and Infrastructure (IWG-FI), under the National Ocean Policy, published a *Federal Oceanographic Fleet Status Report* in May 2013, reviewing the status and describing plans for modernizing the federal and academic oceanographic research and survey fleet. Ship operations and technical services proposals undergo external review by peers every five years. Detailed annual reports describing activities accomplished are provided by the operating institutions and budgets are negotiated yearly since they are dependent on the number of days the ships will be at sea in support of NSF-funded research programs.

Fleet Modernization

- Oversight: The NSF coordinator for Fleet modernization activities is the Program Director for Ship Acquisition and Upgrades, within the Integrative Programs Section (IPS) in OCE, with additional IPS staff providing project management assistance as required.
- Regional Class Research Vessel (RCRV): In March 2012, NSF leadership approved the request to advance the RCRV to the Conceptual Design Review (CDR) phase as a candidate Major Research Equipment and Facilities Construction (MREFC) project. On February 1, 2013, NSF made an award to Oregon State University (OSU) as the lead institution for advancement to CDR. Funds for CDR

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were provided from the Research and Related Activities account. In December 2013, OSU successfully completed all CDR requirements in accordance with NSF's Large Facilities Manual. Consideration for advancement to the Preliminary Design Phase is anticipated in spring 2014, with the Preliminary Design Review (PDR) then planned for August 2014. Management and oversight would be similar to the R/V *SIKULIAQ* project. NSF is continuing discussions with the NOAA Office of Marine and Aviation Operations to explore the potential for collaboration between the two agencies on the design of the RCRV and the modernization efforts being considered for the NOAA mid-size vessels. In addition, NSF is an active participant in the IWG-FI Ship Subcommittee, which developed the update to the 2013 *Federal Oceanographic Fleet Status Report*, an action in the draft *National Ocean Policy (NOP) Implementation Strategy*¹. The RCRV would address requirements across the government agencies for research vessels in support of ocean science research as discussed in the Fleet Status Report Update. Decisions on proceeding to further development stages will be based upon NSF, National Science Board (NSB), and interagency reviews.

Other Ongoing Activities

Major overhaul and upgrade to the submersible Human Occupied Vehicle (HOV) *ALVIN* was completed in FY 2013. The *ALVIN* Upgrade Project is scoped in two phases. Phase I was the integration of a new titanium 6,500-meter-capable personnel sphere with existing *ALVIN* vehicle components. Phase I completion provided a maximum depth capability of 4,500 meters, the limit of the legacy *ALVIN* components retained during Phase I. Phase II would provide upgrades to permit operations to a depth of 6,500 meters, but there has been no implicit or explicit commitment to proceed with Phase II at this time. Sea trials for operation of the Phase I vehicle in November 2013 supported certification for operations to 3,800 meters, and further sea trials to support certification to 4,500 meters are anticipated in 2015. Six *Alvin* science cruises are scheduled for 2014 in the Gulf of Mexico and along the East Pacific Rise.

Renewal/Recompetition/Termination

Ships supported by NSF are operated by academic institutions, each having a cooperative agreement with NSF. All ship cooperative agreements were renewed in FY 2012 using the NSB-approved criteria and review by an external panel. Awardees are subject to additional oversight measures, including BSRs conducted by NSF. In FY 2013 NSF retired R/V *CAPE HATTERAS*, operated by a consortium of Duke University and the University of North Carolina from its homeport at the Duke University Marine Laboratory. This retirement action was completed on March 8, 2013. In FY 2014, NSF plans to retire R/V *POINT SUR*, operated by Moss Landing Marine Laboratories, San Jose University.

R/V *SIKULIAQ*, formerly the Alaska Region Research Vessel (ARRV)

The Research Vessel *SIKULIAQ* (formerly known as the Alaska Region Research Vessel - ARRV) represents NSF's first major contribution to Fleet renewal in over twenty years. Construction of the *SIKULIAQ* was funded through the MREFC account, partially with American Recovery and Reinvestment Act (ARRA) funds. The project is led by the University of Alaska, Fairbanks (UAF) with engineering support from design through construction provided by UAF's naval architect, The Glosten Associates, Inc. Shipyard construction began in early 2011 and the vessel was successfully launched in October 2012. During recent acceptance trials, an issue was detected with one of the ship's propulsion units, which will require reentry into dry-dock to address. Delivery of the *SIKULIAQ* to UAF is now scheduled for May 2014. This will be followed by a period of final outfitting, science trials, and transit to the first science operational area. Science operations are projected to begin in late 2014 with transition to the OCE Ship Operations Program for funding support. Bering Sea Ice trials will be conducted in 2015.

¹ www.whitehouse.gov/administration/eop/oceans/implementationplan

The increased capabilities of the *SIKULIAQ* are expected to dramatically increase NSF's ability to support Arctic science. Individual projects vary greatly in cost, as do the number of projects supported onboard at any given time. Assuming two simultaneous projects onboard for 3-4 weeks at a time and the average grant size in the Division of Ocean Sciences (OCE) in the Directorate for Geosciences (GEO), over \$17.0 million in research conducted from R/V *SIKULIAQ* would be supported annually.

Baseline History

Satellite observations have shown that the perennial ice in the Arctic is thinning at a rate of nine percent per decade, which is beginning to have major regional and global consequences. Research is urgently needed on topics ranging from climate change, ocean circulation, ecosystem studies, and fisheries research, to natural hazards and cultural anthropology. The *SIKULIAQ* will provide a sophisticated and significantly larger platform for scientists, as well as graduate and undergraduate students to participate in complex multidisciplinary research activities and will enable the training of the next generation of scientists with the latest equipment and technology. The *SIKULIAQ* is expected to greatly expand research capabilities in the Arctic with up to 270-300 science days at sea annually. The ice-strengthened hull will allow the vessel to operate in seasonal ice up to one meter thick and an anti-roll tank will permit it to operate effectively in the open waters of the Bering Sea, Gulf of Alaska, and North Atlantic. Due to its size and projected operating area, the *SIKULIAQ* will operate as a Global Class vessel within the U.S. Academic Research Fleet.

Management and Oversight

- **NSF Structure:** NSF oversight is described in the Program's Internal Management Plan (IMP). The NSF Program Officer for Ship Acquisition and Upgrades has primary responsibility for oversight of the project and resides within GEO/OCE/IPS. Periodic oversight is provided by a Project Advisory Team (PAT), which includes staff from GEO, the Division of Acquisition and Cooperative Support (DACS), the Large Facilities Office (LFO), the Office of the General Counsel (OGC), and the Office of Legislative Public Affairs (OLPA). External consultants and staff from IPS, LFO, and DACS provide the Program Officer with routine project management and technical assistance. To ensure effective management and oversight, monthly and annual reports provided by the UAF project office are closely monitored by the *SIKULIAQ* Program Officer for deviations from the established baseline using Earned Value Management. NSF conducted a Business Systems Review (BSR) of UAF as the awardee for the design and construction project and as the future operator of R/V *SIKULIAQ*. A final report was issued in July 2011.
- **External Structure:** UAF maintains project management offices in both Fairbanks and Seward, Alaska. UAF management also includes an experienced on-site team in Marinette, Wisconsin that will remain at the shipyard until delivery. The *SIKULIAQ* Oversight Committee (SOC), which includes community experts in research vessel design, construction, and operations, convenes monthly to review project status and provide technical and science support advice to both UAF and NSF.
- **Reviews:** With the ship now nearing completion, NSF will conduct one more annual project review in February 2014 to assess UAF's readiness for trials and the eventual transition to science operations.

Cost and Schedule

The total project cost approved by NSF and NSB following FDR is \$199.50 million. NSF first requested construction funding for the *SIKULIAQ* through the MREFC account in FY 2007. The project received an initial appropriation of \$9.43 million in that year, followed by an additional appropriation of \$42.0 million in FY 2008. \$148.07 million was provided through ARRA. The majority of this total, \$138.0 million, or 70 percent, is the fixed price contract with the shipyard. UAF management, which includes the purchase of propulsion units as Owner-Furnished Equipment, totals \$34.70 million (17 percent).

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Final outfitting, science trials, and delivery are \$11.20 million (6 percent). Uncommitted project contingency for the shipyard contract is approximately \$6.5 million (3.2 percent).

Risks

Risk mitigation strategies have been employed by UAF, and the risk analyses reviewed by the R/V *SIKULIAQ* Project Review Panel in July 2012 indicated that sufficient contingency was in place to handle the remaining project risks at the time. Remaining project risks and available contingency were assessed by the panel again in February 2014. The panel found that construction of the *SIKULIAQ* is at a high level of completion. Quality is high and, despite the delay, testing is going well which gives a high degree of confidence in ultimately receiving a reliable vessel. The panel noted that the acceptance/delivery schedule is highly compressed due to the delay in delivery to UAF. There is a high likelihood that ice trials will need to be delayed to early FY 2015 and conducted in the Bering Sea instead of Baffin Bay. This delay would have the benefit of adding schedule float. There is no funded planned science for the vessel in the Arctic for FY 2014, so there would be no negative operational impacts from this delay. Virtually all construction risks have been either mitigated or retired, and adequate contingency remains to cover foreseeable remaining risks. Science Trials plans have made significant progress in the past two years, but will continue to be further refined. Operational documentation (both UAF and MMC) appears complete and at an acceptable level of readiness.

Future Operations Costs

Vessel operations will be governed by the terms of a separate cooperative agreement with UAF through the Ship Operations Program within OCE/IPS. Daily rate estimates for both the ship and technical services will be updated in 2014. It is anticipated that OCE will utilize at least 65 percent of the annual vessel availability based on historical data from other Global Class ships in the Academic Research Fleet. Up to 35 percent of the *SIKULIAQ*'s schedule is expected to be available to PLR and to other federal agencies. In short, the *SIKULIAQ* will fold into the established framework for operating the Academic Research Fleet.

ARECIBO OBSERVATORY

\$8,000,000
\$0 / 0.0%

Arecibo Observatory
(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over FY 2014 Estimate	
			Amount	Percent
\$8.30	\$8.00	\$8.00	-	N/A

Totals may not add due to rounding.

The Arecibo Observatory (Arecibo), formerly the National Astronomy and Ionosphere Center, is a center for multidisciplinary research and education enabled by world-class observational facilities. The Observatory’s principal facility is the world’s largest single-dish radio/radar telescope, a 305-meter diameter reflector located near the town of Arecibo in western Puerto Rico on 120 acres of U.S. Government-owned land. Arecibo Observatory is currently operated and managed by SRI International and subawardees Universities Space Research Association (USRA) and Universidad Metropolitana (UMET) under a cooperative agreement with NSF that began on October 1, 2011. The observatory serves over 350 users annually with a wide range of research and observing instrumentation in passive radio astronomy, solar system radar astronomy, and space and atmospheric sciences. A peer-review telescope allocation committee provides merit-based telescope time to users. The committee is common to the three fields, but specific topic experts from outside the observatory are consulted for reviews. NSF does not provide awards targeted specifically for use of Arecibo Observatory, although many users are supported through NSF or NASA grants to pursue scientific programs that require use of the facility.

Arecibo has a staff of about 115 full-time-equivalent positions, of which approximately 90 are supported by NSF funds. A permanent staff of 13 scientists and 31 engineers, technicians, and operators is available to help visiting investigators with observing programs. The remainder includes 21 management, administrative, and clerical positions, 33 maintenance staff, and several postdoctoral scholars and students. Others are involved at the Angel Ramos Foundation Visitor Center.

Total Obligations for the Arecibo Observatory

(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	ESTIMATES ¹				
				FY 2016	FY 2017	FY 2018	FY 2019	FY 2019
Operations and Maintenance	\$8.30	\$8.00	\$8.00	\$8.20	\$8.20	\$8.20	\$8.20	\$8.20
<i>Astronomical Sciences (MPS)</i>	5.00	4.50	4.00	4.10	4.10	4.10	4.10	4.10
<i>Atmospheric & Geospace Sciences (GEO)</i>	3.30	3.50	4.00	4.10	4.10	4.10	4.10	4.10
Total, Arecibo	\$8.30	\$8.00	\$8.00	\$8.20	\$8.20	\$8.20	\$8.20	\$8.20

Totals may not add due to rounding.

¹ Outyear funding estimates are for planning purposes only. The current cooperative agreement ends on September 30, 2016.

Arecibo is jointly supported by the Directorate for Mathematical and Physical Sciences, Division of Astronomical Sciences (AST) in the (MPS/AST) and the Directorate for Geosciences, Division of Atmospheric and Geospace Sciences (GEO/AGS). Planned AST support through FY 2016 is based upon the 2006 AST Senior Review recommendations, guidance from a third-party cost review of AST facilities, and a third-party estimate of Arecibo’s non-scientific costs. Based on the Senior Review

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recommendations, AST has been ramping down support for Arecibo. At the same time AGS has significantly increased support, with funding proposed to ramp up to parity with AST in FY 2015 and beyond. (More on AGS activities at Arecibo can be found below under Management and Oversight.)

In 2010, the National Research Council (NRC) conducted its sixth decadal survey in astronomy and astrophysics to recommend key science questions and new initiatives for the current decade. Since both the NRC recommendations and current programs could not be accommodated within present budget projections, the Division of Astronomical Sciences (MPS/AST), through the Advisory Committee of the Directorate for Mathematical and Physical Sciences, conducted a community-based portfolio review to make implementation recommendations that would best respond to the decadal survey science questions. The resulting report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges* (www.nsf.gov/mps/ast/ast_portfolio_review.jsp), was released in August 2012 and included recommendations related to all of the major telescope facilities funded by NSF. NSF released a Dear Colleague Letter, NSF 14-022, in December 2013 that outlines the current state of the NSF response to the facility recommendations (www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf14022).

The Portfolio Review Committee recommended that support for Arecibo should be continued at funding levels near those currently planned, with a re-evaluation later in the decade, based on science opportunities and budget forecasts at that time. These re-evaluation timescales are roughly coincident with the expiration of the Cooperative Agreement at the end of FY 2016. The MPS and GEO directorates agreed that in view of the long lead time required for conducting a management competition, NSF will conduct a study of future alternative paths for Arecibo to be completed before the end of FY 2015; this study was announced in NSF 14-022 mentioned above.

Partnerships and Other Funding Sources: Arecibo leverages NSF support with funding from other federal and non-federal sources. Since FY 2010, the NASA Near Earth Object Observation Program has committed \$2.0 million annually to Arecibo in support of the planetary radar program; this was increased to \$3.60 million for FY 2013, with more observing time allocated to the NASA Program. NASA support is expected to continue, subject to the availability of appropriated funds. In FY 2010, observatory management finalized an assistance agreement with the Puerto Rico Infrastructure Financing Authority to receive \$3.0 million for one-time major infrastructure improvements at Arecibo Observatory. A grant to the Visitor Center from the Puerto Rico Department of Education was finalized in 2013; this award for \$1.90 million over 7 months will enable large numbers of Puerto Rican school children to visit the site. Extensions of the award are being pursued.



An aerial image of the Arecibo Radio Telescope in Puerto Rico. The platform suspension structure, including the Gregorian dome that houses the main suite of research instruments, is visible over the 305-meter primary reflector dish below. *Credit: Arecibo Observatory/NSF.*

Education and Public Outreach (EPO): Arecibo hosts a Research Experiences for Undergraduates (REU) site, and Ph.D. students receive training through the use of the facility. In collaboration with the National Radio Astronomy Observatory (NRAO), Arecibo holds a summer school on single-dish radio astronomy techniques. Arecibo also sponsors a major outreach program in Puerto Rico via the Angel Ramos Foundation Visitor Center as well as summer workshops for K-12 teachers. This center attracts more

than 80,000 visitors each year; over 1.4 million people have visited since its opening in 1997. With the funds mentioned above from the Puerto Rico Department of Education, Arecibo expects to host approximately 25,000 middle- and high-school children and 600 teachers in a new program sponsored by the Department of Education. This program integrates formal activities at the Angel Ramos Foundation Visitor Center into the STEM curriculum in Puerto Rico. The Arecibo Observatory also hosts several meetings each year within a wide variety of scientific disciplines.

Operations and Maintenance: Arecibo 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 the observing proposals; the current average oversubscription rate of the telescope is approximately 3.5, counting ongoing astronomy surveys, new astronomy projects, solar system observations, and atmospheric sciences programs. About 80 percent of astronomy users conduct their observing remotely via networked control software, while radar observations typically employ on-site users.

In January 2014, a magnitude 6.4 earthquake off the coast of Puerto Rico damaged one of the cables supporting the platform structure high above the main dish. As a safety measure, the platform is not being moved until after temporary repairs can be effectuated, so significant observing time is being lost during FY 2014.

Management and Oversight

- Division of Astronomical Sciences (AST), \$4.0 million: AST funds basic operations costs and science programs in passive radio astronomy and solar system radar astronomy. Funding for the Astronomy program continues to decrease in FY 2014 and FY 2015, in response to recommendations of the AST Senior Review, and reaches an approximate steady state in FY 2015. Operational scope has changed in response to decreased AST support as part of the current five-year award for Arecibo management and operations. Since FY 2010, NASA has provided substantial support for planetary radar astronomy.
- Division of Atmospheric and Geospace Sciences (AGS), \$4.0 million: The incoherent scatter radar at Arecibo is part of an NSF-supported network of radars strategically distributed to observe the transport of radiative energy and charged particles, from their origins at the sun to their deposition in Earth's upper atmosphere. The unique sensitivity of the Arecibo incoherent scatter radar system allows it to measure the density, temperature, and motion of plasma in Earth's ionosphere with unrivaled time and spatial resolution. Arecibo is also the only aeronomy observatory located at tropical mid-latitudes, where many important ionospheric processes take place. An ionospheric high-frequency heating facility is currently under construction at Arecibo with completion anticipated in FY 2014. This heating facility is part of an expanded scope in aeronomy funded by AGS.
- NSF Structure: Ongoing oversight is provided by the lead NSF program officer in AST, in close cooperation with an assigned program officer in AGS and in consultation with community representatives. The program officers make use of detailed annual program plans, long range plans, quarterly technical and financial reports, and annual reports submitted to NSF by SRI. They also attend SRI governance committee meetings, as appropriate. To address issues as they arise, the program officers work closely with other offices at NSF, particularly the Division of Acquisition and Cooperative Support; the Office of General Counsel; and the Large Facilities Office of the Office of Budget, Finance, and Award Management. The AST and AGS program officers conduct periodic site visits and frequent teleconferences.
- External Structure: Management is via a cooperative agreement with SRI and its sub-awardees, USRA and UMET. The awardees provide management and oversight through their own advisory and visiting committees, including an Arecibo Observatory Users Committee, a Scientific Management Advisory Committee, a Council of Puerto Rican Chancellors and Stakeholders, and an Executive

Major Multi-User Research Facilities

Governing Committee. The Arecibo Director, resident at the telescope site, is the Principal Investigator of the operations award for the facility. Three deputy directors in the areas of Atmospheric Sciences, Planetary Radar, and Puerto Rican EPO report to the Arecibo Director.

- Reviews:
 - A review of the proposal for management and operations of Arecibo Observatory was held in 2010, resulting in an award to SRI (see below) from October 2011 to September 2016. The NSF regularly conducts management reviews during the award period; the next is planned for early FY 2015.
 - AST and AGS jointly conduct annual external reviews of Arecibo program plans; the most recent review was held in October 2013. These will continue annually.
 - A Business Systems Review (BSR) involving all three partner organizations of Arecibo was conducted in late 2012.

Renewal/Competition/Termination

The current cooperative agreement with SRI for the management of Arecibo was awarded on October 1, 2011, when SRI succeeded the previous managing organization, Cornell University. This followed a competitive process for a new five-year cooperative agreement, consistent with National Science Board policy. This agreement is in effect through September 30, 2016. The direction beyond that time will be determined after carrying out the study of alternatives discussed earlier in this section.

CORNELL HIGH ENERGY SYNCHROTRON SOURCE

\$20,000,000
\$0 / 0.0%

Cornell High Energy Synchrotron Source

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over FY 2014 Estimate	
			Amount	Percent
\$20.00	\$20.00	\$20.00	-	-

Totals may not add due to rounding.

The Cornell High Energy Synchrotron Source (CHESS) is a high-intensity, high-energy X-ray user facility supported by NSF with interagency support from the National Institutes of Health (NIH). It uses synchrotron light given off by charged particles, both electrons and positrons, as they circulate in a ring at nearly the speed of light. CHESS provides capabilities for X-ray research in physics, chemistry, biology, materials, and environmental sciences. Areas of emphasis include soft matter and thin film studies, solution scattering, nanomaterials, high-pressure science, structural biology, time-resolved studies of materials, and X-ray studies of structural materials. Stewardship and oversight of CHESS is provided through the NSF Division of Materials Research within the Directorate for Mathematical and Physical Sciences (MPS/DMR), as well as the Directorates for Biological Sciences (BIO) and Engineering (ENG).

The FY 2015 Request supports operations of CHESS as a national user facility and is consistent with funding levels in previous years. Support for CHESS has shifted over the past years from research and development to a national user facility, thus the activities are evolving. Funding will allow continued operation of the facility in support of high energy X-ray synchrotron users.

Total Obligations for the Cornell High Energy Synchrotron Source

(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	ESTIMATES ¹				
				FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$20.00	\$20.00	\$20.00	\$20.00	\$20.00	\$20.00	\$20.00	\$20.00
<i>Mathematical & Physical Sciences</i>	20.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
<i>Biological Sciences</i>	-	5.00	5.00	5.00	5.00	5.00	5.00	5.00
<i>Engineering</i>	-	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total, CHESS	\$20.00	\$20.00	\$20.00	\$20.00	\$20.00	\$20.00	\$20.00	\$20.00

Totals may not add due to rounding.

¹ Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in March 2019.

Users number about 600 annually and perform a broad array of research, including computationally-enabled scattering studies of complex materials, structure and processing of designer solids, engineering of materials through time-resolved synchrotron radiation studies, x-ray imaging, spectroscopic studies, energy and structural materials studied under operating conditions, and macromolecules and biochemistry, this latter in collaboration with NIH. X-ray detectors developed at CHESS are now in use at 3rd and 4th Generation X-ray sources around the world, including the world's first hard X-ray laser, the Department of Energy's (DOE) Linear Coherent Light Source.

Major Multi-User Research Facilities

Many examples show that CHESS supports users from academia, industry, and national laboratories. Structures solved for a series of three key HIV reverse transcriptase complexes enabled the design of two FDA-approved treatments for HIV infection, which are marketed by Johnson & Johnson. CHESS is developing a dynamic testing station for structural materials through a collaboration with the U.S. Air Force Research Laboratory. CHESS collaborates with DOE-supported synchrotron facilities such as the Advanced Photon Source and the National Synchrotron Light Source. The Cornell Compact Undulator, which costs an order of magnitude less than current technology, is being adapted at other synchrotrons world-wide. Other innovations such as the optics and detectors also impact the synchrotron field.

CHESS supports and enhances Ph.D. level graduate education, postdoctoral research, and research experiences for undergraduates and for K-12 students and science teachers. Their education and outreach program annually impacts over 6,000 people of all ages, including over 1,400 visitors touring the Cornell facilities. Each year there are about 60 Ph.D. degrees granted as a result of CHESS research. CHESS is a key training ground for X-ray and accelerator scientists, with CHESS graduates being hired to staff other X-ray facilities in the U.S. and around the world.

Management and Oversight

- NSF Structure: CHESS is supported by MPS, ENG, and BIO through a cooperative agreement with Cornell University. The MPS/DMR program director is the primary contact with the facility, and leads an internal NSF team with program directors from BIO and ENG. Additional support is provided by NIH.
- External structure: CHESS is administered by the Cornell Laboratory of Accelerator-based Sciences and Education (CLASSE), which reports to Cornell's Vice-Provost for Research. The principal investigator serves as the CHESS director and reports to the Director of CLASSE. The CHESS director receives guidance primarily from the CHESS executive committee, from an external policy and advisory board, the CHESS diversity committee, and the users' executive committee.
- CHESS is a national user facility accessed on the basis of competitive proposal review. The primary function of CHESS staff is to maintain and operate the facility and to assist users. An annual users meeting and several workshops help disseminate results from the facility.
- Reviews: NSF provides oversight by monitoring annual plans and reports containing user metrics, as well as by conducting monthly phone conferences with the director and annual technical site visits. The annual technical site visits assess user programs, in-house research, long-term plans to contribute significant research developments both nationally and internationally, and operations, maintenance, and facility development. Annual reviews also assess the status of education training and outreach, operations and management efficiency, and diversity plans. In addition to a panel of experts from the community, representatives from other federal agencies such as the NIH attend these site visits. Recent and upcoming reviews include:
 - The CHESS renewal proposal was reviewed in FY 2013-2014.
 - MPS/DMR will conduct a management site visit with external reviewers in Spring 2014. This will focus on operations and strategic planning.
 - A subcommittee of the Mathematical and Physical Sciences Advisory Committee (MPS-AC) is conducting a study to advise on the level and types of investments MPS/DMR should make in X-ray science, other facilities, and instrumentation. The report, expected in Summer 2014, will inform the division's long-term investment plans.

Renewal/Recompetition/Termination

In November 2013, a five-year award was authorized by the National Science Board through March 2019. The cooperative agreement is currently being negotiated.

GEMINI OBSERVATORY

\$20,610,000
+\$1,020,000 / 5.2%

Gemini Observatory

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over FY 2014 Estimate	
			Amount	Percent
\$18.15	\$19.59	\$20.61	\$1.02	5.2%

Totals may not add due to rounding.

The Gemini Observatory consists of twin optical/infrared 8-meter telescopes, one each in the northern and southern hemispheres. Gemini North sits atop Mauna Kea, Hawaii at 4,200 meters elevation, while Gemini South is located on the 2,700 meter summit of Cerro Pachón, Chile. This siting of the two telescopes provides complete coverage of the sky and complements observations from space-based observatories. Both telescopes offer superb image quality and employ sophisticated adaptive optics technology to compensate for the blurring effects of the Earth's atmosphere.

Among the fundamental questions being investigated by today's astronomers are the age and rate of expansion of the universe, the origin of the "dark energy" that is manifested in the cosmic acceleration,



Night at the Gemini North telescope on Mauna Kea, Hawaii. The transparent-dome effect is created by the stacking of many images obtained throughout a night of observing. The central regions of our Milky Way galaxy seen against an incredibly dark sky provide a stunning backdrop to the telescope. *Credit: Gemini Observatory/AURA.*

the nature of non-luminous matter, the processes that give rise to the formation and evolving structures of galaxies, and the formation of stars and planetary systems. The current generation of large optical/infrared telescopes is central to these studies, owing to their unsurpassed sensitivity and spectral and spatial resolution. Technological advances incorporated into the design of the Gemini telescopes optimize their imaging capabilities and infrared performance as well as their ability to rapidly reconfigure the attached instrumentation in response to changing atmospheric conditions.

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 also provides an engaging focal point for public outreach and student training in all of the partner countries, and maintains "sister city" arrangements between the site hosts of Hilo, Hawaii and La Serena, Chile. Gemini-sponsored activities attract students and teachers at all levels of elementary through high school education. Gemini staff members provide guidance and support to the Imiloa Science Center, a public astronomy and cultural center in Hilo, Hawaii.

Total Obligations for the Gemini Observatory

(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	ESTIMATES ¹				
				FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$18.15	\$19.59	\$20.61	\$20.61	\$20.61	\$20.61	\$20.61	\$20.61

¹ Outyear funding estimates are for planning purposes only. The current cooperative agreement ends on December 31, 2015.

The international partnership that operates Gemini currently consists of the U.S., Canada, Australia, Brazil, Argentina, and Chile, with the U.S. as the majority partner. Construction of the telescopes and their instrumentation involved a large number of industrial entities in these and other countries, with areas of specialization that included large and/or complex optical systems, engineering, electronics, electro-mechanical systems, and computing, among others. Continued development in these technological areas is reflected in the instrumentation and facilities renewal activities that are incorporated into the overall budget of the Gemini Observatory.

Laser guide star systems, which greatly improve the telescopes' ability to correct for atmospheric blurring, are available at both facilities. The advanced "multi-conjugate" adaptive optics system on Gemini South is now in regular use, yielding crisper images in the near infrared than orbiting observatories and a larger field of view than any other astronomical adaptive optics system in the world. Several new Gemini instruments are in various states of development. On the southern telescope, a wide-field infrared imager/spectrometer has proven to be a powerful and productive addition, and the state-of-the-art Gemini Planet Imager will be in full operations during FY 2015, leading our quest to directly image and characterize planets around nearby stars.

The dome-shutter drive on Gemini-North failed on December 31, 2013, necessitating removal of the assembly and fabrication of special repair tools before observing could re-commence. Following a 10-day delay caused by inclement weather on Mauna Kea, the repaired drive was reinstalled and science observations restarted in mid-February, 2014.

The U.S. share of Gemini Observatory observing time is open to proposals by any researcher in the U.S. astronomical community, with peer-review allocation committees providing merit-based telescope time. NSF does not provide awards targeted specifically for use of Gemini. However, U.S. users are often supported through separate NSF research awards to pursue scientific programs that require the use of the Observatory.

In 2010, the National Research Council (NRC) conducted its sixth decadal survey in astronomy and astrophysics to recommend key science questions and new initiatives for the current decade. Since both the NRC recommendations and current programs could not be accommodated within present budget projections, the Division of Astronomical Sciences (MPS/AST), through the Advisory Committee of the Directorate for Mathematical and Physical Sciences, conducted a community-based portfolio review to make implementation recommendations that would best respond to the decadal survey science questions. The resulting report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges* (www.nsf.gov/mps/ast/ast_portfolio_review.jsp), was released in August 2012 and included recommendations related to all of the major telescope facilities funded by NSF. NSF released a Dear Colleague Letter, NSF 14-022, in December 2013 that outlines the current state of the NSF response to the facility recommendations (www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf14022).

The Portfolio Review Committee report ranked Gemini Observatory as a critical component of our Nation's future astronomical research resources and recommended that the U.S. retain a majority share in the international partnership for at least the next several years. However, given the constraints that were considered, the Committee recommended that the maximum U.S. contribution to Gemini operations in 2017 and beyond should be \$17.0 million per year. The Committee also recommended that the component of funding set aside for major instrumentation should be competed against other similarly-sized projects in the mid-scale program administered by the NSF Directorate for Mathematical and Physical Sciences, Division of Astronomical Sciences (MPS/AST).

The FY 2015 Request includes the full U.S. contribution to general operations at the level outlined in the Gemini international agreement (\$18.02 million in FY 2015), and a contribution of \$2.59 million to the Gemini Instrument Development Fund, \$1.0 million below the long-term international planning target. Future requirements will be considered in the context of NSF's overall actions on the 2012 Portfolio Review recommendations and discussion of the post-2015 international agreement with Gemini partners.

Management and Oversight

- **NSF Structure:** NSF has one seat on the Gemini Board. An additional NSF staff member serves as the executive secretary to the board. Programmatic management is the responsibility of an NSF program officer in MPS/AST. The program officer monitors operations and development activities at the Observatory, nominates U.S. scientists to Gemini advisory committees, conducts reviews on behalf of the partnership, and approves funding actions, reports, and contracts.
- **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 partnership, carrying out the project on their behalf. The U.S. holds six of the 13 seats on the Gemini Board (including the NSF seat mentioned above). Gemini is currently managed by the Association of 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:** NSF conducts periodic reviews of the management and Observatory programs as requested by the Gemini Board. The most recent mid-term management review was held in September 2008. In addition, NSF conducted a Business System Review of the Observatory in March 2009. The current cooperative agreement to AURA was awarded after a renewal proposal review in March 2011 and extends through December 31, 2015.

Renewal/Recompetition/Termination

In 2009, the United Kingdom announced its intention to withdraw from the Gemini partnership effective December 31, 2012. This required the Observatory to adjust its operations model to an approximately 24 percent reduction in budget, which will result in a reduction in total staffing from about 200 to less than 160 by the end of CY 2015. At present, Australia (6.3 percent share) is unable to commit to a specific funding level beyond 2015, so discussions regarding the distribution of this share are underway with potential international partners. The technical contents of a new International Agreement for the post-2015 years have been agreed on among the current partners. This agreement will enter the formal negotiation stage before FY 2015.

The current NSF cooperative agreement to AURA for managing the Gemini Observatory includes the transition to the new operations model. Reductions in project scope that accompany the decline in budget include a reduced instrument complement on each telescope, a reduction in labor for the scheduling queue, decreased development and outreach activities, and a tighter operational focus on serving the partner user communities vs. internal scientific research activities. The funding recommendation for this plan was approved by the National Science Board in February 2012.

Major Multi-User Research Facilities

In order to provide the most competitive atmosphere for managing the Gemini Observatory after the end of the current cooperative agreement in December 2015, NSF postponed issuance of a solicitation for proposals until summer 2014. This delay moves the Gemini solicitation beyond the timeframe when solicitations for two other major AST facilities are issued. Delaying the Gemini solicitation necessitates a one-year extension of the current Gemini cooperative agreement with AURA, a planned action that has been described to the National Science Board. The ensuing competed agreement for managing the Observatory is targeted to take effect January 1, 2017 and will cover a six-year period through December 31, 2022.

**GEODETIC FACILITIES FOR THE ADVANCEMENT OF
GEOSCIENCE AND EARTHSCOPE**

**\$11,580,000
\$0 / 0.0%**

**Geodetic Facilities for the Advancement of
Geoscience and EarthScope**

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over FY 2014 Estimate	
			Amount	Percent
\$9.28	\$11.58	\$11.58	-	-

The Geodetic Facilities for the Advancement of Geoscience and EarthScope (GAGE) comprise a distributed, multi-user, national facility for the development, deployment, and operational support of modern geodetic instrumentation to serve national goals in basic research and education in the Earth sciences with a focus on studies of Earth's surface deformation at many scales with unprecedented temporal and spatial resolution. GAGE facilities support fundamental research and discovery on continental deformation, plate boundary processes, the earthquake cycle, the geometry and dynamics of magmatic systems, continental groundwater storage, and hydrologic loading. GAGE is managed and operated for NSF by UNAVCO, Inc., a consortium of 106 U.S. universities and non-profit institutions with research and teaching programs in geophysics and geodesy and 88 associate members from foreign institutions. GAGE was formed in late FY 2013 from part of the EarthScope program and UNAVCO. FY 2013 funding is restated in all tables presented for comparative purposes.

Total Obligations for GAGE

(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	ESTIMATES ¹				
				FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$9.28	\$11.58	\$11.58	\$11.58	\$11.58	\$11.58	\$11.58	\$11.58

¹ Outyear funding estimates are for planning purposes only. The cooperative agreement began in FY 2013 and ends in FY 2017.

The ability to determine position with respect to a well-constrained terrestrial reference frame using space geodetic techniques has, over the last three decades, improved to submillimeter capability. Space geodesy applications are extremely broad and expanding to include important societal research on earthquake and tsunami hazards, volcanic eruptions, hurricanes, coastal subsidence, wetlands health, soil moisture, groundwater distribution, and space weather. Applications of geodetic techniques to understanding the complex interplay between climate change, continental ice sheet and mountain glacier dynamics, crustal isostatic adjustments, and sea level change is of foremost relevance to current global issues confronting humanity.

To serve the research needs of the broad Earth science community, GAGE is organized under three primary Service Areas and two Special Emphasis Areas:

- **Geodetic Infrastructure**

- The EarthScope Plate Boundary Observatory (PBO) includes more than 1,100 continuous Global Positioning System (GPS) stations distributed across the United States, and concentrated on the active plate boundaries in the western contiguous U.S. and southern Alaska. PBO also includes 75 borehole strainmeters and 78 borehole seismometers deployed along the San Andreas Fault and above the Cascadia subduction zone and volcanic arc. Tiltmeters (26) and pore pressure

- sensors (22) are also collocated with the other borehole instruments.
- Global GPS Arrays outside of the PBO footprint are supported by GAGE in partnership with investigators. Nearly 600 continuous GPS observations from around the world are maintained, monitored, and data compiled into the GAGE data system. GAGE supports 61 of the over 250 GPS sites in the National Aeronautics and Space Administration (NASA)-supported Global Navigation Satellite System (GNSS) array that supports satellite orbit and clock corrections and the refinement of the International Terrestrial Reference Frame (ITRF). GAGE is also developing a 100 station Caribbean region GPS and meteorological sensor network (COCONet) to support tectonic, volcano, tropical storm, and sea level change investigations.
 - Community GPS receiver and geodetic technology pool includes a pool of over 450 GPS receivers, ancillary equipment, and five terrestrial laser scanners (TLS), which can be used by investigators for short- and long-term deployments on qualified research projects.
 - Polar Networks supports GAGE's polar GPS networks in Antarctica (ANET) and Greenland (GNET) and development of specialized GPS monumentation, power, and telemetry solutions for use in harsh environments. GAGE also provides portable campaign deployment geodetic instrumentation, training, and field support for experiments in the polar regions. Additional supplemental funding for these activities is provided through the Division of Polar Programs (PLR).
 - Investigator Project Support includes project management, field engineering, and technical support services to plan and execute GPS surveys and permanent station installations. GAGE also maintains a staff focused on geodetic technology equipment testing services to evaluate new geodetic technologies and improve performance for science applications.
- **Geodetic Data Services**
Geodetic Data Services manages an archive of over 70 terabytes of GPS, laser scanning, Synthetic Aperture Radar (SAR) and borehole geophysical instruments from all GAGE components including EarthScope PBO, global continuous GPS networks, and campaign GPS observations; operates automated and manual systems to ensure the quality of all data stored in the archive; and provides systems to give the national and international research community timely access to these data. The archive of SAR imagery maintained and distributed by GAGE to support interferometric SAR imagery of continuous surface deformation at scales of 100s to 1,000 km is complementary to discrete GPS measurement of displacement. As the U.S. currently has no civilian spaceborne SAR sensor, UNAVCO, as the manager of GAGE, brokers for cost-effective community access to the SAR imagery acquired by foreign SAR satellite systems.
 - **Education and Community Engagement**
The GAGE Education and Community Outreach (ECE) Program enables audiences beyond geodesists to access and use geodetic data and research for educational purposes, including technical short courses, student internships, web-based materials, and programs for strengthening workforce development and improving diversity in the geosciences.
 - **Special Emphasis Areas**
 - Community Activities include scientific and technical workshops that bring together the international seismic community and publications designed to communicate GAGE activities and results to the community.
 - External Affairs maintains outreach efforts to policymakers and planning for coordination with the international geodesy community.

Besides its role in providing the observational data essential for basic Earth science research, GAGE also plays a significant role providing geodetic infrastructure support to NASA investigators and the

international community through activities in maintaining a subset of the Global GNSS Network (GGN); which supports the refinement of the ITRF and corrections to satellite orbits and clocks, all contributing to the capability for millimeter-level geodetic positioning, subtle observations of Earth's time-varying gravity field and detection of annual millimeter-level changes in sea level.

Commercial surveyors and engineering firms download GAGE facility real-time GPS data daily to support precision positioning. The economic impact of this service to the commercial sector has not been quantified, but is likely substantial.

Management and Oversight

- **NSF Structure:** The Division of Earth Sciences (EAR), through its Instrumentation & Facilities program (IF), provides general oversight of GAGE to help assure effective performance and administration. The program also facilitates coordination of GAGE programs and projects with other NSF-supported facilities and projects, and with other federal agencies, and evaluates and reviews the performance of UNAVCO in managing and operating GAGE. The Deep Earth Processes section head and division director in EAR provide other internal oversight.
- **External Structure:** GAGE is managed and operated by UNAVCO, which is incorporated as a non-profit consortium representing 106 U.S. universities and non-profit organizations with research and teaching programs that rely on geodetic technologies for Earth Science research. Each voting Member Institution of the Consortium appoints a Member Representative, and these Member Representatives elect the seven members of the UNAVCO Board of Directors, five of which are drawn from member institutions, and two Directors-at-Large. The Board members, who serve two-year terms, vet all internal program decisions associated with GAGE management and operation, through consultation with UNAVCO staff and GAGE advisory committees (one for each major GAGE component and additional *ad hoc* working groups appointed for special tasks). The Board of Directors appoints a president of UNAVCO to a renewable two-year term. The president is responsible for UNAVCO operations, all of which are managed through the UNAVCO Corporate Headquarters in Boulder, Colorado.
- **Reviews:** 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. The formal NSF merit review of the five-year proposal for the GAGE facility took place in 2012 and 2013 and was also the most recent review of UNAVCO. Although the *ad hoc* reviewers and two independent review panels had a number of specific recommendations at the working level for GAGE, overall the review found that GAGE was a critical facility for U.S. and international Earth sciences. Furthermore, the reviewers found that UNAVCO is a well-managed and effective organization that has, through its commitment to the collection and open dissemination of the highest quality geodetic data, transformed the discipline of geodesy and its geoscience applications.

Renewal/Recompetition/Termination

The initial cooperative agreement for GAGE began in FY 2013 and ends in FY 2017. In FY 2017, in keeping with the phased integration and recompetition plan presented to the National Science Board in December 2009, NSF intends to solicit proposals for a future facility or facilities to support the Earth sciences research and education community currently supported by GAGE and the related Seismological Facilities for the Advancement of Geoscience and EarthScope (SAGE). NSF is currently considering the precise form of this solicitation, and any possible future facility/facilities are currently being considered within NSF and through discussions with the GAGE and SAGE support communities.

ICECUBE NEUTRINO OBSERVATORY

\$6,900,000
\$0 / 0.0%

IceCube Neutrino Observatory
(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over	
			FY 2014 Estimate Amount	Percent
\$6.90	\$6.90	\$6.90	-	-

IceCube is the world’s first high-energy neutrino observatory, located deep within the ice cap under the U.S. Amundsen-Scott South Pole Station in Antarctica. With the discovery in 2013 of the first neutrinos from beyond our solar system, the Observatory has demonstrated that it represents a new window on the Universe, providing unique data on the engines that power active galactic nuclei, the origin of high-energy cosmic rays, the nature of gamma ray bursts, the activities surrounding supermassive black holes, and other violent and energetic astrophysical processes. Approximately one cubic kilometer of ice is instrumented with photomultiplier (PM) tubes to detect neutrino-induced, charged reaction products produced when a high-energy neutrino interacts in the ice within or near the cubic kilometer fiducial volume. An array of 5,160 Digital Optical Modules (DOMs), each containing a PM and associated electronics, is distributed uniformly from 1.5 km to 2.5 km beneath the surface of the South Pole ice cap, a depth where the ice is highly transparent and bubble-free. The energy and arrival direction of high-energy neutrinos ranging in energy from 100 GeV (10^{11} electron Volts [eV]) to 10 PeV (10^{16} eV) are derived from the IceCube data stream.

The Observatory includes a Deep Core Array (DCA). The DCA is composed of eight strings with the DOMs concentrated in the lower-middle part of the array. The tighter spacing of the DOMs allows the Observatory to detect lower energy neutrinos (down to about 10 GeV), thus opening the door to studies of neutrino oscillation measurements and studies of Weakly Interacting Massive Particles (WIMPs) below 250 GeV. In essence, the DCA closes the energy gap between the IceCube Neutrino Observatory and the Super-Kamiokande detector in Japan, and also allows effective observations of high-energy neutrinos entering from the sky of the southern hemisphere.



The IceCube project has transformed one cubic kilometer of natural Antarctic ice into a particle detector. The sensors keep watch for momentary flashes of blue light made by subatomic particles called muons; some are produced in collisions of neutrinos with atomic nuclei inside or near the detector. Since completion in 2010, the IceCube detector has been taking data in its final configuration with an up-time of well over 99 percent. IceCube detects one neutrino every 6 minutes in a background of 2700 cosmic ray muons per second. To handle the high rates, initial analysis of the data is performed by a cluster of computers housed in a two-story building placed on top of the array. The filtered data is sent over geostationary satellites to the IceCube Research Center at the University of Wisconsin. *Credit: USAP Photo Library, Sven Lidstrom (sic), NSF.*

Total Obligations for IceCube

(Dollars in Millions)

	FY 2013	FY 2014	FY 2015	ESTIMATES ¹				
	Actual	Estimate	Request	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations & Maintenance (MPS)	\$3.45	\$3.45	\$3.45	\$3.45	\$3.45	\$3.45	\$3.45	\$3.45
Operations & Maintenance (GEO)	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45
TOTAL, IceCube	\$6.90	\$6.90	\$6.90	\$6.90	\$6.90	\$6.90	\$6.90	\$6.90

Totals may not add due to rounding.

¹ Outyear funding estimates are for planning purposes only. FY 2015 is the final year of the current cooperative agreement. Funding beyond FY 2015 assumes continued operation of the facility.

The IceCube Neutrino Observatory is led by the University of Wisconsin (UW) and was constructed with support from four countries (U.S., Belgium, Germany, and Sweden). The science collaboration is much broader, currently consisting of 16 U.S. institutions and 22 institutions in nine other countries (Germany, Belgium, Sweden, New Zealand, Australia, Canada, Japan, Switzerland, and the United Kingdom). NSF's foreign partners contribute a *pro rata* share of operations and maintenance costs based on the number of PhD-level researchers involved. IceCube construction was successfully completed at the South Pole on December 18, 2010.

Management and Oversight

- NSF Structure: Oversight of the IceCube Neutrino Observatory is the responsibility of the Geosciences Directorate's Division of Polar Programs (PLR). Support for operations and maintenance, research, and education and outreach is shared by PLR and the Directorate for Mathematical and Physical Sciences (MPS) Physics Division, as well as other organizations and international partners. NSF provides oversight through regular site visits by NSF managers and external reviewers.
- External Structure: The UW management structure for IceCube includes leadership by the project's Principal Investigator and a project director. At lower levels, project management includes international collaboration representatives, as well as participation by staff at collaborating U.S. institutions. UW has in place an external Scientific Advisory Committee and a Software and Computing Advisory Panel that meet annually and provide written advice to the project. UW leadership, including the Chancellor, provides additional awardee-level oversight.
- Reviews: NSF will begin a process for re-competition of the operations and maintenance award in FY 2014. A new award is expected to be in place for FY 2016.

Operations Costs

Full operations and maintenance in support of scientific research began in FY 2011. The associated costs are and will continue to be shared by the partner funding agencies – U.S. (NSF) and non-U.S. – proportional to the number of PhD researchers involved (currently about 55:45). The current NSF award for operations and maintenance constitutes the bulk of the U.S. contribution to general operation of the facility. In addition, work in support of facility operations is performed by students, postdocs, and senior researchers who are participating in research on the data produced by the Observatory.

Support for U.S. institutions working on more refined and specific data analyses, data interpretation (theory support), and instrumentation upgrades is provided through the Research and Related Activities (R&RA) account in response to merit-reviewed proposals.

The general operations of South Pole Station, reported in the Polar Facilities and Logistics narrative, also contribute to supporting IceCube. The cost of IceCube operations shown in the table herein includes only those that are project-specific and incremental to general South Pole Station operations. The expected

operational lifespan of the IceCube Neutrino Observatory is 25 years beginning in FY 2011.

Education and Outreach

IceCube provides a vehicle for helping to achieve national and NSF education and outreach goals. Specific outcomes include the education and training of next-generation leaders in astrophysics, including undergraduate students, graduate students, and postdoctoral research associates; K-12 teacher scientific/professional development, including development of new inquiry-based learning materials and using the South Pole environment to convey the excitement of astrophysics, and science generally, to K-12 students; increased opportunity for involvement of students in international collaborations; increased diversity in science through partnerships with minority institutions; and enhanced public understanding of science through broadcast media and museum exhibits (such as the Adler Planetarium) based on IceCube science and the South Pole environment. NSF supports evaluation and measurement-based education and outreach programs under separate grants to universities and other organizations that are selected following standard NSF merit review.

Renewal/Recompetition/Termination

The current IceCube maintenance and operations award expires in September 2015. A solicitation for re-competition, conducted in accordance with NSF policy, will be issued in spring 2014; a new award is expected to be in place at the start of FY 2016.

THE INTERNATIONAL OCEAN DISCOVERY PROGRAM

\$48,000,000
-\$2,000,000 / -4.0%

International Ocean Discovery Program

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over FY 2014 Estimate	
			Amount	Percent
\$47.70	\$50.00	\$48.00	-\$2.00	-4.0%

The International Ocean Discovery Program (IODP) began in FY 2014 as the replacement for the Integrated Ocean Drilling Program and the prior Ocean Drilling Program. The new IODP represents an international partnership of the scientists, research institutions, and funding organizations of 28 nations to explore the evolution and structure of Earth as recorded in the ocean basins. The new program management structure is streamlined and focused on maximizing facility efficiency, while retaining the intellectual cooperation and exchange of the previous drilling programs. NSF, the Ministry of Education, Culture, Sport, Science and Technology (MEXT) of Japan, and the European Consortium for Ocean Research Drilling (ECORD) continue to provide drilling platforms. IODP platforms provide sediment and rock samples (cores), in-situ monitoring, sampling, and measurement from borehole observatories, shipboard and shore-based descriptive and analytical facilities, down-hole geophysical and geochemical measurements (logging), and opportunities to conduct experiments to determine in-situ conditions beneath the sea floor.



JOIDES Resolution underway for a science expedition, March 10, 2009. Credit: NSF

Total Obligations for IODP

(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	ESTIMATES ¹				
				FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$47.70	\$50.00	\$48.00	\$47.00	\$46.00	\$45.00	\$45.00	\$45.00

Totals may not add due to rounding.

¹ Outyear funding estimates are for planning purposes only. Funding for FY 2016 through FY 2019 is estimated for planning purposes only.

Annual operations and maintenance support for operating the *JOIDES Resolution*, the most-used platform of IODP, represents NSF’s primary contribution to IODP. The *JOIDES Resolution* is leased from an offshore drilling contractor under a long-term contract with favorable day rates. Another commercial contractor provides down-hole-logging services. Maintaining databases and core repositories, preparing scientific publications emerging from *JOIDES Resolution* IODP expeditions, and management of international program proposal review through an IODP Support Office represent additional NSF IODP science integration costs, made minimal to NSF because of international contributions to the program. In addition, NSF provides support for U.S. scientists to sail on IODP drilling platforms and to participate in IODP advisory panels through an associated grants program. The annual costs for the associated science

integration and science support (not included in the table above) are approximately \$8.0 million.

The new IODP scientific program includes emphasis on the following research themes:

- Climate and Ocean Change: Reading the Past, Informing the Future;
- Biosphere Frontiers: Deep Life, Biodiversity, and Environmental Forcing of Ecosystems;
- Earth Connections: Deep Processes and Their Impact on Earth's Surface Environment; and
- Earth in Motion: Processes and Hazards on Human Time Scales.

An umbrella IODP Forum provides a venue for all IODP entities to exchange ideas and views on the scientific progress of the program. In the simplified new IODP management structure, each drillship is governed by independent facility boards, each unique and optimized for their respective drilling platform. In the case of the *JOIDES Resolution* Facility Board (JRFB), two advisory panels review proposals and give science and safety advice. A U.S. scientist leads the JRFB, with other members from the scientific community, funding agencies, and the facility operator. The other IODP platforms utilize the JRFB advisory panels for drilling proposal review.

IODP participants include the United States, Japan, ECORD (Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Israel, Italy, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, and the United Kingdom), Brazil, the People's Republic of China, Korea, India, Australia, and New Zealand, with all participants except Japan providing financial contributions to *JOIDES Resolution* operations. Japan provides program support through substantial investment in *Chikyu* operations, with U.S. and Japanese scientists enjoying reciprocal rights on each drilling vessel.

Nearly 3,400 scientists from 51 nations have participated on Ocean Drilling Program and Integrated Ocean Drilling Program expeditions since 1985, including 1,450 U.S. scientists from over 150 universities, government agencies, and industrial research laboratories. Samples and data have been distributed to at least 1,000 additional U.S. scientists. Scientists from these groups propose and participate in IODP cruises, are members of the program's advisory panels and groups, and supply data for planning expeditions and interpretation of drilling results.

Management and Oversight

- NSF Structure: The Division of Ocean Sciences (OCE) in the Directorate for Geosciences (GEO) manages IODP operations of the *JOIDES Resolution* and the IODP Support Office under the NSF Ocean Drilling Program. NSF's Ocean Drilling Program is located within the Integrative Programs section, with two program officers dedicated to its oversight. One of the program officers has responsibility for two cooperative agreements supporting *JOIDES Resolution* operations and the IODP Support Office, while the other oversees the NSF ODP grants program.
- External Structure: NSF provides the *JOIDES Resolution* as the light IODP drillship through a cooperative agreement with Texas A&M University. MEXT provides the *Chikyu* as the heavy IODP drillship through the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), while the British Geological Survey manages ECORD drilling contributions through single-use Mission-Specific Platforms. Each entity providing an IODP drilling platform is responsible for sample and data storage, publications, and other science costs associated with the respective platform operations.
- IODP *JOIDES Resolution* operations are determined by the JRFB, utilizing advice and recommendations provided by the Science Evaluation Panel (SEP) and the Environmental Protection and Safety Panel (EPSP). Representation on the panels is determined by contribution level to *JOIDES Resolution* operations and exchange with other facility boards.
- Reviews: Performance of the *JOIDES Resolution* facility will be reviewed by NSF panel yearly in consultation with the JRFB. Substantive review of management performance regarding *JOIDES Resolution* operations will occur in the third year of the cooperative agreement to guide renewal or re-

competition decisions. Review of scientific progress in broader thematic areas is conducted under the authority of the IODP Forum.

Renewal/Recompetition/Termination

After competitive selection, Texas A&M University was selected in FY 2014 to be the *JOIDES Resolution* operator under a cooperative agreement. This cooperative agreement contains language encouraging the awardee to facilitate novel partnerships involving support of *JOIDES Resolution* operations between the U.S. scientific drilling community and commercial industry, thereby providing new intellectual opportunities and potential reduction in overall facility cost.

To facilitate and support the activities of U.S. scientists participating in IODP activities, an IODP Science Support Office was funded in July 2013 at the University of California, San Diego after competitive selection.

The *JOIDES Resolution* operations and science support cooperative agreements contain a provision for annual external review of performance by an independent panel. A more intensive mid-award review at the end of the third year, in FY 2017, will consider whether the cooperative agreement should be extended or re-competed. NSF and its IODP partners contributing funds to *JOIDES Resolution* operations are negotiating formal agreements, which identify rights of participation on the *JOIDES Resolution* and its facility board and advisory panels based upon partner financial contributions to *JOIDES Resolution* operations. A brief letter of understanding regarding berthing exchange has been negotiated between NSF and the Japanese Agencies MEXT and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Similarly, MEXT manages its drillship through JAMSTEC, while the British Geological Survey manages ECORD drilling contributions.

LARGE HADRON COLLIDER

\$18,000,000
+\$630,000 / 3.6%

Large Hadron Collider

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over	
			FY 2014 Estimate Amount	Percent
\$18.00	\$17.37	\$18.00	\$0.63	3.6%

Totals may not add due to rounding.

The Large Hadron Collider (LHC), an international project at the CERN laboratory in Geneva, Switzerland, is the most powerful particle accelerator ever constructed. It produces the most intense and highest energy particle beams ever created, making it the premier facility in the world for research in elementary particle physics. The LHC consists of a superconducting particle accelerator providing two counter-rotating beams of protons, approximately 16.5 miles in circumference, each beam with up to 7 TeV (1TeV=10¹² electron volts) of energy. It can also provide colliding beams of heavy ions, such as lead. Data-taking with colliding proton beams at 4 TeV ended in December 2012 at which point the LHC was reconfigured to deliver heavy ion collisions for six weeks. In March 2013, the LHC began a 20-month period of extensive repairs and enhancements that will enable it to operate at the full design energy of 7 TeV per beam.

Four large particle detectors collect the data delivered by the LHC. A world-wide dedicated cyber-infrastructure allows scientists to access and analyze the vast data sets. The U.S. participates in the two of the largest particle detectors, a Toroidal LHC Apparatus (ATLAS) and the Compact Muon Solenoid (CMS). These have been built to characterize the reaction products produced in the high-energy proton-proton collisions and heavy ion beam collisions. A total of 45 international funding agencies provide support for scientists in the ATLAS experiment and 42 for the CMS experiment. NSF and the Department of Energy (DOE) provide support for U.S. participation in both experiments. CERN is responsible for meeting the goals of the international LHC project. During periods of LHC operations, the ATLAS and CMS detectors collect data approximately 200 days per year. The remaining time is used for maintenance and testing. During the 20-month maintenance period noted above, the detectors are also undergoing an extensive series of repairs and enhancements to prepare for higher-energy operations.

The successful operation during 2012 of the accelerator complex, the ATLAS and CMS detectors, and the world-wide LHC computing grid culminated in the first major discovery at the LHC. On July 4, 2012, the CMS and ATLAS collaborations announced the discovery of a particle consistent with the long-sought Higgs boson. Further study of the properties of this new particle suggest that it is probably the Higgs boson that is predicted in the Standard Model of particle physics, which provides a deeper understanding of the origin of mass of known elementary particles. This achievement was recognized by the 2013 Nobel Prize in Physics to Francois Englert and Peter Higgs for the “theoretical discovery of a mechanism that contributes to our understanding of the origin of mass.” The LHC program also includes searches for particles predicted by a powerful theoretical framework known as supersymmetry, which may provide clues as to how the known forces – weak, strong, electromagnetic, and gravitational – 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 www.quarknet.fnal.gov).

Total Obligations for LHC

(Dollars in Millions)

	FY2013	FY2014	FY 2015	ESTIMATES ¹				
	Actual	Estimate	Request	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$18.00	\$17.37	\$18.00	\$18.00	\$20.00	\$20.00	\$20.00	\$20.00

¹ Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2016.

The U.S. LHC collaboration continues to be a leader in the development and exploitation of distributed computing. The LHC grid enables U.S. universities to access LHC data and computing resources, and thus train students, in both state of the art science and computational techniques. The distributed computing tools and techniques developed for the LHC are expected to have broad application throughout the scientific and engineering communities.

Both collaborations continue to operate the detectors smoothly and to analyze the collected data efficiently using world-wide computing resources. The LHC experiments are also adapting to the continued increases in beam energy and intensity. While challenging, these increases significantly enhance the chances of more ground-breaking discoveries at the LHC. During the current accelerator shut-down period, the collaborations are carrying out needed maintenance on the detectors while continuing to analyze the many Petabytes of data collected in the previous two years.

Management and Oversight

- NSF Structure: A program director in the NSF Directorate for Mathematical and Physical Sciences, Division of Physics (MPS/PHY) is responsible for day-to-day project oversight.
- 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. NSF support for operations is provided through cooperative agreements with Princeton University for US-CMS and with Columbia University for ATLAS.
- Reviews: There is one major management/technical review each year with a panel of external, international experts, as well as bi-weekly telephone reviews by NSF/DOE program directors to monitor progress. The next major management/technical review is scheduled for March 2014. Two JOG review meetings per year monitor overall program management.



CMS Detector undergoing maintenance in December 2013. Credit: CERN.

Renewal/Recompetition/Termination

The LHC project is expected to continue at least through the end of the next decade. In December 2011, new cooperative agreements were negotiated with the ATLAS and CMS collaborations to extend funding for an additional five years (end of 2016) to support their role in the international collaborations. It is anticipated that the U.S. ATLAS and CMS collaborations will submit renewal proposals during 2016 for a continuation of support for an additional five years beyond the current agreements, beginning in FY 2017.

LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY

\$39,430,000
+\$3,000,000 / 8.2%

Laser Interferometer Gravitational-Wave Observatory

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over FY 2014 Estimate	
			Amount	Percent
\$30.50	\$36.43	\$39.43	\$3.00	8.2%

Totals may not add due to rounding.

Einstein’s theory of general relativity predicts that cataclysmic processes involving extremely dense objects in the universe, such as the collision and merger of two neutron stars or black holes, will produce gravitational radiation. Detection of these gravitational waves is of great importance for fundamental physics, astrophysics, and astronomy. 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 an optical interferometer. The interferometers are used to measure minute changes in the distances between mirrors 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 source is on the order of one part in 10^{21} , meaning that the expected change over the apparent 4-km length is only on the order of 4×10^{-18} meters, 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 from both interferometers simultaneously increases the likelihood for gravitational wave detection.

Components for a third interferometer, initially intended for installation at Hanford as a further tool to discriminate candidate signals from random noise, have been set aside in response to an initiative from the Government of India to establish a gravitational wave observatory there. If realized, this third interferometer would, in addition to increasing noise immunity, greatly enhance LIGO’s angular resolution of candidate gravitational wave sources, facilitating follow-up investigations using optical and radio telescopes.

In April 2008 construction began on the Advanced LIGO (AdvLIGO) Major Research Equipment and Facility Construction (MREFC) project, which is designed to increase the sensitivity of LIGO tenfold. AdvLIGO is being built within the existing LIGO laboratory. LIGO's current and projected operations and maintenance expenses are designed to sustain operation of the LIGO laboratory while construction is underway, as well as to commission and operate the upgraded apparatus following the completion of construction in 2015. These include support for basic infrastructure costs not directly related to the AdvLIGO construction project, analysis and



An aerial view of the Livingston, LA LIGO site. Credit: Caltech/MIT LIGO Laboratory.

dissemination of data obtained from the interferometers, maintenance of computational resources for data storage and analysis, complementary research and development expected to enhance operational performance and reduce technical risk, and education and outreach activities associated with the laboratory.

The LIGO Science Education Center at the Livingston site is the focal point for augmenting teacher education at Southern University and other student teacher activities state wide through the Louisiana Systematic Initiative Program. The LIGO Science Education Center's programs include funding for an external evaluation firm that provides both assistance in aligning future activities with proposed goals and evaluating outcomes.

In order to meet its cutting-edge performance requirements, substantial connections with industry have resulted from the undertaking of the AdvLIGO project. Innovations across a diverse range of technologies have led to new techniques with broad applications, and in other cases have resulted in patents and commercial products.

Total Obligations for LIGO

(Dollars in Millions)

	FY2013	FY2014	FY 2015	ESTIMATES ¹				
	Actual	Estimate	Request	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$30.50	\$36.43	\$39.43	\$39.43	\$39.43	\$39.43	\$39.43	\$39.43

¹ Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2018.

The LIGO Scientific Collaboration (LSC), an open collaboration that organizes the major international groups doing research supportive of LIGO, has more than 80 collaborating institutions in 15 countries with more than 900 participating scientists. LSC membership is growing at a rate of approximately 10 percent per year. The LSC plays a major role in many aspects of the LIGO effort, including establishing priorities for scientific operation, data analysis and validation of scientific results, and for instrumental improvements at the LIGO facilities, as well as fostering education and public outreach programs. NSF supports LSC activities at \$7.0 to \$8.0 million per year, which is provided through regular disciplinary program funds.

Upon completion of the AdvLIGO project, expected in April 2015, LIGO operations will expand to encompass commissioning and operation of the new instrumentation. NSF has determined operating budget requirements by assessing cost data from initial LIGO interferometer operation and scaling appropriately to reflect the increased support that will be needed to support the more complex AdvLIGO apparatus.

For more information on AdvLIGO, see the MREFC chapter.



Installation of a quantum-mechanical squeezing experiment at LIGO in 2011. The temporary experiment allowed LIGO to increase its sensitivity by more than 20 percent over most of its frequency range. Such research is conducted by LIGO Laboratory and the LIGO Scientific Collaboration to reduce risk in the Advanced LIGO construction project. *Credit: Caltech/MIT LIGO Laboratory.*

Management and Oversight

- NSF Structure: NSF oversight is coordinated internally by the LIGO program director in the NSF Directorate for Mathematical and Physical Sciences, Division of Physics (MPS/PHY), who also chairs the PHY AdvLIGO Project Advisory Team, comprised of the Physics Division Director, MPS Facilities Coordinator, staff from the NSF Office of General Counsel, Office of Legislative and Public Affairs, International Science and Engineering, program directors from elsewhere in NSF, as well as the the Deputy Director for Large Facility Projects in the Office of Budget, Finance, and Award Management.
- External Structure: LIGO is managed by the California Institute of Technology under a cooperative agreement. The management plan specifies significant involvement by the user community, represented by the LSC, and collaboration with the other major gravitational-wave detector activities in Asia, Europe, and Australia. External peer-review committees organized by NSF help provide oversight through an annual review.
- Reviews after 2010:
 - AdvLIGO Annual Review, April 2011
 - LIGO Annual Review and AdvLIGO Interim Review, November 2011
 - LIGO Annual Review and AdvLIGO Interim Review, November 2012
 - LIGO Annual Review and AdvLIGO Interim Review, May 2013
 - Additional reviews of Advanced LIGO construction and LIGO operation are planned during 2014.

Renewal/Recompetition/Termination

LIGO began operating under a new five-year cooperative agreement in early FY 2009. Following approval by the National Science Board in August 2013, the cooperative agreement was renewed at the beginning of FY 2014 for five additional years. 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.

NATIONAL HIGH MAGNETIC FIELD LABORATORY

\$33,670,000
+\$1,040,000 / 3.2%

National High Magnetic Field Laboratory

(Dollars in Millions)

FY 2013	FY 2014	FY 2015	Change over	
			FY 2014 Estimate	
Actual	Estimate	Request	Amount	Percent
\$31.62	\$32.63	\$33.67	\$1.04	3.2%

Totals may not add due to rounding.

The National High Magnetic Field Laboratory (NHMFL) is operated by Florida State University (FSU), University of Florida (UF), and Los Alamos National Laboratory (LANL). NHMFL develops and operates high magnetic field facilities that scientists and engineers use for research in condensed matter and material physics, materials science and engineering, chemistry, biology, biochemistry, neuroscience, energy, and the environment. It is the world’s premier high magnetic field laboratory with a comprehensive assortment of high-performing magnet systems and extensive support services. The facilities are available to all qualified scientists and engineers through a peer-reviewed proposal process. Users number about 1,100 per year, including faculty and staff at the three host institutions.

The laboratory is an internationally recognized leader in magnet design, development, and construction, including the development of conducting and superconducting materials. Many of the unique magnet systems were designed, developed, and built by the Magnet Science and Technology (MS&T) Division of the NHMFL. Since 2012, the laboratory has held the world’s record for the highest nondestructive pulsed magnetic field at 100.75 tesla. The 45 tesla hybrid magnet currently provides the highest steady-state magnetic fields in the world. Both magnets enable scientists to get new insights into the electronic structures of novel materials such as graphene, topological insulators, high temperature superconductors, and more. MS&T works with industry and other international magnet laboratories on a variety of technology projects. These include design and construction, component development, coil fabrication, cryogenics, system integration, and testing.

A \$15.0 million award funded by the American Recovery and Reinvestment Act of 2009 (ARRA) through the NSF Directorate for Mathematical and Physical Sciences, Division of Chemistry (MPS/CHE) enabled the purchase of a 21 tesla magnet for the construction of a Fourier Transform Ion Cyclotron Resonance Spectrometer (FT-ICR) that will be unprecedented in sensitivity and selectivity. This instrument will be capable of analyzing chemical samples of great complexity, such as biological fluids and biofuels, and with unprecedented resolution and speed. This new capability will have high impact in areas such as chemistry, molecular biology, and heavy petroleum analysis. The 21 tesla magnet is currently scheduled for delivery in late March 2014. Instrument development will follow for six to twelve months, and then it will be opened as a user facility.

The FY 2015 Request will allow the facility to continue operations, focus on magnet development, and strengthen education, training, user support, and in-house research. It is consistent with prior levels for this activity. A potential impact of this investment is the successful construction of a high temperature superconducting magnet, which would make very high magnetic fields attainable less expensively and using less energy. This would open the door for many laboratories to access high magnetic fields that would be transformational in many research areas, including the study of superconductivity. Another example of a potential breakthrough is in new imaging techniques for studying the brain. Currently Magnetic Resonance Imaging (MRI) and functional MRI have been based on imaging proton spin density

and intrinsic tissue relaxation rates. With higher magnetic field strengths, NHMFL is pushing to use other nuclei. New insights into mapping the brain and neurochemistry may result.

Total Obligations for NHMFL

(Dollars in Millions)

	FY2013	FY2014	FY 2015	ESTIMATES ¹				
	Actual	Estimate	Request	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$31.62	\$32.63	\$33.67	\$34.66	\$35.79	\$35.79	\$35.79	\$35.79

¹ Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in December 2017.

NHMFL collaborates with more than 60 private sector companies, including Cryomagnetics, Pfizer, SuperPower, and Oxford Superconductor Technologies, 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 at Argonne National Laboratory. International collaboration is strong; NHMFL recently delivered a 13 Tesla, 5-ton Superconducting Coil to the Helmholtz-Zentrum Berlin (HZB), where it will be used for neutron scattering experiments. Collaborations also exist with the International Thermonuclear Experimental Reactor (ITER) in France, and national magnet labs in France, the Netherlands, Germany, and China.

NHMFL provides a unique interdisciplinary learning environment. The Center for Integrating Research and Learning at NHMFL conducts education and outreach activities, which include a Research Experience for Undergraduates (REU) program, summer programs for teachers, a summer camp for middle school girls, and activities to raise the scientific awareness of the general public.

Management and Oversight

- NSF Structure: NHMFL is supported by the MPS Division of Materials Research (MPS/DMR), with the DMR program director as the primary contact for most of the laboratory. The MPS Division of Chemistry (MPS/CHE) supports the Fourier Transform Ion Cyclotron Resonance (FT-ICR) Laboratory, which is overseen by a CHE program director.
- External Structure: A consortium of three institutions (FSU, UF, and LANL) operates NHMFL 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 and reports to the FSU Vice President for Research. Four senior faculty members are co-principal investigators. The NHMFL director receives guidance primarily from the NHMFL executive committee and the NHMFL science council. He also receives recommendations from an external advisory committee, the NHMFL diversity committee, and the users' executive committee.
- Reviews: NSF conducts annual external reviews, 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. In addition to a panel of experts from the community, representatives from other federal agencies such as DOE and the National Institutes of Health (NIH) attend these site visits. Recent and upcoming reviews include:
 - Annual Site Review by external panel of site visitors, February 2014.
 - NSF initiated a broad-based community study through the National Research Council on opportunities in high magnetic field research. This report entitled "High Magnetic Field Science and Its Application in the United States," will be presented to the National Science Board in May

2014. Public town halls are planned at several relevant professional society meetings by both DMR and CHE. The report will inform future plans for investments in this area.

Renewal/Recompetition/Termination

A comprehensive renewal review was conducted in FY 2012 for a five year renewal award covering FY 2013 – FY 2017.

**NEXT-GENERATION NATIONAL NANOTECHNOLOGY
INFRASTRUCTURE NETWORK**

**\$15,460,000
\$0 / 0.0%**

**Next Generation National Nanotechnology
Infrastructure Network**

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	FY 2015 Request Change over FY 2014 Estimate	
			Amount	Percent
\$16.07	\$15.46	\$15.46	-	-

The National Nanotechnology Infrastructure Network (NNIN) completed its 10-year authorized funding in FY 2013. The National Science Foundation, having held an open competition, plans to establish a Next-Generation National Nanotechnology Infrastructure Network (NG NNIN) for FY 2014-2018. The competition for the NG NNIN has built upon the concept of NNIN in comprising multiple university sites to form an integrated national network of user facilities supporting research and education across diverse domains in nanoscale science, engineering, and technology. NG NNIN will continue to provide users across the Nation with access, both on-site and remotely, to leading-edge tools, instrumentation, and expertise for fabrication, synthesis, characterization, design, simulation, and integration. In addition, NG NNIN will offer a much-broadened scope and user base. The network will more fully serve users in the biological sciences, geosciences, and environmental sciences communities. It will provide a new generation of nanotechnology tools with advanced capabilities such as heterogeneous integration of complex systems, multi-dimension hierarchical design and fabrication, and fabrication in soft matter. NG NNIN will also emphasize nanoscale devices and systems with relevance in emerging nanotechnology applications and provide linkages with other federally supported networks and infrastructure investments.

Total Obligations for NG NNIN

(Dollars in Millions)

	FY 2013	FY 2014	FY 2015	ESTIMATES¹				
	Actual	Estimate	Request	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$16.07	\$15.46	\$15.46	\$16.00	\$16.00	\$16.00	\$16.00	\$16.00

¹ Outyear funding estimates are for planning purposes only. FY 2014 will be the first year of the cooperative agreement for NG NNIN. Funding beyond FY 2014 assumes continued operation of the facility as the next-generation NNIN, as described in the Renewal/Recompetition/Termination section of this narrative.

NG NNIN will continue, as have NNIN user facilities, by enabling the Nation’s researchers from academia, small and large industry, and government to pursue transformative research, seek new discoveries and applications in a broad range of domains of nanoscale science and engineering, and stimulate technological innovation. The current NNIN network has also developed 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. The NNIN user facilities have promoted interdisciplinary research by bridging the gap between materials, mechanics, electronics, photonics, biology and diverse fields, and enabling longitudinal pathways from fundamental studies to devices and systems.

NNIN has undertaken, 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 has been 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 has sought 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 has shared expertise and perspectives, provided specialized training opportunities, coordinated access to unique instrumentation, and transferred newly developed technologies.

NNIN has leveraged research strengths of universities to bring them to the external community. The institutions comprising the NNIN have had strong underlying internal research programs that provided the knowledge base for developing new processes, methodologies, and instrumentation, as well as much of the capital infrastructure. NSF and other agencies independently have awarded research grants to principal investigators who used NNIN facilities to carry out some aspects of their research projects.

During NNIN's tenth and final full-year of operation (encompassing the period from March 2013 through February 2014), 6,464 unique users performed a significant or critical part of their experimental work at the NNIN 14 facilities. This is an increase of one percent over the previous year period. Of these, 5,395 were U.S. academic users (roughly 85 percent graduate students, seven percent undergraduate students, and eight percent postdocs) from over 210 different academic institutions. In addition, 1,008 were U.S. industrial users, of which 766 were from small U.S. companies (representing 88 large U.S. companies and 371 small companies). Over 3,000 publications, patents, and patent applications, several of them significant scientific and engineering highlights of the year, resulted from the work of the user community. A major task of staff of NNIN is in training of this user community, particularly graduate students from across the United States, which has a continuous and significant turnover. A total of 2,569 new users were trained in the vast instrument set, large and small, at the networks facilities.

Management and Oversight

- NSF structure: In preparation for a new award for NG NNIN, NSF will continue to provide oversight under a cooperative agreement with the lead institution. The cognizant program officer for the NG NNIN activity will reside in the Division of Electrical, Communications and Cyber Systems (ECCS) in the Directorate for Engineering (ENG). The program officer will coordinate NG NNIN oversight with the NG NNIN working group comprised of representatives from all NSF directorates and the International Science and Engineering section of the Office of International and Integrative Activities. NG NNIN will be reviewed annually through site reviews held at one of the network sites. These reviews will involve an external team of experts selected by the NSF working group.
- External structure: NSF anticipates establishing a management structure for the NG NNIN that will be similar in concept to that for NNIN. Currently, 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 provides intellectual leadership for the network and is also responsible, in cooperation with the Network Executive Committee, for developing strategies, operational plans, and coordination of the activities of the network, and serves as the principal contact on behalf of the network with NSF. An external Network Advisory Board meets at least annually and provides independent advice and guidance to the network director and Executive Committee concerning the network's programs, activities, vision, funding allocations, and new directions. The Advisory Board shares its major recommendations with NSF. The site directors are responsible for local management functions of 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.

Renewal/Recompetition/Termination

The National Science Board, in its December 2008 meeting, authorized renewal of the NNIN award for a final five-year period from FY 2009-2013, stated that NSF was to “convene a panel of recognized national experts to look broadly at the future needs of, and appropriate investments in, the national infrastructure for nanotechnology.” Accordingly, a Nanotechnology Infrastructure Workshop was held in April 2012 that served to develop a vision for a next-generation nanotechnology infrastructure network. The workshop vision helped to form the basis of the NG NNIN solicitation for an open national competition for FY 2014 and beyond. The NG NNIN solicitation NSF 13-521 was released in December 2012, with the intent of making a new five-year award for FY 2014-2018. The potential award is to be renewable once, without recompetition, for an additional five years, subject to satisfactory review of performance and availability of funds. Multiple network proposals were submitted to the NG NNIN competition. These proposals collectively involved participation by a total of 38 individual academic institutions. The review process was conducted at NSF in two stages: mail and panel review; and reverse site review panel. The award decision is under final consideration at NSF.

NATIONAL SOLAR OBSERVATORY

\$13,000,000
+\$5,000,000 / 62.5%

National Solar Observatory

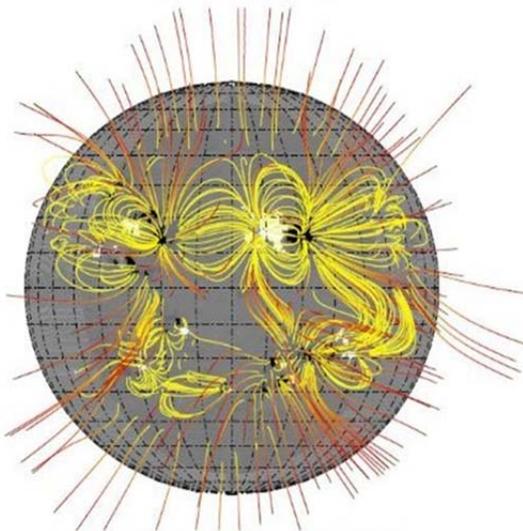
(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over FY 2014 Estimate	
			Amount	Percent
\$8.00	\$8.00	\$13.00	\$5.00	62.5%

Totals may not add due to rounding.

The FY 2015 Budget Request for the National Solar Observatory (NSO) is \$13.0 million. This is a \$5.0 million (62.5 percent) increase above the FY 2014 Estimate. This increase marks the beginning of a five-year funding ramp that will bring the NSO budget to a level commensurate with requirements to operate the Daniel K. Inouye Solar Telescope (DKIST)². This profile will fund the development of the DKIST science operations and data center concepts in preparation for full DKIST operations expected to begin in 2019.

NSO currently operates facilities in New Mexico and Arizona as well as a coordinated worldwide network of six telescopes specifically designed to study solar oscillations. NSO also provides leadership to the solar community through construction of DKIST. (See the Major Research Equipment and Facilities Construction (MREFC) chapter for more information.) 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 also provides routine and detailed, synoptic solar data used by individual researchers and other government agencies through the NSO Digital Library. NSO data is also made available to the user community via the Virtual Solar Observatory.



The solar magnetic field as derived from magnetograms produced by NSO's SOLIS Vector Spectromagnetograph (VSM) Instrument. Credit: Tadesse et al. 2013, *Astronomy & Astrophysics*, 550, A14.

NSO telescopes are open to all astronomers regardless of institutional affiliation on the basis of peer-reviewed observing proposals. In FY 2013, 64 unique observing programs from 16 U.S. and 11 foreign institutions were carried out using NSO facilities. Students were involved in 28 percent of these programs, which included 11 Ph.D. thesis projects. Over ten terabytes of NSO synoptic data were downloaded from the NSO Digital Library, with approximately 65 percent of the downloads coming from U.S. science institutions (.gov, .edu, and .mil), five percent from other U.S. sources (.com, .net, etc.), and the remaining 30 percent of the downloads coming from international sources. Approximately 137 staff members were employed at NSO in FY 2013, including 50 FTEs employed on the DKIST construction project funded via the MREFC account as mentioned above.

² On December 15, 2013, the Advanced Technology Solar Telescope was renamed after the late Senator Daniel K. Inouye as an acknowledgement of his profound commitment to fundamental scientific research and discovery.

Major Multi-User Research Facilities

In 2010, the National Research Council (NRC) conducted its sixth decadal survey in astronomy and astrophysics to recommend key science questions and new initiatives for the current decade. Since both the NRC recommendations and current programs could not be accommodated within present budget projections, the Division of Astronomical Sciences (MPS/AST), through the Advisory Committee of the Directorate for Mathematical and Physical Sciences, conducted a community-based portfolio review to make implementation recommendations that would best respond to the decadal survey science questions. The resulting report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges* (www.nsf.gov/mps/ast/ast_portfolio_review.jsp), was released in August 2012 and included recommendations related to all of the major telescope facilities funded by NSF. NSF released a Dear Colleague Letter, NSF 14-022, in December 2013 that outlines the current state of the NSF response to the facility recommendations (www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf14022).

Prior to receiving the Portfolio Review report, NSF had instructed NSO to begin divestment of the McMath-Pierce solar telescope on Kitt Peak, thereby accelerating the already-planned divestment by a few years. The Portfolio Review Committee endorsed this decision. In addition, the Portfolio Review Committee recommended continued operation of the Dunn Solar Telescope through 2017 and reduced support of the NSO synoptic program. For NSO, the next steps identified in NSF 14-022 involve testing a new consortium arrangement for operating the McMath-Pierce, assessing the NSO plan for the synoptic program in the context of the NSO renewal proposal, and deferring a decision on the Dunn Solar Telescope until a time closer to operational readiness of DKIST.

Total Obligations for NSO

(Dollars in Millions)

	FY 2013	FY 2014	FY 2015	ESTIMATES ^{1,2}				
	Actual	Estimate	Request	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
NSO Operations	\$7.70	\$7.75	\$7.75	\$6.75	\$5.75	\$4.75	\$3.75	\$3.75
NSO Education & Public Outreach	0.30	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DKIST Operations ²	-	-	5.00	9.00	11.50	14.50	17.00	17.50
Total, NSO	\$8.00	\$8.00	\$13.00	\$16.00	\$17.50	\$19.50	\$21.00	\$21.50

Totals may not add due to rounding.

¹ Outyear funding estimates are for planning purposes only. The current cooperative agreements ends on Dec. 31, 2014.

² Total Research and Related Activities funding for DKIST consists of \$5.0 million through NSO, as shown above, and \$2.0 million for cultural mitigation activities as agreed to during the compliance process that is not funded through NSO. See the MREFC chapter for more information on DKIST.

Partnerships and Other Funding Sources: The managing organization for NSO is the Association of Universities for Research in Astronomy, Inc. (AURA), which comprises 39 U.S. member institutions and seven international affiliate members. NSO partners include the U.S. Air Force Research Laboratory (AFRL), U.S. Air Force Weather Agency (AFWA), NASA, and industrial entities. The Air Force is the most significant source of external funding to the NSO, providing \$785,000 in operational support for FY 2014. Approximately \$400,000 is provided by AFRL in exchange for NSO support for AFRL staff at the Sacramento Peak facility. The remaining \$385,000 is provided by AFWA in support of Global Oscillations Network Group (GONG) operations that are used for operational space weather prediction. Other funding entities include universities and institutes, which collaborate with NSO on solar instrumentation development and on the design and development of DKIST. New telescopes, instrumentation, and sensor techniques are developed through industry sub-awardees in aerospace, optical fabrication, and information technology.

NSO Operations, \$7.75 million: NSO Operations includes operations at Sacramento Peak Observatory in New Mexico, facilities based on Kitt Peak, Arizona, and the world-wide NSO Integrated Synoptic Program consisting of the GONG array and the SOLIS (Synoptic Optical Long-term Investigations of the

Sun) telescope.

DKIST Operations, \$5.0 million: The initial request for DKIST Operations represents the beginning of a five-year funding ramp that will bring the NSO budget to a level commensurate with requirements to operate the Daniel K. Inouye Solar Telescope (DKIST). This profile will fund the development of the DKIST science operations and data center concepts in preparation for full DKIST operations expected to begin in 2019. DKIST construction is not funded here, but instead through the MREFC account. After FY 2015, DKIST is expected to dominate the NSO Operations budget.

Education and Public Outreach, \$250,000: NSO supports U.S. education goals by promoting public understanding and support of science and by providing education and training at all levels. NSO introduces undergraduate students to scientific research by providing stimulating environments for basic astronomical research and related technologies through NSF's Research Experiences for Undergraduates (REU) program. NSO has diverse education programs, including teacher training and curriculum development, visitor centers, and a web-based information portal at www.nso.edu.

Management and Oversight

- **NSF Structure:** An NSF program officer in AST provides continuing oversight, including consultation with an annual NSF program review panel. The program officer makes use of detailed annual program plans, annual long-range plans, quarterly technical and financial reports, and annual reports submitted by NSO as well as attending AURA Solar Observatory Council meetings. The latter committee is formed from the national solar physics community and provides a window into community priorities and concerns. The AST program officer works closely with other offices at NSF, particularly the Division of Acquisition and Cooperative Support, the Office of General Counsel, and the Large Facilities Office in the Office of Budget, Finance, and Award Management.
- **External Structure:** AURA is the managing organization for NSO. The NSO Director reports to the president of AURA, who is the principal investigator on the FY 2010 NSF cooperative agreement. AURA receives management advice from its Solar Observatory Council, composed of members of its scientific and management communities. NSO employs visiting and users committees for the purposes of self-evaluation and prioritization. The visiting committee, composed of nationally prominent individuals in science, management, and broadening participation, reviews for AURA all aspects of the management and operations of NSO. The users committee, composed of scientists with considerable experience with the observatory, reviews for the NSO Director all aspects of NSO that affect user experiences at the observatory.
- **Reviews:** In addition to reviews held mid-way through all cooperative agreements, NSF conducts periodic and ad hoc reviews, as needed, by external committees. The last extensive NSO review was in FY 2008 and led to the award of a new cooperative agreement in early FY 2010. A Business Systems Review was held in Spring 2013. A re-baseline review for the DKIST project, described in the DKIST narrative in the MREFC chapter, was held in October 2012. The next extensive review of NSO is being conducted in early 2014 as part of the renewal of the cooperative agreement.

Renewal/Recompetition/Termination

The National Science Board (NSB) authorized a cooperative agreement with AURA for management and operation of NSO for October 1, 2009 through March 31, 2014. Since NSO is the home for the DKIST construction project, and DKIST is not expected to begin operation until 2019, it was determined that competition of the NSO cooperative agreement should take place after DKIST has achieved full operations. Thus, the current cooperative agreement was extended through December 31, 2014, and a proposal for the longer-term renewal of the agreement was requested from AURA. This proposal was received by NSF in October 2013 and is undergoing merit review. Following the conclusion of the review process, a new cooperative agreement is expected to be presented to NSB in August 2014.

NATIONAL SUPERCONDUCTING CYCLOTRON LABORATORY

\$22,500,000
\$0 / 0.0%

National Superconducting Cyclotron Laboratory

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over	
			FY 2014 Estimate Amount	Percent
\$21.50	\$22.50	\$22.50	-	-

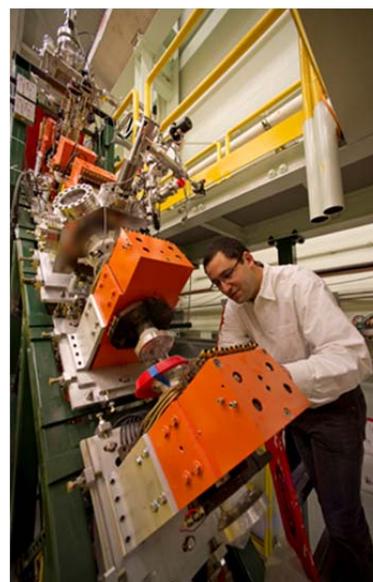
The National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) is a university-based national user facility. With two linked superconducting cyclotrons, K500 and K1200, it is the leading rare isotope research facility in the U.S. and is among the world leaders in heavy ion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

NSCL scientists employ a range of tools for conducting advanced research in fundamental nuclear science, nuclear astrophysics, and accelerator physics. Applications of research conducted at 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 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. The laboratory has completed construction and is commissioning an MSU-funded reaccelerator facility (ReA3) that will enable experiments at very low energies – a domain of particular interest to nuclear astrophysics. In 2013, NSCL was the first laboratory to host a new DoE-funded gamma-ray detector (GRETINA), and it completed a very successful campaign of research experiments employing it.

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. The lab also provides research experiences for undergraduate students, K-12 students, and K-12 teachers.

The coupled cyclotron facility supports a broad experimental program. The mix of experiments is determined by beam use proposals. An external program advisory committee selects the best proposals at a typical success rate of about 50 percent. The science output of NSCL is driven by these experiments, with most running one to three days.



Research Physicist Fernando Montes inspects a beamline at the reaccelerated beam facility (ReA3) at NSCL. Credit: NSCL.

Total Obligations for NSCL

(Dollars in Millions)

	FY 2013	FY 2014	FY 2015	ESTIMATES ¹				
	Actual	Estimate	Request	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$21.50	\$22.50	\$22.50	\$22.50	\$22.50	\$22.50	\$20.00	\$15.00

¹ Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2016.

Management and Oversight

- NSF Structure: MSU operates NSCL under a cooperative agreement with NSF. NSF oversight is provided through annual site visits by the cognizant program officer of the NSF Directorate for Mathematical and Physical Sciences, Division of Physics (MPS/PHY) and other staff, accompanied by external experts.
- External Structure: NSCL is managed by a director and four associate directors for research, education, operations, and new initiatives. The director has the authority to appoint associate directors and designate responsibilities, notifying NSF of changes. NSCL’s research program is guided by a program advisory committee of external experts as well as an in-house expert, and includes the chairperson of the full NSCL user group. The procedure for users includes writing and submitting proposals to the NSCL director and oral presentations. There are two proposal submission opportunities each year. About 4,000 beam hours are provided for experiments annually, with a backlog of at least a year.
- Reviews:
 - A 5-year review in FY 2011 covered results and achievements related to intellectual merit and broader impacts for the past five years (FY 2007 – FY 2011) and future funding for the next five years (FY 2012 – FY 2016).
 - Latest Review: An annual review of the science, operations, and future funding was in June 2013.
 - Next Review: An annual review is planned for June 2014.

Renewal/Recompetition/Termination

Over the next several years, NSCL will transition to the new Facility for Rare Isotope Beams (FRIB), which will be built by the Department of Energy (DOE) on the site of the present NSCL and will make use of much of the NSCL beamlines and general infrastructure. MSU will be the performing institution under a cooperative agreement with DOE for the future FRIB. To facilitate interagency planning and allow for a smooth transition from the NSF-funded NSCL to the DOE-funded FRIB, a Joint Oversight Group (JOG) of DOE and NSF personnel has been established. NSF anticipates eventually phasing out funding for operations and maintenance for the NSCL facility, as indicated in the table above for FY 2016 through FY 2020. DOE and NSF will coordinate transfer of facility stewardship as it transitions from NSCL to FRIB. NSF will continue to fund individual investigators carrying out research at the new FRIB.

NETWORK FOR EARTHQUAKE ENGINEERING SIMULATION **\$12,000,000**
-\$8,000,000 / -40.0%

Network for Earthquake Engineering Simulation

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	FY 2015 Request Change over FY 2014 Estimate	
			Amount	Percent
\$21.82	\$20.00	\$12.00	-\$8.00	-40.0%

The Network for Earthquake Engineering Simulation (NEES) is a national, networked simulation resource of 14 advanced, geographically distributed, multi-user 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 United States, networked together through a high performance Internet2 cyberinfrastructure system (NEEShub). NEES completed construction on September 30, 2004, and opened for user research and education projects on October 1, 2004. NEES was operated during FY 2005-FY 2009 by NEES Consortium, Inc., located in Davis, CA. During FY 2008 and FY 2009, NSF recompeted NEES operations using program solicitation NSF 08-574, George E. Brown, Jr. Network for Earthquake Engineering Simulation Operations (NEES Ops) FY 2010-FY 2014. The outcome of that competition was an award to Purdue University for a five-year cooperative agreement with NSF to operate NEES from FY 2010-FY 2014. Purdue University operates the NEES experimental facilities and cyberinfrastructure; coordinates education, outreach, and training; and develops national and international partnerships.

Total Obligations for NEES

(Dollars in Millions)

	FY 2013	FY 2014	FY 2015	ESTIMATES¹				
	Actual	Estimate	Request	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$21.82	\$20.00	\$12.00	\$13.00	\$12.50	\$12.50	\$12.00	\$12.00

¹ Outyear funding estimates are for planning purposes only. FY 2014 is the final year of the current cooperative agreement. Funding beyond FY 2014 assumes continued operation of the facility as a second generation NEES, as described in the Renewal/Recompetition/Termination section of this narrative.

NEES' broad-based national research facilities and cyberinfrastructure enable 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. Purdue University develops 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. Purdue

also organizes an annual meeting for NEES users/researchers and facility operators.

Through the National Earthquake Hazards Reduction Program (NEHRP), which includes the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST) as the lead agency, the U.S. Geological Survey (USGS), and NSF, NEES supports research and outreach 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 leverages and complements its capabilities through connections and collaborations with large testing facilities at foreign earthquake-related centers, laboratories, and institutions. NSF has developed a partnership to utilize the NEES infrastructure with the 3-D Full-Scale Earthquake Testing Shake Table Facility (E-Defense), located in Miki City, Japan, and built by the Japanese National Research Institute for Earth Science and Disaster Prevention (NIED), which became operational in 2005. To facilitate NEES/E-Defense collaboration, 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. In August 2011, two NSF-supported research projects used a full-scale, five-story steel frame structure at the E-Defense facility to test new seismic base isolation concepts and the response of non-structural systems during strong seismic motion, and in 2012 an NSF-supported research project participated in large-scale experiments at the E-Defense facility to investigate soil-structure interaction of underground structures.



Using a unique landslide tsunami generator, researchers at the Georgia Institute of Technology in cooperation with faculty at University of Alaska at Fairbanks are investigating a methodology for improved assessment and mitigation of landslide and tsunami hazards. Field data from landslide-generated tsunamis events are limited to very few cases with marginal data that are generally missing the most important information related to tsunami generation characteristics. Researchers are compensating for this lack of field data by creating physical models of three-dimensional tsunami generation by deformable landslides and source run-up in the NEES Tsunami Wave Basin at Oregon State University. *Credit: Devin K. Daniel, California Polytechnic State University, San Luis Obispo, NEES summer 2010 REU student.*

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 NEEShub 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, primarily funded through annual NEES research program solicitations, average approximately \$9.0 million. These awards support basic research in multi-hazard engineering involving experimental and computational simulations at the NEES facilities, addressing important challenges in earthquake and tsunami engineering research. ENG support for NEES Operations will continue to support core research conducted at the 14 network sites through FY 2014.

Management and Oversight

- NSF structure: NSF provides oversight to NEES operations through a cooperative agreement with Purdue University during FY 2010-FY 2014. NEES operations are reviewed through annual and periodic site visits to the individual NEES facilities. The annual site reviews are held at either the headquarters or at NSF. All reviews involve an external team of experts selected by NSF staff. The NSF program manager for NEES is located in the Division of Civil, Mechanical and Manufacturing Innovation (CMMI) in the Directorate for Engineering (ENG). The Deputy Director of the Large Facilities Office in the Office of Budget, Finance and Award Management (BFA) provides advice and

Major Multi-User Research Facilities

assistance.

- External structure: Purdue University currently provides the headquarters and staffing to coordinate network-wide operation of the NEES experimental facilities, cyberinfrastructure, and education, outreach, and training activities as well as develop national and international partnerships. Day-to-day operations of the network are overseen by the headquarters staff led by a director. A governance board meets several times a year and provides independent advice and guidance to the director concerning the network's programs, activities, vision, funding allocations, and new directions. The governance board shares its major recommendations with NSF. Each of the current 14 experimental facilities has an on-site director responsible for local day-to-day equipment management, operations, and interface with Purdue, other NEES facilities, users, and the NEEShub for network coordination. The NEEShub provides telepresence, the NEES Project Warehouse data repository, and 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
 - Transition review: April 2010
 - Management reviews: NSF BFA Business Systems Review: March 2011
 - Mid-award operations reviews: NSF Annual Merit Reviews: FY 2010-FY 2014
 - Experimental facility reviews: Up to three annually: FY 2010-FY 2013

Renewal/Recompetition/Termination

In FY 2010, NSF supported two studies for the assessment of the need for earthquake engineering experimental and cyberinfrastructure facilities beyond 2014, as described in the Dear Colleague Letter NSF 10-071 (<http://nsf.gov/pubs/2010/nsf10071/nsf10071.jsp>). One study, a workshop held by the National Research Council on the Grand Challenges in Earthquake Engineering Research, was completed in FY 2011 and the second study was completed in FY 2012. These studies provided input to NSF for the determination of support for future earthquake engineering research infrastructure beyond 2014. The plan to support, as the outcome of an open recompetition to be held during FY 2013 – FY 2014, a smaller “second generation” NEES during FY 2015 – FY 2019 was presented to the National Science Board at their July 2012 meeting and described in the Dear Colleague Letter NSF 12-107 (www.nsf.gov/pubs/2012/nsf12107/nsf12107.jsp). The smaller “second generation” network would result in significantly lower annual operations costs, reflected in the FY 2015 request total (-\$8.0 million). These lower operations cost will allow additional investments to be made in earthquake engineering research. In February 2013, the Foundation released solicitation NSF 13-537 to re-compete and operate the second generation of NEES (NEES2) for the five-year period from FY 2015 – FY 2019. Based on the merit review of proposals submitted under NSF 13-537, NSF made no award. NSF is currently developing an integrated plan for continued support for natural hazards research and related research infrastructure, including earthquake engineering, for FY 2015 – FY 2019. This plan, together with appropriate solicitations for the future operations and maintenance of an earthquake engineering facility, will be issued in FY 2014. NSF will also support longer-term community planning for FY 2020 – FY 2029.

POLAR FACILITIES AND LOGISTICS

\$296,230,000
+\$320,000 / 0.1%

Polar Facilities and Logistics
(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over	
				FY 2014 Estimate Amount	Percent
Polar Facilities	\$180.01	\$187.55	\$190.07	\$2.52	1.3%
Polar Logistics	108.50	108.36	106.16	-2.20	-2.0%
Total, Polar Facilities and Logistics	\$288.51	\$295.91	\$296.23	\$0.32	0.1%

Totals may not add due to rounding.

Polar Facilities

The Division of Polar Programs (PLR) within the Directorate for Geosciences (GEO) provides the infrastructure needed to support U.S. research conducted in Antarctica, including research funded by U.S. mission agencies, for year-round work at three U.S. stations, on two research ships, and at a variety of remote field camps. One example of support to other agencies includes mission-essential satellite communications support at McMurdo Station for the Joint Polar Satellite System (JPSS) and the National Aeronautics and Space Administration’s (NASA) Ground Networks for the relay of data. In addition, PLR enables important climate monitoring activities for the National Oceanic and Atmospheric Administration (NOAA) at the Clean Air Facility at South Pole Station, one of only five such sites around the globe. PLR also provides support for NASA’s Long Duration Balloon program that enables research in fields ranging from astrophysics to cosmic radiation to solar astronomy. PLR also provides support to the U.S. Geological Survey’s (USGS) South Pole Remote Earth Science and Seismological Observatory (SPRESSO), the most seismically-quiet station on earth, and access to the Global Navigation Satellite System (GNSS).

All support for these activities is provided by PLR, including transportation, facilities, communications, utilities (water and power), health and safety infrastructure, and environmental stewardship. The U.S. Antarctic Program (USAP) maintains the U.S. presence in Antarctica in accordance with U.S. policy, and supports Antarctic Treaty administration under State Department leadership.

Total Obligations for Polar Facilities

(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	ESTIMATES ¹				
				FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Antarctic Infrastructure & Logistics	\$180.01	\$187.55	\$190.07	\$190.07	\$190.07	\$190.07	\$190.07	\$190.07
Total, Polar Facilities	\$180.01	\$187.55	\$190.07	\$190.07	\$190.07	\$190.07	\$190.07	\$190.07

Totals may not add due to rounding.

¹ Outyear funding estimates are for planning purposes only.

PLR contracts with a prime contractor for science support, operations, the leasing of research vessels, and the maintenance of the Antarctic stations and related infrastructure in New Zealand and Chile. The contractor is selected through a competitive process. Rotary- and fixed-wing aircraft used in support of research are also provided through separate competitively-awarded contracts. Other agencies and

contractors provide technical support in areas of expertise such as engineering, construction, and communications. In FY 2014 the U.S. Coast Guard (USCG)'s *Polar Star* provided icebreaking services for the McMurdo Station resupply effort. USCG estimates that the vessel, now operational following a major refurbishment program, will be available for the next seven to eight years.

Management and Oversight

- NSF Structure: PLR staff, including subject matter experts in operational and scientific disciplines, have overall responsibility for funding and managing Polar Facilities under the USAP that NSF budgets for and manages on behalf of the Nation. This includes planning all activities and overseeing contractors. PLR's Antarctic Sciences section funds merit-reviewed research proposals for which access to Antarctica is essential to advancing the scientific frontiers and that can only be achieved or are best achieved with research work in Antarctica and the Southern Ocean. Research is conducted in a broad array of geo- and bio- sciences, including earth system science, as well as space and astrophysical sciences. The Antarctic Infrastructure & Logistics section enables research in Antarctica on behalf of the U.S. Government through a network of stations, labs, equipment, and logistical resources. The Environment, Health, and Safety section oversees the environmental, health, and safety aspects of research and operations conducted in Polar Regions.
- External Structure: The Antarctic support contract was competed and awarded to Lockheed Martin Corporation in December 2011. There are many separate subcontractors for supplies and technical services, and other services are procured through separate competitively bid contracts.
- Reviews: PLR evaluates the performance of the Antarctic support contractor annually via an Award Fee Plan, which involves multiple tiers of review, including a Performance Evaluation Board (PEB) composed of representatives from PLR and the Office of Budget, Finance, and Award Management (BFA). In addition, PLR's performance is reviewed externally by Committees of Visitors and the GEO Advisory Committee. The USAP Blue Ribbon Panel (BRP) released a report on its review of the program in July 2012.³ The NSF response to the USAP Blue Ribbon Panel report was released in March 2013.⁴



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), including the recently-constructed South Pole Station, are currently operating normally.
- The South Pole Station is an elevated complex with two connected buildings, supporting 150 people in the summer and 50 people in the winter. The station provides 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. Operations and maintenance of South Pole Station is consolidated within the requested budget for polar facilities.
- The USAP BRP report concluded that ushering in a new age of Antarctic science simply by expanding traditional methods of logistical support would be prohibitively costly. Instead, they recommended numerous ways to more efficiently and cost-effectively support research while maintaining high standards of safety and increasing the flexibility to support evolving science foci in the future. NSF's response to the report, released in March 2013, addresses the ten overarching

³ www.nsf.gov/od/opp/usap_special_review/usap_brp/rpt/index.jsp

⁴ www.nsf.gov/od/opp/usap_special_review/usap_brp/rpt/nsf_brp_response.pdf

recommendations made by the BRP and includes information on planned improvements over the near- and long-term, such as roboticizing the South Pole traverse, improving boating access at Palmer Station, conducting a study to improve fire suppression capabilities, and initiating design work to consolidate warehousing facilities at McMurdo Station. For additional information on planned BRP response activities during FY 2014 and FY 2015, see the PLR narrative in the GEO chapter.

Renewal/Recompetition/Termination

- In FY 2012, Lockheed Martin Corporation was awarded a 13.5-year contract, consisting of a five-year base period and four option periods, exercised on the basis of performance, and totaling an additional 8.5 years.
- A new contract for helicopter support was awarded to Petroleum Helicopters, Inc., the incumbent, in May 2013. The award term is for one year, with the possibility of four additional one-year options exercised on the basis of performance.
- 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. The research emphases at the three stations change as the scientific forefronts addressed there evolve with time, as does the infrastructure needed to support it.

Polar Logistics

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

Total Obligations for Polar Logistics

(Dollars in Millions)

	FY 2013	FY 2014	FY 2015	ESTIMATES ¹				
	Actual	Estimate	Request	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
U.S. Antarctic Logistical Support	\$64.51	\$67.52	\$67.52	\$67.52	\$67.52	\$67.52	\$67.52	\$67.52
Arctic Research Support and Logistics	43.99	40.84	38.64	38.64	38.64	38.64	38.64	38.64
Total, Polar Logistics	\$108.50	\$108.36	\$106.16	\$106.16	\$106.16	\$106.16	\$106.16	\$106.16

Totals may not add due to rounding.

¹ Outyear funding estimates are for planning purposes only.

The U.S. Antarctic Logistical Support program funds support activities provided by the U.S. Department of Defense (DoD). DoD operates as a logistical support provider on a cost-reimbursable basis. Major funding elements of DoD support include: military personnel, LC-130 flight operations and maintenance support through the 109th Airlift Wing of the New York Air National Guard in Scotia, New York, and Antarctica; transportation and training of military personnel supporting the USAP; support for air traffic control, weather forecasting, and ground electronics 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 section of PLR responds to science supported by the section. Funding is provided directly to grantees or to key organizations that provide or manage Arctic research support and logistics. A contractor provides research support and logistics

Major Multi-User Research Facilities

services for NSF-sponsored activities in the Arctic. Additional major support components include: access to USCG 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. observatories linked to similar efforts in Europe and Canada.

Management and Oversight

- NSF Structure: PLR has overall responsibility for U.S. Antarctic Logistical Support and Arctic Research Support & Logistics.
 - U.S. Antarctic Logistical Support is budgeted for and managed by the Antarctic Infrastructure and Logistics section, which includes managers with operational expertise responsible for planning and overseeing all USAP support.
 - Arctic Sciences personnel support merit-reviewed research proposals in social, earth systems, and a broad range of natural sciences; its Research Support & Logistics program responds to research by assisting researchers with access to the Arctic and sharing of plans and results with local Arctic communities. The Environment, Health, and Safety section oversees the environmental, health, and safety aspects of research and operations conducted in polar regions.
- External Structure:
 - DoD operates as a 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.
 - The Arctic support contract was re-competed and awarded to the incumbent, CH2M Hill, in September 2011. There are many separate subcontractors for supplies and technical services, and other services are procured through separate competitively bid contracts.
- Reviews: PLR evaluates the performance of the Arctic support contractor informally on an ongoing basis and formally each year using feedback from the research community they support, and by conducting site visits that include representatives from PLR and BFA. PLR's performance is externally reviewed by Committees of Visitors and the GEO Advisory Committee.

Current Status

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

Renewal/Recompetition/Termination

- NSF re-competed the Arctic support contract and made an award to the incumbent contractor, CH2M Hill, in September 2011. The contract has an initial term of four years and the possibility of two, two-year extensions exercised on the basis of performance.

**SEISMOLOGICAL FACILITIES FOR THE ADVANCEMENT
OF GEOSCIENCE AND EARTHSCOPE**

\$24,350,000
\$0 / 0.0%

**Seismological Facilities for the Advancement of
Geoscience and EarthScope**

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over FY 2014 Estimate	
			Amount	Percent
\$24.35	\$24.35	\$24.35	-	-

The Seismological Facilities for the Advancement of Geoscience and EarthScope (SAGE) comprise a distributed, multi-user, national facility for the development, deployment, and operational support of modern digital seismic instrumentation to serve national goals in basic research and education in the Earth sciences, earthquake research, global real-time earthquake monitoring, and nuclear test ban verification. SAGE is managed and operated for NSF by the Incorporated Research Institutions for Seismology (IRIS), a consortium of 121 U.S. universities and non-profit institutions with research and teaching programs in seismology, 22 educational affiliates, two U.S. affiliates, and 118 foreign affiliates. SAGE was formed in late FY 2013 from part of the EarthScope program and the IRIS facility. FY 2013 funding is restated in all tables presented for comparative purposes.

Total Obligations for SAGE

(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	ESTIMATES ¹				
				FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$24.35	\$24.35	\$24.35	\$24.35	\$24.35	\$24.35	\$24.35	\$24.35

¹ Outyear funding estimates are for planning purposes only. The cooperative agreement began in FY 2013 and ends in FY 2017.

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 Earth science community, SAGE is organized under three primary Service Areas and two Special Emphasis Areas:

• **Instrumentation Services**

- The Global Seismographic Network (GSN) consists of over 150 permanently installed broadband digital seismic stations, most of which have real-time data access.
- Portable Seismology (PS) includes a pool of over 5,200 portable seismometers that are made available to the Earth science research community for a wide range of principal investigator-driven experiments largely funded through the NSF merit review process, and incorporates equipment from the former Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL) and EarthScope USArray/Flexible Array (FA) activities.
- Polar Support Services (PSS) supports the development of specialized seismic equipment for use in harsh environments and provides instrumentation, training, and field support for experiments in the Polar regions. Additional supplemental funding for these activities is provided through the Division of Polar Programs (PLR).
- The Transportable Array (TA) is a continental-scale seismic observatory designed to provide a

foundation for multi-scale integrated studies of continental lithosphere and deep Earth structure. TA incorporates over 400 stations across the lower 48 states, Alaska, and Canada.

- The Magnetotelluric (MT) component exploits the natural variations in Earth's magnetic and electric fields to provide information on the distribution and composition of fluids in Earth's crust and upper mantle, which gives constraints on Earth's structure that are complementary to those resulting from seismology. MT comprises seven long-term, continuously operating backbone stations and 21 transportable instruments used for short-term deployments.
- Instrumentation Services-Coordinated Activities include future-focused efforts to develop the next generation of seismic instrumentation for large-scale scientific experiments; global scale geophysical networks; and training courses to distribute best practices to partners worldwide.
- **Data Services**
SAGE Data Services (DS) manages an archive of 200 terabytes of seismic, magnetotelluric, and other data from all SAGE components, the EarthScope program, and numerous affiliated networks; operates automated and manual systems to ensure the quality of all data stored in the archive; and provides systems to give the national and international research community with timely access to these data.
- **Education and Public Outreach**
The SAGE Education and Public Outreach (EPO) Program enables audiences beyond seismologists to access and use seismological data and research, including student internships, and programs for under-resourced educational institutions.
- **Special Emphasis Areas**
 - Community Activities include scientific and technical workshops that bring together the international seismic community and publications designed to communicate SAGE activities and results to the community.
 - International Development Seismology (IDS) leverages the core SAGE Service Areas to provide capacity building and training for earthquake hazard mitigation in developing countries, through technical assistance and research collaborations with scientists at U.S. academic institutions.

Besides its role in providing the observational data essential for basic Earth science research, SAGE also plays a significant role providing real-time seismic data to the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA) for global earthquake, volcano, and tsunami monitoring; international seismic monitoring of compliance with the Comprehensive Test Ban Treaty; and bringing seismology to students and the public through the activities of its EPO program.

SAGE 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 GSN stations are designated as the official stations for nuclear test ban monitoring in their host countries. SAGE also provides 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 for accelerated development of the GSN, shared operation and maintenance of the GSN, and accelerated development of the



A student volunteer prepares to deploy a sensor on a wind farm near Palm Springs, California, that will record high-frequency seismic waves for the Salton Sea Imaging Project. Principal Investigators: John Hole, Virginia Tech, Joann Stock, Caltech, and Gary Fuis, USGS. *Credit: IRIS.*

Portable Seismology instrument pool.

The use for investigations of the shallow crust by instruments made available through SAGE Portable Seismology component 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 EarthScope, Geophysics, GeoPRISMS, and Tectonics Programs in the Division of Earth Sciences (EAR); the GeoPRISMS and Marine Geology and Geophysics Programs in the Division of Ocean Sciences (OCE); and the Geology and Geophysics Program and the Glaciology Program in the Antarctic Research Section of the Division of Polar Programs (PLR) provide most of the funds, totaling approximately \$15.0 million per year, for NSF-sponsored research making use of SAGE. Funds permit deployment of portable seismic instruments and use of data managed by Data Services to solve major Earth science problems.

Management and Oversight

- NSF Structure: The Division of Earth Sciences (EAR), through its Instrumentation & Facilities program (IF), provides general oversight of SAGE to help assure effective performance and administration. The program also facilitates coordination of SAGE programs and projects with other NSF-supported facilities, and with other federal agencies, and evaluates and reviews the performance of IRIS in managing and operating SAGE.
- External Structure: SAGE is managed and operated by IRIS, which is incorporated as a non-profit consortium representing 121 U.S. universities and non-profit organizations with research and teaching programs in seismology. Each voting Member Institution of the Consortium appoints a Member Representative, and these Member Representatives elect the nine members of the IRIS Board of Directors. The Board members, who serve three-year terms, vet all internal program decisions associated with SAGE management and operation, through consultation with IRIS staff and SAGE advisory committees (one for each major SAGE component and additional *ad hoc* working groups appointed for special tasks). The Board of Directors appoints a president of IRIS to a renewable two-year term. The president is responsible for IRIS operations, all of which are managed through the IRIS Corporate Office located in Washington, DC.
- Reviews: 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. The formal NSF merit review of the five-year proposal for the SAGE facility took place in 2012 and 2013 and was also the most recent review of IRIS. Although the *ad hoc* reviewers and two independent review panels had a number of specific recommendations at the working level for SAGE, overall the review found that SAGE was a critical facility for U.S. and international Earth sciences. Furthermore, the reviewers found that IRIS is a 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.

Renewal/Recompetition/Termination

Funding for the current cooperative agreement for SAGE began in FY 2013 and ends in FY 2017. In FY 2017, in keeping with the phased integration and recompetition plan presented to and concurred with by the National Science Board in December 2009, NSF intends to solicit proposals for a future facility or facilities to support the Earth sciences research and education community currently supported by SAGE and the related Geodetic Facilities for the Advancement of Geoscience and EarthScope (GAGE). NSF is currently considering the precise form of this solicitation, and any possible future facility/facilities are currently being considered within NSF and through discussions with the SAGE and GAGE support communities.

FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTERS (FFRDCs)

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH **\$98,200,000**
+\$3,000,000 / 3.2%

National Center for Atmospheric Research

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over	
			FY 2014 Estimate Amount	Percent
\$95.75	\$95.20	\$98.20	\$3.00	3.2%

The National Center for Atmospheric Research (NCAR) is a Federally Funded Research and Development Center (FFRDC) serving a broad research community, including atmospheric and geospace scientists and researchers in complementary areas of the environmental and geosciences. NCAR is managed under a cooperative agreement between NSF and the University Corporation for Atmospheric Research (UCAR), a university-governed and university-serving organization comprising 104 degree-granting academic institutions.



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

As of January 2014, NCAR supported a total of 803.5 full time equivalents (FTEs), of which 363.8 are funded under the NSF primary award to UCAR.

Number of FTEs Supported at NCAR

FTEs	Primary Award ¹	All Funding
Career Scientists	81.8	114.7
Scientific Support ²	247.8	545.3
Other Staff ³	34.2	143.5
Total	363.8	803.5

¹ The primary award supports substantial facility infrastructure that does not include staff

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, including world-class supercomputing services, research aircraft, a transportable ground-based radar system, atmospheric sounding, and other surface sensing systems for atmospheric research, to university, NCAR, and other atmospheric researchers. NCAR operates several facilities dedicated to the study of the Sun and solar phenomena (e.g., the Mauna Loa Solar Observatory), space weather, and the responses of the upper atmosphere to the Sun's output.

Total Obligations for NCAR

(Dollars in Millions)

	FY 2013	FY 2014	FY 2015	ESTIMATES ¹				
	Actual	Estimate	Request	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Aircraft Support	\$9.22	\$9.17	\$9.46	\$9.46	\$9.46	\$9.46	\$9.46	\$9.46
Computational Infrastructure	26.22	26.07	26.90	26.90	\$26.90	\$26.90	\$26.90	\$26.90
Other Facility Support	20.50	20.37	21.01	21.01	\$21.01	\$21.01	\$21.01	\$21.01
Research & Education Support	39.81	39.59	40.83	40.83	\$40.83	\$40.83	\$40.83	\$40.83
Total, NCAR	\$95.75	\$95.20	\$98.20	\$98.20	\$98.20	\$98.20	\$98.20	\$98.20

Totals may not add due to rounding.

¹ Outyear funding estimates are for planning purposes only.

Partnerships and Other Funding Sources: NCAR leverages NSF support with funding provided by other federal agencies and non-federal sources. In FY 2013, NCAR received approximately \$40.40 million in support from other federal agencies, such as the National Oceanographic and Atmospheric Administration (NOAA) and the Federal Aviation Administration (FAA), and \$17.30 million from non-federal sources.

Major Investments in FY 2015: In FY 2015, investments at NCAR will focus on fundamental research in atmospheric chemistry, climate (including continued development of advanced climate models), cloud physics, severe storms, weather and climate impacts on society, and interactions between the Sun and Earth. In all of these areas, NCAR scientists will work with their university colleagues to further understand the fundamental physical processes that control the Earth’s climate and weather. This will include research thrusts in areas such as the role of the chemical composition of the atmosphere and impacts of changes in that composition on the climate system, better understanding of the structure and nature of hurricanes and the impacts of the Sun on space weather and weather on Earth.

Aircraft Support: NCAR operates two NSF aircraft: a C-130Q Hercules and a Gulfstream-V (G-V, also known as the High Altitude Instrumented Airborne Platform for Experimental Research, or HIAPER), both of which are highly modified and equipped with specialized instrumentation, to enable the support of research activities designed to provide new insights into atmospheric chemical processes, the dynamics and coupling of the atmosphere’s layers, and interactions between the atmosphere and Earth’s surface. The two aircraft will support several community-originated projects deemed by peer review to be of exceptional scientific merit.

Computational Infrastructure: NCAR operates a petascale supercomputing facility in Cheyenne, Wyoming (the NCAR-Wyoming Supercomputing Center), that supports high-end community modeling programs in climate, weather, and other Earth Systems processes. This includes the development and application of the Interagency United States Global Change Research Program (USGCRP) Community Earth System Model (CESM), which uses mathematical formulas to simulate and better understand the chemical and physical processes that drive Earth's climate system. NCAR also maintains extensive data archives, providing access to a vast collection of observational, experimental and modeling data, together with sophisticated analysis and visualization facilities, and training and support for users of all levels.

Other Facility Support: In addition to the C-130 and G-V aircraft, NCAR provides support for a number of other atmospheric observing platforms through its Earth Observing Laboratory (EOL), including a large, deployable, dual-wavelength Doppler radar, upper atmosphere observing capabilities, an advanced coronagraph, and other experimental systems. NCAR develops and makes available to the research community advanced weather and climate models.

Research and Education Support: Total funding for research and education support at NCAR is estimated to be \$41.30 million in FY 2014. 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 local and regional weather; and
- examination of human society's impact on and response to global environmental change.

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.

Educational activities include the SOARS (Significant Opportunities in Atmospheric Research and Science) program that integrates research, education, and mentoring to bridge the undergraduate-to-graduate transition and to broaden participation in the atmospheric and related sciences.

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. Professional training courses, innovative and award-winning science education websites⁵, as well as the directed activities of NCAR's education and outreach programs are further examples of how NSF's goal of integrating research and education is attained through NCAR activities.

Management and Oversight

- **NSF Structure:** NSF's Division of Atmospheric and Geospace Sciences (AGS), along with the Division of Acquisition 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 cooperative agreement between UCAR and NSF encourages interactions between NCAR scientists and AGS staff and ensures close coordination between AGS and NCAR management. The agreement contains requirements necessary for AGS's oversight of the NCAR program and UCAR management activities that affect NCAR. These include a provision that UCAR submit for AGS approval an annual program plan that provides details about 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 AGS, UCAR, and NCAR are held to ensure that scientific and facility priorities remain consistent with those of NSF.
- **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 the National Aeronautics and Space Administration (NASA), NOAA, the Department of Energy (DOE), the Department of Defense (DOD), the Environmental Protection Agency (EPA), and the Federal Aviation Administration (FAA)

⁵ www.spark.ucar.edu

support research collaboration wherever it enhances NCAR's basic NSF-supported research goals or facilities missions.

- **Reviews:** A Committee of Visitors (COVs) is convened every three years to evaluate AGS oversight of NCAR. The most recent COV was conducted in FY 2012 with the next anticipated in FY 2015. A Business Systems Review (BSR) was conducted in FY 2011, and the next review will take place in FY 2016. No significant issues were raised in either of the most recent reviews. Based on a thorough review of NCAR's performance as a center and UCAR's management of NCAR, UCAR was awarded a new five-year cooperative agreement to manage NCAR beginning in FY 2014. It is anticipated that the management of NCAR will be re-competed prior to the next award period, beginning in FY 2019.

NATIONAL OPTICAL ASTRONOMY OBSERVATORY

\$25,500,000
\$0 / 0.0%

National Optical Astronomy Observatory

(Dollars in Millions)

FY 2013	FY 2014	FY 2015	Change over	
			FY 2014 Estimate	
Actual	Estimate	Request	Amount	Percent
\$25.50	\$25.50	\$25.50	-	-

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 (O/IR) astronomy. NOAO is the gateway for the U.S. astronomical community to the International Gemini Observatory and to other U.S. O/IR telescopes that offer public access. These O/IR telescopes enable science via imaging and spectroscopic observations of planets, stars, galaxies, and their environs, and having multiple telescopes with different instrumentation enables a broad range of investigations to be carried out. For the telescopes offering public access, NOAO peer-review telescope allocation committees provide competitive merit-based telescope time allocation, but no financial support. NOAO manages national community involvement in the development of potential future infrastructure projects and is closely involved in the design, development, and potential construction and operations of the Large Synoptic Survey Telescope (LSST). LSST was the highest priority recommendation for “New Ground-Based Activities – Large Projects” of the 2010 Decadal Survey conducted by the National Research Council’s Astronomy and Astrophysics Survey Committee, and has been requested for an FY 2014 construction start funded through the Major Research Equipment and Facilities Construction (MREFC) account. Presently NOAO is expected to be responsible for the telescope and site during the construction phase of the LSST project.

NOAO telescopes are open to all astronomers regardless of institutional affiliation on the basis of peer-reviewed observing proposals. They serve nearly 1,200 U.S. and foreign scientists annually. Doctoral dissertation students and non-thesis graduate students from U.S. institutions use NOAO telescopes for research projects. In FY 2013 NOAO employed 350 personnel in Arizona and Chile, including 45 support scientists and 10 postdoctoral fellows.

In 2010, the National Research Council (NRC) conducted its sixth decadal survey in astronomy and astrophysics to recommend key science questions and new initiatives for the current decade. Since both the NRC recommendations and current programs could not be accommodated within present budget projections, the NSF Directorate for Mathematical and Physical Sciences, Division of Astronomical Sciences (MPS/AST), through the Advisory Committee of the Directorate for Mathematical and Physical Sciences conducted a community-based portfolio review to make implementation recommendations that would best respond to the decadal survey science questions. The resulting report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges* (www.nsf.gov/mps/ast/ast_portfolio_review.jsp), was released in August 2012 and included recommendations related to all of the major telescope facilities funded by NSF. NSF released a Dear Colleague Letter, NSF 14-022, in December 2013 that outlines the current state of the NSF response to the facility recommendations (www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf14022).

The recommendations from the Portfolio Review Committee’s report included divesting NSF support from three nighttime O/IR telescopes located on Kitt Peak: the 4-meter Mayall telescope, the 2.1-meter

telescope, and the 3.5-meter WIYN (Wisconsin-Indiana-Yale-NOAO) telescope. The first two of these telescopes are NOAO facilities that are fully available (except for closure due to weather or maintenance) for public access. The WIYN telescope is owned and operated by a collaboration among three universities (University of Wisconsin, Indiana University, and Yale University) and NOAO. NOAO's share of the WIYN telescope time for public access is 40 percent. The aforementioned Dear Colleague Letter, NSF 14-022, indicates that studies of alternative futures for the 2.1-meter and Mayall telescopes will be carried out in 2014, while consideration of the future of WIYN is currently being led by the WIYN Consortium Board.

Total Obligations for NOAO

(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	ESTIMATES ¹				
				FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
NOAO-Operations	\$15.50	\$15.50	\$17.00	\$15.00	\$15.45	\$15.92	\$16.38	\$16.89
NOAO-Development	3.40	3.40	3.40	2.00	2.06	2.12	2.19	2.25
NOAO-Research and Education	0.60	0.60	0.60	0.50	0.52	0.53	0.55	0.56
Mayall Telescope	4.50	4.50	4.50	3.50	3.50			
LSST Development ²	1.50	1.50	-	-	-	-	-	-
Total, NOAO	\$25.50	\$25.50	\$25.50	\$21.00	\$21.53	\$18.57	\$19.12	\$19.70

Totals may not add due to rounding.

¹ Outyear funding estimates are for planning purposes only, and are consistent with the amounts in the NOAO Management Solicitation, NSF 13-582. The current cooperative agreement ends in FY 2015.

² Funding for LSST development is zero after FY 2014 because of the start of construction through the MREFC account expected to begin in late FY 2014.

Partnerships and Other Funding Sources: The managing organization for NOAO is the Association of Universities for Research in Astronomy, Inc., (AURA), which is comprised of 39 U.S. member institutions and seven international affiliate members. A key ongoing NOAO partnership with the Department of Energy (DOE) has focused on the preparation of the 4-meter CTIO Blanco telescope for the Dark Energy Survey, which began operation in August 2013. This survey is a collaboration with the DOE to conduct a five-year survey of the southern sky to investigate the nature of dark energy. Along with the WIYN telescope mentioned above, NOAO is a partner in the 4.1-meter SOAR (Southern Astrophysical Research) telescope at CTIO. SOAR partners include the University of North Carolina, Chapel Hill; Michigan State University; and the Ministério da Ciência, Tecnologia, e Inovação of Brasil.

A large number of U.S. universities support their own astronomical facilities at KPNO and CTIO with reimbursed services provided by NOAO. Development of new telescopes, instrumentation, and sensor techniques is done in partnership with universities and with industry through subawards to aerospace, optical fabrication, and information technology companies. NOAO leverages NSF support with funding from other federal agencies and non-federal sources. NOAO typically receives approximately \$10 million each year for reimbursed services from partnerships and tenant observatory support, from the Kitt Peak Visitors' Center, and from grants from other federal agencies.

Education and Public Outreach: NOAO supports U.S. education goals by promoting public understanding and support of science and by providing education and training at all levels. Over 200 U.S. and foreign graduate students observe on NOAO telescopes yearly and a significant fraction of the observations contribute to Ph.D. dissertations. The observatories introduce undergraduate students to scientific research by providing stimulating environments for basic astronomical research and related

Major Multi-User Research Facilities

technologies through NSF's Research Experiences for Undergraduate Students (REU) program. NOAO has a diverse education program, visitor centers, and a web-based information portal at www.noao.edu.

NOAO-Operations: \$17.0 million; + \$1.50 million from FY 2014: NOAO-Operations support covers the operation of facilities at KPNO, excluding the Mayall telescope, CTIO, and the headquarters, offices, laboratories, and workshops in Tucson, Arizona and La Serena, Chile. The \$1.50 million increase in increase FY 2015 derives from the planned zeroing out of the LSST Design and Development (D&D) line in the NOAO base budget in FY 2015 (described below). These funds were originally in the NOAO-Operations line before being moved to LSST D&D, and they are now being returned. The additional funds in NOAO-Operations in FY 2015 will be used to prepare the organization for a revised and reduced scope of operations beginning in FY 2016.

NOAO-Development: \$3.40 million: This supports the modernization of telescopes as well as the development of new instrumentation for telescopes at KPNO and CTIO. In FY 2010, NOAO began a multi-year effort to introduce new capabilities to the U.S. community. Three new instruments have been under development as part of this program – two were put on telescopes in 2013 and the third will be available in 2015.

NOAO-Research and Education: \$600,000: NOAO links the research conducted at its facilities to education of the public through its education and public outreach office in Tucson.

Mayall Telescope: \$4.50 million: In response to Portfolio Review recommendations, the Mayall 4-meter telescope on Kitt Peak will be removed from the NOAO base operations budget in FY 2016. NSF is investigating other sources of funding to continue to operate the telescope; NSF would provide bridge funding in FY 2016 and perhaps FY 2017 to accommodate implementation of the other funding.

LSST: \$0.0 million, -\$1.50 million from FY 2014: This line supported LSST design, development, and planning activities in FY 2013 and 2014. This line is zero in FY 2015 based on the projected LSST construction start late in FY 2014.

Management and Oversight

- **NSF Structure:** An NSF program officer in the Division of Astronomical Sciences (AST) provides continuing oversight, including consultation with an NSF Program Review Panel of external reviewers that meets twice a year. The program officer reviews detailed annual program plans, annual long range plans, quarterly technical and financial reports, and annual reports submitted by NOAO. The NSF program officer also attends AURA governance committee meetings. Governance committees are formed from the national astronomical community and provide additional avenues for input of community priorities and concerns. The AST program officer works closely with other offices at NSF, particularly the Office of General Counsel, and the Division of Acquisition and Cooperative Support and the Large Facilities Office in the Office of Budget, Finance, and Award Management.
- **External Structure:** AURA is the managing organization for NOAO. The NOAO director reports to the president of AURA, who is the principal investigator on the FY 2009 NSF cooperative agreement. AURA receives management advice from an observatory council composed of members of its scientific and management communities. NOAO employs 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. User committees, composed of scientists with considerable experience with the observatories, review for the NOAO Director all aspects of user experiences at the observatory.
- **Reviews:** In addition to reviews held mid-way through all cooperative agreements, NSF conducts

both periodic and ad hoc external reviews of AURA management. A Business Systems Review was carried out in FY 2013.

Renewal/Recompetition/Termination

A management review of AURA's performance was carried out in August 2006. In response to the review, the National Science Board extended the previous 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 a new cooperative agreement with AURA for the management and operation of NOAO for the period October 1, 2009, through March 31, 2014. AST will extend the current cooperative agreement through FY 2015. The extension will accommodate a competition for the management and operation of NOAO and will allow for the implementation of Portfolio Review recommendations that will alter the scope of work to be managed under a new cooperative agreement to begin in FY 2016. A solicitation was published in July 2013 (NSF 13-582) for competition for the management of NOAO, with the new management award slated to begin on October 1, 2015.

NATIONAL RADIO ASTRONOMY OBSERVATORY

\$80,170,000
+\$2,760,000 / 3.6%

National Radio Astronomy Observatory
(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change over	
			FY 2014 Estimate Amount	Percent
\$73.92	\$77.41	\$80.17	\$2.76	3.6%

Totals may not add due to rounding.

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. Headquartered in Charlottesville, Virginia, NRAO is the North American (NA) implementing organization for the international Atacama Large Millimeter/submillimeter 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. They annually serve over 1,500 users worldwide. The Observatory allocates telescope time on the basis of merit and provides some financial support to students. 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 facilities.



The Atacama Large Millimeter/submillimeter Array (ALMA) is in science operations. Remaining elements of construction will be completed in FY 2014. ALMA, an international partnership between North America, Europe, and East Asia, provides orders-of-magnitude improvement in observing sensitivity and image quality over previous facilities. *Credit: NRAO/AUI.*

Including the ALMA operations staff located at NRAO, Observatory staff consists of 477 full-time equivalent positions (FTEs) in the operations and maintenance components of the Observatory: 290 in telescope operations, 26 in science support and research, 25 in development programs, 76 in computing and data management, 34 in administrative services, and 26 in the Director’s office. In addition, the NRAO managing organization, Associated Universities, Inc. (AUI), employs the local ALMA Operations staff in Chile, currently consisting of approximately 200 FTEs.

In 2010, the National Research Council (NRC) conducted its sixth decadal survey in astronomy and astrophysics to recommend key science questions and new initiatives for the current decade. Since both the NRC recommendations and current programs could not be accommodated within present budget projections, the Directorate for Mathematical and Physical Sciences, Division of Astronomical Sciences (MPS/AST), through the Advisory Committee of the Directorate for Mathematical and Physical Sciences, conducted a community-based portfolio review to make implementation recommendations that would

best respond to the decadal survey science questions. The resulting report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges* (www.nsf.gov/mps/ast/ast_portfolio_review.jsp), was released in August 2012 and included recommendations related to all major telescope facilities funded by NSF. NSF released a Dear Colleague Letter, NSF 14-022, in December 2013 that outlines the current response to facility recommendations (www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf14022).

The Portfolio Review Committee report gave very high priority ranking to two NRAO telescopes: ALMA and the Karl G. Jansky Very Large Array (VLA). The Robert C. Byrd Green Bank Telescope (GBT) and the Very Long Baseline Array (VLBA) were recommended for divestment from AST funding because of less compelling mapping onto the science questions of the 2010 decadal survey. In the Dear Colleague Letter mentioned above, NSF outlined the next steps to be taken in response to the GBT and VLBA recommendations, specifically including a formal study of alternative futures for these telescopes.

Total Obligations for NRAO

(Dollars in Millions)

	FY 2013	FY 2014	FY 2015	ESTIMATES ¹				
	Actual	Estimate	Request	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Operations and Maintenance	\$41.00	\$43.14	\$40.00	\$40.00	\$40.00	\$40.00	\$40.00	\$40.00
<i>Observatory Management</i>	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
<i>Observatory Operations</i>	30.20	32.34	29.20	29.20	29.20	29.20	29.20	29.20
<i>Science, Acad. Affairs, EPO</i>	3.44	3.44	3.44	3.44	3.44	3.44	3.44	3.44
<i>Central Development Lab</i>	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63
ALMA Operations	32.92	34.27	40.17	40.17	40.17	40.17	40.17	40.17
Total, NRAO	\$73.92	\$77.41	\$80.17	\$80.17	\$80.17	\$80.17	\$80.17	\$80.17

Totals may not add due to rounding.

¹ Outyear funding estimates are for planning purposes only; updated outyear forecasts will be included in the solicitation for the NRAO management competition, to be released early in 2014. The current cooperative agreement ends in September 2015.

Increased funding in FY 2015 supports the planned ramp up to full ALMA operations, including projected increases in power costs in Chile.

Partnerships and Other Funding Sources: NRAO supplements AST support with funding provided by other NSF sources, other federal agencies, and non-federal sources. In FY 2013, NRAO received approximately \$230,000 from non-AST sources at NSF, \$2.0 million from other federal agencies, and \$2.10 million 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 conducted in partnership with relevant industries through competitive sub-awards to various large and small aerospace companies, radio antenna manufacturing firms, and specialized electronics and computer hardware and software companies.

Education and Public Outreach: NRAO supports a comprehensive outreach program that makes information about radio astronomy available to the public (<https://public.nrao.edu/>). With over 150 students involved per year, NRAO facilities are used by graduate students carrying out dissertation research and work experience programs and by undergraduate students participating in the Research Experiences for Undergraduates (REU) program. NRAO sites also support visitor and education centers and conduct active educational and public outreach programs. The Green Bank Science Center and the visitor center at the VLA together attract over 60,000 public visitors each year.

Observatory Management, \$5.73 million: This includes support for the director's office, administrative

Major Multi-User Research Facilities

services, and the New Initiatives Office.

Observatory Operations, \$29.20 million: This includes support for operating facilities at Green Bank, West Virginia, in New Mexico, and the computer and information services that support the facilities.

Science & Academic Affairs and EPO, \$3.44 million: 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), \$1.63 million: 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.

ALMA Operations, \$40.17 million: NRAO is engaged in construction and operation of the international ALMA Observatory, which, in FY 2014, is in the final stages of construction funded through the Major Research Equipment and Facilities Construction (MREFC) account. Early operations funding for ALMA began in FY 2005 and ramps up sharply from FY 2008 to FY 2015. A funding profile through FY 2015 was authorized by the National Science Board in February 2011.

As part of ALMA Operations, 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. NAASC is increasing its activity in conjunction with the ramp up in ALMA operations. NAASC serves two key functions: (1) supporting basic ALMA operations as an ALMA Regional Center, providing day-to-day support for ALMA operations carried out in Chile, and (2) providing easy access and strong support to the broad astronomical community that will be using ALMA. NAASC organizes summer schools, workshops, and courses in techniques of millimeter and submillimeter astronomy.

Management and Oversight

- **NSF Structure:** Continuing oversight and assessment is carried out for NRAO and ALMA by dedicated AST program officers 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, as well as by the attendance of AST program officers and AST management at ALMA governance board and governance committee meetings of the managing organization, AUI. To address issues as they arise, AST works closely with other NSF offices, such as the Office of General Counsel, the Office of International and Integrative Activities, the Division of Acquisition and Cooperative Support, and the Large Facilities Office in the Office of Budget, Finance, and Award Management.
- **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. Oversight of the international ALMA project is vested in the ALMA Board, which includes a member from NSF; coordination and management of the merged international efforts are the responsibility of the Joint ALMA Observatory (JAO) whose staff includes an ALMA director. An international ALMA review committee advises the ALMA Board.
- **Reviews:** NSF conducts annual reviews of the NRAO Program Operating Plan, the Long Range Plan, ALMA construction and operations, and the AUI Management Report. A Business Systems Review and mid-term Management Review were conducted in FY 2012.

Renewal/Recompetition/Termination

A management review of AUI's performance and plans was carried out in 2008. In response, the National Science Board authorized renewal of the cooperative agreement with AUI for the management and operation of NRAO for the period October 1, 2010 through September 30, 2015. Preparations are

underway for a NRAO management and operations solicitation that will be promulgated in FY 2014 for a new cooperative agreement to begin on approximately April 1, 2016, as well as the concomitant adjustment to the term of the present cooperative agreement.

As announced in a Dear Colleague Letter, NSF 13-074, NSF will separate GBT and VLBA from the upcoming competition in order to sustain the scientific and operational synergies of North American ALMA and the VLA, while increasing flexibility for exploring cost-efficient operational models and sustainable partnerships for GBT and VLBA.

OTHER FACILITIES FUNDING

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, refer to the MREFC chapter of this Budget Request.

Preconstruction Planning

Within the R&RA account, funds are provided for preconstruction studies for prospective large facility projects. This funding generally supports such activities as design, cost estimates, and other actions that prepare potential projects for oversight review, agency decisions milestones, and potential implementation.