MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION

Major Research Equipment and Facilities Construction Funding

(Dollars in Millions)

	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request	Change Over FY 2010 Estimate Amount	Change Over FY 2010 Estimate Percent
Major Research Equipment and Facilities Construction	$160.76	$254.00	$117.29	$165.19	$47.90	40.8%

The Major Research Equipment and Facilities Construction (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. Initial planning and design, and follow on operations and maintenance costs of the facilities are provided through the Research and Related Activities (R&RA) account.

MREFC Account Funding, by Project

(Dollars in Millions)

	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	FY 2016 Estimate
AdvLIGO	$51.43	-	$46.30	$23.58	$20.96	$15.17	$14.92	-	-
ATST[1]			13.00	17.00	20.00	20.00	20.00	20.00	20.00
ARRV	14.13	148.07	-	-	-	-	-	-	-
ALMA	82.25	-	42.76	13.91	3.00	-	-	-	
IceCube	11.85	-	0.95	-	-	-	-	-	-
NEON	-	-	-	20.00	87.92	101.07	103.43	86.23	32.07
OOI	-	105.93	14.28	90.70	102.80	46.80	20.00	-	-
SPSM	1.10	-	-	-					
MREFC Account Total	**$160.76**	**$254.00**	**$117.29**	**$165.19**	**$234.68**	**$183.04**	**$158.35**	**$106.23**	**$52.07**

Totals may not add due to rounding.

[1]Funds appropriated for ATST through ARRA in FY 2009, totalling $146.0 million, were obligated in January 2010.

The future progress of some subfields of research depends heavily upon access to new generations of powerful research tools. Increasingly, these tools are large and complex, and have a significant information technology component.

In order for a project to be considered for MREFC funding, NSF requires that it represent an exceptional opportunity that enables research and education. In addition, the project should be transformative in nature in that it should have the potential to shift the paradigm in scientific understanding and/or infrastructure technology. The projects included in this budget request meet these criteria based on NSF and National Science Board (NSB) review.

All of the projects in the MREFC account have undergone major cost reviews to establish baseline definitions of each project's scope, budget, and schedule, as required by guidelines instituted by NSF over the last few years. Most recently, the projects that received funding through the American Recovery and Reinvestment Act of 2009 (ARRA), the Alaska Region Research Vessel (ARRV), the Ocean Observatories Initiative (OOI), and the Advanced Technology Solar Telescope (ATST), completed Final

Design Reviews and have subsequently received approval from the NSF Director and NSB to initiate construction.

In FY 2011, NSF requests funding to continue construction of four projects: Advanced LIGO (AdvLIGO), the Atacama Large Millimeter Array (ALMA), ATST, and OOI. In addition, NSF requests $20.0 million to initiate construction of the National Ecological Observatory Network (NEON).

NSF maintains a "no cost overrun" policy, which requires that each project's total cost estimate developed at the preliminary design stage include adequate contingency to cover all foreseeable risks, and further requires that any total project cost increases not covered by contingency be accommodated by reductions in scope. NSF senior management has instituted agency-wide procedures to assure that the cost tracking and management processes are robust and that the project management oversight has sufficient authority to meet this objective. If total project estimates for the current slate of projects are revised, NSF will identify potential mechanisms for offsetting any cost increases in accordance with this policy.

<u>Appropriation Language</u>

For necessary expenses for the acquisition, construction, commissioning, and upgrading of major research equipment, facilities, and other such capital assets pursuant to the National Science Foundation Act of 1950, as amended (42 U.S.C. 1861-1875), including authorized travel, ~~$117,290,000,~~*$165,190,000,* to remain available until expended~~: *Provided*, That none of the funds may be used to reimburse the Judgment Fund~~.

Major Research Equipment and Facilities Construction
FY 2011 Summary Statement
(Dollars in Millions)

	Enacted/ Request	Carryover/ Recoveries	Transfers	Total Resources	Obligations Incurred/ Estimated
FY 2009 Omnibus	$152.01	$66.48		$218.49	$160.76
FY 2009 ARRA	400.00			400.00	254.00
FY 2010 ARRA	-	146.00		146.00	146.00
FY 2010 Estimate	117.29	57.73		175.02	175.02
FY 2011 Request	165.19			165.19	165.19
$ Change from FY 2010 Estimate					-$9.83
% Change from FY 2010 Estimate					-5.6%

Totals may not add due to rounding.

<u>Explanation of Carryover:</u>

Regular Discretionary

Within the **Major Research Equipment and Facilities Construction (MREFC)** appropriation, a total of $57.73 million was carried forward into FY 2010. This includes:

Alaska Region Research Vessel (ARRV):	$33.23 million
Ocean Observatories Initiative (OOI):	$5.91 million
IceCube Neutrino Observatory (IceCube):	$7.39 million
South Pole Station Modernization (SPSM):	$1.20 million
Advanced Technology Solar Telescope (ATST):	$7.0 million
National Ecological Observatory Network (NEON):	$3.0 million

- Reason for Carryover: For continuing costs associated with multi-year construction project.
- Expected Obligation: Funds will be obligated and expended over the remaining period of construction.

American Recovery and Reinvestment Act of 2009 (ARRA)

Within the **Major Research Equipment and Facilities Construction** appropriation, a total of $146.0 million was carried forward for the Advanced Technology Solar Telescope (ATST).

- Reason for Carryover: Cooperative agreement currently being implemented. Approved by NSB in August.
- Obligated: January 2010.

The MREFC Account in FY 2011:

The following pages contain information on NSF's ongoing and requested projects in FY 2011, organized by sponsoring directorate. These are:

BIOLOGICAL SCIENCES

The National Ecological Observatory Network — $20,000,000

The FY 2011 Budget Submission for the National Ecological Observatory Network (NEON) is $20.0 million, which represents the first year of a five-year project that spans six fiscal years and totals an estimated $433.72 million.

Appropriated and Requested MREFC Funds for the National Ecological Observatory Network
(Dollars in Millions)

	Prior Years[1]	FY 2009	FY 2010 Estimate	FY 2011 Request	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	FY 2016 Estimate	Total Project Cost
Regular Appropriations	$3.00	-	-	$20.00	$87.92	$101.07	$103.43	$86.23	$32.07	$433.72
Total, NEON	**$3.00**	**-**	**-**	**$20.00**	**$87.92**	**$101.07**	**$103.43**	**$86.23**	**$32.07**	**$433.72**

[1] Per P.L. 110-161, $4.0 million was rescinded from prior year unobligated balances.

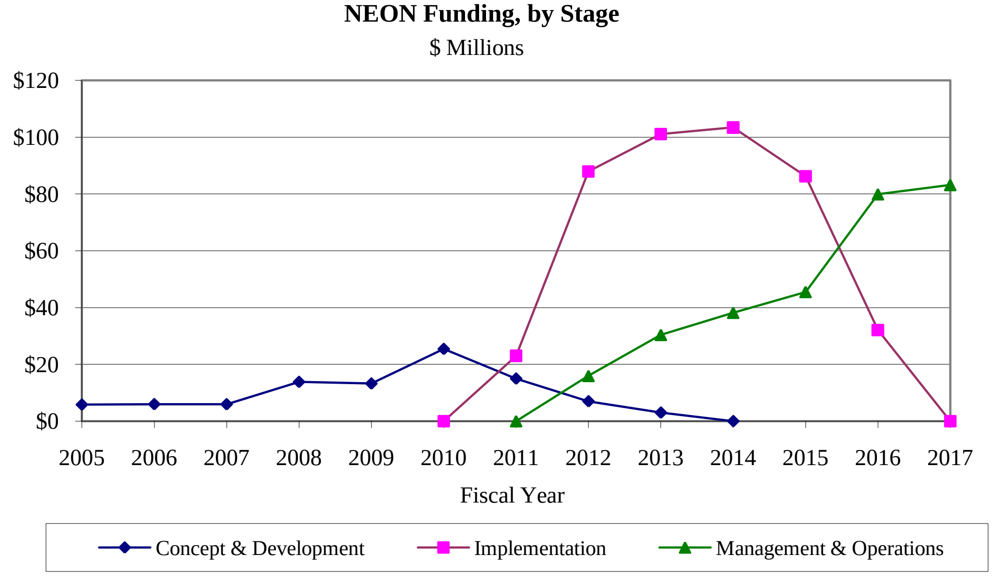
Baseline History: In 2004 the National Research Council (NRC) evaluated the original NEON design of loosely confederated observatories and recommended that it be reshaped into a single integrated platform for regional to continental scale ecological research. Congress appropriated a total of $7.0 million through the MREFC account for NEON in FY 2007 and FY 2008, $4.0 million of which was rescinded in FY 2008. At that time, the total estimated cost for construction was $100.0 million. A Preliminary Design Review (PDR) was completed in June 2009; a Final Design Review (FDR) was completed in November 2009; project planning will continue through FY 2010; and construction is scheduled to begin in 2011. A formal construction baseline review and cost review occurred as part of the Final Design Review (FDR) and an additional baseline review will be conducted in early FY 2011 prior to initiation of construction to ensure there are no significant changes to cost and the estimated schedule baselines.

NEON will consist of geographically distributed field and lab infrastructure networked via cybertechnology into an integrated research platform for regional to continental scale ecological research. Cutting-edge sensor networks, instrumentation, experimental infrastructure, natural history archive facilities, and remote sensing will be linked via the internet to computational, analytical, and modeling capabilities to create NEON's integrated infrastructure.

Total Obligations for NEON
(Dollars in Millions)

	Prior Years	FY 2009 Actual	FY 2010 Estimate	FY 2011 Request	ESTIMATES FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
R&RA Obligations:									
Concept & Development	$31.58	$13.26	$25.45	$15.00	$7.00	$3.00	-	-	-
Management and Operations	-	-	-	-	15.93	30.39	38.18	45.51	79.91
Subtotal, R&RA Obligations	31.58	13.26	25.45	15.00	22.93	33.39	38.18	45.51	79.91
MREFC Obligations:									
Implementation	-	-	-	23.00	87.92	101.07	103.43	86.23	32.07
Subtotal, MREFC Obligations	-	-	-	23.00	87.92	101.07	103.43	86.23	32.07
Total: NEON Obligations	**$31.58**	**$13.26**	**$25.45**	**$38.00**	**$110.85**	**$134.46**	**$141.61**	**$131.74**	**$111.98**

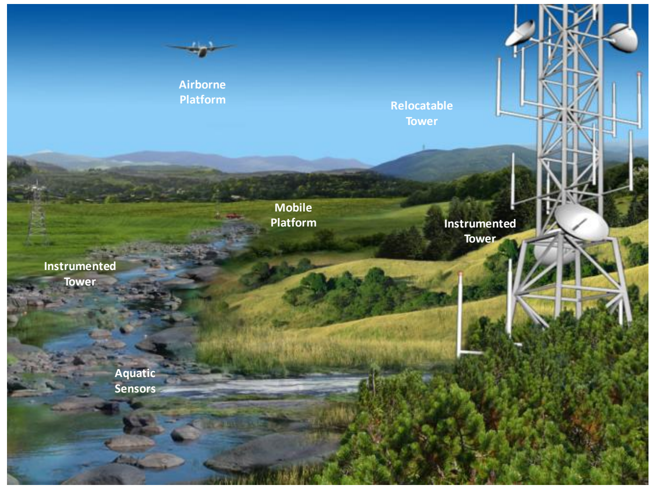
Totals may not add due to rounding.



Since NSF supports 63 percent of the fundamental environmental biology research at U.S. academic institutions, advances in the field of ecology and the infrastructure to enable those advances depend largely on support from NSF. Current research infrastructure is inadequate to enable studies to address the complex phenomena driving ecological change in real time and at the scales appropriate for studying many grand challenge questions in ecology. The Long Term Ecological Research (LTER) program is an ecosystem based research program. NEON is a research facility that will enable research at regional to continental scale. NEON infrastructure will be co-located at eleven LTER sites. When operational, NEON will not replace LTER, but will allow LTER researchers to expand the scale of their research to understand larger scale dynamics affecting their ecosystems. As a continent-wide research instrument, NEON will support a large and diverse group of organizations and individuals; foremost are the scientists, educators, and engineers who will use NEON infrastructure in their research and educational programs. A NEON cyberinfrastructure gateway will provide resources to support formal and informal public education and provide opportunities for citizens to participate in scientific investigations. Data from standard measurements made using NEON will be available in "near real time". The basic NEON datastreams will be open-access via web portals and available as soon as possible once basic QA/QC procedures have been applied.

Recent USGCRP assessments indicate that U.S. ecosystems will experience abrupt and unpredictable changes from a suite of human-driven processes in the near future. The Administration has identified these environmental issues as among the most important, demanding, and urgent global problems of our time, and scientific discovery and science-based decision making are critical to selecting mitigation and adaptation policies and strategies. NEON is the platform to provide the scientific foundation needed to address these environmental challenges, and the urgency of these issues to our national resources, economic vitality, health, quality of life, and national security supports beginning to build NEON in FY 2011. With a construction start in FY 2011, NEON will provide an unprecedented opportunity to detect environmental signals as early as FY 2012.

NEON will enable research on the impacts of climate and land use change, unsustainable water use, and invasive species on the Nation's living ecosystems at the temporal and spatial scales that are relevant to human well-being. NEON will be the first research platform and the only national experimental facility specifically designed to enable such basic research. All prior basic research infrastructure was designed and deployed on an ad hoc, question-, mission-, or site basis. NEON is unique. Its statistically-determined, continental-scale design, with data products, data management, and standardization will support research on the dynamics of complex coupled systems needed for modeling and understanding rates of change on regional and continental scales. No other standalone system – federal or private – can provide the scientifically validated suite of data measurements that NEON anticipates providing. For example, federal operational agencies, such as EPA, provide comprehensive, sustained, and dependable observations in real time on a broad geographic basis, similar to the observations supporting the forecasts of the National Weather Service; these observations support information needs and forecasts for resource management. In contrast, NEON will provide infrastructure to enable hypothesis-driven basic biological and ecological research, with data and high-level data products available in close to real-time. NEON scientists will develop and use the latest technologies and sensors to push the envelope of knowledge. Just as NEON researchers will benefit from access to data from Federal Agency networks that provide spatial and temporal coverage of the US, so will federal agencies benefit as the techniques, sensors and knowledge gained through NEON-enabled activities migrate from research to societal applications and inform management decisions.



Caption: NEON infrastructure on the landscape will include sensors deployed on towers at the Core site, towers that can be relocated, mobile tower systems to study acute or episodic phenomena, below the soil, and in proximate water bodies such as streams or lakes. These sites will be sampled routinely by airborne sensing to permit the site based sensor information to be scaled to the landscape and regional scales. *Credit: CH2M Hill for the NEON Environmental Assessment.*

NSF and NEON, Inc. coordinate with other federal agencies through the NEON Federal Agency Coordinating Committee, Memorandum of Understanding (MOU), Memoranda of Agreements, and Cooperating Agency Agreements. Areas of coordination include planning, design, construction, deployment, environmental assessment, data management, geospatial data exchange, cyberinfrastructure, research, and modeling. In addition, NSF will continue to seek opportunities for new interagency and international partnerships. Examples of current partnerships include:

- Design: Jet Propulsion Laboratory (JPL) designed and is building the hyperspectral sensor for the NEON airborne observation platform;
- NEON infrastructure deployment sites: USDA Forest Service, USDA Agricultural Research Service, Bureau of Land Management, Department of Energy (DOE), and National Park Service;
- Sharing of geospatial data, in-situ verification, and archival of NEON aerial remote sensing data with the U.S. Geological Survey (USGS);
- Partners in research; modeling; data exchange, standards, and protocols: National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and Environmental Protection Agency (EPA); and
- International: Discussions have begun between NEON, Inc. and Mexican and Canadian scientists to broaden linkages with NEON and expand the research capability to the North American continent.

Private organizations (e.g., the Heinz Center, Nature Serve, and the Science and Engineering Alliance) participated in NEON design and development activities. The Science and Engineering Alliance and the Ecological Society of America are assisting NEON, Inc. with education and inclusion of minority serving institutions in NEON science and education. Building enhanced accessibility for all institutions into the design will broaden the impact of NEON science and education to the next generation of scientists and educators. While the bulk of NEON's infrastructure and instrumentation will be "commercial off-the-shelf", NEON's scientific and networking design required certain technological innovations. Consequently, BIO has provided Research and Related Activities funds for advanced research and development (R&D) activities in the areas of sensors and cyberinfrastructure.

Project Report:

Management and Oversight:

- NSF Structure: The NEON program is managed in the BIO Office of the Assistant Director (OAD/BIO) as part of Emerging Frontiers. OAD/BIO provides overall policy guidance and oversight, and the location of the NEON program in Emerging Frontiers fosters its interdisciplinary science connections. The NEON program is managed by a dedicated program officer. A business oversight team chaired by the NEON program officer advises and assists with the business framework of the project. A BIO-NEON committee, which includes the Deputy Director for Large Facility Projects in the Office of Budget, Finance and Award Management (BFA), and a cross-NSF Program Advisory Team (PAT), formulates program planning for NEON. The NEON program officer is the contracting officer's technical representative (COTR) for the NEON environmental assessment and is assisted by the NEON Environmental Assessment Team (EA) that provides technical advice on environmental assessment, National Environmental Policy Act (NEPA) compliance, and NSF environmental policy.

- External Structure: The NEON project is funded through cooperative agreements with NEON, Inc., a non-profit, membership-governed consortium, established to oversee the design, construction, management and operation of NEON for the scientific community. Within that organization, the CEO provides overall leadership and management; the project manager oversees all aspects of the project design, review, construction, and deployment; and the director of computing is responsible for oversight of the cyberinfrastructure and embedded sensor development. A Board of Directors, a Science, Technology, and Education Advisory Committee (STEAC) and a Program Advisory Committee (PAC), composed of members of the NEON user community, each provide oversight and guidance to the project and help ensure that NEON will enable frontier research and education.

- Reviews:

  - Technical reviews: The NEON Observatory Design Review (including site selection and deployment design) was successfully completed in February 2009.
  - Management, Cost, and Schedule reviews:
    - The Conceptual Design Review (CDR) was held in November 2006;
    - A combined Preliminary Design Review (PDR)/Final Design Review (FDR) of the airborne observation platform was successfully completed in February 2009;
    - A PDR for the entire project was successfully completed in June 2009;
    - An FDR was successfully completed in November 2009, including construction and cost reviews;
    - An operations review of the project's operating plan and anticipated budget is scheduled for April 2010; and
    - An additional baseline review, to ascertain readiness to begin construction, is scheduled for FY 2011 prior to construction.

Current Project Status:

In November 2009, the final design, scope, schedule, and risk-adjusted costs were reviewed and the project's baseline scope, budget, and schedule were found to be credible. The review panel endorsed the remaining pre-construction planning activities slated for this year that will enable the project to commence construction should the proposed FY2011 budget be available. Following the recommendations of the FDR panel, contingency has been increased to cover known risks. The NEON, Inc. Project Office has completed the final design, NEON project execution plan (PEP), and maintenance and operations plan. The site selection and associated deployment plan is complete and has been merit reviewed. The NEPA environmental assessment was completed in November 2009 and a "Finding of No Significant Impact" was signed by NSF in December 2009. This will allow construction to commence as soon as MREFC funds are available.

Cost and Schedule:

The projected length of the project is five years covering six fiscal years, with a six-month schedule contingency. The risk adjusted cost of $433.72 million includes a contingency budget of 19 percent.

Support is requested through the Research and Related Activities (R&RA) account for the NEON Project Office, housed in Emerging Frontiers (EF). R&RA funds will be used to scale up final project activities, including retiring risk and completing detailed construction-ready design documents. Activities include establishment of the NEON Calibration/Validation Laboratory for sensors and instrumentation; advanced design for the first six NEON domains and all NEON core sites; and biological assessment and permitting for the first six domains.

Funding appropriated through the MREFC account in FY 2008 will continue to be carried over. Contingent on approval of a construction award by the NSB, MREFC funds will be used to begin construction of NEON in the fourth quarter of FY 2011. Early construction focuses on establishment of the NEON Data Center and beginning construction of two domains.

NEON project planning will continue through FY 2010, and construction will begin in 2011.

Risks:

- Technical: Dependence on commercial off-the-shelf technology will be mitigated by long-lead purchase orders and alternative vendors. Production quality, embedded and system-level cyberinfrastructure will be addressed by a combination of "in-house" design, commercial, contracts, and targeted research (e.g., cyber-dashboard).

- Deployment: Environmental assessment and permitting may impact schedule and costs. These risks have been and continue to be addressed through multiple means, including: the direct contracting of the environmental assessment by NSF; the hiring of two national firms by NEON, Inc. for engineering and permitting; by identification of alternative sites if the primary sites are determined to have significant risk; and the allocation of two full-time equivalents (FTE) by the U.S. Forest Service to assist with environmental compliance issues on Forest Service lands.

- Geospatial Data Acquisition: A potential risk is the long-term availability of satellite (e.g., LANDSAT and MODIS) borne sensors. This risk is mitigated through a partnership with the USGS EROS Data Center that has the federal responsibility for curation and management of LANDSAT and MODIS images and having alternative satellite sensor sources to purchase images (e.g., SPOT -

France, AWIFS – India, Terra and Aqua - US). The proposed NEON airborne observatory platform (AOP) sensor system design and aircraft availability are a source of technical and implementation risk. To minimize this risk, the AOP is being developed by the Jet Propulsion Laboratory (JPL); similar instrument packages are being prototyped by NASA and Carnegie Mellon Institute at Berkley University. The sensor system fits multiple aircraft, including commercial aircraft. Experienced flight design engineers were contracted by NEON, Inc. to provide the baseline operations plans, aircraft analysis, and assessment of commercial companies that could support NEON flight operations and experienced research aircraft pilots serve on the design team.

Future Operations Costs:

Preliminary management and operations costs were reviewed at the NEON FDR in November 2009. A final operations review, specifically focused on anticipated maintenance and operations (M&O) costs for the project, is scheduled for April 2010. NEON is reliant on sensors and cyberinfrastructure that have a defined lifecycle. Operations costs include scheduled replacement and refreshing of sensor, instrumentation, and cyberinfrastructure technology. NEON operations also include significant labor costs due to the labor-intensive processes required as part of the Fundamental Sentinel Unit (FSU), which is a major component of each domain.

GEOSCIENCES

Alaska Region Research Vessel $0

The FY 2011 Budget Submission does not request funds for the Alaska Region Research Vessel (ARRV). The remaining project balance was provided through the American Recovery and Reinvestment Act of 2009 (ARRA) as shown in the table below. The estimated project cost is $199.50 million.

Appropriated and Requested MREFC Funds for the Alaska Region Research Vessel
(Dollars in Millions)

	FY 2007	FY 2008	FY 2009	FY 2010 Request	FY 2011 Request	Total
Regular Appropriations	$9.43	$42.00	-	-	-	$51.43
ARRA	-	-	148.07	-	-	148.07
Total, ARRV	**$9.43**	**$42.00**	**$148.07**	**-**	**-**	**$199.50**

Baseline History: NSF first requested construction funding for the ARRV 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. In FY 2009, NSF delayed acquisition of the ARRV to incorporate updated pricing information into the construction plan. Rapid inflation in the shipbuilding industry made it difficult to accurately project the final construction cost for the ARRV. A revised project estimate was provided during the Final Design Review (FDR) held in October 2008. The new baseline, which was presented to and approved by the National Science Board in March 2009, incorporates an updated technical scope for the ship in order to meet current regulatory requirements, proper administrative support by the awardee, a realistic construction schedule, and an independent, risk-adjusted cost estimate for construction. The final construction baseline against which progress will be monitored is under development according to a schedule agreed upon by NSF and the awardee.

Total Obligations for the ARRV
(Dollars in Millions)

	Prior Years	FY 2009 Actual	FY 2010 Estimate	FY 2011 Request	ESTIMATES FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
R&RA Obligations:									
Concept & Development	$2.24	-	-	-	-	-	-	-	-
Management and Operations	-	-	-	-	-	-	4.17	8.34	8.50
Subtotal, R&RA Obligations	2.24	-	-	-	-	-	4.17	8.34	8.50
MREFC Obligations:									
Implementation	4.06	14.13	40.00	-	-	-	-	-	-
ARRA	-	148.07	-	-	-	-	-	-	-
Subtotal, MREFC Obligations	4.06	162.20	40.00	-	-	-	-	-	-
Total: ARRV Obligations	**$6.30**	**$162.20**	**$40.00**	**-**	**-**	**-**	**$4.17**	**$8.34**	**$8.50**

Totals may not add due to rounding.

The ARRV will replace the R/V *Alpha Helix*, which, at 40 years of age prior to its decommissioning, was the oldest ship in the national Academic Research Fleet. Science activities in the Arctic have been limited by the capabilities of the *Alpha Helix*, which was restrictively small and could not operate in ice or in severe winter weather in the open seas. With its ice-strengthened hull, the ARRV has been designed to operate year round in the challenging waters of the Chukchi, Beaufort, and Bering Seas, as well as the open Gulf of Alaska, coastal Southeast Alaska, and Prince William Sound, including operations in seasonal ice up to 3.9 feet thick.

Satellite observations have shown that the perennial ice in the Arctic is thinning at a rate of 9 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. Furthermore, the ARRV will provide a sophisticated and significantly larger platform for scientists, 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. Broadband satellite communications capable of relaying data, including high definition video from tools such as remotely operated vehicles that explore under the ice and the ocean depths, will bring research into the K-12 classroom and to the general public.

This image is an artist's rendition of the ARRV, which will replace the R/V *Alpha Helix.*

The construction phase of the project is being led by the University of Alaska, Fairbanks (UAF). A complete contract level design package has been completed by UAF's naval architect, The Glosten Associates, Inc. It is anticipated that the ARRV will greatly expand research capabilities in the region, going from a maximum of 160 ship operating days with the R/V *Alpha Helix*, up to 270-300 days with the ARRV. The vastly increased capability of the ARRV, both with regard to its ability to accommodate much larger interdisciplinary research teams and greatly enlarged geographical and seasonal ranges, will dramatically increase the number of proposals addressed to NSF for its utilization. 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 would be supported annually.

Project Report:

<u>Management and Oversight:</u>

- 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 the Integrative Programs Section (IPS) of the Division of Ocean Sciences (OCE), Directorate for Geosciences (GEO). Periodic oversight is provided by a Project Advisory Team (PAT) which includes staff from GEO and OPP, the Division of Acquisition and Cooperative Support (DACS), the Large Facilities Office (LFO), the Office of the General Counsel (OGC), and Office of Legislative Public Affairs (OLPA). Additional staff from IPS, the LFO, and DACS, as well as external consultants, help provide the Program Officer with routine project management and technical assistance.

- External Structure: UAF has established a project management office in Fairbanks, AK, a component of which will eventually include an on-site team that will remain in the shipyard throughout the construction process. The ARRV Oversight Committee (AOC), which includes community experts in research vessel design, construction, and operations, has been commissioned and convenes monthly to review project status and provide technical and science support advice to both UAF and NSF.

- Reviews:
  - Final Design Review (FDR): FDR was completed in October 2008. The Panel advised that both the design and Project Execution Plan were "sound" and ready to proceed with construction. UAF presented a risk adjusted project baseline that was considered realistic based on market conditions just prior to FDR. NSF used Panel recommendations to increase confidence levels and account for recent global market volatilities to arrive at the final estimated project cost of $199.50 million.
  - Acquisition Strategy Review: NSF conducted a final review of UAF's vessel and propulsion acquisition strategies in January 2009 based on Panel comments from FDR. Final NSF guidance was given to UAF and revised documents have been received and approved by NSF.
  - Consent Reviews: NSF has conducted two internal reviews during Phase II to evaluate UAF's shipyard and thruster (Z-drive) selection processes. A third consent review was conducted following receipt of cost proposals and UAF's "best value" determination in November 2009.
  - Upcoming Reviews: NSF will conduct annual project reviews once construction begins using panels of experts familiar with ship construction, project management, and earned value management (EVM) reporting. The first such panel is expected to convene in mid-2010.

<u>Current Project Status:</u>

Thruster selection is complete and the contract with the vendor has been executed. Proposals from interested U.S. shipyards have been received and evaluated by UAF. The shipyard contract was signed on December 18, 2009.

<u>Cost and Schedule:</u>

The total estimated project cost following FDR is $199.50 million. The majority of this total, an estimated $123.18 million or 55 percent, is the fixed price contract with the shipyard. UAF management, including purchase of propulsion units as Owner-Furnished Equipment, is $21.40 million, or 11 percent. Final outfitting, science trials, and delivery are $23.60 million, or 12 percent. Due to extreme global market volatility, the total required project contingency is $44.50 million, or 22 percent.

Construction is anticipated to take thirty to thirty-six months. Preliminary vessel acceptance from the shipyard is anticipated for mid-FY 2013 followed by a year of science trials, final outfit, and transit to Alaska. The transition to operations is anticipated to take place in conjunction with a partial operating year in FY 2014 with the first full year of operations occurring in FY 2015.

<u>Risks:</u>

A formal risk assessment and management plan was developed by UAF in accordance with NSF guidelines and presented at FDR. Following FDR, the Risk Management Plan and Risk Register will be formally updated monthly by UAF and reviewed by NSF on a routine basis. Significant risks at this stage of the project include:

- Technical Risk: Any component of the vessel not meeting technical requirements of the specifications resulting in loss of capability or increased costs to correct after installation or delivery.

- Change Risk: Shipyard contract disputes and claim potential associated with design development due to changing regulatory body requirements and owner initiated design changes.
- Schedule Risk: Extension of the construction and delivery schedule which would result in project cost increases due to inflation and UAF standing army costs.

Mitigation strategies have been employed by UAF and the risk analysis indicates that sufficient contingency is currently in place to handle these project risks. The bid risk for the thrusters has been retired. Costs came in lower than FDR estimates due to a reduction in demand that has followed a slower global ship construction market. Proper change and contingency management control processes are in place to facilitate the project coming on time and within budget.

Future Operations Costs:

Vessel operations will be governed by the terms of a separate cooperative agreement with UAF through the Ship Operations Program within IPS. Daily rate estimates for both the ship and technical services were provided by UAF at FDR. It is anticipated that OCE will pay for approximately 65 percent of the annual vessel operating costs ($8.40 million per year) based on historical data from other global ships within the academic research vessel fleet. The remaining 35 percent of the funding support for the ARRV is expected to come from the Office of Polar Programs (OPP) and other federal agencies. In short, the ARRV will fold into an already well established framework for operating the academic research vessel fleet.

Ocean Observatories Initiative $90,700,000

The FY 2011 Budget Submission for the Ocean Observatories Initiative (OOI) is $90.70 million, which represents the second year of a six year construction project totaling $386.42 million.

Appropriated and Requested MREFC Funds for the Ocean Observatories Initiative
(Dollars in Millions)

	Prior Years[1]	FY 2009	FY 2010 Estimate	FY 2011 Request	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	Total
OOI Regular Appropriations and Requests	5.91	-	14.28	90.70	102.80	46.80	20.00	280.49
ARRA	-	105.93	-	-	-	-	-	105.93
Total, OOI	**$5.91**	**$105.93**	**$14.28**	**$90.70**	**$102.80**	**$46.80**	**$20.00**	**$386.42**

Per P.L. 110-161, $5.12 million was recsinded from prior year unobligated balances.

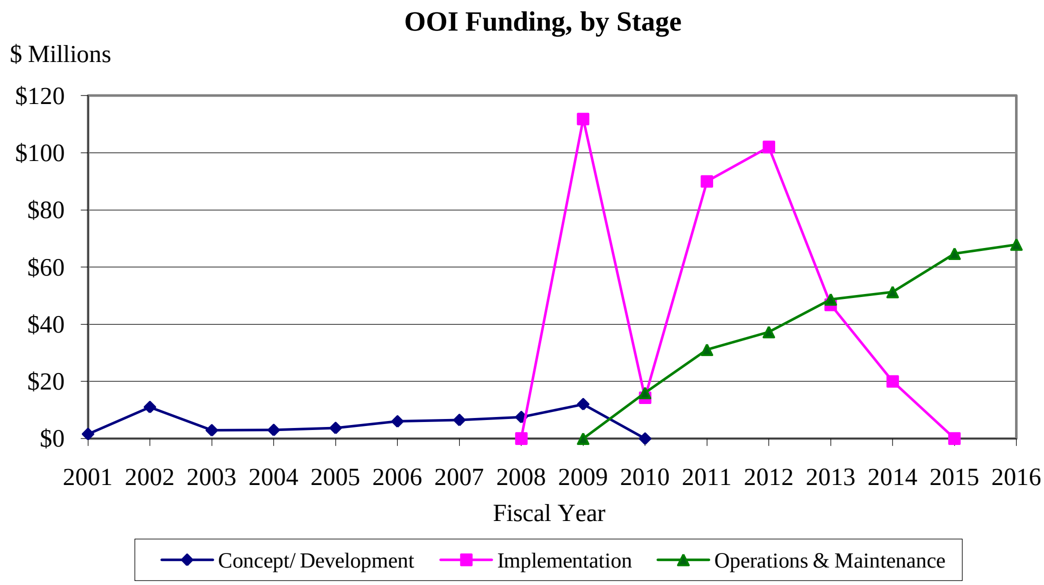
The OOI will consist of an integrated observatory network that will provide the oceanographic research and education communities with continuous, interactive access to the ocean. The OOI will have three elements: 1) deep-sea buoys with designs capable of deployment in harsh environments such as the Southern Ocean; 2) regional cabled nodes on the seafloor spanning several geological and oceanographic features and processes; and 3) an expanded network of coastal observatories. A cutting edge, user-enabling cyberinfrastructure will link the three components of the OOI and facilitate experimentation using assets from the entire OOI network.

Baseline History: NSF first requested construction funding for OOI through the MREFC account in FY 2007 and received an initial appropriation of $5.12 million in that year. The OOI has undergone a series of technical reviews, with the Final Design Review (FDR) conducted on November 6-7 and 12-14, 2008. The FDR panel determined that OOI was ready to move to construction assuming some adjustments to the baseline with respect to schedule and overall project contingency. Following the FDR, in an effort to focus OOI more specifically on high priority science issues related to climate change, ocean acidification, carbon cycling, and ecosystem health, NSF initiated a rapid turn-around process to develop a modified network design in January 2009, referred to as the Variant Design. An additional Science Review Panel and Cost/Schedule Review Panel convened by NSF in March 2009 supported proceeding with the Variant Design and the project was approved at the May 2009 National Science Board meeting.

Total Obligations for OOI
(Dollars in Millions)

	Prior Years	FY 2009 Actual	FY 2010 Estimate	FY 2011 Request	ESTIMATES FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
R&RA Obligations:									
Concept & Development	$57.06	$17.84	-	-	-	-	-	-	-
Management and Operations			16.50	27.50	35.70	47.20	52.30	64.70	67.90
Subtotal, R&RA Obligations	57.06	17.84	16.50	27.50	35.70	47.20	52.30	64.70	67.90
MREFC Obligations:									
Implementation	-		20.19	90.70	102.80	46.80	20.00	-	-
ARRA	-	105.93	-	-	-	-	-	-	-
Subtotal, MREFC Obligations	-	105.93	20.19	90.70	102.80	46.80	20.00	-	-
Total: OOI Obligations	**$57.06**	**$123.77**	**$36.69**	**$118.20**	**$138.50**	**$94.00**	**$72.30**	**$64.70**	**$67.90**

Totals may not add due to rounding.



NOTE: FY 2009 implementation funding includes $105.93 million provided through the American Recovery and Reinvestment Act.

Deployed in critical parts of the global and U.S. coastal ocean, OOI's 24/7 telepresence will capture climate, carbon, ecosystem, and geodynamic changes on the time scales at which they occur, rather than when research vessels are able to be in the area. Data streams from the air-sea interface through the water column to the seafloor will be openly available to educators and researchers in any discipline, making oceanography available to citizens and scholars who might never go to sea. Science themes for OOI include the ocean carbon cycle and its response to global change, ocean acidification, the impact of climate variability and ocean circulation, coastal ocean dynamics and ecosystem response, and the interplay of tectonically-driven fluid flow on the carbon cycle, deep ocean ecosystems, and earthquakes.

The education and public engagement infrastructure of OOI will complement and leverage existing ocean education efforts, and build off of the cyberinfrastructure to provide an interactive digital presence to educators and the public alike. Educational links will be made with the Division of Ocean Sciences (OCE) Centers for Ocean Science Education Excellence (COSEE). In addition, with the establishment of the National Integrated Ocean Observing System (IOOS), there will be an unprecedented need for a STEM workforce and oceanographers skilled in the use and manipulation of large, oceanographic, time-series datasets. The facilities comprising OOI will provide the ideal platforms to train this new generation of oceanographers. These activities will include rigorous evaluation and measurement.

Some of the component technologies that are part of OOI are currently in use or in development as part of the telecommunication and exploration industries. These groups have been engaged in drafting components of the OOI Network Design as well as in reviews of OOI planning. Industry will also be important participants in the construction and implementation phase of OOI, as well as in the future development of sensors critical to the evolution of the OOI network. Most recently, industry representatives joined with the OOI Project Team to discuss OOI sensor requirements at a joint workshop.

OOI will be coordinated with the IOOS to support operational mission objectives of agencies such as the National Oceanic and Atmospheric Administration (NOAA), the U.S. Navy, the National Aeronautics and Space Administration (NASA), and the U.S. Coast Guard.

Science proposals using the OOI network will be solicited as part of the normal competition for funds in OCE. The research envisioned for OOI encompasses a broad range of disciplines, and therefore no special research program will be established. Instead, proposals will be reviewed and competed with other research proposals submitted to OCE.

Project Report:

Management and oversight:

- NSF Structure: The project is managed and overseen by a program manager in OCE in the Directorate for Geosciences (GEO). The program manager receives advice and oversight support from an NSF Project Advisory Team (PAT) that includes representatives from GEO, the Directorates for Biological Sciences (BIO) and Engineering (ENG); the Office of Budget, Finance and Award Management (BFA); the Office of International Science and Engineering (OISE); the Office of General Counsel (OGC); and the Office of Legislative and Public Affairs (OLPA). The Deputy Director for Large Facility Projects (DDLFP) in BFA is also a member of the PAT and provides advice and assistance.

- External Structure: For the construction phase of OOI, management, coordination, and oversight of OOI is the responsibility of the OOI project director operating from the Ocean IES Project Office (systems integrator) at the Consortium for Ocean Leadership (Ocean Leadership), established through a cooperative agreement with NSF in 2004. This project director is accountable to NSF, the Ocean Leadership Board of Trustees, and an external scientific and technical advisory committee. The OOI Project Advisory Committee membership is drawn from individuals with expertise in ocean observing science and engineering. Subawards have been issued by Ocean Leadership to establish three Implementing Organizations (IOs). These IOs provide the detailed management and oversight for implementation of the regional cabled observatory (led by the University of Washington), cyberinfrastructure (led by the University of California-San Diego/Scripps Institution of Oceanography), and coastal/global observatories (led by Woods Hole Oceanographic Institution). These IOs report directly to the Project Office, which ensures cooperation and coordination between the IOs.

- Reviews:

    - Technical reviews: NSF organized a series of external science reviews for OOI, including the Blue Ribbon Review in July 2006, which assessed whether the ocean observing network proposed in the OOI Conceptual Network Design (CND) would provide the capabilities for the ocean researchers to answer high priority science questions that require *in situ*, real-time measurements across the three scales of OOI. A second Blue Ribbon Review in October 2007 assessed whether the OOI Preliminary Network Design provided the experimental capabilities needed to address the scientific scope outlined for OOI. These science reviews provided a general endorsement of OOI, supplemented by a series of recommendations for improvement. These reviews also served as input to the paired design reviews (Conceptual and Preliminary). NSF convened a Blue Ribbon Review in March 2009 to assess a modified OOI network design and its ability to provide transformative research capabilities for the ocean science community. This OOI Variant Design is a modification to the existing network design that more closely focuses OOI infrastructure on climate processes, carbon cycling, ocean acidification, and ecosystem health. The Blue Ribbon Review panel noted that the OOI, as described by the Variant Network Design, remains a worthy investment, providing a transformative capability for the ocean science community.

- Management, Cost, and Schedule reviews:
  - The OOI Conceptual Design Review (CDR), held August 2006, reviewed the scope and system level implementation plans for OOI, including management plans and budgeting. It discussed whether all major risks with this project have been identified and whether appropriate initial system development specifications (performance requirements, major system components, and interfaces) have been established for each sub-element of OOI.
  - The Preliminary Design Review (PDR) in December 2007 assessed the robustness of the technical design and completeness of the budget and construction planning for the OOI. The PDR panel also reviewed progress made by the OOI Project Team on the findings of the CDR.
  - The FDR in November 2008 assessed whether OOI's project plans were fully ready for construction and determined that there was a high degree of confidence that the scope, as proposed, could be delivered within the parameters defined in the project baseline.
  - A Cost-Schedule Review Panel in March 2009 assessed whether the OOI Variant Design project plans were fully ready for construction and determined that there was a high degree of confidence that the scope, as proposed, could be delivered within the parameters defined in the project baseline.

- Upcoming reviews:
  - Semi-annual and/or annual external reviews of the OOI Project will occur during the construction phase. A semi-annual review cycle is planned for the first year of construction.

<u>Current Project Status:</u>

In FY 2009, the OOI received $105.93 million of ARRA funds to initiate construction, and a Cooperative Agreement was awarded in September 2009 to the Consortium for Ocean Leadership. These funds will support a suite of efforts across the OOI project in the first two years of construction, including production engineering and prototyping of key coastal and global components (moorings, buoys, sensors), award of the primary cable contract, completion of the shore station, data sensing and acquisition digital capabilities, and instrument agent development. The initial construction activities of hiring project staff, mobilizing project control systems, and entering into major subawards are underway. Subawards to University of California at San Diego, Woods Hole Oceanographic Institution and University of Washington were completed in October/November 2009.

<u>Cost and Schedule:</u>

In FY 2009, OOI received ARRA funding in the amount of $105.93 million to initiate construction. In addition, $5.91 million was appropriated in FY 2008 and was carried over into FY 2009. These funds will support a suite of efforts across the OOI project in the first two years of construction, including production engineering and prototyping of key coastal and global components (moorings, buoys, sensors), award of the primary cable contract, completion of the shore station, data sensing and acquisition digital capabilities, and instrument agent development. An $89.0 million contract for the Primary Undersea Cable Infrastructure was awarded in November 2009. Initiation of such activities during FY 2009 and FY 2010 will provide risk reduction for the project.

Estimated requests in FY 2011 and beyond, totaling $260.30 million for construction and an estimated $223.40 million for initial operations will enable the completion of construction activities and initiation of the operations phase. Construction activities include acquisition and deployment of OOI instruments and sensors as well as coastal and open ocean moorings. Initial operations include post commissioning activities such as network sensing, data acquisition, and data delivery to the scientific community.

Risks:

- Oversight risk: The complexity of the OOI and the need for the Project Office and Implementing Organizations to coordinate and integrate construction activities and network implementation under the schedule, cost, and scope constraints of the project presents a project risk. OOI relies heavily on open lines of communication and effective cooperation between the managing entities (Project Office and IOs) and NSF. Both the PDR and the FDR panels were very supportive of the management structure. To ensure effective management and oversight, monthly and annual reports provided by the Project Office and IOs will be closely monitored by the OOI Program Manager and Contracts Officer for deviations from established baselines (using Earned Value Management) and annual site visits and reviews will be used to gain a more detailed understanding of the integrative nature of the project teams. In addition, weekly teleconferences with the program staff from both the Project Office and IOs will help ensure that all groups are up to date with current activities. NSF will conduct programmatic reviews on an annual or semi-annual basis, as needed, in addition to assessments by an external scientific oversight committee. Lastly, NSF's OOI Program Director will attend the Project Office's own internal reviews to ensure that OOI implementation is proceeding according to established principles as outlined in the cooperative agreement.

- Scope contingency: The Project Team has provided an appropriate level of contingency for OOI as dictated by a comprehensive (top-down and bottom-up) risk analysis. Should this contingency be exhausted, reductions in the scope of the OOI network plan will be required. These potential reductions, or scope contingency, must be implemented based on clearly articulated scientific priorities. Any changes to scope (as well as cost or schedule) will follow the OOI Change Control Process, which has a tiered evaluation process for evaluating and determining any change to the project.

- Risks Related to the OOI Cyberinfrastructure (CI): The OOI CI will not only provide the network integration needed to achieve the scientific goals of OOI, but a robust, user-friendly CI will be essential to develop a vigorous OOI user community. Ensuring the "usability" of the CI was a key topic of discussion at the preliminary and final design reviews. Addressing recommendations from the FDR, the CI Implementing Organization was required by NSF to incorporate continued engagement of the user community during development and testing of the cyberinfrastructure. Additionally, continued involvement of Office of Cyberinfrastructure (OCI) Program Managers, via the PAT, and participation in reviews of the OOI network, will help mitigate risks associated with development and construction of the OOI CI.

Future Operations Costs:

Operations costs will ramp up to $64.70 million in FY 2015 as depicted in the obligations table. The expected operational lifespan of this project is 25 years. Operations cost reviews will be conducted prior to and throughout the operations phase to assess the project and inform future budget requests.

MATHEMATICAL AND PHYSICAL SCIENCES

Advanced Laser Interferometer Gravitational-Wave Observatory $23,580,000

The FY 2011 Budget Request for the Advanced Laser Interferometer Gravitational-Wave Observatory (AdvLIGO) is $23.58 million, which represents the fourth year of a seven-year project totaling an estimated $205.12 million.

Appropriated and Requested MREFC Funds for the Advanced Laser Interferometer Gravitational-Wave Observatory

(Dollars in Millions)

FY 2008	FY 2009	FY 2010 Estimate	FY 2011 Request	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	Total
$32.75	$51.43	$46.30	$23.58	$20.96	$15.17	$14.92	$205.12

Baseline History: NSF first requested FY 2008 construction funds for AdvLIGO through the MREFC account in the FY 2006 Budget Request to Congress. The original proposal received in 2003 estimated a total construction cost of $184.35 million. A baseline review in June 2006 established the project cost at $205.12 million, based upon known budget inflators at the time and a presumed start date of January 1, 2008. A second baseline review, held in June 2007, confirmed this cost, subject to changes in budget inflators. Final Design Review in November 2007 recommended that construction begin in FY 2008. The National Science Board approved the project at a cost of $205.12 million in March 2008, and the project began in April 2008.

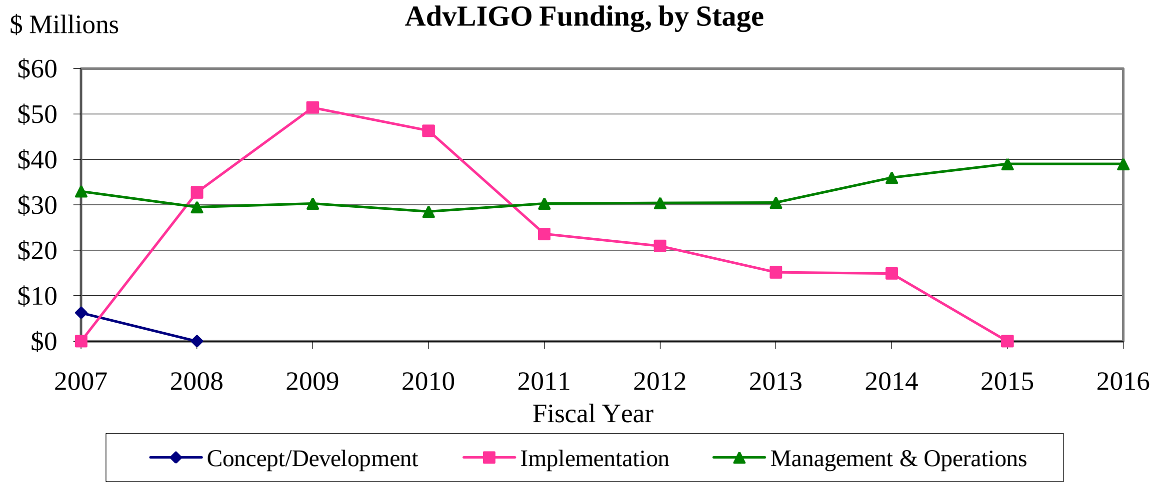
AdvLIGO is the planned upgrade of the Laser Interferometer Gravitational-Wave Observatory (LIGO) that will allow LIGO to approach the ground-based limit of gravitational-wave detection. LIGO consists of the world's most sophisticated optical interferometers, operating at two sites 3,000 km apart: Hanford, WA and Livingston, LA. These interferometers measure minute changes in arm lengths resulting from the passing of wave-like distortions of spacetime called gravitational waves, caused by cataclysmic processes in the universe such as the coalescence of two black holes or neutron stars. LIGO is sensitive to changes as small as one one-thousandth the diameter of a proton over the 4-km arm length; AdvLIGO is expected to be at least 10 times more sensitive. The LIGO program has stimulated strong interest in gravitational-wave research around the world, producing vigorous programs in other countries that provide strong competition as well as highly beneficial collaborations. LIGO has pioneered and led the field of gravitational-wave detection, and a timely upgrade is necessary to sustain progress in this area.

Total Obligations for AdvLIGO

(Dollars in Millions)

	Prior Years	FY 2009 Actual	FY 2010 Estimate	FY 2011 Request	ESTIMATES FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
R&RA Obligations:									
Concept & Development	$40.74	-	-	-	-	-	-	-	-
Management & Operations	29.50	30.30	28.50	30.30	30.40	30.50	36.00	39.00	39.00
Subtotal, R&RA Obligations	70.24	30.30	28.50	30.30	30.40	30.50	36.00	39.00	39.00
MREFC Obligations:									
Implementation	32.75	51.43	46.30	23.58	20.96	15.17	14.92	-	-
Subtotal, MREFC Obligations	32.75	51.43	46.30	23.58	20.96	15.17	14.92	-	-
Total: AdvLIGO Obligations	**$102.99**	**$81.73**	**$74.80**	**$53.88**	**$51.36**	**$45.67**	**$50.92**	**$39.00**	**$39.00**

Totals may not add due to rounding.



Note: Management & Operations refers to the continued operations of LIGO during the construction phase and the onset of operations for the newly constructed AdvLIGO in FY 2015.

Active outreach programs have been developed at both the Hanford and Livingston sites. Teams at both sites have provided visual displays, hands-on science exhibits, and fun activities for visiting students and members of the public. In the last three years an average of over 2,000 students per year have taken advantage of this opportunity. More formal programs at the sites include participation in the Research Experiences for Teachers (RET) program, a set of "scientist-teacher-student" research projects in support of LIGO, and participation in the Summer Undergraduates Research Fellowships/Research Experiences for Undergraduates (SURF/REU) programs for college students. Both sites have developed web-based resources for teachers that include information on research opportunities for schools and a set of standards-based classroom activities, lessons, and projects related to LIGO science. The LIGO Science Education Center at the Livingston site contains many Exploratorium exhibits and 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.

Substantial connections with industry have been required for the state-of-the-art construction and measurements involved in the LIGO projects, with some partnerships leading to the development of new products. Areas of involvement include novel techniques for fabrication of LIGO's vacuum system, seismic isolation techniques, ultrastable laser development (new product introduced), high-power active optical components (new products), the development of new ultra-fine optics polishing techniques, and the development of new optical inspection equipment (new product).

LIGO has extensive international ties. The LIGO Scientific Collaboration, which sets the scientific agenda for LIGO, is an open collaboration that has established formal ties with institutions from 13 foreign countries. Close collaboration is maintained with two other gravitational-wave observatories: GEO, a UK-German collaboration, and Virgo, a French-Italian collaboration. LIGO has signed an agreement with Virgo under which all data will be shared and analyzed cooperatively and all discoveries will be jointly credited. New technologies critical to AdvLIGO are being contributed by foreign institutions: the pre-stabilized laser source, funded and developed by the Max Planck Gesellschaft; the mirror/test mass suspension systems, funded and developed by the GEO collaboration; and the auxiliary optical components, developed by the Australian National University and Adelaide University. The laser has essentially attained its design specifications; the suspension systems are being tested in European gravitational-wave facilities; and prototypes of some of the auxiliary optical components have been tested with LIGO's current configuration.

Assembly and testing of AdvLIGO optical suspension components for use in high vacuum. *Credit:* LIGO Laboratory.

Project Report:

Management and Oversight:

- NSF Structure: NSF oversight is coordinated internally by a dedicated LIGO program director in the Division of Physics (PHY) in the Directorate for Mathematics and Physical Sciences (MPS), who also participates in the LIGO Advisory Team (LIGO PAT). The LIGO PAT includes staff from the Offices of Budget, Finance, and Award Management (BFA), General Counsel (OGC), and Legislative and Public Affairs (OLPA). Formal reporting consists of submitted quarterly and annual reports and brief monthly status reports to the LIGO program officer, who in turn reviews, edits, comments, and submits the reports to the Deputy Director for Large Facility Projects.

- External Structure: LIGO is managed by California Institute of Technology under a cooperative agreement. The project has a detailed management structure in place.

- Reviews:
  - Technical Reviews: NSF conducts annual scientific and technical reviews involving external reviewers, participates in meetings of the LIGO Scientific Collaboration (LSC), and conducts site visits to the Hanford and Livingston interferometers.
  - Management, Cost, and Schedule Reviews: (1) AdvLIGO construction proposal review in 2003; (2) first baseline review in June 2006; (2) second baseline review in June 2007; (3) final readiness review in November 2007.
  - The first AdLIGO review of the active project was held in November 2008.

- AdvLIGO's first annual review was held in April 2009, and an interim review was conducted in December 2009; the second annual review is scheduled for April 2010; and the third will be held in April 2011.
- Continuing annual reviews will be conducted by external panels throughout construction; these reviews will be supplemented by smaller interim reviews held concurrently with the LIGO facility annual reviews, which are held in the November/December timeframe each year.

Current Project Status:

The National Science Board approved funding for the AdvLIGO in March 2008, and the project began in April 2008. Major initial activities include the placing of long lead-time orders and the preparation of the sites for the upgrade. The project has met its milestone dates so far, including the ordering of major items such as core optics blanks and their polishing and coating, and the ordering of components for the seismic isolation systems. The current performance is consistent with ending on time and on budget. Total project contingency usage as of November 2009 is $1.72 million of an initial $39.10 million, or 4.4 percent of contingency for 16.1 percent of the project completed.

Shutdown of the LIGO observatories is not planned until autumn 2010 and winter 2011. Until that time, the LIGO Laboratory has incorporated some AdvLIGO components into the two 4-km interferometers and is conducting a science run (S6) at higher sensitivities than was attained with the initial LIGO interferometers. The primary purpose of this run is to test AdvLIGO components; the run is a success from both a scientific and a technical standpoint. Minor redesigning of some AdvLIGO components is proceeding, and the sensitivity of the S6 run in its early stages is about 50 percent higher than that at the beginning of the S5 run.

Cost and Schedule:

The projected length of the project is seven years, with an 11-month schedule contingency. The risk-adjusted cost of $205.12 million included a contingency budget of 23.7 percent (at the time of the award).

Risks:

The AdvLIGO project underwent a comprehensive external annual review in April 2009. The review panel found the project "…to be on-track. The budget, schedule, contingency, and risk are being managed well." The panel believed the current contingency level, which is slightly above the initial level, to be adequate. NSF program staff are confident that risk is being managed effectively but are monitoring progress and conducting frequent reviews.

Technical risks include uncertainties about such topics as eliminating parametric instabilities in the optical cavities, the minimization of thermal noise in the mirror optical coatings, and the mitigation of possible electrical charges on optical elements. The LIGO Laboratory has been conducting research to minimize these risks, and an internal risk management team oversees these efforts. Risk management and its results are topics of internal and biannual external reviews.

Management risks include the planned decommissioning and installation procedures as well as risks involving adherence to the project timelines and budget. NSF staff conduct weekly meetings with the project management to oversee the progress of the project; monthly, quarterly, and annual reports, as well as annual reviews (supplemented by interim reviews), are also important project monitoring instruments. The project status is tracked with earned value management parameters.

Environmental risk is being effectively mitigated. The freely-suspended optical elements at the core of the observatory are carefully protected from earthquakes. Anthropogenic noise at the Livingston site due to logging and oil exploration has been mitigated by communication with local industry and by the early adoption of AdvLIGO seismic noise isolation technology.

Safety is maintained by adherence to institutional guidelines and to published LIGO Laboratory safety practices, overseen by dedicated safety officers at both facility sites. Hazard analysis is conducted before work is begun, and hazard mitigation is performed. External review panels have consistently found safety procedures to be satisfactory.

Future Operations Costs:

Future operations and maintenance costs will be approximately $39.0 million per year and will be funded through NSF's Division of Physics.

Advanced Technology Solar Telescope $17,000,000

The FY 2011 Budget Request for the Advanced Technology Solar Telescope (ATST) is $17.0 million. FY 2011 represents the second year of an eight-year construction project. The total project cost, $297.93 million, was finalized after a Final Design Review (FDR) in May 2009. The National Science Board approved an award for this amount at the NSF Director's discretion, contingent upon completion of compliance with relevant environmental and cultural/historic statutes.

The environmental compliance requirements were completed on November 20, 2009, and the Record of Decision authorizing the construction was signed by the NSF Director on December 3, 2009.

Appropriated and Requested MREFC Funds for the Advanced Technology Solar Telescope

(Dollars in Millions)

	FY 2009	FY 2010 Estimate	FY 2011 Request	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	FY 2016 Estimate	FY 2017 Estimate	Total
Regular Approps	$7.00	$13.00	$17.00	$20.00	$20.00	$20.00	$20.00	$20.00	$14.93	$151.93
ARRA	146.00	-	-	-	-	-	-	-	-	146.00
Total, ATST	**$153.00**	**$13.00**	**$17.00**	**$20.00**	**$20.00**	**$20.00**	**$20.00**	**$20.00**	**$14.93**	**$297.93**

Baseline History: Beginning in 2001, NSF provided funds to the National Solar Observatory (NSO) for an eight-year design and development program for ATST and its initial complement of instruments through the Division of Astronomical Sciences (AST) and the Division of Atmospheric and Geospace Sciences (AGS; formerly ATM). The current ATST design, cost, schedule, and risk were scrutinized in an NSF-conducted Preliminary Design Review (PDR) in October-November 2006. The Final Design Review (FDR) held in May 2009 determined that the ATST project is fully-prepared to begin construction. A number of specific panel recommendations on contracting strategy, contingency estimating, and other items, were subsequently included in the project execution plan.

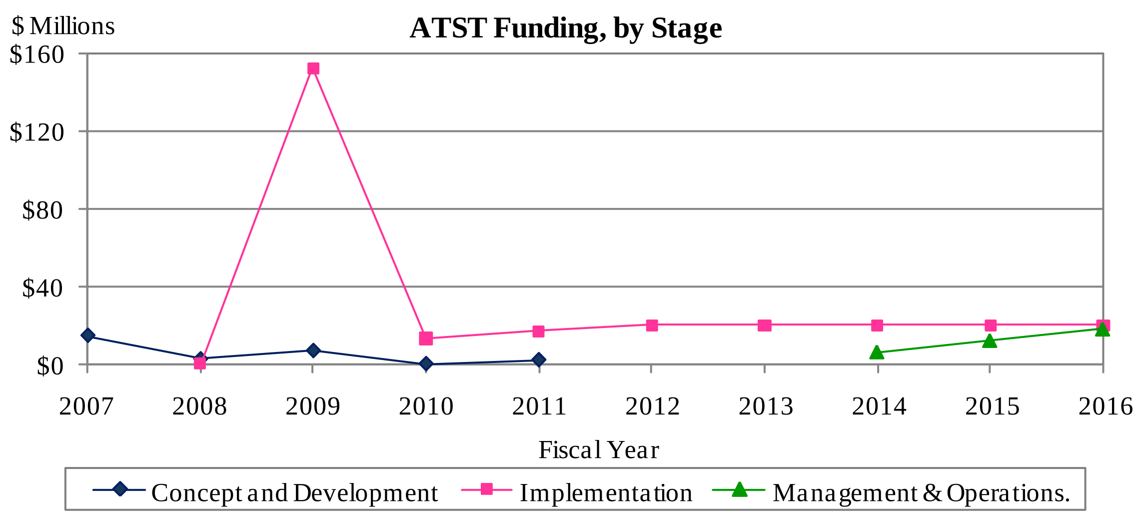
In FY 2009, $6.67 million was provided in the R&RA account to support design activities to complete a construction-ready design. Of these R&RA funds, $3.10 million was appropriated through the American Recovery and Reinvestment Act of 2009 (ARRA) for risk reduction, prototyping, and design feasibility and for cost analyses in areas identified at preliminary and systems design reviews. The funds will also support several new positions to complete preparation for the start of construction. Also in FY 2009, $153.0 million was provided through the MREFC account to initiate construction. Of these MREFC funds, $146.0 million was appropriated through ARRA. Construction is scheduled to commence in FY 2010.

Total Obligations for ATST

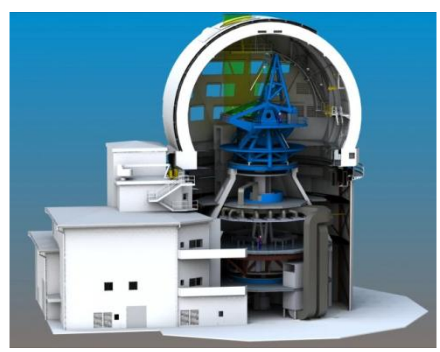
(Dollars in Millions)

	Prior Years	FY 2009	FY 2010 Estimate	FY 2011 Request	ESTIMATES FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
R&RA Obligations:									
Concept & Development	$16.84	$3.57	-	$2.00	-	-	-	-	-
Management & Operations	-	-	-	-	-	-	6.00	12.00	18.00
ARRA		3.10	-	-	-	-	-	-	-
Subtotal, R&RA Obligations	16.84	6.67	-	2.00	-	-	6.00	12.00	18.00
MREFC Obligations:									
Implementation	-	-	20.00	17.00	20.00	20.00	20.00	20.00	20.00
ARRA	-		146.00	-	-	-	-	-	-
Subtotal, MREFC Obligations	-	-	166.00	17.00	20.00	20.00	20.00	20.00	20.00
Total: ATST Obligations	**$16.84**	**$6.67**	**$166.00**	**$19.00**	**$20.00**	**$20.00**	**$26.00**	**$32.00**	**$38.00**

Totals may not add due to rounding.



ATST will enable the study of magneto-hydrodynamic phenomena in the solar photosphere, chromosphere, and corona. Determining the role of magnetic fields in the outer regions of the Sun is crucial to understanding the solar dynamo, solar variability, and solar activity, including flares and mass ejections, which can affect civil life on Earth and may have impact on the terrestrial climate.



Cutaway view of the ATST Facility. *Credit: National Solar Observatory.*

The project is a collaboration of scientists and engineers at more than 20 U.S. and international organizations. Other potential partners include the Air Force Office of Scientific Research and international groups in Germany, the United Kingdom, and Italy. Now that there is firm funding for construction, details of these partnerships are being discussed. Currently:

- The US Air Force has recently replaced the aluminizing chamber at the AEOS telescope on Maui and sized it to accommodate the ATST mirror. This obviates the need to build a dedicated chamber for the ATST primary;
- Kiepenheuer Institut fuer Sonnenphysik (Freiburg, Germany) plans to contribute a narrow-band visible tunable filter, a first-light instrument;
- Queens University Belfast is considering contributing very high speed cameras for ATST instrumentation; and
- Arcetri Observatory (Italy) is considering the design and construction of an adaptive secondary (an upgrade to the current plans), as well as an infrared tunable filter.

Discussions of other possible contributions for second-generation instruments are continuing.

Project Report:

Management and Oversight:

- NSF Structure: Oversight from NSF is handled by a program manager in the MPS AST Division working with staff from the Offices of Budget, Finance and Award Management (BFA), General Counsel, Legislative and Public Affairs, and AGS in GEO. The Deputy Director for Large Facilities in BFA also provides advice and assistance.

- External Structure: The ATST project is managed by NSO. NSO operation and maintenance and ATST design and development are funded by NSF via a cooperative agreement with the Association of Universities for Research in Astronomy, Inc (AURA). The NSO Director serves as the director of the ATST project; a senior NSO scientist is the project scientist; and an experienced full-time project manager coordinates the project activities. Several councils and working groups provide input from the solar and space physics communities.

- Reviews:
  - Technical Reviews: Reviews have been conducted throughout the design and development phase. The preliminary design was found to be robust in the NSF-conducted Conceptual Design Review in March 2005 and Preliminary Design Review in October-November 2006. The project has completed a comprehensive set of system-level design reviews for all major sub-systems.
  - Management, Cost, and Schedule Reviews: The ATST cost, schedule, and risk were scrutinized and validated at the Preliminary Design Review.
  - The Final Design Review (FDR): The FDR was held on May 18-21, 2009 in Tucson, Arizona. The unanimous finding of the review panel was that the ATST project is fully-prepared to begin construction. A number of specific panel recommendations on contracting strategy, contingency estimating, and other items, were subsequently included in the project execution plan.
  - Upcoming Reviews: Annual reviews of the construction will start in mid-FY 2010.

Current Project Status:

Current activities include finalizing the design and retiring the remaining areas of risk. The project has chosen the Haleakala High Altitude Observatory on the island of Maui, Hawaii as the ATST site. The Final Environmental Impact Statement was submitted to the Environmental Protection Agency on July 24, 2009. Consultation with Native Hawaiian stakeholders has resulted in a fully-executed programmatic agreement that details steps to minimize the impact on the traditional cultural assets on Haleakala, thereby completing compliance with the National Historic Preservation Act. All environmental compliance requirements are now complete. Application for final construction permits required for the ATST site is underway now that the record of decision (ROD) authorizing the commencement of construction in FY 2010 was published in the Federal Register on December 9, 2009.

Costs and Schedule:

The baseline not-to-exceed cost was established following the FDR. Funding will derive from ARRA ($146.0 million) and expected annual appropriations in the MREFC account ($151.93 million). Because it is necessary to clearly separate funds from the two sources, the project developed two separate statements of work, dividing their resource-loaded Work Breakdown Structure (WBS) between large contracts to be funded early in the project by ARRA, and smaller procurements and project costs such as labor and rent, to be funded by future annual MREFC appropriations. In January 2010, the project submitted a revised budget for the construction proposal for use of MREFC funds, along with a revised statement of work and budget justification for funds from the ARRA. The resulting funding profile extends for nine years. The extreme front-loading of funding as well as judicious choice of the WBS elements expected to be funded by future MREFC appropriations, allow for a constant funding ramp in the outyears while maintaining a reasonable spend-and-commit profile for both cost and contingency. Assuming a construction start in FY 2010, full science operation will begin in FY 2017.

The $3.10 million of ARRA funding within the R&RA account is being used to fund risk-reduction work, prototyping and design feasibility, and cost analyses. The highest priority of these activities is the completion with industry of the site architectural and engineering work required for the detailed foundation design. These studies drive the schedule for work on site and therefore drive the construction critical path. Other recommended work includes adaptive optics deformable mirror prototyping ($400,000) and wavefront sensor camera development ($400,000), and software and controls development. These risk-reduction efforts with industry flow directly from recommendations made by design and cost-review committees. This funding has also allowed staff additions to the project, including an experienced contracts officer and engineers, to complete preparation and planning for construction.

Risks:

Cost and contingency have been validated and essentially all technical risks have been retired. The design is mature and ready for construction contracts to be let. Project management control, interface control, and change control, have all been established. If construction begins early in FY 2010, ATST can be built and commissioned on schedule for a risk-adjusted not-to-exceed cost of $297.93 million.

Technical: The remaining technical risk is very low as a result of the long design and development phase. Risk reduction undertaken post-FDR using $3.10 million of ARRA funds includes the prototyping of a cooled deformable mirror, development of high-speed cameras, and completion of the foundation design.

Environmental and Cultural Compliance: Given the recent history of telescope construction on mountains sacred to Native American and Native Hawaiian people, there is still risk of delay in obtaining permission to begin construction. The Division of Astronomical Sciences, NSF's Office of the General Counsel, and the ATST project have worked carefully through the processes of the applicable statutes such that a protracted delay is not expected. However, a delay early in the construction process may result in the construction missing the first construction window constrained by the breeding season of the Hawaiian Petrel (April-July) but, as noted by the FDR panel, the completion schedule would only slip by three months as a result. The schedule and cost contingency include estimates for such a delay.

Geological: While Haleakala is a dormant volcano, the Hawaiian Islands are seismically active. ATST has been designed according to the required building codes for the appropriate level of earthquake activity, as are other telescopes located in active regions. On the morning of October 15, 2006, a magnitude 6.6 earthquake occurred with its epicenter between Maui and Hawaii. While there was essentially no impact on the existing facilities on Haleakala, several of the large telescopes on Mauna Kea suffered some damage. None of the damage was extensive and all were returned to operation within weeks. Through the Gemini Observatory, NSF convened a lessons-learned workshop involving all of the Hawaiian observatories (including ATST) in March 2007, recommendations from which have been incorporated in the ATST design and operations plan.

Environmental Health and Safety: NSO has a well-developed safety program that is engendered in the ATST project. However, it is imperative that a culture of safety be imposed on the contractors on site. The NSF Program Officer will require the project to develop a site safety plan and conduct a construction readiness review prior to starting construction.

Future Operations Costs:

Estimates for annual ATST operations cost are $12.0 to $14.0 million. A revised operations plan was presented at FDR. Since ATST will become the flagship solar telescope of NSO and will render several telescopes obsolete, about $5.0 to $7.0 million per year of NSO operations cost will be recovered from the closure or divestment of redundant facilities. NSO has developed a preliminary transition plan that will be revised and externally reviewed after approval of construction funds.

Atacama Large Millimeter Array $13,910,000

The FY 2011 Budget Request for the Atacama Large Millimeter Array (ALMA) is $13.91 million, which represents the tenth year of an eleven-year project totaling an estimated $499.26 million.

Appropriated and Requested MREFC Funds for the Atacama Large Millimeter Array

(Dollars in Millions)

FY 2006[1] & Earlier	FY 2007	FY 2008	FY 2009	FY 2010 Estimate	FY 2011 Request	FY 2012 Estimate	Total
$190.97	$64.30	$102.07	$82.25	$42.76	$13.91	$3.00	$499.26

[1]An additional $31.99 million was appropriated through the MREFC account prior to FY 2005 for concept and development.

Baseline History: A $26.0 million, three-year design and development phase was originally planned for a U.S.-only project, the Millimeter Array. NSF first requested funds for the design and development for this project in FY 1998. In June 1999, the U.S. entered into a partnership via a Memorandum of Understanding (MOU) with the European Southern Observatory (ESO), a consortium of European funding agencies and institutions. The MOU committed the partners to construct a 64 element array of 12-meter antennas. NSF received $26.0 million in appropriations between FY 1998 and FY 2000. Because of the expanded managerial and technical complexity of the joint U.S./ESO project, now called ALMA, an additional year of design and development was provided by Congress in FY 2001 at a level of $5.99 million. In FY 2002, $12.50 million was appropriated to initiate construction of ALMA; the U.S. share of the cost was estimated to be $344.0 million. The National Research Council (NRC) of Canada joined ALMA as a partner in 2003. In 2004, Japan entered under the provisions of a MOU between NSF, ESO, and the National Institute of Natural Sciences of Japan.

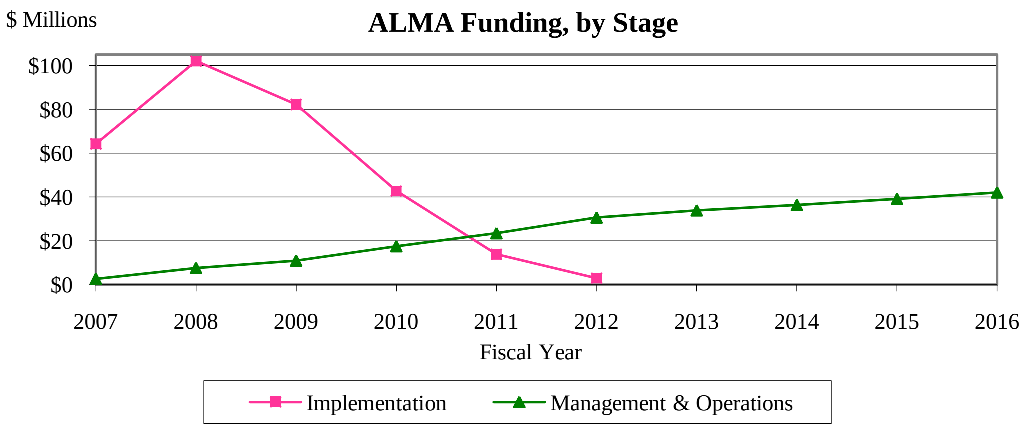
The ALMA Board initiated rebaselining in the fall of 2004 under the direction and oversight of the Joint ALMA Office (JAO) Project Manager. The project was at that point sufficiently mature that the baseline budget and schedule established in 2002, prior to the formation of the partnership, could be refined based on experience. The rebaselining process took approximately one year, scrutinizing cost and schedule throughout the project, assessing technical and managerial risk, and ultimately revising the assumptions on the scope of the project. The new baseline plan developed by the JAO assumed a 50-antenna array as opposed to the original number of 64, extended the project schedule by 24 months, and established a new U.S. total project cost of $499.26 million. The FY 2009 Request was increased by $7.50 million relative to the rebaselined profile in order to allow more strategic use of project contingency to buy down near-term risk, as recommended by the 2007 annual external review. The increase in FY 2009 was offset by a matching decrease in FY 2011.

The global ALMA project will be an aperture-synthesis radio telescope operating in the wavelength range from 3 to 0.4 mm. ALMA will be the world's most sensitive, highest resolution, millimeter-wavelength telescope, combining sub-arcsecond angular resolution with the sensitivity of a single antenna nearly 100 meters in diameter. The array will provide a testing ground for theories of planet formation, star birth and stellar evolution, galaxy formation and evolution, and the evolution of the universe itself. The interferometer is under construction at 5,000 meters altitude near San Pedro de Atacama in the Antofagasta (II) Region of Chile, the ALMA host country.

Total Obligations for ALMA
(Dollars in Millions)

	Prior Years	FY 2009 Actual	FY 2010 Estimate	FY 2011 Request	ESTIMATES FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
R&RA Obligations:									
Concept & Development	$6.50	-	-	-	-	-	-	-	-
Management & Operations	7.64	11.00	17.57	23.50	30.65	33.92	36.41	39.17	42.10
Subtotal, R&RA Obligations	14.14	11.00	17.57	23.50	30.65	33.92	36.41	39.17	42.10
MREFC Obligations:									
Concept & Development	31.99	-	-	-	-	-	-	-	-
Implementation	357.34	82.25	42.76	13.91	3.00	-	-	-	-
Subtotal, MREFC Obligations	389.33	82.25	42.76	13.91	3.00	-	-	-	-
Total: ALMA Obligations	**$403.47**	**$93.25**	**$60.33**	**$37.41**	**$33.65**	**$33.92**	**$36.41**	**$39.17**	**$42.10**

Totals may not add due to rounding.



Once completed, ALMA will be the most capable imaging radio telescope ever built and will bring to millimeter and submillimeter astronomy the high-resolution aperture synthesis techniques of radio astronomy. ALMA will image at 1 millimeter wavelength with the same 0.1 arcsecond resolution achieved by the Hubble Space Telescope at visible wavelengths, and will form a critical complement to the leading-edge optical, infrared, ultraviolet, and x-ray astronomical instruments of the twenty-first century.

ALMA will help educate and train U.S. astronomy and engineering students; at least 15 percent of ALMA's approximately 1,000 yearly users are expected to be students. There is already substantial involvement by graduate students in applied physics and engineering at universities participating in the ALMA Design and Development program, providing an opportunity to broaden participation in science and engineering by members of underrepresented groups.

Extensive public and student ALMA outreach programs will be implemented in North America, Europe, and Chile as ALMA approaches operational status. ALMA education and public outreach (EPO) programs are funded regionally, through the Associated Universities Incorporated/ National Radio Astronomy Observatory (AUI/NRAO), ESO, and the National Astronomical Observatory of Japan (NAOJ), and jointly by the ALMA partnership in Chile. AUI/NRAO's request for NSF funding (including partnership activities) will be critically evaluated as a component of the proposal review in mid-2010 and thereafter as part of the annual external reviews. NRAO's EPO activities are included in

The first US (left) and Japanese (right) antennas, now at the high altitude site of the ALMA Observatory in Chile.
Credit ALMA/ESO/NAOJ/NRAO.

their annual program plan and the status, performance, and issues are assessed by program staff through regular quarterly reports. ESO and NAOJ will follow their own processes for review of their contributions. These reviews include consideration of plans for educational evaluation and measurement of all programs. A visitors' center will be constructed at the 2,800 meter-altitude Operations Support Facility gateway to the ALMA site near San Pedro de Atacama in northern Chile. The project also supports a fund for the Antofagasta (II) Region of Chile that is used for economic, scientific, technical, social, and cultural development, particularly within the nearby towns of San Pedro de Atacama and Toconao.

North America and Europe are equal partners in the core ALMA instrument. Japan joined ALMA as a third major partner in 2004, and will deliver a number of enhancements to the baseline instrument. The North American side of the project, consisting of the U.S., Canada, and Taiwan, is led by AUI/NRAO. Funding and execution of the project in Europe is carried out through the ESO. Funding of the project in Japan is carried out through the National Institutes of Natural Sciences of Japan and project execution is the responsibility of the NAOJ.

From an industrial perspective, ALMA instrumentation will push gallium arsenide and indium phosphide transistor amplifier technology to high frequencies, will challenge production of high-density, high-speed integrated circuits for computational uses, and is expected to stimulate commercial device and communication technologies development.

Peer-review telescope allocation committees will provide merit-based telescope time but no financial support. NSF will not provide awards targeted specifically for use of ALMA. Most U.S. users will be supported through NSF or National Aeronautics and Space Administration (NASA) grants to pursue research programs that require use of ALMA.

Construction progress continues in FY 2010, both at the site in Chile and within the ALMA partner countries. In FY 2009, five production antennas have been delivered to Chile and acceptance testing for two antennas has been completed. In FY 2010 the first antennas will be transported to the final, high-altitude site and science commissioning will begin. Early science operations are expected to commence in FY 2011 and completion of the construction project and the start of full science operations are planned to occur around the end of FY 2012.

Project Report:

Management and Oversight:

- NSF Structure: Programmatic management is the responsibility of the ALMA program manager in the Division of Astronomical Sciences (AST) in the Directorate for Mathematical and Physical Sciences (MPS). An NSF advisory group consisting of representatives from the Office of General Counsel, the Office of Budget, Finance, and Award Management, the Office of International Science and Engineering, and the Office of Legislative and Public Affairs, serves as a standing ALMA Project Advisory Team (PAT). The NSF Deputy Director for Large Facility Projects (DDLFP) is a member of the PAT and provides advice and assistance.

- External Structure: An international ALMA Management Advisory Committee (AMAC) advises AST and the ALMA Board. Management of the NRAO effort on ALMA is carried out under a cooperative agreement with AUI. Oversight of the full international project is vested in the ALMA Board, whose membership includes an NSF member; coordination and management of the merged international efforts is the responsibility of the Joint ALMA Office (JAO), whose staff includes the ALMA Director, project manager, and project engineer.

- Reviews:
  - Technical reviews: The JAO holds frequent technical and schedule reviews at appropriate design and fabrication milestones. For example, a series of reviews to assess the robustness and risks to the schedule was held in November 2008 through January 2009. An operational readiness review of NRAO's receiver integration center was held in April 2009 and others are planned for FY 2010. A function of the AMAC is to conduct project-wide external reviews and to audit internal reviews on behalf of the ALMA Board.
  - Management, Cost, and Schedule reviews: NSF, through the ALMA Board, holds external reviews of the broad project and in targeted areas. A review of the operations plan was conducted in February 2007. A project-wide annual review, held in December 2008, assessed management, cost and schedule performance, status, issues, and risks. NSF also requests broad external assessments, such as the aforementioned management review, and specific assessments, such as the safety review conducted in October 2008. The project-wide annual reviews will continue. A review of schedule and schedule drivers was held in July 2009. This review found that the project is taking all appropriate steps to complete the North American work within budget, that the current forecast completion date of end-2012 is aggressive, and that the budget contingency appears to be sufficient.
  - Upcoming reviews: There will be a performance review of the labor management and practices at the Chilean sites in mid 2010. Annual external reviews occur in November 2009 and late 2010, and a full operations review is planned in 2010.

<u>Current Project Status:</u>

- Major project milestones attained in FY 2009 included:
  - Acceptance of the first three North American and the first Japanese antennas;
  - Continued delivery of North American antennas at a rate of one every two months. By the end of FY 2009, thirteen North American antennas were in Chile at various stages of assembly and test;
  - Delivery of the first European antennas to Chile;
  - Delivery of the second quadrant of the correlator;
  - Delivery of the third and fourth North American and East Asian receivers;
  - Test interferometry at the mid-level facility in Chile using two antennas; and
  - The first three antennas were transported to the final, high-altitude site and their signals combined in a nascent array in late CY 2009.

- Major milestones for FY 2010 are expected to include:
  - Acceptance of the first European antennas;
  - Continued delivery of North American antennas at a rate of one every two months;
  - Acceptance of the fourth through fourteenth North American antennas and the remaining three Japanese antennas;
  - Transport of accepted antennas to the high-altitude site in Chile; and
  - Start of commissioning.

- Major milestones for FY 2011 are expected to include:
  - Acceptance of first Japanese 7-meter antenna;
  - Installation and acceptance of third and fourth quadrants of the correlator;
  - Installation and acceptance of central local oscillator (serves all ALMA Antennas);
  - Call for proposals for early science; and
  - Start of early-science (August 2011).

<u>Cost and Schedule:</u>

The current schedule performance is slightly behind plan due to equipment delivery delays, in particular delivery of the first antennas and receivers. Consequently, the major milestones of early-science and full-science are forecast to be delayed by three to nine months, although schedule recovery is possible. Cost performance is very good at this stage in the project — cost variance is –1 percent and schedule variance is –5 percent relative to the 2005 baseline — with about 40 percent contingency remaining in the uncommitted budget. A cost-to-complete exercise is underway to assess the remaining work, likely liens and other risk-weighted costs against the remaining budget. Significant expenditure of budgeted contingency is foreseen during the remainder of the project.

<u>Risks:</u>

- Full handover of the first North American and Japanese antennas will enable the other delivered antennas to be tested and accepted swiftly. The schedule for production of the European antennas should begin to stabilize once the first few antennas are delivered to Chile. Acceptance of European antennas in Chile is a pacing item for the schedule.
- While fabrication of the individual receiver components is making good progress, their integration into complete receiver systems and subsequent testing are the pacing items for the schedule and will be one of the key challenges for the project in the coming months.
- For operations, the principal challenge is to ramp-up the staffing to 200 technically qualified personnel over the next two years.
- The schedule for the start of initial scientific observations in 2011 depends upon successful commissioning of the first three antennas at the final high-altitude site during 2010.
- Note that the earlier problem of the supply of power to ALMA (a European deliverable) has been resolved and will be accomplished using multi-fuel generators located at the mid-level site.

<u>Future Operations Costs:</u>

Operations and maintenance funds phase in as initial site construction is completed and antennas begin to be delivered. Funds will be used to manage and support site and instrument maintenance, array operations in Chile, early-science (FY 2011) and eventually full-science operations, and in support of ALMA observations by the U.S. science community. Full ALMA science operations are anticipated to begin around the end of FY 2012. An operations plan and a proposal for North American operations were externally reviewed in FY 2007 and a funding profile through FY 2011 was authorized by the National Science Board in December 2007. The operations estimates for FY 2012 and beyond are based on current cost projections. The anticipated operational lifespan of this project is at least 30 years.

MATHEMATICAL AND PHYSICAL SCIENCES/POLAR PROGRAMS

IceCube Neutrino Observatory $0

The FY 2011 Budget Request does not request MREFC funds for the IceCube Neutrino Observatory. The FY 2010 Budget Request to Congress requested $950,000, which represented the final amount necessary to complete the nine-year project, totaling an estimated $279.47 million. $242.07 million of the total project cost has been funded through NSF's MREFC account, and the balance of $37.40 million has been provided by foreign partners in the project. Operations funding is provided through the Research and Related Activities account.

Appropriated and Requested MREFC Funds for the IceCube Neutrino Observatory
(Dollars in Millions)

FY 2004 & Earlier	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010 Estimate	Total
$81.29	$47.62	$49.85	$28.65	$22.38	$11.33	$0.95	$242.07

Total may not add due to rounding.

Baseline History: Congress provided initial appropriations for IceCube of $15.0 million in FY 2002 and $24.54 in FY 2003 for "Start-up Activities", including development of an enhanced hot water drill. NSF requested construction funding for IceCube in the FY 2004 Budget Request, and the total cost of the project (including start-up activities) was estimated to be $271.77 million at that time ($242.07 from NSF and the balance from the international partners). NSF carried out a comprehensive external baseline review of the entire project, including cost, schedule, technical, and management review, in February 2004; this rebaselining effort confirmed the U.S. total project cost of $242.07 million.

The IceCube hot-water drilling rig set up at South Pole Station. *Credit: Jim Haugen, University of Wisconsin.*

Foreign partners provided an additional $7.70 million in FY 2009 to provide additional sensor strings that will add to the capability of instrument. This increase in non-U.S. contributions brings the total project cost to $279.47 million. NSF's cost, however, remains constant at $242.07 million.

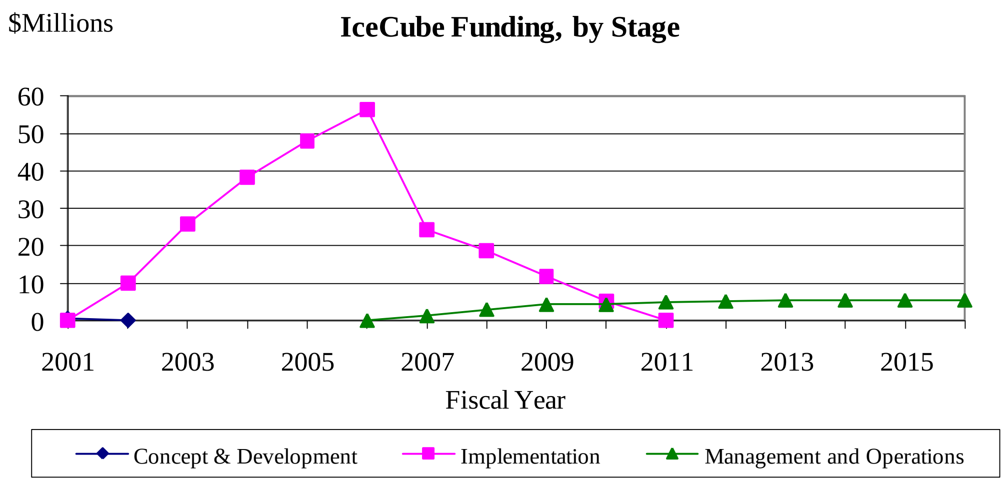
IceCube is the world's first high-energy neutrino observatory, located deep within the ice cap under the South Pole in Antarctica. It represents a new window on the universe, providing unique data on the engines that power active galactic nuclei, the origin of high energy cosmic rays, the nature of gamma ray bursters, the activities surrounding supermassive black holes, and other violent and energetic astrophysical processes. Approximately one cubic kilometer of ice is being 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 Digital Optical Modules (DOMs), each containing a PM and associated electronics, will be 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. When completed, IceCube will record 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).

The project includes a Deep Core Array (DCA), situated within the geometry of the larger IceCube Observatory. The DCA will be composed of six strings with the DOMs concentrated in the lower-middle part of the array. The tighter spacing of the DOMs will allow 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, this change closes the energy gap between the IceCube Observatory and the SuperKamiokande detector in Japan. This positioning will also allow effective observations of high energy neutrinos entering from the sky of the southern hemisphere.

Total Obligations for IceCube
(Dollars in Millions)

	Prior Years	FY 2009 Actual	FY 2010 Estimate	FY 2011 Request	ESTIMATES FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
R&RA Obligations:									
Concept & Development	$0.50	-	-	-	-	-	-	-	-
Operations & Maintenance (OPP)	1.50	2.16	2.15	2.50	2.60	2.75	2.75	2.75	2.75
Operations & Maintenance (PHY)	1.50	2.16	2.15	2.50	2.60	2.75	2.75	2.75	2.75
Subtotal, R&RA Obligations	3.50	4.32	4.30	5.00	5.20	5.50	5.50	5.50	5.50
MREFC Obligations:									
Implementation	221.90	11.85	5.20	3.12	-	-	-	-	-
Subtotal, MREFC Obligations	221.90	11.85	5.20	3.12	-	-	-	-	-
Total: IceCube Obligations	**$225.40**	**$16.17**	**$9.50**	**$8.12**	**$5.20**	**$5.50**	**$5.50**	**$5.50**	**$5.50**

Totals may not add due to rounding.



The principal tasks in the IceCube project are: production of the needed DOMs and associated electronics and cables; production of an enhanced hot water drill and a DOM deployment system capable of drilling holes for and deploying DOM strings in the ice at the Pole; refurbishment and outfitting of the IceCube Laboratory (ICL) at the South Pole; the actual drilling of the deep-ice holes, deployment of the needed DOMs, and their commissioning and verification; installation of a surface array of air shower detectors ('IceTop') to both calibrate and eliminate background events from the IceCube DOM array; construction of data acquisition, handling, archiving, and analysis systems; and associated personnel and logistics support.

IceCube construction is being carried out by the IceCube Collaboration, led by the University of Wisconsin (UW). The IceCube Collaboration consists of 12 U.S. institutions and institutions in three other countries: Belgium, Germany, and Sweden. NSF's foreign partners are contributing approximately $37.40 million to the project, as well as a pro rata share of IceCube operations and maintenance costs based on the number of PhD-level researchers involved. NSF's share of the operations and maintenance costs is estimated at approximately $5.0 million in FY 2011. Future operations and maintenance costs are currently under review.

View down one of IceCube's deep ice holes during hot-water drilling. *Credit: Jim Haugen, University of Wisconsin.*

NSF will support activities at U.S. institutions working on more refined and specific data analyses, data interpretation (theory support), and instrumentation upgrades through ongoing research programs. The annual support for these research activities at U.S. institutions will be provided through the R&RA account in response to merit-reviewed proposals.

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. Education and outreach activities so far have been supported principally by participating institutions, leveraged by the IceCube construction and research activities. NSF expects to support evaluation and measurement-based education and outreach programs under separate R&RA grants to universities and other organizations that are selected following standard NSF merit review.

Project Report:

<u>Management and Oversight:</u>

- NSF Structure: Oversight responsibility for IceCube construction is the responsibility of OPP, and a project coordinator manages and oversees the NSF award. Support for operations, research, education, and outreach will be shared by OPP and MPS as well as other organizations and international partners. Besides annual progress reviews and other specialized reviews (e.g., a safety review), the project provides monthly progress reports and quarterly reports. NSF conducts site visits, weekly teleconferences with the project managers, and internal NSF project oversight and management meetings.

- External Structure: The UW management structure for the IceCube project includes leadership by a project director and a project manager. At lower levels, project management includes international participation as well as participation by staff at collaborating U.S. institutions. This framework was put in place during the start-up phase of IceCube and provided a sound basis for initiation of full construction with FY 2004 funding as soon as the project was baselined. UW has in place an external Scientific Advisory Committee, an external Project Advisory Panel, and a high-level Board of Directors (including the UW Chancellor) providing awardee-level oversight of the project.

- Reviews: NSF carried out a comprehensive external baseline review of the entire project (including cost, schedule, technical, and management) in February 2004. There was a follow-up external cost review in Fall 2004. Comprehensive external reviews are held each spring following the annual deployment season; such reviews were held annually from 2005 through 2009. The next review is scheduled for May 2010.

<u>Current Project Status:</u>

- In FY 2009, the project exceeded the season's goal of deploying 14-16 new DOM strings by deploying 19 strings, including one Deep Core Array prototype string. In FY 2010, the project met its stretch goal by deploying 20 strings,bringing the total number of strings to 79. A UW proposal to authorize placement of six Deep Core Array strings was presented as a Director's Review Board (DRB) information item in June 2009, presented to the National Science Board as an information item in August 2009, and subsequently approved. This array is in the lower-middle part of the overall IceCube Observatory allowing measurements to lower energy and effectively removing the observational energy gap between IceCube and the SuperKamiokande detector in Japan.

<u>Cost and Schedule:</u>

- IceCube is 94.3 percent complete (as of 1 November 2009) in terms of earned value measures, well within the originally proposed budget and approximately on schedule. Contingency is $6.85 million, or approximately 44.4 percent of the value of the remaining work. Contingency continues to be carefully managed to ensure the successful completion of the project.

- Projected out-year milestones (FY 2010-2011) are based on current project planning and represent a general outline of anticipated activities. These activities are also dependent on weather conditions and the Antarctic logistics schedule. These include:
  - Continue DOM and IceTop module production and testing, and continue to drill, deploy, test, and commission strings and the corresponding IceTop modules, including installation and testing of the associated data acquisition (DAQ) elements;
  - Complete installation and commissioning of the Deep Core Array within the authorized funding for the IceCube Observatory; and
  - Ramp up to full operation and scientific exploitation of IceCube in FY 2011.

<u>Risks:</u>

- The enhanced hot water drill used to melt the 2.5 km water columns, into which the strings of DOMs are deployed, continues to perform well, with fuel efficiency better than planned and with a penetration rate that meets specifications. Of the DOMs deployed thus far, 98.5 percent are now working at or better than design specifications. Based on performance thus far, a mean-time-to-failure analysis predicts a survival fraction of just over 97 percent after 15 years, better than the original 95 percent reliability specification for the project. Installation of the IceTop surface array is proceeding according to schedule, with elements deployed on the surface at each string location. DOM production and cold-testing facilities in the U.S. and Europe continue to work with high efficiency, producing reliable DOMs that continue to meet or exceed requirements.

- Based on the above achievements, the project has retired major technical risks. A key factor to the success of IceCube, and a remaining risk, is the logistics support chain required to transport all material and personnel to the South Pole, and this, too, continues to perform at a very high level.

Future Operations Costs

Operations and maintenance in support of scientific research began in FY 2007, and will ramp up in subsequent years to full science operations in FY 2011 following completion of drilling and DOM deployment in that year. The associated costs are and will continue to be shared by the partner funding agencies – U.S. (NSF) and non-U.S. – on a pro rata basis according to the number of PhD researchers involved (currently about 55:45). In FY 2010, the U.S. share of operations and maintenance is currently budgeted at $4.30 million pending NSF review of an updated operations and maintenance proposal.

The annual cost of the data analysis that will be carried out by the collaborating U.S. and foreign institutions in FY 2010 is estimated at $9.0 million, of which $5.0 million will come from NSF for support of the U.S. analytical groups, and which is separate from support for operations and maintenance (e.g., the data acquisition and data handling systems, data quality monitoring, information technology (IT) upgrades). In FY 2011, the U.S. share of data analysis and modeling costs is estimated at $5.5 million.

The general operations of South Pole Station, reported in a separate section, 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. Progress in IceCube operations will be reviewed annually. The expected operational lifespan of this project is 25 years beginning FY 2011.