U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

HEARING CHARTER

NSF Major Research Equipment and Facilities Management: Ensuring Fiscal Responsibility and Accountability

Thursday, March 8, 2012
10:00 a.m. - 12:00 p.m.
2318 Rayburn House Office Building

1. Purpose

On Thursday, March 8, 2012, the Committee on Science, Space, and Technology Subcommittee on Research and Science Education will hold a hearing to examine the management and operations of Major Research Equipment and Facilities Construction (MREFC) projects at the National Science Foundation.

2. Witnesses

Dr. Cora Marrett, Deputy Director, National Science Foundation

Dr. José-Marie Griffiths, Chairman, Subcommittee on Facilities, National Science Board; Vice President of Academic Affairs, Bryant University

Mr. James H. Yeck, IceCube Project Director, University of Wisconsin-Madison

Dr. Tony Beasley, COO/Project Manager, Neon, Inc.

Dr. Tim Cowles, Vice President and Director, Ocean Observing, Consortium for Ocean Leadership

3. Overview

- Providing support for major research equipment and facilities is a component of support for basic research.

- The National Science Foundation (NSF) supports basic scientific research in a number of ways, including through agency-wide capital investments in "major science and engineering infrastructure projects that cost more than one program's budget could support."[1]

[1] Congressional Research Service, *U.S. National Science Foundation: Major Research Equipment and Facility Construction*, p. 2.

- According to the most recent NSF strategic plan for 2011 through 2016, "The Foundation aims to develop and maintain infrastructure that enhances researchers' and educators' capabilities and productivity through management that accounts for and demonstrates best practices."[2]

- NSF funds large research infrastructure projects through the Major Research Equipment and Facilities Construction (MREFC) account. "…[T]he facility projects supported through the MREFC account are highly visible because of their large project budgets, their potential to shape the course of future research in one or more fields, their potential economic benefits for particular regions, their effects on international cooperation research, and their prominence in an increasing number of research fields."[3]

- The Fiscal Year 2013 (FY13) NSF budget request highlights six MREFC projects:
  - The Advanced Laser Interferometer Gravitational-Wave Observatory (AdvLIGO) is an upgrade of the existing Laser Interferometer Gravitational-Wave Observatory (LIGO) that will allow the Observatory to approach the ground-based limit of gravitational-wave detection.
  - The Atacama Large Millimeter Array (ALMA) is an aperture-synthesis radio telescope.
  - The Advanced Technology Solar Telescope (ATST) will enable the study of magneto-hydrodynamic phenomena in the solar photosphere, chromospheres, and corona.
  - The IceCube Neutrino Observatory (IceCube) is the world's first high-energy neutrino observatory.
  - The National Ecological Observatory Network (NEON) will result in an integrated research platform consisting of geographically distributed field and lab infrastructure.
  - The Ocean Observatories Initiative (OOI) will be an integrated network of ocean observatories.

4. Background

In order to conduct basic research in every field of science and engineering, students, teachers and researchers must have access to powerful, cutting-edge infrastructure, infrastructure that has a major impact on broad segments of scientific and engineering disciplines. Large and up-to-date research equipment and facilities are essential to the fundamental process of basic research. These equipment and facilities may consist of multi-user facilities, large-scale computational infrastructures, or networked instrumentation and equipment. "Many fields of scientific inquiry require capital intensive investments in major research infrastructure to maintain or advance their capabilities to explore the frontiers of their respective disciplines."[4] Telescopes, particle accelerators, gravitational wave observatories, and research vessels are only a handful of examples of major research infrastructure projects.

Major Research Infrastructure and the National Science Foundation (NSF)

As the primary federal agency supporting basic scientific research, the National Science Foundation (NSF) plays a key role in the construction and operation of major research equipment

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[2] *NSF Strategic Plan FY2011-2016*, p. 9.
[3] The National Academy of Sciences, *Setting Priorities for Large Research Facility Projects Supported fy the National Science Foundation*, p. 9.
[4] National Science Foundation, *2008 Facility Plan*, p. 40.

and facilities. NSF funds a variety of large research projects, from multi-user research facilities to tools for research and education and distributed instrumentation networks. Funding support for these types of projects is coordinated with other agencies, organizations and countries to ensure projects are integrated and complementary.

Major Multi-User Research Facilities Funding[5]

(dollars in millions)

	FY11 Actual	FY12 Estimate	FY13 Request	Change Over FY12 Estimate	
				Amount	Percent
Total, Research and Related Activities	**913.54**	**909.70**	**923/30**	**13.6**	**1.5**
Operations and Maintenance (O&M) of Existing Facilities	*673.63*	*655.37*	*647.35*	*-8.02*	*-1.2*
Federally Funded R&D Centers	*195.25*	*195.85*	*191.71*	*-4.14*	*-2.1*
O&M of Facilities under Construction	*17.49*	*44.73*	*72.49*	*27.76*	*62.1*
R&RA Planning and Concept Devcelopment	*27.17*	*13.75*	*11.75*	*-2.00*	*-14.5*
Major Research Equipment and Facilities Construction	**125.37**	**197.06**	**196.17**	**-0.86**	**-0.5**
Total, Major Multi-User Research Facilities	**1038.91**	**1106.76**	**1119.47**	**12.71**	**1.1**

In 1995, NSF created an agency-wide budgetary account to promote effective planning and management in the Foundation's support for large investments in major research equipment and facilities. The Major Research Equipment and Facilities Construction (MREFC) account supports the acquisition, construction, and commissioning of major research facilities and equipment. "The MREFC account was created to separate the construction funding for a large facility – which can rise and fall dramatically over the course of a few years – from the more continuous funding of facility operations and individual-investigator research."[6]

In order to be considered for MREFC funding, NSF requires that the project not only represent an exceptional opportunity to enable research and education, but also "should be transformative in nature, with the potential to shift the paradigm in scientific understanding."[7]

In the early 2000s, Congress and the scientific community raised concerns over planning, management, and oversight issues within the MREFC account. In response, the NSF worked to establish practices and create additional guidelines for MREFC projects, including the creation of the role of Deputy Director for Large Facilities. The Deputy Director and the Large Facilities Office are "the NSF's primary resource for all policy or process issues related to the development, implementation, and oversight of MREFC projects, and are NSF-wide resource on project management."[8]

In 2004, the National Academies released a report, *Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation*. This report made recommendations about establishing a long term roadmap for major research infrastructure projects and involving the National Science Board (NSB) in the NSF process for identifying and approving the construction and maintenance of these projects. In 2005, the NSB and NSF responded to the

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[5] NSF FY13 Budget Request – Facilities, p. 1.
[6] The National Academy of Sciences, *Setting Priorities for Large Research Facility Projects Supported fy the National Science Foundation*, p. 8.
[7] NSF FY12 Budget Request – MREFC p. 1.
[8] http://www.nsf.gov/bfa/lfo/index.jsp

National Academies report through a complementary joint NSB NSF management report identically titled, *Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation*. The NSB NSF report highlighted the creation of a roadmap through a regularly reported Facility Plan, which would include details on major facilities under construction, the science and objectives that provide the need for the project, and a process for large facility project development. The Facility Plan would be updated regularly and made public.

Today, the evolution of the processes is evident in the dynamic and clearly identified MREFC process:

> MREFC-funded construction projects proceed through a progressive sequence of increasingly detailed development and assessment steps prior to approval for construction funding. Initially, NSF reacts to opportunities articulated and advocated by the research community during the earliest stage of consideration. These ideas are subjected to external merit review, and those ideas or concepts of exceptional merit are further developed into conceptual designs that define the key research questions the proposed facility is intended to address.[9]

(See Appendix A for a visual representation of the NSF MREFC process.)

Since the creation of the MREFC account, NSF has funded 17 projects. In the FY13 budget request, NSF is requesting funding for four facilities: Advanced Laser Interferometer Gravitational-Wave Observatory (AdvLIGO); Advanced Technology Solar Telescope (ATST); National Ecological Observatory Network (NEON); and Ocean Observatories Initiative (OOI). Two other facilities, Atacama Large Millimeter Array (ALMA) and IceCube Neutrino Observatory (IceCube) are transitioning from the MREFC account to the appropriate research directorates for operations and maintenance. At this time, there are no new proposed facilities.

The FY13 budget request for the MREFC account is $196.17 million.

MREFC Account Funding Request[10]

(dollars in millions)

MREFC Project	FY11 Actual	FY12 Estimate	**FY13 Request**	FY14 Estimate	FY15 Estimate	FY16 Estimate	FY17 Estimate	FY18 Estimate
AdvLIGO	23.58	20.96	**15.17**	14.92				
ALMA	13.92	3.00						
ATST	5.00	10.00	**25.00**	42.00	20.00	20.00	9.93	
IceCube	5.29							
NEON	12.58	60.30	**91.00**	98.20	91.00	80.66		
OOI	65.00	102.80	**65.00**	27.50				

[9] National Science Foundation, *2008 Facility Plan*, p. 40.
[10] NSF FY13 Budget Request – MREFC, p. 1.

Major Research Infrastructure Process at NSF

Funding for projects within the MREFC account ranges from tens of millions to hundreds of millions of dollars. "A research facility is considered 'major' if its total cost of construction and/or acquisition constitutes an investment that is more than 10 percent of the annual budget of the sponsoring directorate or office."[11] Due to the significant costs associated with MREFC projects NSF has established a detailed multi-stage process for each project to complete.

The genesis for an MREFC project begins with Horizon Planning, where the relevant research community presents a compelling case for a scientific tool or facility. Part of this process includes identifying the way in which a potential project is aligned with NSF's strategic plan and its compatibility with the existing MREFC portfolio. The Foundation informs the NSB of projects in the Horizon Planning stage.

In the Conceptual Design stage, project proponents identify specific requirements and risks and begin to define a schedule for the project. At this stage, they draft initial cost estimates, including costs to operate the program once construction is complete. "Early in the Conceptual Design stage, NSF and/or other institutions begin to invest research and development funds in conceptual development and design, and in efforts that promote community building and planning. Investments in fundamental research activities, community building, and initial planning activities may occur over many years."[12] Projects progress from Conceptual Design to Preliminary Design after completing a Conceptual Design Review (CDR). At this stage, the NSF Director approves the continued movement of the project and officially notifies the NSB. Horizon Planning and Conceptual Design stages are supported by NSF program offices from the Research and Related Activities (RRA) account with design and development grants.

During the Preliminary Design stage, the major elements of the project are more defined and detailed, including identifying risk, schedule, partnerships and cost estimates. During Preliminary Design, cost estimates are risk-adjusted total cost estimates. Budget estimates resulting at this stage must be accurate to present to the NSF Director, the NSB, the Office of Management and Budget (OMB) and Congress. The goal of the Preliminary Design stage is to determine project readiness and produce a project baseline. After a Preliminary Design Review (PDR), a project may be approved by the NSB to move forward to Final Design and Construction. It is at this stage that the project can appear as a line-item in the President's Fiscal Year Budget Request.

The Final Design stage is used to advance the project to construction. At this time, project managers are refining cost estimates based on vendor quotes, putting construction teams in place, and finalizing details necessary to begin construction. A Final Design Review (FDR) includes a construction-ready design, the technologies and tools necessary for construction, a project management plan, and an updated budget and contingency.

The Construction stage begins after Congress appropriates the funding and NSF is able to award the contract for construction. Contract awardees are required to provide periodic financial and technical reports to NSF, the terms of which are established by cooperative agreements. During

[11] Congressional Research Service, *U.S. National Science Foundation: Major Research Equipment and Facility Construction*, p. 2.
[12] *National Science Foundation Large Facilities Manual*, March 31, 2011, p. 11.

the Construction stage, the project manager must adhere to the project baseline. If the baseline is not being met, a project may need to be re-baselined or have its scope readjusted.

The life-cycle of a MREFC project takes into account the steps from Horizon Planning to construction and beyond. The completion of construction does not mean that NSF has completed the scientific endeavor. The Foundation accounts for the operations and maintenance (O&M) of the equipment or facility from project inception. A program officer from the appropriate RRA Directorate is assigned to carry through the life of the project. In the 2002 NSF Authorization Act, Congress codified that this program manager must be a permanent NSF employee. Maintaining a permanent science based program officer helps to smooth the transition from inception of the project through construction and to post-construction O&M. Often the operations of the project begin before construction is complete. Like the pre-construction activities, post-construction O&M are funded through the RRA or the Education and Human Resources (EHR) accounts.

Contingencies

In an effort to keep MREFC project costs from escalating during construction, NSF has instituted a "no cost overrun policy" on any new MREFC-funded construction projects. "This policy requires that the total project cost estimate developed at the Preliminary Design Stage have adequate contingency to cover all forseeable risks, and that any cost increases not covered by contingency be accommodated by reductions in scope."[13]

The use of contingency funding relative to MREFC projects has recently been under review by the NSF Inspector General (IG). In the September 2010, March 2011 and September 2011 Seminanual Reports to Congress, the IG highlighted audits of MREFC projects focused on "unallowable contingency costs." "The audit did not find any controls or technical barriers to prevent the organization from drawing down contingency funds and spending them without NSF approval."[14] According to NSF, the construction contingency policies are consistent with the GAO Cost Estimating and Assessment Guide and the OMB Capital Programming Guide and are part of the budget to be maintained by the project manager.

The FY12 Commerce, Justice, and Science Appropriations Conference Report addressed the contingency issue:

> The conferees remain concerned about how NSF and its grantees are defining, estimating and managing construction funding, particularly contingency funds. Stronger management and oversight of these funds could result in improved project efficiencies and, ultimately, cost savings. NSF is directed to report to the Committees on Appropriations on the steps it is taking to impose tighter controls on the drawdown and use of contingencies, as well as steps intended to incentivize grantees to complete construction under budget, for projects managed through the MREFC appropriation and for other large facility projects.[15]

[13] Ibid, p. 18.
[14] *NSF OIG Semiannual Report to Congress*, September 2010, p. 5.
[15] Conference Report 112-284 to accompany H.R. 2112, p. 264.

IceCube Neutrino Observatory (IceCube)[16]

The IceCube Neutrino Observatory (IceCube) is the world's first high-energy neutrino observatory, located deep within the ice cap under the South Pole in Antarctica. It provides 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.

NSF requested construction funding for IceCube in the FY04 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. IceCube construction was carried out by the IceCube Collaboration, led by the University of Wisconsin and consisting of 11 other U.S. institutions and institutions in 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.

Oversight responsibility for IceCube construction was the responsibility of the Office of Polar Programs (OPP). Support for operations and maintenance, research, education, and outreach will be shared by OPP and the Directorate for Mathematical and Physical Sciences (MPS), as well as other organizations and international partners. NSF expects to support evaluation and measurement-based education and outreach programs under separate RRA grants to universities and other organizations that are selected following standard NSF merit review.

IceCube construction was successfully completed at the South Pole on December 18, 2010. The Observatory consists of 5,160 optical sensors installed at a depth between 1.5 and 2.5 kilometers on 86 cables and 324 optical sensors placed in 162 surface tanks. All cables are routed into the IceCube laboratory located in the center of the surface array.

O&M in support of scientific research began in FY07 and cost approximately $5 million per year. Full science operations began in FY11. The associated costs are and will continue to be shared by the partner funding agencies – U.S. (NSF) and non-U.S. – proportional to the number of PhD researchers involved (currently about 55:45). Starting in FY12, the U.S. share of full science operations and maintenance is $6.90 million annually. In FY12, the U.S. share of data analysis and modeling costs is estimated at $5.50 million. The expected operational lifespan of this project is 25 years beginning in FY11.

The FY13 MREFC budget request does not include funding for IceCube as the program will close out all construction activities in 2012.

The National Ecological Observatory Network (NEON)[17]

In 2004, the National Research Council (NRC) evaluated the original National Ecological Observatory Network (NEON) design of loosely confederated observatories and recommended that it be reshaped into a single integrated platform for regional to continental scale ecological

[16] NSF FY12 Budget Request – MREFC p. 23-27.
[17] NSF FY13 Budget Request – MREFC, p. 18-24.

research. Congress originally appropriated a total of $7 million for NEON in FY07 and FY08, $4 million of which was rescinded in FY08. A PDR was completed in June 2009 and a FDR was completed in November 2009. 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 pre-construction planning activities in 2011 that enabled the project to commence construction in FY11. Contingency was increased to cover known risks per panel recommendations.

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.

NEON 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. NSF and NEON, Inc. coordinate with other federal agencies (National Aeronautics and Space Administration, Department of Energy, U.S. Department of Agriculture, U.S. Geological Survey, Environmental Protection Agency, and the National Oceanic and Atmospheric Administration) through the NEON Federal Agency Coordinating Committee. Areas of coordination include planning, design, construction, deployment, environmental assessment, data management, geospatial data exchange, cyberinfrastructure, research, and modeling.

The NEON program is managed through the Directorate for Biological Sciences (BIO) as part of Emerging Frontiers. BIO provides overall policy guidance and oversight. The NEON program is managed by a dedicated program officer. An NSF/NEON project manager was added in FY11 to oversee construction and participate in planning, development, and oversight of management and operations.

The projected length of the project is six fiscal years, with a six-month schedule contingency. The risk-adjusted cost of $433.72 million includes a contingency budget of 19 percent. The first NEON Airborne Observatory platform is expected to be completed, fully instrumented, and flight-tested in preparation for delivery to Observatory operations in FY14.

The FY13 budget request for NEON is $91 million, which represents the third year of the six-year construction project. The FY13 request also includes $30.39 million from the RRA account for O&M of the five domains commissioned, including related management and technical support, seasonal biological sampling, and domain facilities costs. The current request incorporates a three year initial operations request to allow NEON to gain operational experience and explore opportunities for schedule and cost efficiencies. For the outyears, the costs are held constant at the projected operations ceiling reviewed at both the PDR and FDR. After gaining operational experience, NEON, Inc. will submit a plan for the remaining five years.

Ocean Observatories Initiative (OOI)[18]

The Ocean Observatories Initiative (OOI) will provide the oceanographic research and education communities with continuous, interactive access to the ocean through an integrated network of observatories. 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. 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.

OOI has 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 OOI and facilitate experimentation using assets from the entire network. Data from the network will be made publicly available via the Internet.

NSF first requested construction funding for OOI through the MREFC account in FY07 and received an initial appropriation of $5.12 million in that year. The OOI has undergone a series of technical reviews, with the FDR conducted in November 2008.

The project is managed and overseen by a program director in the Division of Ocean Sciences (OCE) in the Directorate for Geosciences (GEO). NSF established an Ocean Observing Science Committee (OOSC) via the University National Oceanographic Laboratory System (UNOLS). The Committee is made up of ocean science community representatives and is charged with providing guidance on decisions and plans from the science perspective related to all NSF observing systems.

NSF established a cooperative agreement with the Consortium for Ocean Leadership for the construction and initial operation of the OOI in September 2009. NSF conducts a weekly meeting, attends weekly calls, convenes external panels, and reviews monthly Earned Value Management reports from the project team. NSF attends internal project reviews, critical design reviews, and conducts vendor site visits as required.

The FY13 budget request for OOI is $65 million, which represents the fourth year of a six-year construction project totaling $386.42 million. The project is currently in year three of the construction and transition to O&M efforts. Major construction milestones were achieved on time and within budget. OOI transition to O&M was funded in FY11 and FY12. The request for O&M funding for FY13 is $40.1 million. Full O&M is planned for FY15. The expected operational lifespan of this project is 25 years.

Advanced Laser Interferometer Gravitational-Wave Observatory (AdvLIGO)

The Advanced Laser Interferometer Gravitational-Wave Observatory (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

[18] NSF FY13 Budget Request – MREFC, p. 25-29.

world's most sophisticated optical interferometers, operating at two sites 3,000 km apart: Hanford, WA and Livingston, LA. The 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.

NSF first requested FY08 construction funds for AdvLIGO through the MREFC account in the FY06 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 inflators. An FDR in November 2007 recommended that construction begin in FY08. The NSB approved the project at a cost of $205.12 million in March 2008, and the project began in April 2008.

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). LIGO is managed by the California Institute of Technology under a cooperative agreement with NSF. An Executive Director has overall responsibility for the LIGO Laboratory. Substantial connections with industry have been required for the construction and measurements involved in the LIGO projects.

On October 20, 2010, the final LIGO science run ended and the facility was turned over to the AdvLIGO project for the installation of the advanced components. The project has pushed back completion of installation at Livingston and at Hanford by three months due to procurement difficulties, but no effect on the project completion date is expected. The removal of initial LIGO instruments is nearing completion with the end of a highly successful quantum-squeezing experiment and the decommissioning of the final initial LIGO interferometer. The major current project activity is the assembly and installation of large subsystem components, testing of which will begin this year. The current project performance is consistent with ending on time and on budget. Total project contingency usage as of November 2011 is $23 million of an initial $39.1 million, or 59 percent of initial contingency for 64 percent of the project completed.

The FY13 budget request for AdvLIGO is $15.17 million, which represents the sixth year of a seven-year project totaling an estimated $205.12 million. 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. Future O&M costs will be approximately $39 million per year funded through PHY.

Atacama Large Millimeter Array (ALMA)

The origin of the Atacama Large Millimeter Array (ALMA) began as a $26.0 million, three-year design and development phase plan for a U.S.-only project, the Millimeter Array. NSF first requested funding for design and development of this project in FY98. 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 million in appropriations between FY98 and FY00. Because of the expanded managerial and technical complexity of the joint US/ESO project, now called ALMA, Congress provided $5.99 million in FY01 for an additional year of design and development. In FY02, $12.5 million was appropriated to initiate construction. The U.S. total share of the cost was estimated to be $344 million.

The global ALMA project will be an aperture-synthesis radio telescope operating in the wavelength range from 3 mm to 0.4 mm. ALMA will be the world's most sensitive, highest resolution millimeterwavelength 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.

The ALMA Board initiated rebaselining in the fall of 2004 under the direction and oversight of the Joint ALMA Office (JAO) Project Manager. At that point, the project was sufficiently mature that the baseline budget and schedule established in 2002, prior to the formation of the partnership, could be refined. 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 FY09 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 FY09 was offset by a matching decrease in the FY11 budget request.

Construction continues in FY12, both at the site in Chile and within the ALMA partner countries. In FY11, delivery of North American production antennas continued at the planned rate of one every two months, and a total of twenty antennas were accepted or assembled and tested in Chile. Following assembly and testing, antennas were transported to the final, high-altitude site. Early science operations began in late FY11 and completion of the construction project and the start of full science operations are forecast to occur in FY13.

Programmatic management is the responsibility of the ALMA program manager in the Division of Astronomical Sciences (AST). 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 (including Taiwan) is led by the Associated Universities Incorporated/National Radio Astronomy Observatory (AUI/NRAO).

The current schedule performance is slightly behind plan due to equipment delivery delays, specifically delivery of receivers and European antennas. Consequently, the major milestone of full-science is forecast to be delayed by nine to twelve months when compared to the baseline plan. However, early science commenced in September 2011 as predicted a year ago. Cost performance is good at this stage — cost variance is on track with the reference baseline and schedule variance is -6 percent relative to the reference — with about 25 percent contingency remaining in the uncommitted budget.

No additional MREFC funds are requested for the Atacama Large Millimeter Array (ALMA) in the FY13 budget request. The FY12 appropriation provided $3 million, which represents the final amount necessary to complete funding for the eleven-year project, totaling $499.26 million. O&M funding will phase-in as initial site construction is completed and antennas are delivered. Funds will be used to manage and support site and instrument maintenance, array operations in Chile, early- and eventually full-science operations, as well as support ALMA observations by the U.S. science community. Full ALMA science operations are forecast to begin in 2013. The anticipated operational lifespan of this project is at least 30 years.

Advanced Technology Solar Telescope (ATST)

To be constructed at the Haleakala High Altitude Observatory on the island of Maui in Hawaii, the Advanced Technology Solar Telescope (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 coronal mass ejections. These can affect civil life on Earth through the phenomena generally described as "space weather" and may have impact on the terrestrial climate.

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.

The current design, cost, schedule, and risk were scrutinized in an NSF-conducted PDR in October-November 2006. The FDR held in May 2009 determined that the project was fully-prepared to begin construction. In FY09, $6.67 million was provided through the RRA account. Of this total, $3.57 million in regular RRA funds supported design activities to complete a construction-ready design, and $3.1 million through the American Recovery and Reinvestment Act of 2009 (ARRA) supported risk reduction, prototyping, design feasibility, and cost analyses in areas identified at preliminary and systems design reviews. ARRA funding also provided for several new positions to complete preparation for the start of construction. Also in FY09, $153 million was provided through MREFC account to initiate construction. Of these MREFC funds, $146 million was appropriated through ARRA. Given the timing of the receipt of budget authority and the complexity of project contracting, the entire $153 million was carried over from FY09 and subsequently obligated in FY10.

Oversight from NSF is handled by a program manager in AST. The project is managed by the National Solar Observatory (NSO). NSF funds NSO operation and maintenance and ATST design and development via a cooperative agreement with the Association of Universities for Research in Astronomy, Inc. (AURA).

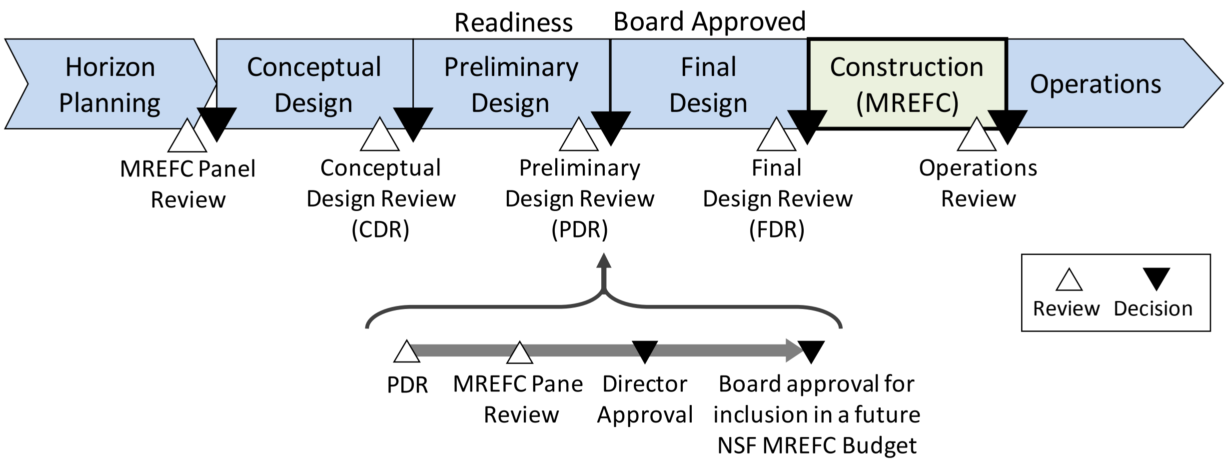
The baseline not-to-exceed cost was established following the FDR. Funding is derived from ARRA ($146 million) and annual appropriations in the MREFC account ($151.93 million). In order to clearly separate funds from the two sources, the project developed two statements of work, dividing their resource-loaded Work Breakdown Structure 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.

The FY13 budget request for ATST is $25 million. The total project cost to NSF, $297.93 million, was finalized after a FDR in May 2009. The NSB 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. The Board on Land and Natural Resources (BLNR) approved the project's application for a Conservation District Use Permit (CDUP) on December 1, 2010. After a lengthy challenge to the CDUP by a Native Hawaiian organization, a hearing officer overturned the challenge on February 24, 2012, clearing the way for site preparation and construction to begin.

The estimated annual operations cost is projected to be $18 million in FY18, including $2 million annually for cultural mitigation. Approximately $5-$7 million per year of NSO costs will be recovered from the closure or divestment of redundant facilities. NSO has a preliminary transition plan that will be revised and externally reviewed after construction begins.

APPENDIX A: NSF MREFC Process

NSF's updated large facility project planning process



- **Horizon/Conceptual Design MREFC Panel Review**
  - –Compelling science case, aligned with NSF's strategic plan and compatible with existing facilities portfolio, reasonable development timeline, potentialities for partnership, assessment of any major challenges to NSF
- **Conceptual Design Stage**
  - –Requirements, initial estimates of cost (including operations), risk and schedule
- **Preliminary Design ("Readiness") Stage**
  - –Definition and design of major elements, detailed estimates of cost, risk and schedule, partnerships, siting
- **Final Design ("Board Approved") Stage**
  - –Interconnections and fit-ups of functional elements, refined cost estimates based substantially on vendor quotes, construction team substantially in place