U.S. National Science Foundation: Major Research Equipment and Facility Construction

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Summary

The Major Research Equipment and Facilities Construction (MREFC) account of the National Science Foundation (NSF) supports the acquisition and construction of major research facilities and equipment that are to extend the boundaries of science, engineering, and technology. The facilities include telescopes, earth simulators, astronomical observatories, and mobile research platforms. Currently, the NSF provides approximately $1.0 billion annually in support of facilities and other infrastructure projects. While the NSF does not directly design or operate research facilities, it does have final responsibility for oversight and management. Questions have been raised by many in the scientific community and in Congress concerning the adequacy of the planning and management of NSF facilities. In addition, there has been debate related to the criteria used to select projects for MREFC support.

The Administration's FY2013 budget request for the NSF is $7,373.1 million, a 4.8% increase ($340.0 million) over the FY2012 estimated level of $7,033.1 million. Included in the request total is $196.2 million for MREFC, slightly below the FY2012 estimate of $197.1 million. The FY2013 request proposes support for four projects—Advanced Laser Interferometer Gravitational-Wave Observatory ($14.9 million), Advanced Technology Solar Telescope ($42.0 million), Ocean Observatories Initiative ($27.5 million), and the National Ecological Observatory Network ($98.2 million).

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Background

The Major Research Equipment and Facilities Construction (MREFC) account of the National Science Foundation (NSF) was established in FY1995 and supports the acquisition, construction, and commissioning of major research facilities and equipment that are to extend the boundaries of science and engineering. Major research facilities are complex in their design, construction, and operation and require a large investment over a limited period of time. Examples of some of the funded projects include telescopes, research vessels, accelerators, networked high-tech research platforms, advanced computing resources, astronomical observatories, and earthquake simulators. These complex projects sometimes involve the participation of international partners. Currently, the NSF provides approximately $1.0 billion annually in support of facilities and other infrastructure projects. The funding for construction of individual facilities ranges from several tens of millions to hundreds of millions of dollars. Additional funding is required annually for operation, maintenance, upgrades, and retooling of the facilities.

With the significant exception of research facilities in the Antarctic, the NSF does not directly design or operate research facilities. Rather, it makes awards to other organizations, such as universities, consortia of universities, or nonprofit organizations, which have the responsibility of construction, operation, and management. The NSF enters into cooperative agreements with these external entities, and has the final responsibility for oversight of the development, management, and performance of the facilities.

During the past few years, NSF's portfolio of facilities has expanded and diversified to include complex multidisciplinary projects and distributed projects. Because these major facility projects are multi-year, their accounting, management, and oversight require more complexity and detail than the traditional average grant award. There are concerns from Congress and from some in the academic and scientific community about the adequacy of the planning and management of NSF facilities. Discussions have focused on how major facility projects are selected for funding. Other questions have centered on the types of costs to be funded through the MREFC account and NSF personnel involved in major facility projects. In the FY2002 budget submission, President Bush directed the NSF to develop clearer policies and procedures for managing all aspects of large facility projects, including funding controls and effective project management.[1] The FY2002 budget document, *A Blue Print for New Beginnings: A Responsible Budget for America's Priorities*, directed that "NSF will develop a plan to enhance its capability to estimate costs and provide oversight of project management and construction. This plan should help ensure that NSF is able to meet and stick to cost and schedule commitments for major facility projects."[2]

[1] In December 2000, the Office of Inspector General (OIG) of the NSF released an audit of the Gemini Project, reporting that the Gemini Project had cost overruns exceeding its approved construction level of $184 million. The OIG further stated that the NSF had used or was planning to use approximately $52.8 million from the Research and Related Activities Account (RRA) to cover the excess construction and commission costs. NSF management refuted the conclusions of the OIG, maintaining that the excess costs were operational in nature and as a result, properly supported through the RRA as opposed to the MREFC account.

[2] Office of Management and Budget, *A Blueprint for New Beginnings: A Responsible Budget for America's Priorities,* Washington, February 28, 2001, http://www.whitehouse.gov/news/usbudget/blueprint/budi.htm, p. 161.

Definition of a Major Research Facility

The MREFC is an agency-wide capital asset account that funds major science and engineering infrastructure projects that cost more than one program's budget could support.[3] Major research facility projects are defined as those awards made for establishing and/or operating a major tool or facility that will potentially benefit a community of researchers and/or educators. A project should "offer the possibility of transformative knowledge and the potential to shift existing paradigms in scientific understanding, engineering processes and/or infrastructure technology."[4] A research facility is considered "major" if its total cost of construction and/or acquisition constitutes an investment that is more than 10% of the annual budget of the sponsoring directorate or office. The majority of large facility projects are funded through the MREFC, but some also receive support through the Research and Related Activities Account (RRA).[5]

Congressional Hearing on Planning and Management Issues

On September 6, 2001, the House Committee on Science, Subcommittee on Research, held a hearing on planning and management issues associated with major research facilities at the NSF. These hearings resulted from concerns expressed by some in the academic and scientific community and in Congress about the management and oversight of major projects selected for construction and the need for prioritization of potential projects funded in the MREFC. In testimony before the Subcommittee on Research, then NSF Director Rita R. Colwell stated that the draft of the *Large Facility Projects Management and Oversight Plan* codifies practices already in place and develops new guidelines for oversight of financial and business functions. She responded to criticism that the lines of authority for project management included in the draft plan were ambiguous and that those with oversight functions for the projects were program officers who may not have the expertise necessary for overseeing a complex project. The *Plan* established a new position—Deputy Director for Large Facility Projects. Under the *Plan*, the Deputy Director would be responsible for implementing and managing guidelines and procedures for facility management and oversight, maintaining lines of authority for facility management, and providing project management training for NSF staff engaged in large facility projects.

[3] The proposed facilities are too large to fit within the account of any one directorate or program. The concern is that support for such large projects would "disrupt" the budgets of other programs and jeopardize NSF's traditional support of "core" research programs.

[4] U.S. National Science Foundation, *Facility Plan*, September 2005, Arlington, VA, p. 6.

[5] Since its establishment, the MREFC has funded the following projects: Atacama Large Millimeter Array (ALMA), IceCube Neutrino Observatory, High-Performance Instrumented Airborne Platform for Environmental Research (HIAPER), Large Hadron Collider, Terascale Computing System and Distributed Terascale Facility, Laser Interferometer Gravitational-Wave Observatory (LIGO), George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), Polar Support Aircraft Upgrades, South Pole Safety Project and South Pole Station Modernization (SPSM), EarthScope, National Ecological Observatory Network (NEON), Gemini Observatory, Scientific Ocean Drilling Vessel (SODV), Alaska Region Research Vessel (ARRV), Advanced LIGO, Ocean Observatories Initiative (OOI), and the Advanced Technology Solar Telescope (ATST). For a discussion of these projects, see, for example, U.S. National Science Foundation, *NSF-Supported Research Infrastructure: Enabling Discovery, Innovation and Learning*, NSF09-13, February 2009, Arlington, VA, 148 pp.

There has been considerable debate concerning the selection of major research facility projects for funding. In testimony before the Subcommittee on Research, Anita K. Jones, then Vice Chair, National Science Board (NSB), stated that because not all facilities can be built at the time they are considered, the NSB established guidelines for approving major facility projects.[6] She emphasized that there is a prioritization process for selecting major projects, one that involves the NSF and the community, with the NSB actually making the priority decisions. The NSB, she asserted, reviews the need for the facility, the research that will be enabled, the readiness of plans for construction and operation, construction budget estimates, and operations budget estimates before making its decisions. Another issue brought before the subcommittee was that of maintaining distinct records of spending activities in the MREFC. Subcommittee members questioned the types of costs to be funded through the MREFC account because the differentiation between construction and operation is not always clearly defined.[7] The Subcommittee noted that internal mechanisms needed to be created in order to prevent the combining of MREFC and RRA funds.

Audit of Funding for Major Research Equipment and Facilities

In May 2002, the NSF's Office of Inspector General (OIG) released a draft report, *Audit of Funding for Major Research Equipment and Facilities*.[8] The report noted that the current policy for major research equipment and facilities projects is limited to only the MREFC and does not include major facilities for other programs in NSF. In addition, the existing guidelines stipulate a single financial review and do not offer directives on how the review should be conducted. Also, according to the audit, the current policies did not provide direction to NSF program mangers on how to address the problem of potential cost overruns. While federal guidelines require that the total cost of major research facilities be tracked through all stages of a project, NSF's policies and procedures did not provide full accounting costs in its financial reports in accordance with federal standards. Because of NSF's inconsistencies in tracking costs and funding sources of its major research facilities, the OIG recommended that NSF revise its policies and procedures by complying with the directives that were detailed in the FY2002 appropriation bill.

Congressional Activity

In June 2002, Congress requested the National Academy of Sciences (NAS) to review NSF's management of its large facility projects.[9] The study began in February and examined how the NSF sets priorities in determining which competing projects to fund, and offered recommendations on how to strengthen the process. The recommendations are contained in a

[6] National Science Board, *Guidelines for Setting Priority for Major Research Facilities*, NSB01-204, Arlington, VA, November 15, 2001, 2 pp.

[7] Acquisition, construction and commissioning are funded through the MREFC. Planning, design, and development are supported through the R&RA, in addition to operations and maintenance upon completion of the project.

[8] U.S. National Science Foundation, Office of Inspector General, *Audit of Funding for Major Research Equipment and Facilities*, OIG02-2007, May 1, 2002, Arlington, VA, 17 pp.

[9] The NSF Authorization Act of 2002 (P.L. 107-368, H.R. 4664) contained language directing the NAS to conduct the study of NSF's priority-setting process of its large facility projects.

January 2004 report prepared jointly by the NSB and the NSF—*Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation.*[10] At an October 2004 meeting of the NSB, the NSF was directed to begin implementation of the proposed large facility project review and prioritization process outlined in the report. The report revealed that in addition to there being a backlog of approved but unfunded projects, there was a lack of support for disciplines conducting idea-generating activities, and a lack of funding for conceptual development, planning, and design.

On March 8, 2012, the House Subcommittee on Research and Science Education held a hearing on the management and accountability concerns being raised relative to MREFC at NSF.[11] Testifying at the hearing was Jum Yeck, Project Director for IceCube, a MREFC facility. Yeck stated that the management of large facilities continues to evolve and improve; that the rules are "stabilizing"; and that considerably more confidence is being voiced in its management practices. He also stated that the director of any project ensures that proper project management and reporting systems are implemented. Also testifying was Cora B. Marrett, Deputy Director, NSF. Marrett reiterated that the NSB provides oversight during the complete life-cycle process for planning, constructing, operating, and possibly terminating support for a particular facility. This oversight occurs while simultaneously providing guidance between the balance for investments in research infrastructure and support for other NSF programs and activities. Marrett further explained the importance and necessity for external review committees to evaluate management capabilities and the need for investment in effective management techniques. She stated that

> Project Management Control Systems are essential for determining the project's technically limited construction schedule and the associated funding profile, and so that, once in construction, the project manager can effectively ascertain technical and financial status, obtain a detailed picture of risks and contingency usage, and provide the necessary transparency to the agency needed to carry out an effective oversight role.[12]

Planning and Management Issues

The March 2011 report, *Large Facilities Manual,* details the procedures by which large facility research projects advance through a multi-phase internal and external review and approval process.[13] According to the *Manual*, an MREFC Panel evaluates the projects based on, among other things, project definition; intellectual justification; connection to NSF strategic goals and priorities; life-cycle cost profile; partnerships; and project management plans, schedules, and reviews. Based on the review, the MREFC Panel submits to the NSF Director its recommendation on the project's relative importance, eligibility, and readiness, with readiness defined as its ability to be included in the upcoming budget request. The Director then makes the selection of projects based on (1) strength and substance of the information; (2) the appropriate balance among various fields, disciplines, or directorates; and (3) opportunities to leverage MREFC funds. The Director

[10] National Academy of Sciences, Committee on Science, Engineering, and Public Policy, and Global Affairs Division, Board on Physics and Astronomy, *Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation*, Washington, DC, January 14, 2004, 215 pp.

[11] U.S. Congress, House Committee on Science, Space, and Technology, Subcommittee on Research and Science Education, *NSF Major Research Equipment and Facilities Management: Ensuring Fiscal Responsibility and Accountability,* Hearing, 112th Congress, 2nd Sess., March 8, 2012.

[12] Ibid., Written Testimony of Cora B. Marrett, Deputy Director, NSF, p.10.

[13] U.S. National Science Foundation, *Large Facilities Manual,* NSF10-12, Arlington, VA, March 31, 2011, 68 pp.

submits his selections to the NSB for project approval. After the NSB approves a project for future budget cycle funding, it prioritizes among the projects.[14] On an annual basis, the NSB reviews all NSB-approved projects that have not been funded as yet to determine if any changes are necessary to the priority order of the projects.[15] If a project is not approved, or if a project's plans are no longer determined to be "clearly and fully construction ready," the project will be returned to the preliminary design/readiness phase for additional work. A project can be resubmitted to the NSB the following year. While the NSB may approve a project for inclusion in a future budget request, it does not necessarily mean that it will receive funding in the upcoming budget request. It does indicate that the project is to be considered for inclusion, depending on current budget levels and constraints.

The *2012 NSF Facility Plan* was presented to the NSB on February 2, 2012.[16] The *Plan* covers readiness stage projects through those projects that are in the process of completion. In addition, the report includes NSF's support for major research infrastructure and the operational facilities that have received new or renewed awards, interrelationships among the portfolio of research facilities, life-cycle considerations, and sunsetting provisions. The *2012 Facility Plan* describes NSF's goals and strategies for incorporating the existing approaches and practices into a system for selecting, managing, and overseeing large facility projects to make certain that a large facility is both constructed properly and is the appropriate facility to build. Included in the report also are detailed procedures for termination or renewal of a large facility. The *Plan* includes a multi-stage development, review, and approval process. NSF has designated four project evolution phases: (1) conceptual design review, (2) preliminary design review, (3) final design review (readiness), and (4) construction and operation. The projects under construction and those being considered for construction are indicative of NSF's long-term investment priorities for new capabilities and next-generation facilities that will "transform research in science and engineering." The NSF questions

> Is the proposed project, when compared to other proposed projects—whether within the same field, across related fields, or across different fields—among the very highest priorities for potential new facilities?[17]

The *2012 Facility Plan* describes a team approach and details the cooperation between the scientific and technical staff and the business operations staff. The lines of authority and responsibility are defined for the NSF Director, the participating Division Director, the NSF Program Manager, and the awardees' project director. In every large facility project, the NSF Program Manager, with the support of the participating Division Director, has primary responsibility for all aspects of management. In addition, the NSF Program Manager is responsible for determining whether the project director and project management staff have the necessary training and skills for working on the project.

[14] First priority is given to projects under construction. Second priority is for NSB-approved new starts. There are projects that are classified as being in the readiness stage or recommended for advancement to the readiness stage. Also, there are projects classified as being under exploration.

[15] The Office of Management and Budget (OMB) may reject or change the NSF's prioritizations.

[16] U.S. National Science Foundation, *2012 NSF Facility Plan*, Office of Budget, Finance, and Award Management, Arlington, VA, February 2012, 55 p.

[17] Ibid., p. 6.

Termination of a Major Research Project

The Rare Symmetry Violating Processes Project (RSVP) was initially NSB-approved for funding in October 2000, and was included in the FY2005 budget request as a new construction project. While the RSVP was in the design phase, an analysis revealed that there could be significant increases in construction and operating costs. The cost overruns generated interest from Congress and the international scientific community. An evaluation was conducted by scientific personnel internal and external to NSF in an attempt to resolve the cost increases in various elements of the project. In August 2005, on the recommendation from NSF management, the NSB terminated the RSVP. NSF determined that continued support for the RSVP would cause "unacceptable loss of research opportunities in elementary particle physics and other areas of science."[18] The RSVP underwent a series of phase-out activities.

The March 2011 *Large Facilities Manual* includes a discussion of termination of a large facility. Language included in the report states that

> To remain at the research frontier and support new facilities, NSF should retire existing facilities when the science they enable is of lower strategic priority than science that could be enabled by alternate use of the funds. Such decisions will be difficult to make, in part because of the number of stakeholders and interested parties, and will require extensive community consultation and input, which may come from "blue ribbon" panels, National Academies committees and professional societies. In some cases in which a facility can continue to be productive, it may be possible to transfer ownership to another agency, a university or a consortium of universities. It is the responsibility of the Directorate and Divisions to periodically review their facilities portfolio and to consider which facilities may have reached an appropriate end of NSF support.[19]

MREFC Support in the FY2013 Budget Request

The Major Research Equipment and Facilities Construction (MREFC) account receives $196.2 million in the FY2013 budget request,[20] slightly below the FY2012 estimated level of $197.1 million.[21] The MREFC supports the acquisition and construction of major research facilities and

[18] U.S. National Science Foundation, "NSF Terminates Rare Symmetry Violating Processes (RSVP) Project," Press Release 05-138, Arlington, VA, August 11, 2005.

[19] National Science Foundation, *Large Facilities Manual*, p.33.

[20] The MREFC proposed funding for FY2013 accounts for approximately 2.7% of the budget request for NSF. While it is a small percentage of total agency funding, it does provide significant support for a small number of projects.

[21] Language was included in the conference report for FY2012 giving the agency the authority to move as much as $50.0 million into the MREFC from the R&RA, Such flexibility for movement of funding would allow the account to receive an amount close to that which was requested by the Administration. Language in the conference report was directed at the management of construction funding. The report stated that "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." U.S. Congress, House Committee on Appropriations*, Agriculture, Rural Development, Food and Drug Administration, and Related Agencies Programs for the Fiscal Year Ending September 30, 2012, and for Other Purposes*, Hearing, 112th Congress, 1st Sess., H.Rept. 112-284, to accompany H.R. 2112, November 14, 2011, p. 264. (Also known as Consolidated and further Appropriations Act, 2012. Signed by President Obama on November 18, 2011.)

equipment that extend the boundaries of science, engineering, and technology.[22] According to NSF, it is the primary federal agency providing support for forefront instrumentation and facilities for the academic research and education communities. NSF states that "Modern and effective research infrastructure is critical to maintaining U.S. leadership in science and engineering. The future success of entire fields of research depends upon access to new generations of powerful research tools. Increasingly, these tools are large and complex, and have a significant information technology component."[23] NSF gives highest priority to ongoing projects, and second-highest priority to projects that have been approved by the NSB for new starts. To qualify for support, NSF required MREFC projects to have "the potential to shift the paradigm in scientific understanding."[24] The FY2013 request proposes support for the National Ecological Observatory Network, $98.2 million (NEON); Advanced Laser Interferometer Gravitational Wave-Observatory, $14.9 million (AdvLIGO);[25] Advanced Technology Star Telescope, $42.0 million (ATST); and the Ocean Observatories Initiative, $27.5 million (OOI).[26] Funds were not included in the budget request for the Atacama Large Millimeter Array (ALMA). The funding received for ALMA in the FY2012 appropriation ($3.0 million) was the final support required to complete the eleven-year project.[27]

The NSF has instituted tighter standards and requirements for receiving funding in this account. Included in the more stringent procedures was the implementation of a "no cost overrun" policy for major projects.[28] All projects seeking funding and construction support in the MREFC must move through a series of detailed steps and "should be transformative in nature, with the potential to shift the paradigm in scientific understanding."[29] The cost estimates for projects developed at the preliminary design phase must include adequate contingencies. In the absence of such contingencies, any cost increase would result in reduction in scope for the project.[30] NSF states that

> If total cost for a project is revised during construction for reasons other than inadequate funding, NSF will identify mechanisms for offsetting any cost increases in accordance with

[22] MREFC funding supports the construction phase of an approved facility. Preconstruction planning and design and post-construction operations and maintenance of a facility are supported within the R&RA budget of the sponsoring program office or directorate.

[23] U.S. National Science Foundation, National Science Foundation*: FY2013 Budget Request to Congress*, Arlington VA, February 13, 2012, p. MREFC-1.

[24] Ibid.

[25] AdvLIGO underwent both a comprehensive review in April 2010 and an interim review in December 2010 to determine if the project was "on-track." Concerns had been voiced about technical, environmental, and management risks as they related to AdvLIGO.

[26] The NEON is an integrated research platform consisting of geographically distributed field and laboratory infrastructure. AdvLIGO is an upgrade of the existing LIGO that would allow it to approach the ground-based limit of gravitational-wave detection. ATST would allow for the study of magneto-hydrodynamic phenomena in the solar photosphere, chromospheres, and corona. OOI is an integrated network of ocean observatories that capture climate, carbon, ecosystems, and geodynamic changes on the time scales at which they occur.

[27] Total funding provided by NSF for ALMA was $499.3 million. In addition, project closure activities and associated costs are being finalized for IceCube Neutrino Observatory and South Pole Station Modernization.

[28] The "no cost overrun policy" was implemented in the FY2009 budget justification.

[29] U.S. National Science Foundation, *FY2013 Budget Request to Congress*, p. MREFC-1.

[30] As an example, three projects that appeared in the FY2008 request (Alaskan Regional Research Vessel—ARRA, Ocean Observatories Initiative—OOI, and the National Ecological Observatory Network—NEON) had to undergo a revised baseline budget and risk management plan. The projects were still supported by NSF, but had to be considered for inclusion in the next budget cycle following submission of their final design review.

the no overrun policy. In addition, all of the projects funded through the MREFC account undergo major cost and schedule reviews as required by NSF guidelines.[31]

The following table provides funding levels for current and out-years for projects in the MREFC account.

Table 1. MREFC Account Funding, by Project

(dollars in millions)

	FY2011 Actual	FY2012 Estimate[a]	FY2013 Request	FY2014 Estimate	FY2015 Estimate	FY2016 Estimate	FY2017 Estimate	FY2018 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[b]	5.29	—	—	—	—	—	—	—
NEON	12.58	60.30	91.00	98.20	91.00	80.66	—	—
OOI	65.00	102.80	65.00	27.50	—	—	—	—
MREFC Total	**$125.37**	**$197.06**	**$196.17**	**$182.62**	**$111.00**	**$100.66**	**$9.93**	**—**

Source: U.S. National Science Foundation, *FY2013 Budget Request to Congress*, p. MREFC-1.

Notes: Totals may not add due to rounding.

a. In FY2012, $30.0 million was transferred from the R&RA to the MREFC, as provided by the Science Appropriations Act, 2012, P.L. 112-55.

b. IceCube and South Pole Station Modernization are expected to report FY2012 actual funding from FY2011 carryover.

[31] U.S. National Science Foundation, *FY2013 Budget Request to Congress*, p. MREFC-2.

Appendix.

Figure A-1. Advanced Laser Interferometer Gravitational-Wave Observatory (AdvLIGO)

Total NSF Cost = $205.1 Million

Source: National Science Foundation, *2012 NSF Facility Plan*, p. 22.

Note: Movement of end-test mass vacuum chamber of AdvLigo.

Figure A-2. Advanced Technology Solar Telescope (ATST)

Total NSF Cost = $297.9 Million

Source: National Science Foundation, *2012 NSF Facility Plan*, p. 24.

Note: ATST primary mirror blank with convex rear surface.

Figure A-3. National Ecological Observatory Network (NEON)

Total NSF Cost = $433.7 Million

Source: National Science Foundation, *2012 NSF Facilities Plan*, p. 31.

Note: Sensor tower at NEON headquarters.

Figure A-4. Ocean Observatories Initiative (OOI)

Total NSF Cost = $386.4 Million

Source: National Science Foundation, *2012 NSF Facility Plan*, p. 33.

Note: Deployment locations.

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