MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION

$200,310,000
-$450,000 / -0.2%

Major Research Equipment and Facilities Construction Funding
(Dollars in Millions)

	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request	Change Over FY 2015 Estimate Amount	Change Over FY 2015 Estimate Percent
Major Research Equipment and Facilities Construction	$200.00	$200.76	$200.31	-$0.45	-0.2%

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, design, and post-construction operations and maintenance are funded through the Research and Related Activities (R&RA) account. No new starts are proposed.

MREFC Account Funding, by Project
(Dollars in Millions)

	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request	FY 2017 Estimate	FY 2018 Estimate	FY 2019 Estimate	FY 2020 Estimate	FY 2021 Estimate
AdvLIGO	$14.92	-	-	-	-	-	-	-
DKIST	36.88	25.12	20.00	20.00	20.00	16.13	-	-
LSST	27.50	79.64	99.67	67.12	55.80	47.89	45.75	39.90
NEON	93.20	96.00	80.64	-	-	-	-	-
OOI	27.50	-	-	-	-	-	-	-
Total	**$200.00**	**$200.76**	**$200.31**	**$87.12**	**$75.80**	**$64.02**	**$45.75**	**$39.90**

Totals may not add due to rounding.

Modern and effective research infrastructure is critical to maintaining U.S. leadership in science and engineering (S&E). 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.

To be considered for MREFC funding, NSF requires that a project represent an exceptional opportunity to enable research and education. The project should be transformative in nature, with the potential to shift the paradigm in scientific understanding. The projects included in this budget request meet these criteria based on NSF and National Science Board (NSB) review.

In FY 2016, NSF requests funding to continue construction of three projects: the Daniel K. Inouye Solar Telescope (DKIST), the National Ecological Observatory Network (NEON), and the Large Synoptic Survey Telescope (LSST). The Advanced Laser Interferometer Gravitational Wave Observatory (AdvLIGO) and the Ocean Observatories Initiative (OOI) received their final construction funding in FY 2014. NSF is not requesting funds to begin any new projects in FY 2016. For more detailed information on these projects, please refer to the following individual narratives.

Since FY 2009, projects funded through the MREFC account have been subject to NSF's "no cost overrun" policy. As a result, NSF processes and procedures must assure the development of realistic and

well supported total project cost estimates for major research facilities such that approved budgets are sufficient to accomplish the scientific objectives.

The current policy requires that (1) the total project cost estimate when exiting the preliminary design phase includes adequate contingency to cover foreseeable risks, and (2) any cost increases not covered by contingency be accommodated first by reductions in scope; provided that the actual enacted funding levels have been consistent with the established annual cash flow requirements. NSF procedures are also designed to assure that contingency use tracking is robust, and that program and recipients have sufficient oversight and management authority (respectively) to meet project objectives. In FY 2014, NSF moved to improve its internal procedures by requiring an independent cost assessment for MREFC projects. In addition, all of the projects funded through the MREFC account undergo periodic cost, schedule, and risk reviews as required by NSF's Large Facilities Manual, as well as the terms and conditions of the cooperative agreements.

Appropriations Language

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 (42 U.S.C. 1861 et seq.), including authorized travel, ~~$200,760,000,~~*$200,310,000*, to remain available until expended.

Major Research Equipment and Facilities Construction
FY 2016 Summary Statement
(Dollars in Millions)

	Enacted/ Request	Unobligated Balance Available Start of Year	Unobligated Balance Available End of Year	Adjustments to Prior Year Accounts	Transfers	Obligations Actual/ Estimates
FY 2014 Appropriation	$200.00	$0.38	-$0.39	$0.01	-	$200.00
FY 2015 Estimate	200.76	0.39			-	201.15
FY 2016 Request	200.31					200.31
$ Change from FY 2015 Estimate						-$0.84
% Change from FY 2015 Estimate						-0.4%

Totals may not add due to rounding.

Explanation of Carryover

Within the **Major Research Equipment and Facilities Construction** account an amount of $390,592 was carried over into FY 2015.

The MREFC Account in FY 2016

The following pages contain information on NSF's ongoing projects in FY 2016, grouped by sponsoring organization. These are:

DANIEL K. INOUYE SOLAR TELESCOPE $20,000,000

The FY 2016 Budget Request for the Daniel K. Inouye Solar Telescope (DKIST) is $20.0 million. This represents the eighth year in an eleven year funding profile, with an estimated total project cost of $344.13 million.

The original total project cost to NSF, $297.93 million, was finalized after a Final Design Review (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 Hawaii Board on Land and Natural Resources (BLNR) approved the project's application for a Conservation District Use Permit (CDUP) on December 1, 2010. A challenge to the CDUP organization was resolved in November 2012 and full access to the site atop Haleakala on Maui, Hawaii followed shortly thereafter. Site preparation and excavation began in December 2012.

The unexpected length of the delay associated with the environmental compliance process led to a reassessment of the project schedule and total project cost in early 2012. The revised baseline and an increase in the total project cost of approximately $46.20 million was reviewed by an external panel of experts and subsequently considered by the NSB, which approved a revised total project cost of $344.13 million at their August 2013 meeting.

Appropriated and Requested MREFC Funds for the Daniel K. Inouye Solar Telescope

(Dollars in Millions)

	Prior Years	FY 2013 Actual	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request	FY 2017 Estimate	FY 2018 Estimate	FY 2019 Estimate	Total Project Cost
MREFC Approp.	$35.00	$25.00	$36.88	$25.12	$20.00	$20.00	$20.00	$16.13	$198.13
ARRA MREFC Appropriation	146.00	-	-	-	-	-	-	-	146.00
Total, DKIST	**$181.00**	**$25.00**	**$36.88**	**$25.12**	**$20.00**	**$20.00**	**$20.00**	**$16.13**	**$344.13**

Totals may not add due to rounding.

Baseline History

DKIST 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 relevance of DKIST's science drivers was reaffirmed by the National Academy of Sciences 2010 Astronomy and Astrophysics Decadal Survey: *New Worlds, New Horizons*[1] as well as the 2012 Solar and Space Physics Decadal Survey: *A Science for a Technological Society*.[2]

Beginning in 2001, NSF provided funds to the National Solar Observatory (NSO) for an eight-year design and development program for DKIST and its initial complement of instruments through the Division of Astronomical Sciences (AST) in the Directorate for Mathematical and Physical Sciences (MPS) and the

[1] www.nap.edu/catalog.php?record_id=12951
[2] www.nap.edu/search/?term=13060&x=0&y=0

Division of Atmospheric and Geospace Sciences (AGS) in Directorate for Geological Sciences (GEO). The current design, cost, schedule, and risk were scrutinized in an NSF-conducted Preliminary Design Review in October-November 2006. The FDR held in May 2009 determined that the project was fully-prepared to begin construction.

In FY 2009, $153.0 million was provided through the Major Research Equipment and Facilities Construction (MREFC) account to initiate construction. Of these MREFC funds, $146.0 million was appropriated through the American Recovery and Reinvestment Act (ARRA). Given the timing of the receipt of budget authority and the complexity of project contracting, the entire $153.0 million was carried over from FY 2009 and subsequently obligated in FY 2010. Since then, contracts for the acquisition of DKIST major subsystems and instruments have been issued. A Habitat Conservation Plan, designed to protect and rehabilitate habitats of the endangered Hawaiian petrel and Hawaiian goose that could potentially be affected by the construction of DKIST, has been approved by the Hawaii BLNR. Formal consultation with the U.S. Fish and Wildlife Service with regard to the endangered Hawaiian petrel was completed in calendar year 2011.

Total Obligations for DKIST

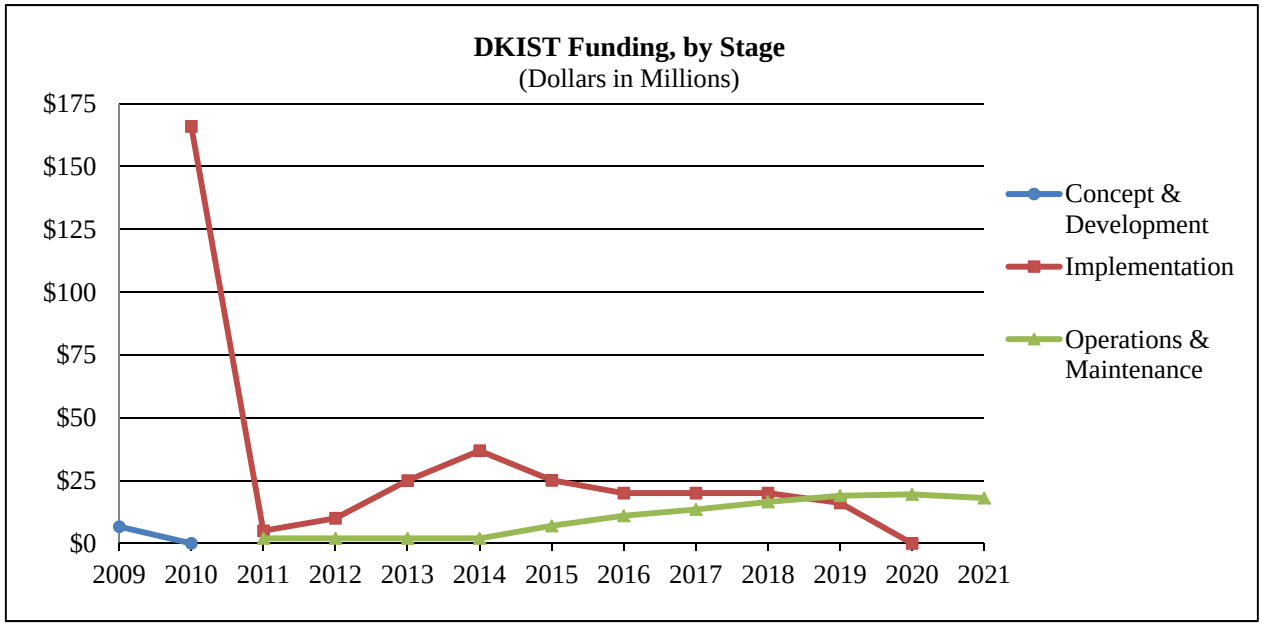
(Dollars in Millions)

					ESTIMATES				
	Prior Years[1]	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
R&RA Obligations:									
Concept & Development	$20.41	-	-	-	-	-	-	-	-
Operations & Maintenance[2]	2.00	2.00	7.00	11.00	13.50	16.50	19.00	19.51	18.04
ARRA	3.10	-	-	-	-	-	-	-	-
Subtotal, R&RA Obligations	$25.51	$2.00	$7.00	$11.00	$13.50	$16.50	$19.00	$19.51	$18.04
MREFC Obligations:									
Implementation	60.00	36.88	25.12	20.00	20.00	20.00	16.13	-	-
ARRA	146.00	-	-	-	-	-	-	-	-
Subtotal, MREFC Obligations	$206.00	$36.88	$25.12	$20.00	$20.00	$20.00	$16.13	-	-
TOTAL Obligations	**$231.51**	**$38.88**	**$32.12**	**$31.00**	**$33.50**	**$36.50**	**$35.13**	**$19.51**	**$18.04**

Totals may not add due to rounding.

[1] Concept & Development funding and Implementation funding are cumulative of all prior years; Operations & Maintenance funding reflects prior year actual obligations only.

[2] Of the total Operations & Maintenance funding, $2.0 milllion per year for FY 2011 through FY 2020 is for cultural mitigation activities as agreed to during the compliance process.



The DKIST 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. These include the following activities:

- The U.S. Air Force has replaced the aluminizing chamber at their Advanced Electro-Optical System telescope on Maui and sized it to accommodate the DKIST primary mirror. This obviates the need to build a new aluminizing chamber for DKIST.
- Kiepenheuer-Institut fuer Sonnenphysik (Freiburg, Germany) is constructing a narrow-band visible tunable filter based first-light instrument.
- Queens University Belfast (Belfast, Northern Ireland) is seeking funding for a contribution of high speed cameras for DKIST instrumentation.

Discussions of other possible contributions for second-generation instruments, algorithm development, coordinated observations, and student exchange are ongoing.

Management and Oversight

- NSF Structure: Oversight from NSF is handled by a program officer in AST working cooperatively with staff from MPS, the Office of Budget, Finance, and Award Management (BFA), and the Offices of the General Counsel and Legislative and Public Affairs. The Large Facilities Office, as part of BFA, also provides advice and assistance to program staff and assists with agency oversight and assurance.
- External Structure: The construction project is managed by NSO. NSF funds NSO operations and maintenance (O&M) and DKIST design and construction via separate cooperative support agreements (CSAs) beneath an overarching cooperative agreement (CA) with the Association of Universities for Research in Astronomy, Inc. (AURA). The NSO CA and O&M CSA were renewed for a period of ten years, starting in January 2015. This period covers the DKIST construction phase and the achievement of sustainable operations of the completed facility. The DKIST director is a senior NSO scientist who was a leader in the development of the science case and an expert in the field of solar adaptive optics, a critical technology for the DKIST. The project manager has experience in several other NSF-funded large projects including the Atacama Large

Millimeter/submillimeter Array and the Expanded Very Large Array. 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: DKIST scope, schedule, budget estimate, and risk-adjusted total project cost were scrutinized and validated at the Preliminary Design and Final Design Reviews.
- Final Design Review (FDR): The FDR was held on May 18-21, 2009. The unanimous finding of the review panel was that the DKIST project was fully prepared to begin construction.
- Re-baseline review: A review of the revised project cost, schedule, and risk was held in October 2012. The project responded to the recommendations of the review panel and follow-up discussions were completed in April 2013. The new baseline was approved by the National Science Board and the NSF Acting Director in August 2013.
- Annual reviews of progress commence in early 2015.

Project Status

Current activities include finalizing the detailed construction-ready designs, ongoing fabrication of DKIST subsystems and instruments, and site preparation and excavation.

The mount base structure under construction. C*redit: M. Warner, DKIST.*

Haleakala High Altitude Observatory on the island of Maui was chosen as the DKIST 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 impacts on the traditional cultural assets on Haleakala, thereby completing compliance with the National Historic Preservation Act. The record of decision authorizing the commencement of construction in FY 2010 was signed by the NSF Director and published in the Federal Register on December 9, 2009. All federal environmental compliance requirements are now complete. Following a challenge to the issuance of the State of Hawaii's Conservation District Use Permit, site access was granted in November 2012, at which time all relevant permits were in place.

Highlights of construction include:

- Erection of the telescope's support and operations building; this will continue throughout FY 2015.
- Assembly of the large, rotating enclosure (dome) site this will continue throughout FY 2015, starting with the installation of its track.
- The telescope mount assembly has completed factory acceptance test and is being shipped to Maui.
- The deformable mirror system was completed and integration and testing is ongoing.
- All first-light instrument detailed designs are complete and fabrication contracts have been let.

In FY 2016, the Support and Operations building will be completed and its Beneficial Occupancy Date achieved. Site testing of the Enclosure will be finished and the Telescope Mount Assembly Coudé Rotator will be installed in the pier. The Telescope Mount base erection will begin inside the facility, along with the start of the electrical installation. The instrument lab will be prepared in anticipation of use by the first light instruments in 2017. The Coudé Optics will pass through factory acceptance testing prior to shipment to Maui.

Cost and Schedule

The original baseline not-to-exceed, risk-adjusted cost was established following FDR. A revised project baseline review was held in October 2012; the National Science Board approved the new baseline in August 2013. Total project cost of $344.13 million is derived from ARRA ($146.0 million) and annual appropriations in the MREFC account ($198.13 million). Full science operations will begin in mid-2019.

Risks

Project management control, interface control, and change controls are in place. Delay in obtaining full access to the site and associated complexities and legal fees have impacted the total projected cost and schedule, resulting in a revised baseline cost and schedule.

Technical: The remaining technical risk is very low as a result of the long design and development phase.

Environmental and Cultural Compliance: AST, NSF's Office of the General Counsel and the DKIST project have worked carefully through the processes of the applicable statutes, and a cultural monitor has been retained during construction. All required permits are in place and twice annual consultations with a Native Hawaiian working group continue.

The Coudé Rotator loaded down with dummy masses for final acceptance testing. *Credit: M. Warner, DKIST.*

Environmental Health and Safety: NSO has a well-developed safety program engendered in the DKIST project. The DKIST project has developed a site safety plan and conducted a thorough construction readiness review in 2011 and conducts annual safety reviews.

Future Operations Costs

Estimated annual operations and maintenance cost is $17.0 million in FY 2019. DKIST will become the flagship telescope for the solar community, rendering some current facilities obsolete. NSO will realize significant savings through the closure or divestment of telescopes replaced by DKIST. A transition plan for the divestment of these facilities is part of the renewal of the NSO cooperative agreement and was externally reviewed. Cultural mitigation commitments have been made pursuant to terms of DKIST environmental and cultural compliance as described in the final environmental impact study and the subsequent Record of Decision, and the Programmatic Agreement. These include $2.0 million of R&RA funding annually for 10 years for programs on Maui, supporting science, technology, engineering, and mathematics education and workforce development with an emphasis on Native Hawaiian students. A ten-year award to develop and administer these programs was made to the University of Hawaii, Maui College in 2011.

Sunrise over the DKIST construction project atop Haleakala in December 2014. *Credit: B. Simison, DKIST.*

LARGE SYNOPTIC SURVEY TELESCOPE $99,670,000

The FY 2016 Budget Request for the Large Synoptic Survey Telescope (LSST) is $99.67 million. This is the third year of support for a nine-year project that began in August 2014. The total project cost to NSF is estimated at $473.0 million.

Appropriated and Requested MREFC Funds for the Large Synoptic Survey Telescope

(Dollars in Millions)

FY 2014 Actual	FY 2015 Estimate	FY 2016 Request	FY 2017 Estimate	FY 2018 Estimate	FY 2019 Estimate	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate	Total Project Cost
$27.50	$79.64	$99.67	$67.12	$55.80	$47.89	$45.75	$39.90	$9.73	$473.00

Totals may not add due to rounding.

LSST Science Mission

LSST will be an 8-meter-class wide-field optical telescope designed to carry out surveys of nearly half of the sky. The initial 10-year survey has a cadence enabling repeat observation of each survey field approximately twice weekly. The requirements for LSST were defined by considering four key science areas:

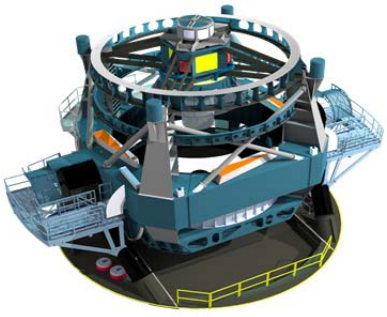
- Understanding the physics of dark energy and dark matter;
- Making a census of the small bodies in the solar system, including potentially hazardous Near Earth Objects;
- Mapping the structure and contents of the Milky Way galaxy;
- Understanding the nature of transient astronomical objects on time scales ranging from seconds to years.

By satisfying the requirements defined by these key investigations, the LSST survey also will result in a comprehensive data set that will enable hundreds of other fundamental astrophysical studies by the entire research community. Thus, LSST has the potential to change every field of astronomical study, from the inner Solar System to the large-scale structure of the Universe.

Baseline History

Construction of LSST is a joint NSF/Department of Energy (DOE) effort to realize an instrument that has been in design and development for over 15 years and that was ranked as the top large ground-based astronomy project by the National Research Council (NRC) 2010 Decadal Survey.[3]

Prior to NSF's MREFC construction award, over $130.0 million was invested by NSF, DOE, and private (non-federal) partners, with about 70 percent in design and development, and 30 percent, from the private funding, in early construction. The non-federal funding supported casting, figuring, and preliminary polishing of the innovative combined primary-tertiary mirror, initial site preparation, and prototype detector creation and evaluation, all of which have significantly reduced construction risks. The large design effort gives confidence in the final project cost estimate.



2013 rendering of the telescope. *Credit: LSST.*

[3] http://sites.nationalacademies.org/bpa/BPA_049810

Total Obligations for LSST

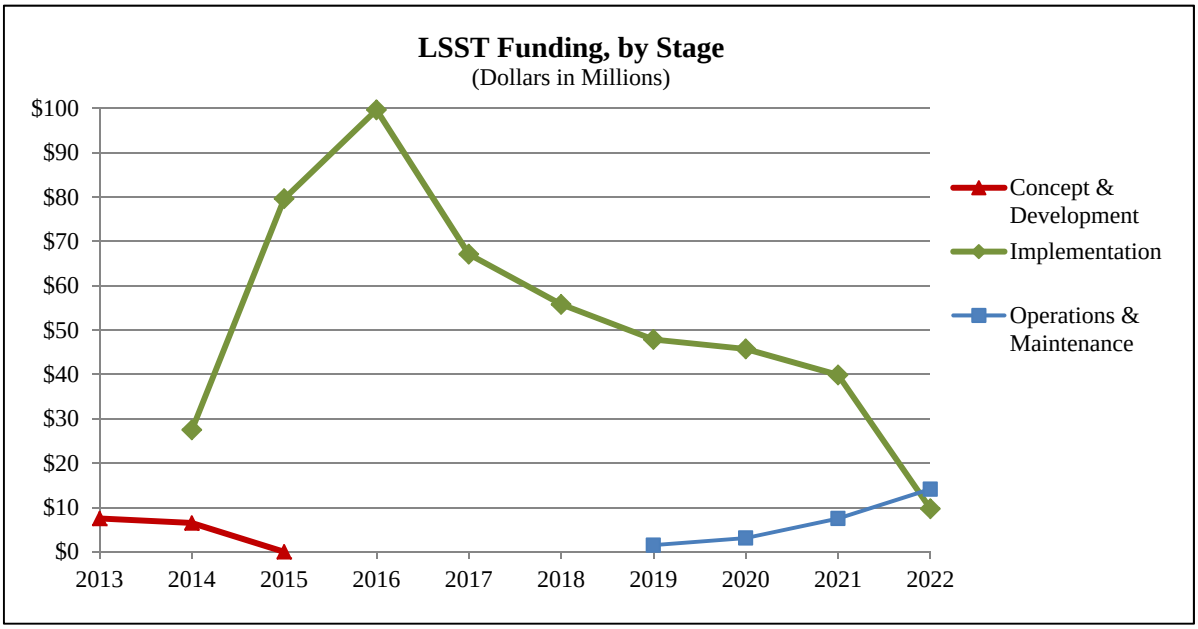
(Dollars in Millions)

	Prior Years[1]	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request	ESTIMATES FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
R&RA Obligations:									
Concept & Development	$50.63	$6.50	-	-	-	-	-	-	-
Operations & Maintenance	-	-	-	-	-	-	1.49	3.10	7.50
Subtotal, R&RA Obligations	$50.63	$6.50	-	-	-	-	$1.49	$3.10	$7.50
MREFC Obligations:									
Implementation	-	27.50	79.64	99.67	67.12	55.80	47.89	45.75	39.90
Subtotal, MREFC Obligations	-	$27.50	$79.64	$99.67	$67.12	$55.80	$47.89	$45.75	$39.90
TOTAL Obligations	**$50.63**	**$34.00**	**$79.64**	**$99.67**	**$67.12**	**$55.80**	**$49.38**	**$48.85**	**$47.40**

Totals may not add due to rounding.

[1] Concept & Development funding and Implementation funding are cumulative of all prior years; Operations & Maintenance funding begins in FY 2019.

The project was originally baselined following a series of reviews conducted by NSF and DOE in 2011 and 2012, including the NSF Preliminary Design Review (PDR) and a subsequent cost estimation review. Since that time, the construction plan has been kept up-to-date to synchronize the DOE and NSF funding profiles and adjust schedule contingency, as described below in the Cost and Schedule section.



LSST Science Plan

LSST will be an 8.4-meter primary, 6.7-meter effective aperture, special purpose optical telescope to be located on Cerro Pachón, Chile. The Chilean site was selected because of the excellent sky transparency and image quality ("seeing"), dark skies, small fraction of cloudy nights, and the geological characteristics that enable the rapid telescope motions required to carry out the LSST survey. LSST will collect nearly 40 terabytes of multi-color imaging data every night for 10 years, producing a long-lived dataset of considerable utility. It will produce the deepest, widest-field sky image ever, and issue alerts for moving and transient objects within 60 seconds of their discovery. Repeated deep imaging of every part of the accessible sky will turn up transient and explosive events such as cataclysmic variable stars, supernovae, and the optical counterparts of X-ray flashes, as well as less spectacular moving objects.

LSST data will be widely accessible, and discovery opportunities will be available to the K-12 student as well as to the professional astronomer. An innovative citizen science program will involve people of all ages in LSST discoveries. More than half of the cost during operations is for data management, including user-friendly interfaces tailored for the different anticipated communities. The survey strategy makes the same dataset usable for almost all of the astronomy community as well as for educators and the general public. The primary data archive will be located at the National Center for Supercomputing Applications (NCSA) in Illinois.

Management and Oversight

- NSF Structure: NSF oversight is the responsibility of the LSST program officer in the Division of Astronomical Sciences (AST) working with staff from the Directorate for Mathematical and Physical Sciences (MPS) and the Office of Budget, Finance, and Award Management (which includes the Large Facilities Office) through the newly-established Integrated Project Team (IPT) approach. The NSF program officer works closely with counterparts in the DOE Office of High Energy Physics, who have oversight responsibility for the LSST Camera sub-project. Inter-agency coordination is accomplished through regular meetings of a Joint Oversight Group (JOG) each week and was formalized through a memorandum of understanding (MOU) signed in July 2012.
- External Structure: The responsible awardee for LSST construction is the Association of Universities for Research in Astronomy (AURA), Inc., a non-profit science management corporation consisting of 39 U.S. institutional members and seven international affiliates. AURA works closely with the LSST Corporation (LSSTC), which initiated the LSST development and remains responsible for the privately raised funding. AURA and LSSTC established the LSST Project Office as an AURA-managed center for the construction period; this Project Office is overseen by the AURA Management Council for LSST. The LSST Project Director and the LSST Project Manager are experienced in large facility construction and operation and are appointed by AURA, with the involvement and approval of the LSSTC and NSF.

Reviews

- Technical Reviews: Reviews have been conducted throughout the design and development phases. A Conceptual Design Review (CDR), conducted in September 2007, found the design to be robust. The PDR followed release of the NAS 2010 Decadal Survey and was completed in September 2011. The DOE Critical Decision (CD) review of the camera led to CD-1 approval ("Approve Alternative Selection and Cost Range") in April 2012. All major sub-systems undergo regular system-level design reviews organized by the LSST Project Office with external participants.
- Management, Cost, and Schedule Reviews: Cost, schedule, and risk are scrutinized by all of the regular technical reviews. During construction, NSF and DOE will hold annual joint progress reviews. Specific milestone reviews for management, cost, and schedule also are described below:
    - Recommendations from the NSF PDR and the DOE CD-1 review led to a Joint Interface and Management Review and a Cost Estimation Review, both held in May 2012. DOE later held a status review of the camera sub-project in June 2013, which led to an increased duration for the LSST construction project, including additional schedule contingency, and a small increase in scope. These changes were necessitated when DOE was not permitted to begin the camera construction within their FY 2013 appropriation.
    - NSF's Final Design Review (FDR) was held in December 2013 with DOE involvement. Fifteen panelists with wide-ranging experience in large projects gave the project a thorough review. Although the final report includes 34 recommendations, these recommendations only adjust the relative emphasis of project activities or endorse existing plans. The panel concluded: "We have no hesitation in our assessment that the project will be ready for the start of construction on July 1, 2014." The National Science Board (NSB) authorized NSF management to proceed with the construction award on May 7, 2014 (NSB-14-24).

  - An NSF internal cost analysis in 2013 was followed by a Cost Estimation Sufficiency Review conducted by an independent contractor to validate the LSST Project's Basis of Estimate documentation. These checks were in addition to the FDR and to the 2012 and 2011 reviews. The external report gave the LSST cost estimate an overall rating assessment of Adequate. Ten evaluation areas met the adequacy standards, and NSF secured improvements to the estimate from the awardee in three areas.
- DOE CD-3a review (long lead procurements) was held on May 6 – 7, 2014 and CD-3a approval was issued in July.
- DOE CD-2 review was successfully completed in November 2014. CD-2 approval, including setting the not-to-exceed Total Project Cost for the DOE sub-project, was issued on January 7, 2015.

Project Status

NSF's construction award was issued on August 1, 2014. The project worked closely with NSF's Division of Acquisition and Cooperative Support (DACS) to satisfactorily resolve all major cost issues in accordance with the NSB resolution. Total project contingency estimates and the resulting Risk Register are undergoing a final internal NSF review with the Large Facilities Office and are expected to be settled in early FY 2015. Design and development support from both agencies enabled readiness for construction, including the preparation of "design with option to build" bid packages that can be awarded quickly. This sped up project activities during the first full year of MREFC support: major work packages for the Telescope Mount Assembly and for the Summit Facility were contracted early in FY 2015, with other contracts anticipated during the year, for example, for data management systems. DOE funding covered significant hardware purchases for the camera in FY 2014, which continue in FY 2015. NSF and DOE supported activities remain tightly coordinated, both at the project level and between agency program officers.

While the facility, telescope, and camera are being built, the project will continue to address data access, computation, and collaboration needs. Because there will be different communities of users, there will be various concurrent modes of access. Development of the data access policy is expected to be a continuing activity as there are multiple promising approaches, and the details continue to be the subject of very active discussion within the project, with internal and external advisory committees, and with potential international partners.

Cost and Schedule

After a delay in the camera construction schedule, a DOE status review in June 2013 concluded that additional time would be needed. This led to a complete bottom-up re-planning of the project prior to the NSF FDR. The FDR panel found the NSF Total Project Cost (TPC) of $473.0 million to be reasonable and justifiable if the project implements descoping options and also generates extra descope options that can be implemented later if additional risk reduction is necessary. The resulting extended schedule and TPC increase were predicated on a July 1, 2014 start for MREFC funding from NSF. While the actual date was August 1, 2014, this slight delay has not had a significant impact on this new schedule.

In addition to NSF's contribution, DOE's baseline for the camera was fixed at $168.0 million when CD-2 approval was issued on January 7, 2015. Project construction includes $38.97 million from non-federal sources, nearly all of which has been expended.

Risks

Technical: Much of the technical risk has been retired by design and development effort and by investment of non-federal funds in construction, notably for the primary-tertiary mirror, whose polishing was completed in late 2014. Both PDR and CD-1 external reviews identified the camera detectors as a possible risk; this risk continues to be reduced and the project mitigation strategy was again endorsed by a DOE-led status review in June 2013. The risk registry is continually monitored and updated.

Environmental and Cultural Compliance: The Chilean environmental and cultural impact assessment has been completed and was reviewed and subsequently approved by NSF in October 2010, under Executive Order 12114 for extraterritorial projects. Mitigation work has started with the propagation of threatened plant species, and the beginnings of reintegration at the site.

Site: The above environmental and cultural impact assessment, and the subsequent finding equivalent to no significant impact, cleared the way for the preliminary site work. Local contractors have leveled the planned location for LSST and confirmed the geological results from the original test borings. They found no problems that could compromise the stability and rigidity of the mount as currently designed. There appear to be no remaining site risks.

Environmental Health and Safety: The LSST project has a full-time Head of Safety with experience in AURA operations, which include a long positive safety record in Chile. AURA Safety Policy encompasses general guidelines as well as site-specific policies, such as a LSST summit-specific plan. These plans are fully compliant with applicable standards from U.S., Chilean, and participating institutions. The plans will be monitored and updated appropriately and will be reviewed annually.

Partnership Risk: The LSST Project Director oversees the entire project and will be assisted by a Deputy Project Director (to be appointed) with complementary skills and experience. Detailed project management is handled by a single Project Manager, agreed to by both NSF and DOE program management. Budgetary management details are clearly set out between the Project Director, the Project Manager, the project's Change Control Board, the AURA Management Council for LSST, and the agency program officers, grants officers, and financial managers. The commitments by DOE and by NSF were officially recorded in an MOU between the agencies that was signed in July 2012. As the MOU notes, the management structure treats the project as a single team and includes mechanisms and authority to make changes on either side of the DOE/NSF budgetary boundary, and across that boundary, if needed.

Operations Costs: A formal proposal for LSST Operations will be requested approximately two years before the start of early operations. Review of that proposal will result in the baseline project execution plan and operating costs. The project team has spent some effort on possible scope reduction to shrink the total annual cost but has primarily focused on finding partners willing to contribute towards the necessary non-federal contribution of approximately $9.0 million per year. Letters of commitment have been received from 68 institutions in 26 countries for a total annual contribution of over $10.0 million, providing strong confidence that the necessary non-federal contributions will be forthcoming. Negotiations have started for firm agreements and possible advance contributions. An LSST@Europe meeting in September 2013 had attendees from 20 countries and led to detailed discussions about those contributions and agreements. Given the signed NSF/DOE MOU and the high level of signatories to the partner letters of commitment, operational support risk is low. The LSST Project Office plans to form an international finance committee to oversee the use of contributed funds during operation.

Future Operations Costs

Estimated operations costs were calculated in FY 2013 U.S. dollars at $36.63 million per year. Following the recommendation of the NRC 2010 Decadal Survey, MPS/AST has prepared a plan to provide approximately 50 percent of that amount, and the DOE Office of High Energy Physics has committed to another 25 percent. As mentioned previously, the total estimated cost, and the amount required from the non-federal partners, will be determined in review of a future LSST Operations proposal. In their joint MOU, NSF and DOE have agreed together to fund operations, increasing agency support and/or revising the operations plans, as appropriate.

THE NATIONAL ECOLOGICAL OBSERVATORY NETWORK $80,640,000

The FY 2016 Budget Request for the National Ecological Observatory Network (NEON) is $80.64 million, which represents the last funding year of a six-year project that totals an estimated $433.72 million.

Appropriated and Requested Funding for the National Ecological Observatory Network

(Dollars in Millions)

Prior Years	FY 2012 Actual	FY 2013 Actual	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request	FY 2017 Estimate	FY 2018 Estimate	Total Project Cost
$12.59	$60.30	$91.00	$93.20	$96.00	$80.64	-	-	$433.72

Totals may not add due to rounding.

NEON consists 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.

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 initial funding in FY 2007. A Preliminary Design Review (PDR) was completed in June 2009 and a Final Design Review (FDR) was completed in November 2009. The FDR also included a formal construction baseline review and cost review; an additional baseline review was conducted in April 2011 prior to initiation of construction that confirmed the baseline scope, cost, and schedule. Project planning continued through FY 2011 until construction began in August 2011.

Total Obligations for NEON

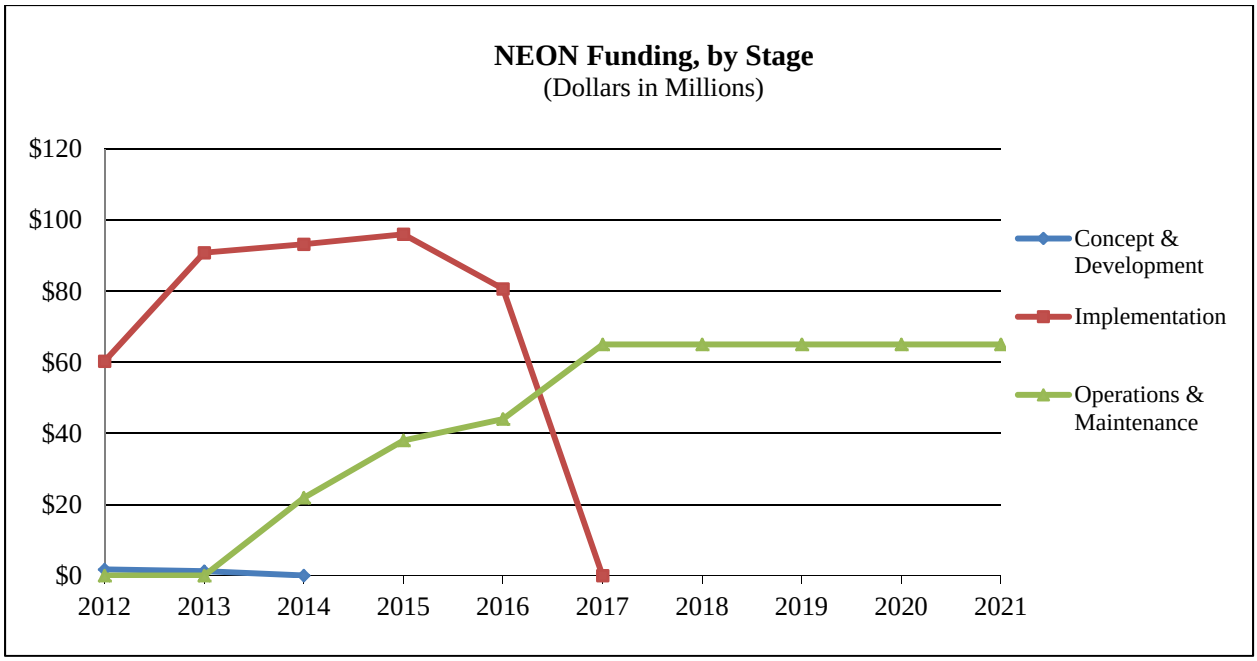
(Dollars in Millions)

	Prior Years[1]	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request	ESTIMATES FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
R&RA Obligations:									
Concept & Development	$91.73	-	-	-	-	-	-	-	-
Operations & Maintenance[2]	-	21.89	38.00	44.04	65.00	65.00	65.00	65.00	65.00
ARRA	9.96	-	-	-	-	-	-	-	-
Subtotal, R&RA Obligations	$101.69	$21.89	$38.00	$44.04	$65.00	$65.00	$65.00	$65.00	$65.00
MREFC Obligations:									
Implementation	163.89	93.20	96.00	80.64	-	-	-	-	-
Subtotal, MREFC Obligation	$163.89	$93.20	$96.00	$80.64	-	-	-	-	-
TOTAL Obligations	**$265.58**	**$115.09**	**$134.00**	**$124.68**	**$65.00**	**$65.00**	**$65.00**	**$65.00**	**$65.00**

Totals may not add due to rounding.

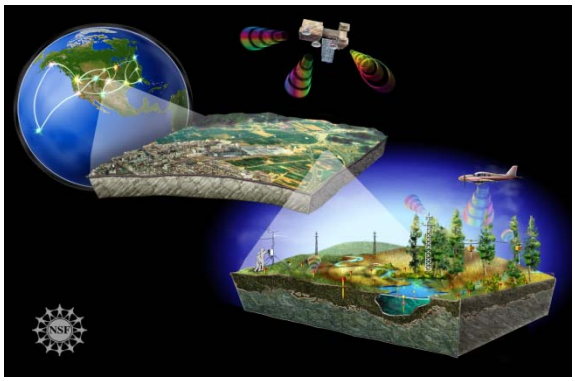
[1] Concept & Development funding and Implementation funding are cumulative of all prior years; Operations & Maintenance funding reflects prior year actual obligations only.

[2] Funding for Operations & Maintenance (O&M) in outyears has been capped at now-year dollars, pending the results of a three year initial O&M testing. A final O&M award, to be made after the three years concludes, will reflect these results.



NEON is the first research platform and the only national experimental facility specifically designed to collect consistent and standardized sensor and biological measurements across 106 sites nationwide in close to real-time, enabling basic research on complex phenomena driving ecological change and at the scales appropriate for studying many grand challenge questions in ecology. NEON allows researchers to expand the scale of their research to understand large scale dynamics affecting ecosystems.

A NEON cyberinfrastructure gateway provides resources to support formal and informal public education and provide opportunities for citizens to participate in scientific investigations. NEON data is open-access via web portals and available as soon as possible, once basic quality assurance and quality control procedures have been applied. Private organizations including the Heinz Center, National Geographic Society, Nature Serve, and the Ecological Society of America are assisting NEON, Inc. to broaden the impact of NEON science and education to the next generation of scientists and educators.



NEON will be a collaborative research platform of geographically distributed infrastructure connected via the latest information technology. By combining in-situ sensing with remote sensing observations, NEON will address pressing environmental questions on regional to continental scales. *Credit: NSF.*

The 2009 United States Global Change Research Program (USGCRP) assessments indicate that U.S. ecosystems will experience abrupt and unpredictable changes from a suite of human-driven processes in the near future.[4] NEON enables research on the impacts of climate and land use change, water use, and invasive species on the Nation's living ecosystems at temporal and spatial scales that are relevant to human well-being. NEON's unique statistically-determined, continental-scale design, with data products, data management, and standardization supports research on the dynamics of complex coupled systems needed for modeling and understanding rates of change on regional and continental scales. No other

[4] Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009.

standalone system – federal or private – can provide the scientifically validated suite of data measurements that NEON provides.

The scientific techniques, sensor data, and basic research knowledge gained through NEON will inform federal resource management decisions necessitated by climate and land use change, water use, and invasive species. They will contribute to societal benefits as identified by the National Science and Technology Council's 2013 National Strategy for Civil Earth Observations and the international Group on Earth Observations 2004 Framework Document. The science that NEON supports is not bound by national boundaries, with regard to climate change, invasive species, and the ecological processes they affect. The repurposing of NEON data and information and establishing interoperability among all earth observations is important to enable the research on continental to global scales. NEON's domestic and international MOUs focus on meeting NEON, Inc.'s Strategic Plan and the U.S. National Plan for Civil Earth Observations both of which call for strengthening international collaboration in Earth Observations, and to improve data access, management, and interoperability.[5] Formal agreements have been signed with the European Union, including the Integrated Carbon Observing System (ICOS) Ecosystem Thematic Center, Infrastructure for Analysis and Experimentation on Ecosystems (AnaEE), Czech Climate Change Research Center (CzechGlobe), and Australia's Terrestrial Ecosystem Research Network (TERN). Areas of coordination include planning, design, construction, deployment, environmental assessment, data management, geospatial data exchange, cyberinfrastructure, research, and modeling. As described in an August 2013 article in the *Engineering News-Record*, NEON construction models are also having an impact on establishment of new standards for construction in environmentally sensitive areas.[6]

Management and Oversight

- NSF Structure: The NEON program is managed in the Directorate for Biological Sciences (BIO) Office of the Assistant Director (OAD/BIO) as part of the Emerging Frontiers (EF) subactivity. OAD/BIO provides overall policy guidance and oversight, and the location of the NEON program in EF within BIO fosters its broader biological and interdisciplinary science connections. The NEON program is managed by a dedicated program officer and a project manager with experience from another NSF MREFC project; two additional program officers participate in planning, development, and oversight of NEON construction and NEON operations and maintenance. An Integrated Project Team (IPT) chaired by the NEON program officer, with representatives from Large Facility Office (LFO), BFA, and program representatives from other NSF large facilities, advises and assists with the business framework of the project. The NEON program officer served as the contracting officer's representative (COR) for the NEON environmental assessment completed in FY 2010. A NEON Environmental Assessment Team (EA) provides ongoing technical advice on the 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 NEON, Inc., the CEO provides overall leadership and management; the Project Manager oversees all aspects of the project design, review, construction, and deployment; the Observatory Director provides leadership for

[5] The US National Plan, which states '…to coordinate, plan, and assess Federal Earth observation activities in cooperation with domestic stakeholders; to foster improved Earth system data management and interoperability throughout the Federal Government; and to engage international stakeholders by formulating the U.S. position for, and coordinating U.S. participation in the intergovernmental Group on Earth Observations.' Holdren, J., T. Dickenson, G. Paulson, et al. 2014. *National Plan for Civil Earth Observations*, National Science and Technology Council, Executive Office of the President, pp. 71. www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/2014_national_plan_for_civil_earth_observations.pdf.

[6] http://enr.construction.com/technology/construction_technology/2013/0828-reaching-zero-the-realities-of-ecologicallyfriendly-engineering-on-a-continental-scale.asp

operations for the facility. A Board of Directors and a Science, Technology, and Education Advisory Committee (STEAC) 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. A Program Advisory Committee (PAC) will be appointed in the second quarter of FY 2015, to provide advice and guidance to the NEON Observatory on the use of NEON facilities.

Reviews

- Technical reviews: The NEON Observatory Design Review (including site selection and deployment design) was successfully completed in February 2009.
- Environmental review: The NEPA environmental assessment was completed in November 2009. A "Finding of No Significant Impact" was signed by NSF in December 2009; the U.S. Fish and Wildlife Service concurred with this finding, as well as with NSF's compliance with the Endangered Species Act. In July 2011, the NSF Record of Decision was signed.
- Construction, Cost, and Schedule reviews:
  - A Conceptual Design Review 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.
  - A Baseline Review, to ascertain readiness to begin construction, was conducted in April 2011 prior to construction.
  - A second Baseline Review was held May 2013 to ascertain the impacts of funding delays on project schedule. A Delta Review – to assess progress in implementing scheduling recommendations received from the baseline review panel – was held in December 2013.
  - A third successful Baseline Review was held in August 2014 confirming the schedule robustness and costs.
  - A Construction Review is conducted annually during the fourth quarter.
- National Science Board (NSB) Review: The Board reviewed and authorized NEON construction subject to final appropriation of funds in May 2010. The Board reviewed and authorized NEON O&M in February 2013.
- Management, Business, and Operations Reviews:
  - NSF conducted a Business Systems Review (BSR) and issued a final report in November 2011.
  - An Operations Review of the project's operating plan and costs for the first three years of operations was held in January 2012.
  - Annual operations and management reviews will be conducted each year starting in FY 2015.
  - A pre-award cost review is proposed prior to full observatory operations 5-year funding.

Project Status

The National Science Board approved funding for NEON in May 2010 and construction was initiated in August 2011. Construction of technical support facilities was completed in September 2013 and these facilities were used to support other construction activities. NEON's airborne observation platform provides remote sensing through aircraft-mounted instrumentation, including an imaging spectrometer operating in the visible to shortwave IR spectral region, a waveform light detection and ranging (wLiDAR) instrument, and a high-resolution digital camera deployed on three aircraft. The first two airborne observatories were constructed and pathfinder missions were conducted in FY 2013 with NASA and supported research studies and management of major forest fires. The third airborne observatory was delivered ahead of schedule and its pathfinder flights occurred in FY 2014. By the fourth quarter of FY 2015, the three airborne observatories will begin to transition to full Observatory operations with the transition complete in FY 2016.

Civil construction of distributed infrastructure is ahead of schedule and deployment of sensor assemblies is fully underway with the resolution of procurement and production difficulties. As a result, it is expected that 30 percent of the Observatory research capabilities will be available by the end of FY 2015 and 60 percent by the end of FY 2016. In FY 2015, civil and facility construction activities are planned for 35 sites in nine domains. By the end of FY 2015, 88 percent of the total civil and facility construction will be complete. The remaining Observatory civil construction at 14 sites in eight domains will be complete in FY 2016. The rate of instrumentation deployment and site commissioning has increased, with initial sensor deployment and commissioning completion anticipated at 33 sites in 15 domains in FY 2015 and full sensor deployment at 21 sites in 13 domains in FY 2016. In FY 2015, biological sampling will occur at 29 sites in 16 domains. In FY 2016, biological sampling is proposed for 26 sites in 15 domains. Aquatic and Stream Experimental and Observatory Network (STREON) site construction is proposed to include 11 sites in nine domains in FY 2015 and 20 sites in 19 domains in FY 2016. In FY 2015, one of the STREON sites will transition to operations and in FY 2016 three STREON sites will become operational.

In FY 2015 and FY 2016, MREFC funds will support continuation of the NEON cyberinfrastructure hardware and software deployments in support of sites and domain Support Facilities acceptance. Funds were requested in FY 2015 to continue data center expansion, to complete biological sampling personal data assistants and NEON central operational support system, and ongoing development of data algorithms and related data release via NEON's web portal. In FY 2016, funds will be used to expand the operational support systems, management system for assets, configuration, inventory, and ongoing development of data algorithms and related data release via NEON's web portal.

In FY 2016, $44.04 million is requested from the Research and Related Activities (R&RA) account for operations and maintenance of the fourteen domains commissioned, including related management and technical support, seasonal biological sampling, analytical and archival costs, and domain facilities costs. Funds will support the Calibration & Validation Laboratories and headquarters functions, such as maintenance of the data center, Observatory monitoring and quality assurance and control. In addition, funds will support the operation and maintenance of the Airborne Observation Platform and related technical facility.

Cost and Schedule

The projected length of the construction project is six fiscal years, with a six-month schedule contingency included. NEON is currently 48.5 percent complete. Current project performance is consistent with ending on time and within budget.

Risks

Technical: Dependence on commercial off-the-shelf technology from single vendors will be mitigated by procurements to enable testing and identification of 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). 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 for a small number of components. Consequently, BIO has provided R&RA funds for advanced research and development (R&D) activities in the areas of sensors, cyberinfrastructure, and remote sensing technology. These development activities are progressing with adequate margin to meet the delivery milestones.

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; the 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 Earth Resources Observation and Science (EROS) Data Center, which has the federal responsibility for curation and management of LANDSAT and MODIS images. This partnership allows NEON to have alternative satellite sensor sources to purchase images (e.g., SPOT - France, AWIFS – India, Terra and Aqua – U.S.). Experienced flight design engineers were contracted by NEON, Inc. to provide the baseline operations plans, aircraft analysis, and assessment of commercial companies that could potentially support NEON flight operations, and experienced research aircraft pilots served on the design team.

Future Operations Costs

NEON is the first research observatory that when complete, will maintain and operate in-situ instrumentation and conduct biological sampling in twenty domains (106 locations); three airborne observatories; a central operating facility; and a cyberinfrastructure center. Support will be provided to monitor the sensors, and receive, process, and archive the data from all measurement systems. NEON operations include significant labor costs due to the labor-intensive processes required for biological sampling and data collection. NEON is reliant on sensors and cyberinfrastructure that have a defined lifecycle, so operations costs include scheduled replacement and refreshing of sensor, instrumentation, and cyberinfrastructure technology. Operations are planned to ramp up commensurate with commissioned sites.

A three year initial award for operations and maintenance began in September 2014 to allow NEON to explore opportunities for schedule and cost efficiencies and provide the basis for funding full Observatory operations for the outyears. For FY 2017 – FY 2021, the costs are held constant at the projected operations ceiling reviewed at both PDR and FDR, pending results of the three year award.