MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION

$193,120,000
-$7,190,000 / -3.6%

Major Research Equipment and Facilities Construction Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Major Research Equipment and Facilities Construction	$144.76	$200.31	$193.12	-$7.19	-3.6%

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.

MREFC Account Funding, by Project

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2018 Estimate	FY 2019 Estimate	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate
DKIST	$25.12	$20.00	$20.00	$20.00	$16.13	-	-	-
LSST	79.64	99.67	67.12	55.80	47.89	45.75	39.90	9.73
NEON[1]	40.00	80.64	-	-	-	-	-	-
RCRV	-	-	106.00	105.00	44.50	-	-	-
Total	**$144.76**	**$200.31**	**$193.12**	**$180.80**	**$108.52**	**$45.75**	**$39.90**	**$9.73**

Totals may not add due to rounding.

[1] Of the $96.0 million appropriated for NEON in FY 2015, $56.0 million was carried over to FY 2016 and is excluded in the amounts above.

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 or cyber-infrastructure 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 review and approval.

In FY 2017, NSF requests $193.12 million to begin construction of one new project, the Regional Class Research Vessels (RCRV), and to continue construction of two projects, the Daniel K. Inouye Solar Telescope (DKIST) and the Large Synoptic Survey Telescope (LSST). Although the construction schedule is going to extend due to management challenges, FY 2016 currently represents the last MREFC funding request for the National Ecological Observatory Network (NEON) as previously planned. For more information on these projects, see the individual narratives later in this chapter.

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 tracking contingency use is robust and that program and recipients have sufficient oversight and management authority (respectively) to meet project objectives. NSF is continually improving its internal processes and procedures on oversight, including the requirement for independent cost estimate reviews (per GAO Cost Estimating Guide) and incurred cost audits for MREFC projects. Further, all 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, ~~$200,310,000~~*,$193,120,000,* to remain available until expended. *(Science Appropriations Act, 2016.)*

Major Research Equipment and Facilities Construction
FY 2017 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 2015 Appropriation	$200.76	$0.39	-$58.06	$1.67	-	$144.76
FY 2016 Estimate	200.31	58.06			-	258.37
FY 2017 Request	193.12					193.12
$ Change from FY 2016 Estimate						-$65.25
% Change from FY 2016 Estimate						-25.3%

Totals may not add due to rounding.

Explanation of Carryover

Within the **Major Research Equipment and Facilities Construction** no-year account, $58.06 million was carried over into FY 2016. This total is composed of:

- National Ecological Observatory Network (NEON): $56.0 million
  - Reason: FY 2015 obligations were limited in connection with the construction management transition. For additional information, please see the NEON section of this chapter.
  - Anticipated Obligation: FY 2016 Quarter 3

- The remaining $2.06 million is due to a settlement of $1.67 million for the Large Hadron Collider project and $390,691 in residual funds from the Advanced Laser Interferometer Gravitational Wave Observatory project.

The MREFC Account in FY 2017

The following pages present detailed information on NSF's ongoing projects in FY 2017, with sponsoring organization noted in parenthesis. These are:

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

The FY 2017 Budget Request for the Daniel K. Inouye Solar Telescope (DKIST) is $20.0 million. This represents the ninth year in an eleven-year funding profile, with an estimated total project cost of $344.13 million. Completion of construction atop Haleakala on Maui, Hawaii is planned for late FY 2019.

When completed in 2019, DKIST will be the world's most powerful solar observatory, poised to answer fundamental questions in solar physics by providing transformative improvements over current ground-based facilities. DKIST will enable the study of magnetic 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. Solar activity can affect civil life on Earth through 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] DKIST will play an important role in enhancing the "fundamental understanding of space weather and its drivers," an objective called out in the National Space Weather Strategy and associated National Space Weather Action Plan, both of which were released by the National Science and Technology Council on October 29, 2015.

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 Actual	FY 2016 Estimate	FY 2017 Request	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

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 Division of Atmospheric and Geospace Sciences (AGS) in the Directorate for Geosciences (GEO). The current design, cost, schedule, and risk were scrutinized in an NSF-conducted Preliminary Design Review in October-November 2006.

The original total project cost to NSF, $297.93 million, was set after a Final Design Review (FDR) in May 2009 determined the project was fully prepared to begin construction. The National Science Board (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. 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 obligated in FY 2010. The environmental compliance requirements were completed on November 20, 2009, and the Record of

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

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 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, was 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. Site construction was halted while a Contested Case challenge to the 2010 CDUP issuance was resolved. The BLNR ruled in favor of the DKIST project and a new CDUP was issued in November 2012. Full access to the site atop Haleakala followed shortly thereafter. Site preparation and excavation began November 30, 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 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.

Total Obligations for DKIST

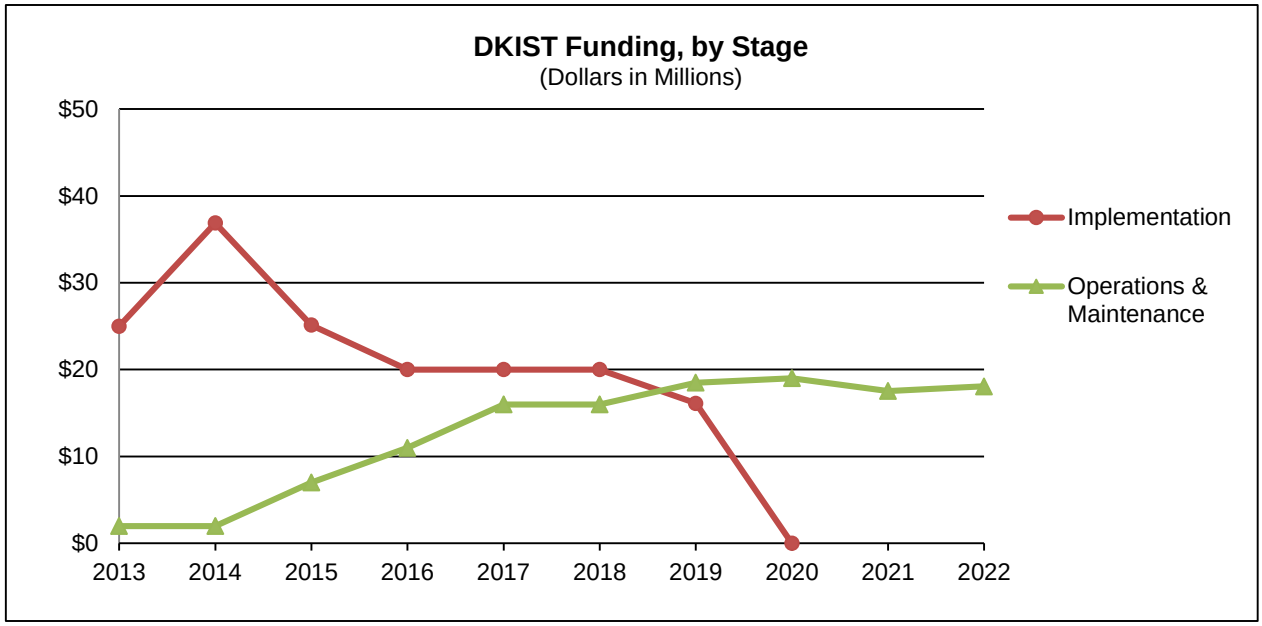
(Dollars in Millions)

					ESTIMATES				
	Prior Years[1]	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
R&RA Obligations:									
Concept & Development	$20.41	-	-	-	-	-	-	-	-
Operations & Maintenance[2]	2.00	7.00	11.00	16.00	16.00	18.50	19.01	17.54	18.08
ARRA	3.10	-	-	-	-	-	-	-	-
Subtotal, R&RA Obligations	$25.51	$7.00	$11.00	$16.00	$16.00	$18.50	$19.01	$17.54	$18.08
MREFC Obligations:									
Implementation	96.88	25.12	20.00	20.00	20.00	16.13	-	-	-
ARRA	146.00	-	-	-	-	-	-	-	-
Subtotal, MREFC Obligations	$242.88	$25.12	$20.00	$20.00	$20.00	$16.13	-	-	-
TOTAL Obligations	**$268.39**	**$32.12**	**$31.00**	**$36.00**	**$36.00**	**$34.63**	**$19.01**	**$17.54**	**$18.08**

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. Also included for FY 2017 is $2.50 million for the DKIST Remote Operations Building (should this option be selected); see the NSO narrative in the Facilities chapter for more information.



The DKIST project is a collaboration of scientists and engineers at more than 20 U.S. and international organizations. Other partners include the Air Force Office of Scientific Research and international groups in Germany, the United Kingdom, and Italy. Some of the activities to be performed through these partnerships include:

- The U.S. Air Force 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 für Sonnenphysik (KIS; Freiburg, Germany) is constructing a narrow-band first-light instrument named the Visible Tunable Filter (VTF).
- Queens University Belfast (Belfast, Northern Ireland) is leading a consortium of institutions from the United Kingdom that will supply high-speed visible cameras to feed the DKIST instruments.

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 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. Representatives from the above NSF offices comprise the DKIST integrated project team (IPT), which meets on a quarterly basis to discuss outstanding project issues.
- External Structure: The construction project is conducted 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 recently renewed for a period of ten years through the end of FY 2024. 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 NSB and the NSF Acting Director in August 2013.
- Programmatic review: A comprehensive review of the DKIST Project Execution Plan and construction progress took place December 7–9, 2015. Discussion topics included: science requirements; project performance and management controls; earned value management; risk management; integration, testing and commissioning; systems engineering; project compliance; stakeholder interactions; and project safety. The review panel debriefed NSF and the project at the end of the meeting stating, ”project performance against the plan defined in the Project Execution Plan is excellent.” The review panel’s final report was delivered in late-December 2015.
- Business Systems Review (BSR): A BSR is currently underway and is projected to last from December 2015 – March 2016.

Project Status

The DKIST project continues to make progress on construction at the summit of Haleakala on Maui, HI, while remaining in compliance with all local, state, and federal environmental and cultural requirements. The project continues to consult with various stakeholders on a regular basis including the Hawaiian Department of Land and Natural Resources, the Hawaiian Department of Fish and Wildlife, the U.S. Fish and Wildlife Service, the Federal Aviation Administration, the National Park Service, and Native Hawaiian cultural practitioners.

Construction highlights include:

- Erection of the large, rotating enclosure (dome) continues in FY 2016. The enclosure will be commissioned, declared watertight, and accepted by the end of FY 2016 (a Level 1 milestone).
- The Coudé rotator platform assembly inside the enclosure continues through FY 2016.
- The telescope mount assembly (TMA) has been shipped to Maui, and assembly of the TMA base inside the enclosure will begin in late FY 2016.
- The main M1 mirror polishing was completed in early FY 2016 (see picture below). The mirror will be stored in Tucson until 2017-2018 and subsequently shipped to Maui for integration.
- Four of the five first-light instruments have undergone critical design review (CDR) and are now in fabrication. Fabrication will continue through FY 2017. The DKIST project management team continues to work with the German KIS team to bring the fifth instrument (the VTF) back on schedule (see risks below).

In FY 2017, the Coudé rotator platform will be commissioned and accepted. The installation of the Telescope Mount Assembly (TMA) electrical systems will be completed, and commissioning and acceptance testing of the TMA will begin. The Coudé lab room will be complete and various components

of the Coudé optics system installed. The first of the five first-light instruments, the visible broadband imager (VBI), will be delivered, assembled and will begin initial checkout.

Cost and Schedule

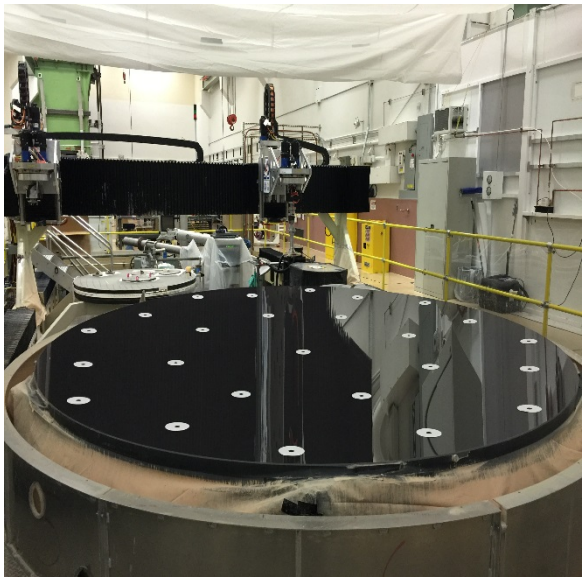
The original baseline not-to-exceed, risk-adjusted cost was established following FDR. As noted above, a revised project baseline review was held in October 2012; NSB approved the new baseline in August 2013. Total project cost of $344.13 million is derived from ARRA ($146.0 million) and annual appropriations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

Risks

Project management control, interface control, and change controls are in place. The project also maintains a risk register that is reviewed and updated on a monthly basis.

Technical: The majority of the remaining technical risk is very low as a result of the long design and development phase, with the exception of one first-light instrument: the VTF described above. This instrument is an in-kind contribution from the German Kiepenheuer-Institut für Sonnenphysik (KIS) being designed and developed through a MoU between AURA and KIS. The VTF instrument has yet to pass the Preliminary Design Review (PDR) phase and there is substantial risk that the instrument will not be available at first light. The DKIST project and the managing organization, AURA, are actively managing the situation and attempting to restore the original VTF schedule.

Environmental and Cultural Compliance: AST, NSF's Office of the General Counsel, and the DKIST project have carefully worked through the applicable statutes, and a cultural monitor has been retained during construction. All required permits are in place and semi-annual consultations with a Native Hawaiian working group continue. There are two outstanding legal appeals with the potential to impact project construction; both are pending decisions in the Hawaiian Supreme Court. In a similar case involving the construction of the Thirty Meter Telescope (TMT) the Court recently (December 2015) invalidated the TMT's CDUP for failure to hold a Contested Case hearing prior to issuance of the CDUP by the Hawaiian BLNR. The DKIST project halted construction under its 2010 CDUP in order to resolve a Contested Case hearing. A second CDUP was approved in November 2012 after the resolution of the Contested Case in favor of the project. Nevertheless, the two pending appeals still represent a significant risk exposure to the DKIST project and to NSF.



The DKIST main (M1) mirror being polished at the University of Arizona's College of Optical Sciences. C*redit: R. Kneale, 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.

DKIST Operations Costs

For the sake of completeness, DKIST operations costs are listed here in the DKIST MREFC narrative; however, DKIST operations are funded through R&RA account (see the NSO narrative in the Facilities chapter for more information). As outlined in the NSO narrative, the request of $16.0 million for FY 2017 includes $11.50 million for the continuing ramp of DKIST operations, $2.50 million to partially fund the Remote Operations Building on Maui (should this alternative be selected by an ongoing environmental review process), and $2.0 million for cultural mitigation activities as discussed below. In FY 2019, the estimated steady-state operations and maintenance cost will be $16.50 million, exclusive of cultural mitigation activities. DKIST will become the flagship telescope for the solar community, rendering some current facilities obsolete. NSO operating costs will be reduced 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.

As noted above, cultural mitigation commitments were 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 (FY 2011 – FY 2020) 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 University of Hawaii, Maui College in September 2011.

Telescope enclosure assembly underway at the DKIST site on Haleakala, Maui, HI, November 2015. C*redit: DKIST project web camera.*

LARGE SYNOPTIC SURVEY TELESCOPE $67,120,000

The FY 2017 Budget Request for the Large Synoptic Survey Telescope (LSST) is $67.12 million. This is the fourth year of support for a nine-year project that began in August 2014. The National Science Board approved not-to-exceed total project cost is $473.0 million for NSF's contribution to the project's scope.

Appropriated and Requested MREFC Funds for the Large Synoptic Survey Telescope

(Dollars in Millions)

FY 2014 Actual	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	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 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 private funding, in early construction. The non-federal funding supported casting and polishing of the innovative combined primary-tertiary mirror (M1M3), initial site preparation, and prototype detector creation and evaluation, all of which significantly reduced construction risks.

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.

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

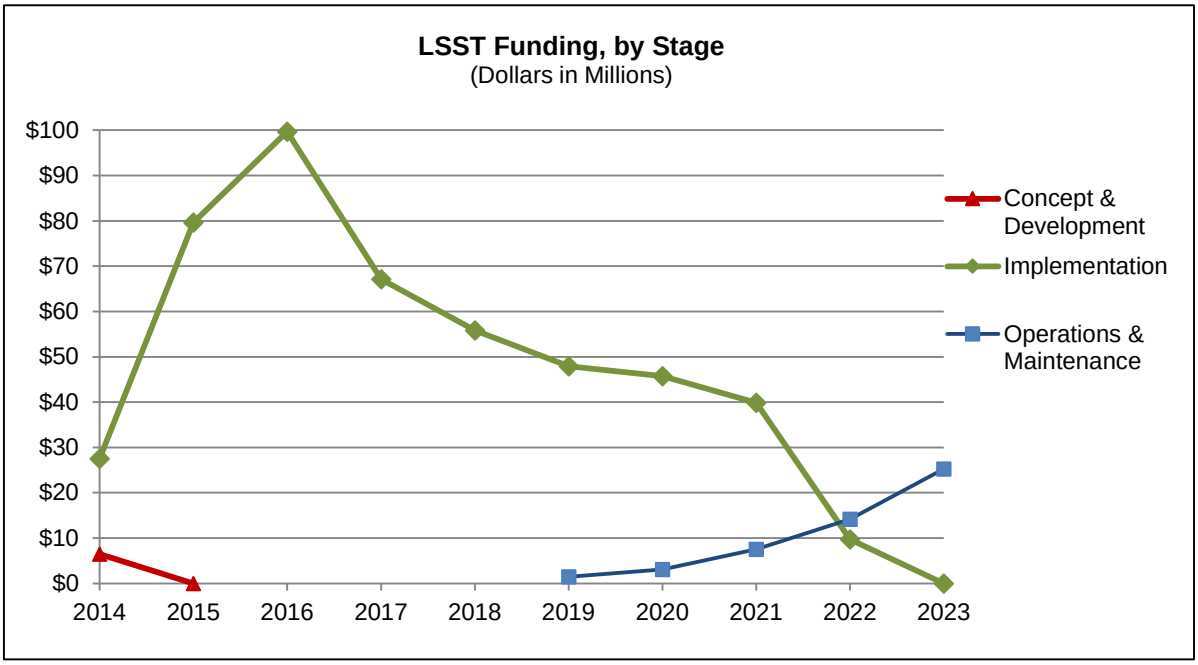
Total Obligations for LSST

(Dollars in Millions)

	Prior Years[1]	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
R&RA Obligations:									
Concept & Development	$57.13	-	-	-	-	-	-	-	-
Operations & Maintenance	-	-	-	-	-	1.49	3.10	7.50	14.13
Subtotal, R&RA Obligations	$57.13	-	-	-	-	$1.49	$3.10	$7.50	$14.13
MREFC Obligations:									
Implementation	27.50	79.64	99.67	67.12	55.80	47.89	45.75	39.90	9.73
Subtotal, MREFC Obligations	$27.50	$79.64	$99.67	$67.12	$55.80	$47.89	$45.75	$39.90	$9.73
TOTAL Obligations	**$84.63**	**$79.64**	**$99.67**	**$67.12**	**$55.80**	**$49.38**	**$48.85**	**$47.40**	**$23.86**

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.



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 is planned to be located at the National Center for Supercomputing Applications (NCSA) in Illinois.

Management and Oversight

- NSF Structure: NSF oversight is the primary 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 recently established integrated project team (IPT). 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 weekly meetings of a joint oversight group (JOG) 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 40 U.S. institutional members and four international affiliates. AURA works closely with LSST Corporation (LSSTC), which initiated LSST development and remains responsible for privately raised funding. AURA and LSSTC established the LSST Project Office as an AURA-managed center for the construction period; this 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 LSSTC and NSF.

Reviews

- Technical Reviews: Reviews were conducted throughout the design and development phase, culminating in NSF's Final Design Review (FDR) in December 2013, with DOE involvement. 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 also scrutinized by the technical reviews. During construction, NSF and DOE are holding regular joint progress reviews.
  - NSF held a recommended Joint Interface & Management Review (with DOE), and a separate Cost Estimation Review, both in May 2012. DOE held a camera status review in June 2013.
  - Subsequent to FDR, the National Science Board (NSB) authorized NSF management to proceed with the construction award on May 7, 2014 (NSB-14-24), subject to additional cost and management scrutiny.
  - An NSF internal cost analysis from 2013 was followed up by a Cost Estimation Sufficiency Review conducted by an independent contractor, which reported in April 2014. Both reports found the LSST Project's Basis of Estimate documentation to be adequate at the time of review, with small improvements requested. NSF secured those additional items from the awardee prior to making the MREFC award in August 2014. Contingency estimates were finalized in April 2015 in accordance with latest NSF policy.
  - The first annual construction review is planned for February 2016.
- As a result of two DOE Critical Decision (CD) reviews, DOE issued CD-3a approval for long-lead procurements in July 2014, and CD-2 approval, including setting the not-to-exceed Total Project Cost for the DOE sub-project, on January 7, 2015. CD-3 review in early August was followed by formal approval for full DOE construction funding on August 27, 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 resolve all major cost issues, in accordance with the

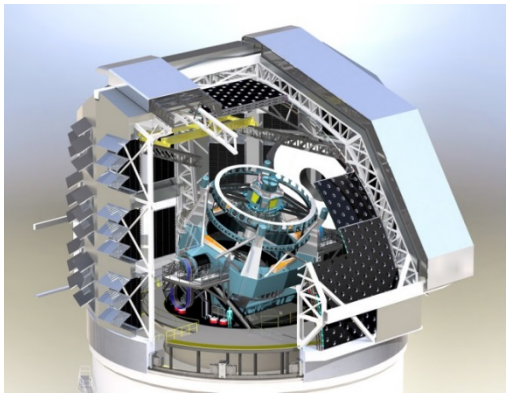
NSB resolution, as detailed below. Major work packages for the telescope mount assembly and for the summit facility were contracted early in FY 2015, quickly followed by contracts for the dome construction, secondary mirror polishing, the camera support systems, and the M1M3 support cell. The base facility and Chilean data center, and the coatings plant, were subject to bid request, review, and selection in FY 2015, and contracts are being negotiated in early FY 2016. Updates to the U.S. data center contract were also approved. The critical M1M3 mirror passed its acceptance tests early in CY 2015 and was carefully coated and crated for storage until needed in Chile. DOE funding supported continued detector development and initial procurement, an important milestone for the camera. Contracts have started for the major lens systems and for the detector support system. 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 a continuing activity as multiple promising approaches exist; 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

There was 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, assuming the project introduced some additional de-scoping options. The resulting project schedule and TPC 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.

Because of changes in NSF's requirements for the estimation of project contingency, the initial award contained only a limited obligation for that purpose. The project established the new contingency methodology throughout their project management control system and calculated a risk-based joint cost and schedule analysis, in close consultation with NSF's Large Facilities Office. The revised amount, at almost the same number as provided at FDR, equates to a better than 90 percent chance of coming in on schedule and within the sum of base plus contingency. This revision was presented to NSF for review. After provision of updated explanatory material, the award was amended in April 2015 to authorize the new level of contingency for the full project duration.



Cutaway of dome showing telescope within. *Credit: LSST.*

NSF recently revised its policy on the use and oversight of management fees. Negotiations between AURA and NSF on the fee are ongoing, but the final fee will come within the approved total project cost.

In addition to NSF's contribution, DOE's baseline for the camera has been fixed at $168.0 million. 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 completed design and development efforts and by investment of non-federal funds in construction, notably for the primary-tertiary mirror, completed in early CY 2015. 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 was completed and reviewed and subsequently approved by NSF in October 2010, under Executive Order 12114 for extraterritorial projects. Mitigation work continues, with the propagation of threatened plant species and their subsequent 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 leveled the planned location for LSST and confirmed the geological results from the original test borings. They found no problems that could compromise the overall stability and rigidity of the mount as currently designed. The only remaining site risks are local geological anomalies that can be mitigated through footer/foundation modifications and the use of contingency.

Environmental Health and Safety: The LSST project has a full-time head of safety with experience in AURA operations, which has 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 is assisted by a deputy project director who started on September 1 2015, 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, being drafted and agreed to amongst the planned operational partners, will be submitted jointly to NSF and DOE about two years before planned early operations. Proposal review will result in the baseline project execution plan and operating costs. The project team has focused on finding partners willing to contribute to 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. Negotiations have started for firm agreements and possible advance contributions. A LSST@Europe meeting in September 2013 included attendees from 20 countries and led to detailed discussions about those contributions and agreements; a second such meeting is scheduled for June 2016. 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 will form an international finance committee to oversee the use of contributed operating funds.

Future Operations Costs

Estimated full operations costs in FY 2013 U.S. dollars were $36.63 million per year at the time of FDR. Following the recommendation of the NRC 2010 Decadal Survey, AST has planned to provide approximately 50 percent of that amount, as well as early operations support ramping up to the full contribution. The DOE Office of High Energy Physics has committed to another 25 percent. The project has started a new analysis to update and verify the cost estimation as part of preparing their operations proposal. The total annual cost, and the amount required from the non-federal partners, will be determined during the review of that proposal, which may lead to updates in the notional operations numbers presented above for FY 2019 and beyond. In the joint MOU, NSF and DOE agreed together to funding operations, increasing agency support, and/or revising the operations plans, as appropriate.

THE NATIONAL ECOLOGICAL OBSERVATORY NETWORK $0

No MREFC funds are requested for the National Ecological Observatory Network (NEON) in the FY 2017 Request. The FY 2016 Request was the final year of construction funding for the six-year project that totals an estimated $433.72 million. Construction is expected to be complete at the end of FY 2017. NEON operations and maintenance will be funded through the Directorate for Biological Sciences.

Appropriated and Requested MREFC Funds for the National Ecological Observatory Network

(Dollars in Millions)

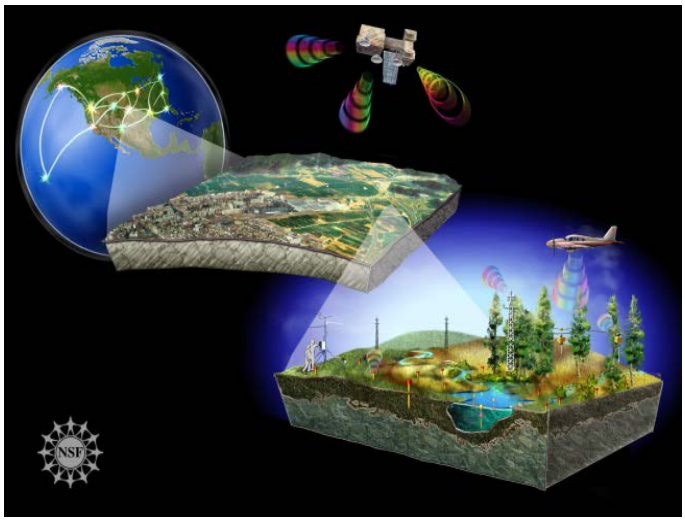
Prior Years	FY 2012 Actual	FY 2013 Actual	FY 2014 Actual	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Total Project Cost
$12.59	$60.30	$91.00	$93.20	$96.00	$80.64	-	$433.72

Totals may not add due to rounding.

NEON consists of geographically distributed field and lab infrastructure networked 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.



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.*

Total Obligations for NEON

(Dollars in Millions)

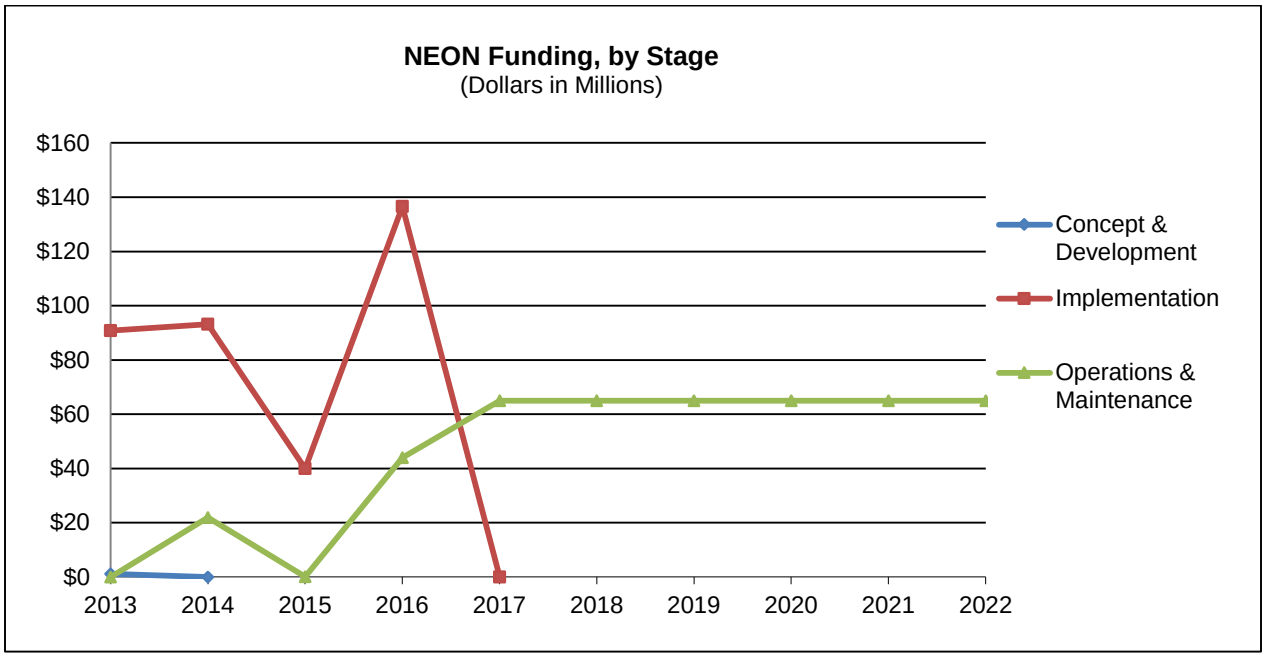
	Prior Years[1]	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
R&RA Obligations:									
Concept & Development	$91.73	-	-	-	-	-	-	-	-
Operations & Maintenance[2]	21.89	0.12	44.04	65.00	65.00	65.00	65.00	65.00	65.00
ARRA	9.96	-	-	-	-	-	-	-	-
Subtotal, R&RA Obligations	$123.58	$0.12	$44.04	$65.00	$65.00	$65.00	$65.00	$65.00	$65.00
MREFC Obligations:									
Implementation[3]	257.08	40.00	136.64		-	-	-	-	-
Subtotal, MREFC Obligation	$257.08	$40.00	$136.64	-	-	-	-	-	-
TOTAL Obligations	**$380.66**	**$40.12**	**$180.68**	**$65.00**	**$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.

[3] FY 2016 MREFC obligations include $56.0 million carried over from FY 2015.



NEON is the first research platform and the only national experimental facility specifically designed to collect consistent and standardized sensor and biological measurements across 82 sites nationwide, representing a reduction from 106 sites following descoping. Measurements will be collected 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.

The 2009 United States Global Change Research Program (USGCRP) assessments[4] indicate that U.S. ecosystems will experience abrupt and unpredictable changes from a suite of human-driven processes in the near future. 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 standalone system – federal or private – can provide the scientifically validated suite of data measurements that NEON will provide.

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 2014 U.S. National Plan for Civil Earth Observations[5] and the international Group on Earth Observations 2005 Framework Document.[6] 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. Domestic and international MOUs focus on meeting NEON's Strategic Plan and the U.S. National Plan for Civil Earth Observations[2] both of which call for strengthening international collaboration in earth observations, and to improve data access, management, and interoperability. 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,*[7] NEON construction models are also having an impact on establishment of new standards for construction in environmentally sensitive areas.

Management and Oversight

- NSF Structure: The NEON program is managed by the Division of Biological Infrastructure (DBI) within the Directorate for Biological Sciences (BIO). Managing the NEON program in DBI helps foster its associations with other BIO facilities and infrastructure investments and its connections to

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

[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] Group on Earth Observations, Global Earth Observation System of Systems (GEOSS): 10-Year Implementation Plan Reference Document, 2005, www.earthobservations.org/documents/10-Year%20Plan%20Reference%20Document.pdf

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

broader biological and interdisciplinary science activities. Within BIO/DBI, a senior Science Advisor (working with the Deputy Division Director) provides overall programmatic oversight for BIO's mid and large scale facilities, while the day-to-day program management is done by a dedicated cognizant program officer with assistance from a program manager experienced with other MREFC projects. Two additional program officers and a project manager assist with planning, development, and oversight of NEON construction, operations and maintenance, and science. An NSF Integrated Project Team (IPT) chaired by the NEON program officer, with representatives from the Large Facility Office (LFO), the Division of Acquisition and Cooperative Support (DACS), and program representatives from other NSF large facilities, provides coordinated agency oversight to the project. The Office of the General Counsel provides ongoing technical advice on the National Environmental Policy Act (NEPA) compliance and NSF environmental policy and also has representation on the IPT. Funding for NEON remains in Emerging Frontiers (EF), a BIO-wide interdisciplinary virtual organization, until funding for a new NEON managing organization (see below), and associated final costs, are determined. The findings of an external cost review are expected mid-March 2016; a decision on a new managing organization is expected by the end of March 2016.

- External Structure: NSF is currently seeking a new managing organization to oversee the construction and initial operations of NEON. A transition in management structure will occur in early 2016. Currently the NEON project is funded through cooperative agreements with NEON, Inc., a non-profit, membership-governed corporation established to manage the design, construction, and operation of NEON for the scientific community. Scientific community oversight will also be revisited as part of the management transition. NEON, Inc. was notified in December 2015 of NSF's intent to transfer responsibility for construction and initial operations to a new management entity.

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. NSF signed a "Finding of No Significant Impact" 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 Baseline Review was held in August 2014 to evaluate re-planned schedule and cost.
  - NEON, Inc. was notified in May 2015 of non-compliance with terms and conditions of the cooperative support agreement, NSF's concerns over increasing schedule slippage, required delivery of a new estimate to complete the project, and NSF's intent to conduct strategic assistive site visits.
  - In June 2015 the NEON, Inc. estimate to complete included a projected cost overrun of $80 million above the approved budget. A baseline Re-Scope Review was held in July 2015 to assess

reductions in scope to bring the costs within the approved budget in accordance with NSF's "No Cost Overrun" policy.
  - NEON, Inc. was notified in July 2015 to reduce the NEON scope and deliver revised project documents, construction schedule, and cost proposal to reflect the scope reduction.
  - A Revised Cost and Schedule Proposal was submitted December 2015 which indicated the potential for an additional $19.0 million cost overrun and further schedule slip leading NSF to make its decision to transfer management responsibility.
  - An independent cost estimate is being obtained by NSF to support its internal cost analysis and award to the new managing organization.
  - A Construction Review will be conducted annually.
- 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 Operations and Maintenance (O&M) in February 2013. In September 2015 the Board established an ad hoc Task Force on NEON Performance and Plans to review the Board's and NSF's processes associated with NEON project management and oversight.
- 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.
  - Beginning in May 2015, NSF has conducted a series of site visits to work with NEON, Inc., on improving business systems including reporting capabilities, cost sufficiency and estimation, and supply chain issues including procurement and contracting.
  - In December 2015 NSF notified NEON, Inc. of its intent to transfer responsibility for construction and initial operations to a new management organization. The transfer is planned to occur in early 2016 following the NSF cost analysis and negotiations with the new organization.
  - With the transition to a new management organization, an extension of the initial operations award is anticipated to allow the project to stabilize. A pre-award cost review prior to full observatory operations funding is expected in FY 2018.
  - Operations and management reviews will be conducted annually starting in FY 2016; delays in construction have impacted rollout of operations by one year.

Project Status

In September 2013, the construction of technical support facilities was completed and used to support other construction activities before transitioning to operations in FY 2015. NEON's airborne observation platform (AOP) 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 with NASA missions conducted in FY 2013 along with research studies on management of major forest fires. The third airborne observatory was delivered ahead of schedule in FY 2014. The three airborne observatories are being flight tested and verified to transition to operations in FY 2016 with completion occurring in FY 2017.

Construction of distributed infrastructure and deployment of sensor assemblies is underway. Procurement and production difficulties have led to delays in some higher-level sensor assemblies. Thirty percent of the Observatory research capabilities were available in July 2015, and 60 percent are expected by the end of FY 2016. While 100 percent capability is planned by the end of FY 2017, delays in production, deployment, and permitting may postpone some deliverables by a year or more. In FY 2016, construction activities are planned to be completed for 25 terrestrial sites. Observatory construction for the remaining 23 terrestrial locations is currently planned to be complete in FY 2017, but may require a few additional months in early

FY 2018. Construction of 16 aquatic sites will be complete in FY 2016 with the remaining 18 planned to be complete in FY 2017.

In FY 2017, MREFC funds will support completion of the NEON cyberinfrastructure hardware and software deployments for various sites as well as domain facilities acceptance. This includes completion of the management system for assets, configuration, inventory, and data algorithms and related data release via NEON's web portal.

Scope Management and De-scoping: Delays in permitting of selected sites, cyberinfrastructure development, and procurements signaled the potential for significant construction cost overruns. Estimates received in June 2015 prompted NSF to assemble leaders from the science community to assess possible scoping strategies for maintaining the project with the approved budget in accordance with NSF's No Cost Overrun policy. A major objective of the meeting was to ensure the delivered Observatory would still enable the transformative regional to continental science as framed in the original NEON Science Strategy. This decision to de-scope was confirmed by the NSF/BIO Advisory Committee. Descoping decisions were finalized and implemented in late July 2015. Revised project documentation including a new cost proposal and schedule-for-completion was delivered in early December 2015. An independent cost review is underway, to be completed in March 2016.

In FY 2017, $65.0 million is requested from the Research and Related Activities (R&RA) account for operations and maintenance (O&M). This represents the final increment from the original three-year O&M award as well as a partial increment for a proposed one-year extension. This additional year in prototype O&M will allow time for a more complete understanding of the services and costs proposed and to prepare for a re-competition for a longer term award. This includes management and technical support, seasonal biological sampling, analytical and archival costs, and domain facilities costs. Funds will also support the calibration and validation laboratories and headquarters functions, such as maintenance of the data center, Observatory monitoring, quality assurance and control, and O&M of the Airborne Observation Platform. In FY 2017, NSF will explore options for operation and maintenance of the full NEON Observatory after construction.

Cost and Schedule

The original projected length of the construction project was six fiscal years, with six-months of schedule contingency included. NEON is now roughly 60 percent complete based on expenditures, with Observatory capability at 30 percent complete. Current project performance, based on an updated cost and schedule for completion developed by NEON management, is running well behind the original plan. Focused scope management and oversight is now required to remain within budget.

Risks

*Technica*l: Technological maturity of commercial sensors, incorporation of sensors into sensor assemblies, production of sensor assemblies, and integration into NEON towers are affecting field deployments and Observatory capabilities. In FY 2015, two planned sensor systems were determined not feasible for deployment and no alternatives are currently available. These sensor systems will be deferred until operations when the technologies are more mature. 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 activities in the areas of sensors, cyberinfrastructure, and remote sensing technology. These development activities are progressing and risks to schedule are being monitored.

Deployment: Environmental assessment and permitting continues to impact schedule. Risk mitigation strategies include the direct contracting of the environmental assessment by NSF, the hiring of national

firms by NEON, Inc. for engineering and permitting, and the identification of alternative sites if primary sites are determined to have significant risk. Some sites were identified as "unable to be permitted" and were part of the scope management actions taken in July 2015. The selection of alternative sites for other high-risk sites is nearing completion and environmental compliance activities are underway.

Management: NSF has determined that it has low confidence in NEON, Inc's ability to effectively manage the project going forward based on the December 2015 deliverables. Evaluation of alternative management organizations is underway.

Future Operations Costs

NEON is the first research observatory that will maintain and operate in-situ instrumentation and conduct biological sampling in twenty domains (82 locations) including three airborne observatories, a central operating facility and a cyberinfrastructure center. Support will be provided to monitor the sensors, and receive, process, and archive data from all measurement systems. NEON operations include significant labor costs due to the manual processes still required for biological sampling and data collection in some fields. 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 will ramp up as sites are commissioned. As part of the scope management plan, sites and infrastructure transition-to-operations will accelerate whenever possible.

A three-year initial award for O&M began September 2014 to allow NEON to explore opportunities for schedule and cost efficiencies and provide a basis for funding the full Observatory operations during out years. A delay in construction has extended that award from FY 2016 through mid-FY 2017, and an extension of the initial operating period is likely under new management to allow the project to stabilize. For FY 2018 – FY 2022, the planned O&M budgets are capped at $65.0 million. O&M will be revised as needed to accommodate that cap.

REGIONAL CLASS RESEARCH VESSELS $106,000,000

The FY 2017 Budget Request for the Regional Class Research Vessel (RCRV) project is $106.0 million. This represents the first year in a three-year funding profile, with an estimated total project cost of $255.50 million.

Appropriated and Requested MREFC Funds for the Regional Class Research Vessel Project

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2018 Estimate	FY 2019 Estimate	Total Project Cost
-	-	$106.00	$105.00	$44.50	$255.50

Totals may not add due to rounding.

The RCRV project will fund construction of two ships to meet anticipated ocean science requirements for the U.S East Coast, West Coast, and Gulf of Mexico. The 2015 National Academies of Science report, *Sea Change: 2015-2025 Decadal Survey of Ocean Sciences*[8], described eight high-priority science questions, all of which will be supported by RCRV in U.S. coastal waters:

1. What are the rates, mechanisms, impacts, and geographic variability of sea level change?
2. How are the coastal and estuarine ocean and their ecosystems influenced by the global hydrologic cycle, land use, and upwelling from the deep ocean?
3. How have ocean biogeochemical and physical processes contributed to today's climate and its variability, and how will this system change over the next century?
4. What is the role of biodiversity in the resilience of marine ecosystems and how will it be affected by natural and anthropogenic changes?
5. How different will marine food webs be at mid-century? In the next 100 years?
6. What are the processes that control the formation and evolution of ocean basins?
7. How can risk be better characterized and the ability to forecast geohazards like mega-earthquakes, tsunamis, undersea landslides, and volcanic eruptions be improved?
8. What is the geophysical, chemical, and biological character of the subseafloor environment and how does it affect global elemental cycles and understanding of the origin and evolution of life?

Baseline History

The RCRV project is a major component in the plan for modernizing the U.S. Academic Research Fleet (ARF).[9] In 2001, a report from the Federal Oceanographic Facilities Committee documented the need for up to three Regional Class vessels. In 2004, NSF and the Naval Sea Systems Command (NAVSEA) entered into an interagency agreement that resulted in two candidate designs for Regional Class ships. In 2007, the Federal Oceanographic Fleet Status Report identified the need for up to three NSF-built Regional Class vessels to meet future science demand. In 2009, another National Academies of Science report, *Science at Sea*, described the desirable characteristics of a modern Regional Class vessel. These characteristics and other science community factors were considered by the review panel when the preferred NAVSEA design was later down-selected. In 2012, NSF issued a solicitation for the refreshed design and potential construction of RCRVs under the MREFC process, and Oregon State University (OSU) was selected as the awardee. Input from external review panels, the University National Oceanographic Laboratory System

[8] The National Academies of Science. Sea Change: 2015-2025 Decadal Survey of Ocean Sciences, 2015. www.nap.edu/read/21655/chapter/1

[9] National Ocean Council. Federal Oceanographic Fleet Status Report, 2013.

(UNOLS), and the *Sea Change* report informed the final decision to pursue construction of two RCRVs. The National Science Board approved inclusion of funds to construct two RCRVs in future budget requests at the NSF Director's discretion. Prior to an MREFC award for construction, the RCRV project will complete a Final Design Review, which is scheduled for Fall 2016.

Total Obligations for RCRV

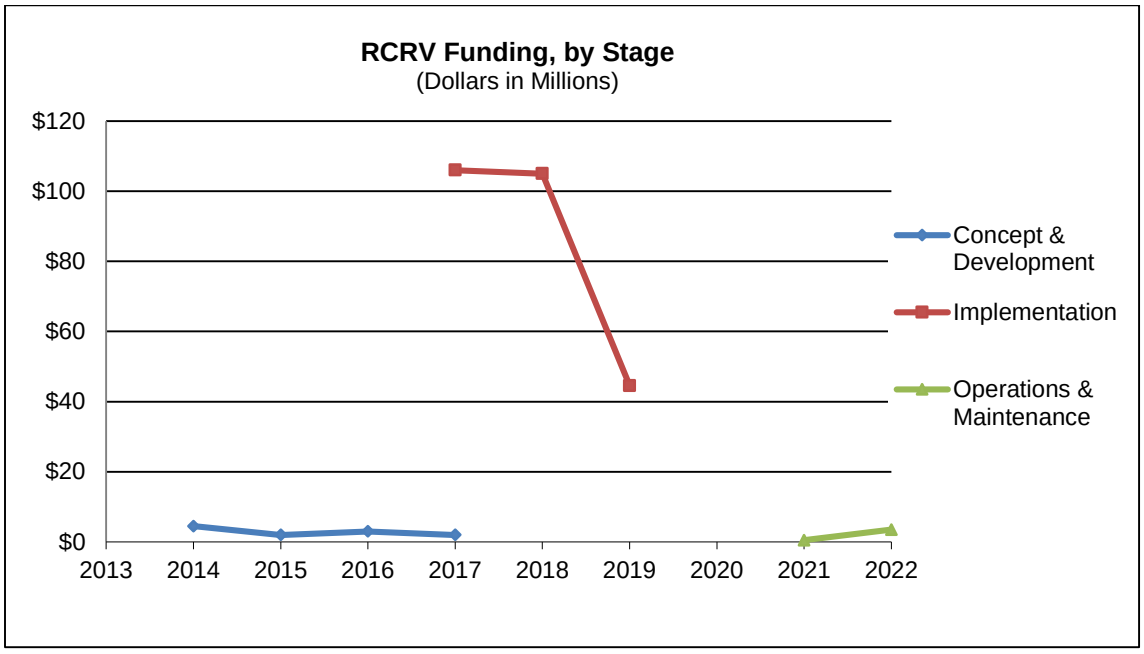
(Dollars in Millions)

	Prior Years[1]	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
R&RA Obligations:									
Concept & Development	$4.49	$2.13	$3.00	$2.00	-	-	-	-	-
Operations & Maintenance[2]	-	-	-	-	-	-	-	2.00	3.50
ARRA	-	-	-	-	-	-	-	-	-
Subtotal, R&RA Obligations	$4.49	$2.13	$3.00	$2.00	-	-	-	$2.00	$3.50
MREFC Obligations:									
Implementation	-	-	-	106.00	105.00	44.50	-	-	-
Subtotal, MREFC Obligations	-	-	-	$106.00	$105.00	$44.50	-	-	-
TOTAL Obligations	**$4.49**	**$2.13**	**$3.00**	**$108.00**	**$105.00**	**$44.50**	**-**	**$2.00**	**$3.50**

Totals may not add due to rounding.

[1] Concept & Development funding and Implementation funding are cumulative of all prior years.

[2] Operations and Maintenance (O&M) for the RCRV project will be included in funding for the Academic Research Fleet. Because the Academic Fleet is operated as a shared multi-agency resource where agencies pay for time use on vessels, the annual operating budget may vary significantly from year to year. Thus, estimates for O&M are provided as a rough guide of likely costs. RCRV is expected to begin O&M funding in late FY 2021.



Management and Oversight

- NSF Structure: The RCRV project is overseen by the Division of Ocean Sciences (OCE) as part of the Ship Acquisition and Upgrade Program. OCE provides overall interdisciplinary science community guidance and oversight, while the location of the RCRV project in the Integrative Programs Section promotes science facilities support expertise and coordination. Within NSF, RCRV project oversight is managed by a dedicated program officer with support from a secondary program officer who has experience with other OCE facilities. Cross-foundation coordination is provided by an integrated project team (IPT). The IPT includes staff from the Office of Budget, Finance, and Award Management (BFA), the Large Facility Office (BFA/LFO), the Division of Acquisition and Cooperative Support (BFA/DACS), the Division of Institution and Award Support (BFA/DIAS), the Office of the Director (OD), the Office of the General Council (OGC), the Office of the Assistant Director for Geosciences (OAD/GEO), and the Office of Legislative and Public Affairs (OLPA).

- External Structure: The RCRV project is funded through a cooperative agreement with Oregon State University (OSU) to manage the design refresh (Conceptual, Preliminary, and Final Designs), construction, testing and trials, and eventual operation of the first RCRV for the scientific community. The principal investigator for the award is the project scientist (PS), who reports directly to OSU leadership. The PS interacts directly with NSF and manages the RCRV administrative staff. The project manager (PM) is a co-PI on the award and reports directly to the PS. The PM manages the core RCRV team including the risk manager, earned value management and schedule specialist, contracting officer, and OSU shipyard representative (SR). The SR in turn manages the naval architect and engineering contract and oversees the OSU shipyard staff, and marine science technical advisors. The RCRV Science Oversight Committee (SOC) with regional representation, multidisciplinary expertise, and science representatives conducting research in mission areas supported by stakeholder federal agencies (e.g., NSF, Office of Naval Research (ONR), and the National Oceanic and Atmospheric Administration (NOAA)) will be active through all project phases. This committee provides guidance to the OSU RCRV project team through the PS and/or the NSF program officer.

Reviews

- Proposal Review: In 2012, NSF issued Solicitation 12-558, Construction of Regional Class Research Vessels, to select a lead institution for construction of up to three RCRVs, with the option to operate one of the ships. An NSF external review panel was convened to evaluate three proposals, and Oregon State University (OSU) was selected.
- Interim Design Review (IDR): Although an Interim Design Review (IDR) was not required by NSF, OSU hosted an IDR on July 23-25, 2013, in Corvallis, OR. NSF program staff assessed the OSU project team performance and concluded the IDR followed closely the NSF requirements, and used the R/V *Sikuliaq* example, as appropriate, to craft the RCRV Project Execution Plan (PEP). Both the design and the PEP were well-developed at this pre-Conceptual Design Review phase; particularly the organizational structure, work breakdown structure (WBS), risk management, and configuration and contingency management.
- Conceptual Design Review (CDR): CDR was conducted December 3-5, 2013, at NSF Headquarters in Arlington, VA. The NSF program staff concurred with the panel's conclusion that the Project Execution Plan and Technical Design Package met, and in some cases exceeded, the requirements of the Conceptual Design Phase.
- Preliminary Design Review (PDR): PDR was conducted August 5-7, 2014, at NSF Headquarters. The panel found that the Project Execution Plan and the technical design package were both well-developed for the PDR phase and recommended that the project proceed to the Final Design Phase.
- Post-PDR Reconciliation: Following PDR, in response to the panel recommendations and NSF program staff direction, OSU incorporated modifications to the design and revised their estimated

program costs and schedule accordingly. The NSB was presented with the post-PDR Project baseline as the basis for their authorization to request funding for two RCRVs in future budget requests.

- Acquisition Strategy Review: A review of all aspects of the shipyard selection process is scheduled for February, 2016. A subset of the PDR panel will perform the review at NSF.
- Interim Design Review (IDR): A second IDR is scheduled in May 2016. Although not required, the value of the previous IDR for improvement to the technical package and the Project Execution Plan was sufficient that another IDR to prepare for FDR is warranted. The review will be hosted by the RCRV Project Team in Corvallis, OR, and will be attended by NSF program staff as well as the RCRV Science Oversight Committee.
- Final Design Review (FDR): FDR is anticipated in Fall 2016 to ensure that anticipated project costs remain realistic and that no unforeseen events have arisen prior to the start of construction during FY 2017. Like CDR and PDR, FDR will be conducted in compliance with NSF's Large Facilities Manual.

Project Status

As stated above, OSU was selected as the lead institution. A cooperative agreement (CA) was awarded to encompass the entire project, including tests and trials. The project was divided into four distinct phases; each to be funded through separate cooperative support agreements (CSA), with award of each phase contingent upon successful completion of the prior phase. These phases are:

Phase I - Project Refresh (Years one to three)
Phase II - Shipyard Selection (Year four)
Phase III - Construction (Years five to nine)
Phase IV - Transition to Operations (Years eight to ten)

The project is in Phase II during CY 2016, during which bids for construction of two RCRVs will be solicited from U.S. shipyards. Through FY 2016, funding is expected to be $9.62 million.

Cost and Schedule

The projected length of the project is ten fiscal years, including a six-month schedule contingency. Funding for the construction of two ships over three fiscal years would support a shipyard contract structure that stipulates an initial ship, plus the option for a second ship. This approach preserves funding flexibility while maximizing shipyard efficiency by potentially having both ships under construction concurrently, but at different stages.

Risks

Bid Risk: OSU provided a bottom-up cost estimate for two vessel construction using various escalation rates. No additional "buffers" or "reserve" are added to the bottom-up estimates. Hull construction uncertainty is addressed by the risk register, and associated contingency per NSF policy on contingency estimating and use. There is a risk that shipyards may respond to the RFP with bids that exceed the estimation. The base estimates from OSU were validated by expert panel review as well as through comparison with an independent cost estimate commissioned by NSF.

Technical: It may be the case that the desired low ship self-noise levels are not initially achieved. Contingency funds are included if a secondary noise mitigation strategy is required to meet the ship specifications. It may also be the case that sonar sensors, science load handling systems and other vessel sub-systems do not perform as required. Contingency funds are included to ensure performance capabilities are met, given that many warranties are not likely to be performance based or be otherwise limited contractually with the shipyard. The ship may be unable to meet the low exhaust gas emissions requirements for the budgeted amount, in which case contingency funds are included to meet emergent regulatory requirements on stack emissions. It is possible a selected shipyard could fail during the

construction phase, in which case contingency is included to facilitate transfer to another shipyard. A science prioritized, time-phased de-scoping plan is in place (per NSF policy) to minimize the impact to science capabilities in the case contingency is insufficient to cover realized risks.

Future Operations Costs

Annual ship operations costs are well understood after several decades of experience with vessels of all types in the U.S Academic Research Fleet. OSU understands how to estimate future costs given their experience operating vessels similar to RCRV, such as R/V *Wecoma* and R/V *Oceanus*. OSU included an estimate for the first year of operations using reasonable assumptions for escalations through 2020. They also assumed a robust but reasonable operating schedule of 200 days per year. OSU estimates RCRV will cost $5.0 million to operate in its first year, resulting in a rate of $25,000 per day. This is comparable to the operation of current similar vessels after applying the appropriate cost escalation factors. NSF supports approximately 70 percent of the utilization of the U.S. Academic Research Fleet, which suggests RCRV is likely to cost NSF $3.50 million in the first year. NSF intends to issue a solicitation for an operator of the second RCRV after construction funds are appropriated and will make an award after a competition is held.

Artist's rendition of the RCRV as constructed. *Credit: The Glosten Associates Inc.*