MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION

$182,800,000
-$58,700,000 / -24.3%

Major Research Equipment and Facilities Construction Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Major Research Equipment and Facilities Construction	$241.50	$193.12	$182.80	-$58.70	-24.3%

The Major Research Equipment and Facilities Construction (MREFC) account supports the acquisition, construction, and commissioning of major research infrastructure 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 2016 Actual	FY 2017 Estimate	FY 2018 Request	FY 2019 Estimate	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate
DKIST	$20.00	$20.00	$20.00	$16.13	-	-	-	-
LSST[1]	92.97	67.12	57.80	48.82	46.34	40.75	5.36	-
NEON[2]	128.51	-	-	-	-	-	-	-
NEON transfers[3]	*[20.00]*	*[15.58]*	-	-		-	-	-
RCRV[4]	-	106.00	105.00	44.50	-	-	-	-
Enhanced Oversight	0.02	-	-	1.00	1.00	1.00	1.00	1.00
Total	**$241.50**	**$193.12**	**$182.80**	**$110.45**	**$47.34**	**$41.75**	**$6.36**	**$1.00**

[1] Of the $99.67 million appropriated for LSST in FY 2016, $6.70 million was carried over to FY 2017 and is excluded in the amounts above. This is being held as part of NSF's enhanced oversight of budget contingency.

[2] Of the $80.64 million appropriated for NEON in FY 2016, $8.40 million was carried over to FY 2017 and is excluded in the amounts above. This is being held as part of NSF's enhanced oversight of budget contingency as well as NSF-held management reserve.

[3] In June 2016, the National Science Board (NSB) approved an increase in NEON's Total Project Cost from $433.72 million to $469.30 million. The $35.58 million increase is provided through transfers from the R&RA account to the MREFC account of $20.0 million from FY 2016 funds (completed) and up to $15.58 million from FY 2017 funds (expected). The $20.0 million transferred in FY 2016 was carried over to FY 2017.

[4] This table does not reflect final action on FY 2017 appropriations, which were enacted too late to be incorporated in this document. P.L. 115-31 provided funding for an additional RCRV. This will impact funding requirements for FY 2017, FY 2019, and FY 2020, and the total project cost. There is no impact on the FY 2018 Budget Request.

Modern and effective research infrastructure is critical to maintaining U.S. international 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 2018, NSF will request $182.80 million to continue construction on three of the four on-going projects; the Daniel K. Inouye Solar Telescope (DKIST), the Large Synoptic Survey Telescope (LSST),

and the Regional Class Research Vessels (RCRV). NEON will be completed in spring 2018 with funds already appropriated per the table above. For more information on each project, 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 infrastructure such that approved budgets are sufficient to accomplish the scientific objectives. The current policy as published in NSF's Large Facilities Manual (LFM) requires that (1) the total project cost estimate when exiting the preliminary design phase includes adequate contingency to cover foreseeable risks, (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, and (3) if the project is approved to continue and further scope reductions become too detrimental to science, then the first 10 percent of any cost increase must be covered by the sponsoring directorate through R&RA funding. This final step was required for NEON, as noted in the table above and described in the individual narrative for the project.

All projects funded through the MREFC account undergo periodic cost, schedule, and risk reviews as required by the LFM and the terms and conditions of the cooperative agreements. NSF policies and reporting requirements are designed to ensure routine and reliable tracking of progress (including the use of Earned Value Management), project spending, and use of contingency and that program and recipients each have sufficient oversight and management authority (respectively) to meet project objectives.

Enhanced NSF Oversight

NSF has greatly strengthened its oversight of major facility projects in recent years, with a number of those enhancements now codified in the American Innovation and Competitiveness Act (AICA) of 2017. One significant enhancement is holding a portion of budget contingency (up to 100 percent) and only allocating to the program for obligation to the project based on demonstrated need. This oversight mechanism will generally result in some MREFC carryover each year; however, future obligation is anticipated to manage project risks. Enhanced oversight of the construction stage now also includes mandatory incurred cost audits and independent cost estimates, as well as other audits and reviews based on an annual major facility portfolio risk assessment. These efforts are conducted by NSF and are generally not attributable to a specific project at the time of budget formulation, nor are they part of the total project cost developed and managed by the recipient. To properly support and transparently account for these efforts, actual costs and future estimates for "Enhanced Oversight" are shown separately from each project in the MREFC account table. Initial funding (FY 2017 and FY 2018) for enhanced oversight activities is $500,000 to $1.0 million annually. These activities are supported with funds recovered from projects completed in previous years.

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,~~*$182,800,000*, to remain available until expended.

(Note – A full-year 2017 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Further Continuing Appropriations Act, 2017 (P.L. 114-254). The amounts included for 2017 reflect the annualized level provided by the continuing resolution.)

Major Research Equipment and Facilities Construction
FY 2018 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 2016 Appropriation	$200.31	$58.06	-$37.21	$2.34	18.00	$241.50
FY 2017 Annualized CR	199.93	37.21			-	237.14
FY 2018 Request	182.80					182.80
$ Change from FY 2017 Annualized CR						-$54.34
% Change from FY 2017 Annualized CR						-22.9%

Explanation of Carryover

Within the **Major Research Equipment and Facilities Construction** no-year account, $37.21 million was carried over into FY 2017.

National Ecological Observatory Network (NEON)
- Amount: $28.41 million
- Reason: FY 2016 obligations were limited due to construction management transition. For additional information, please see the NEON section of the MREFC Chapter.
- Obligated: FY 2017 Quarter 1

Large Synoptic Survey Telescope (LSST)
- Amount: $6.70 million
- Reason: These funds reflect updated NSF policy for the oversight of contingency, as discussed in the Enhanced Oversight section above.
- Anticipated Obligation: TBD - Funds held in reserve until needed.

The remaining $2.10 million is from completed projects. These projects are Ocean Observatories Initiative, Atacama Large Millimeter Array, South Pole Station Modernization, Advanced Laser Interferometer Gravitational Wave Observatory, and Large Hadron Collider. A portion of these carryover funds will be used for the enhanced oversight of MREFC projects.

The MREFC Account in FY 2018

The following narratives present detailed information on NSF's ongoing projects in FY 2018, with the sponsoring organization noted in parenthesis.

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

The FY 2018 Budget Request for NSF's Daniel K. Inouye Solar Telescope (DKIST) is $20.0 million. This represents the 10th year in an 11-year funding profile, with an estimated total project cost of $344.13 million. Completion of construction atop Haleakala on Maui, Hawaii is planned for no later than June 2020.

When completed, 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 2014 Actual	FY 2015 Actual	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	FY 2019 Estimate	Total Project Cost
MREFC Approp.	$60.00	$36.88	$25.12	$20.00	$20.00	$20.00	$16.13	$198.13
ARRA MREFC Appropriation	146.00	-	-	-	-	-	-	146.00
Total, DKIST	**$206.00**	**$36.88**	**$25.12**	**$20.00**	**$20.00**	**$20.00**	**$16.13**	**$344.13**

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, which determined that 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 appropriated to initiate construction. Funding was provided through a combination of the MREFC account ($7.0 million) and the American Recovery and Reinvestment Act (ARRA) account ($146.0 million). 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.

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

The environmental compliance requirements were completed on November 20, 2009, and the NSF Director signed the Record of Decision authorizing construction 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. The Hawaii BLNR approved 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. The U.S. Fish and Wildlife Service completed a formal consultation regarding the endangered Hawaiian petrel in 2011. A contested case challenge to the 2010 CDUP issuance delayed site construction until the BLNR ruled in favor of the DKIST project and issued a new CDUP 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. An external panel of experts reviewed the revised baseline and increased the total project cost by approximately $46.20 million. The NSB also subsequently considered and approved a revised total project cost of $344.13 million at their August 2013 meeting.

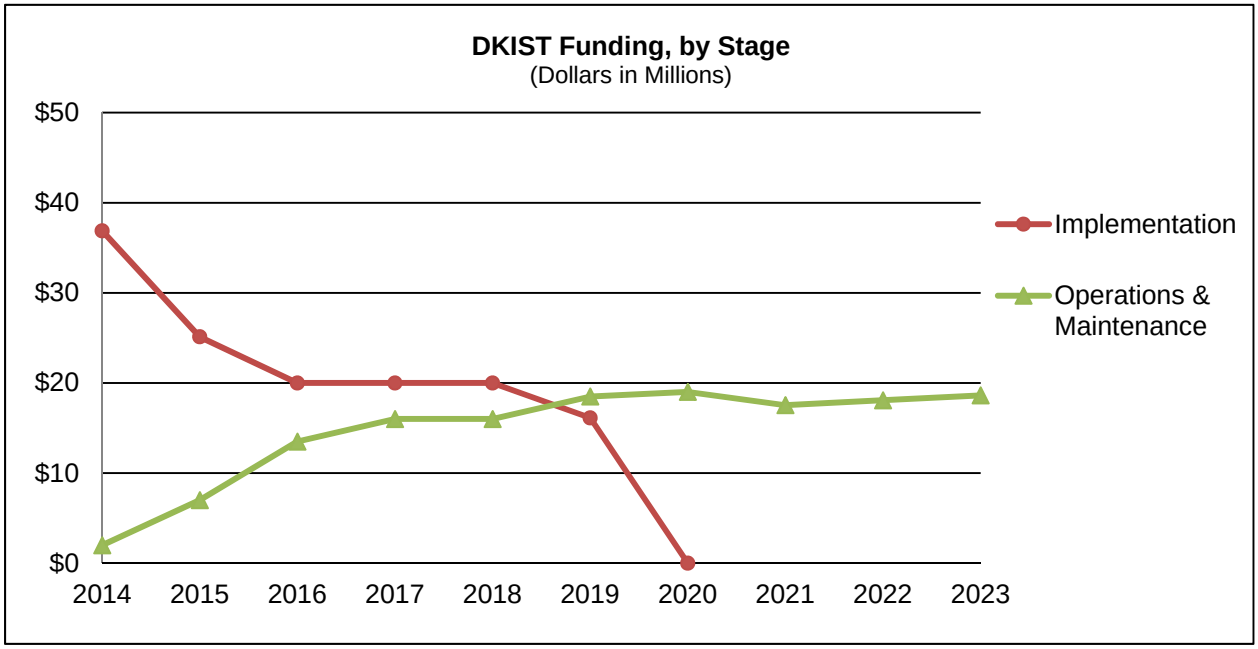
Total Funding Requirements for DKIST

(Dollars in Millions)

	Prior Years[1]	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	ESTIMATES FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
R&RA:									
Concept & Development	$20.41	-	-	-	-	-	-	-	-
Operations & Maintenance[2]	7.00	13.50	16.00	16.00	18.50	19.01	17.54	18.08	18.62
ARRA	3.10	-	-	-	-	-	-	-	-
Subtotal, R&RA	$30.51	$13.50	$16.00	$16.00	$18.50	$19.01	$17.54	$18.08	$18.62
MREFC:									
Implementation	122.00	20.00	20.00	20.00	16.13	-	-	-	-
ARRA	146.00	-	-	-	-	-	-	-	-
Subtotal, MREFC	$268.00	$20.00	$20.00	$20.00	$16.13	-	-	-	-
TOTAL REQUIREMENTS	**$298.51**	**$33.50**	**$36.00**	**$36.00**	**$34.63**	**$19.01**	**$17.54**	**$18.08**	**$18.62**

[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 million 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 partners include the Air Force Office of Scientific Research and international groups in Germany, the United Kingdom, and Italy. Some activities to be performed through partnerships are:

- 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 eliminates 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), the Office of General Counsel, and the Office of Legislative and Public Affairs. Within BFA the Large Facilities Office (BFA/LFO) provides advice 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 CSA for DKIST construction runs through the end of FY 2019. The NSO CA and O&M CSA were 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 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

- 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.
- Business Systems Review (BSR): NSF conducted a BSR covering AURA, NSO, and the DKIST project December 2015 – March 2016. Findings and recommendations from NSF's final report were conveyed to AURA on April 1, 2016, and AURA continues to resolve issues and implement recommendations from the report.
- Contingency Assessment: BFA/LFO and MPS/AST conducted a detailed assessment of the DKIST budget and schedule contingency, February 2016 – July 2016. The assessment found that management of contingency is in compliance with current NSF guidelines and requirements. The remaining project budget and schedule contingency appear to be adequate based on accepted industry standards at an 80 percent confidence level for an on-budget and on-time completion. Findings and recommendations from the final NSF report were conveyed to AURA on August 5, 2016. AURA continues to implement recommendations from the report, while NSF tracks its progress.
- Earned Value Management (EVM) System Review: BFA/LFO and MPS/AST conducted a review of the DKIST project's EVM system, September 20-22, 2016. The external reviewers verified the project's EVM system and conducted interviews with project management and individual cost account managers (CAMs) to validate the input estimates/data into the system. The evaluation team found that the EVMS has been effectively implemented and is being used to provide reliable project management information. The NSF formally accepted the project's EVMS in a notification dated Feb. 22, 2017.
- Software Quality Assurance (SQA) Assessment: BFA/LFO has engaged a contractor to perform an assessment of the DKIST Project's processes and procedures for producing the software systems to be delivered at DKIST first light. The SQA assessment will consist of a document desk review followed by an in-person meeting in June 2017.
- Independent Risk Assessment (IRA): BFA/LFO has engaged a contractor to perform an independent assessment of the project's remaining risks as DKIST enters the critical integration, testing and commissioning (IT&C) stage of construction. The IRA will consist of a document desk review followed by an in-person meeting in September 2017.
- Programmatic Review: A comprehensive programmatic review of the DKIST MREFC construction project will be conducted in Q4 of FY 2017. This external programmatic review will focus on the IT&C phase of construction.

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:

- The project continues to work on interior fit and finish items for the enclosure (dome) and the support and operations (S&O) building.
- Work continues on the critical facility thermal systems (FTS) despite some staffing challenges.
- The Coudé rotator platform assembly inside the enclosure is completed. The Coudé rotator platform is undergoing site acceptance testing expected to be completed in Q3 of FY 2017.

- Assembly of the telescope mount assembly (TMA) continues through FY 2017 into Q2 of FY 2018 (see picture).
- Fabrication of the DKIST first-light instruments continues through FY 2017.

In FY 2018 installation of the TMA will be completed, and commissioning and acceptance testing of the TMA underway. The installation of the telescope structure and mechanical controls will have begun. By the end of FY 2018 the installation of the M1 main mirror will be underway and the alignment of the mirror with the laser metrology system begun. The first of the five first-light instruments, the visible broadband imager (VBI), will be delivered to the site, assembled and will begin initial checkout.

Installation of the saddle sections of the DKIST telescope mount assembly (TMA), March 2017. *Credit: P. Jeffers, DKIST.*

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). A Monte Carlo analysis of the risk-adjusted project end date at the time of the project re-baseline indicated June 10, 2020 at an 80 percent Confidence Level (CL) for successful completion. The project is currently on track for a late 2019 end date.

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 an MOU between AURA and KIS, and therefore the fabrication risks for this instrument remain with the German institute. The VTF recently achieved a technical milestone regarding the precision of the optics. KIS is currently on track to deliver a de-scoped (single etalon) version of the instrument by DKIST first light. The DKIST project and the managing organization, AURA, continue to actively manage the situation. It should be noted that the cooperative support agreement between the NSF and AURA identifies four facility-class instruments (not including the VTF) to be delivered by the DKIST Project at the end of the MREFC construction phase. The Project is currently on track to deliver those four instruments.

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. The two outstanding legal appeals with the potential to impact project construction were resolved in favor of the DKIST project. On October 6, 2016 the Hawaiian Supreme Court ruled against the appellant in the two cases and upheld both the DKIST project's conservation district use permit (CDUP) and the University of Hawaii's Haleakala Observatory Management Plan. These decisions substantially reduce the risks to DKIST construction due to permitting issues.

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

DKIST operations are funded through the Research and Related Activities account (R&RA). (See the NSO narrative in the Facilities chapter for more information.) In FY 2018, the request of $16.0 million includes $14.0 million for the continuing ramp of DKIST operations and $2.0 million for cultural mitigation activities as discussed below.

The need for a Remote Operations Building (ROB) facility located on Maui was identified in the early stages of DKIST development. In FY 2015, the managing organization (AURA) demonstrated to NSF that construction of a dedicated ROB would result in significant savings to the federal government, compared to leasing space over the planned 45-year lifetime of DKIST. Thus, operations costs of DKIST for FY 2018 and beyond have been reduced by $500,000 annually as compared to the FY 2016 NSF Budget Request to Congress. In FY 2019, the estimated steady-state operations and maintenance cost will be $16.50 million, exclusive of the $2.0 million for cultural mitigation activities described below. DKIST will become the flagship telescope for the solar community, rendering some current facilities obsolete.

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.

The DKIST telescope enclosure and Support and Operations building at the site on Haleakala, Maui, HI, March 2017. *Credit: D. Boboltz, NSF.*

LARGE SYNOPTIC SURVEY TELESCOPE $57,800,000

The FY 2018 Budget Request for the Large Synoptic Survey Telescope (LSST) is $57.80 million. This is the fifth 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 Actual	FY 2017 Estimate	FY 2018 Request	FY 2019 Estimate	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate	Total Project Cost
$27.50	$79.64	$99.67	$67.12	$57.80	$48.82	$46.34	$40.75	$5.36	$473.00

LSST is located in Chile and, when completed, 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 set by considering four key science areas:

- the physics of dark energy and dark matter.
- a census of small bodies in the solar system, including potentially hazardous Near Earth Objects.
- the structure and contents of the Milky Way galaxy.
- 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 will result in a comprehensive data set that will enable hundreds of fundamental astrophysical studies by the entire research community on these and other topics. Thus, LSST has the potential to advance every field of astronomical study, from the inner Solar System to the large-scale structure of the Universe.

Baseline History

LSST is a joint NSF/Department of Energy (DOE) project to build an instrument that was ranked the top large ground-based astronomy project by the National Research Council (NRC) 2010 Decadal Survey.[3]

Prior to NSF's construction award, NSF, DOE, and private (non-federal) partners invested over $130.0 million. About 70 percent supported design and development, and about 30 percent, from 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 risk.

NSF and DOE conducted a series of reviews in 2011 and 2012 to determine the project baseline, including the NSF Preliminary Design Review (PDR) and a subsequent cost estimation review. Plans were kept up-to-date to synchronize the DOE and NSF funding profiles as reviews continued, leading to NSF's Final Design Review (FDR) in December 2013. NSF then carried out a detailed cost analysis prior to following through on its approval process and making an award in the last quarter of FY 2014.

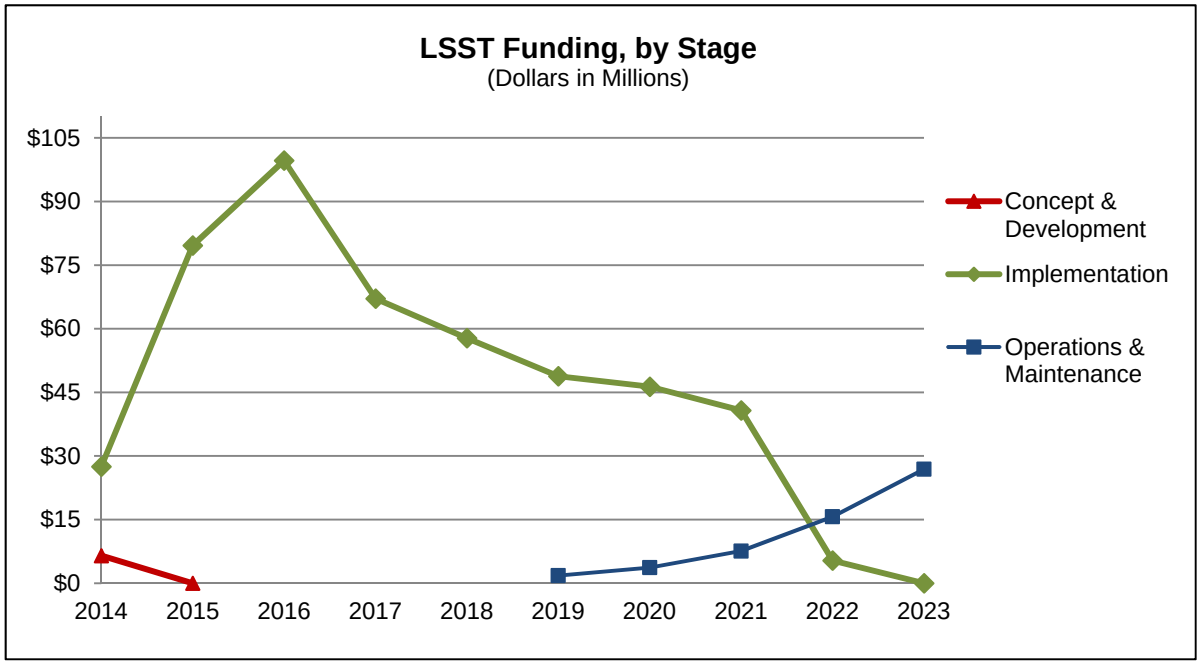
[3] http://sites.nationalacademies.org/bpa/BPA_049810

Total Funding Requirements for LSST
(Dollars in Millions)

	Prior Years[1]	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	ESTIMATES FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
R&RA:									
Concept & Development	$57.13	-	-	-	-	-	-	-	-
Operations & Maintenance	-	-	-	-	1.80	3.70	7.60	15.70	26.90
Subtotal, R&RA	$57.13	-	-	-	$1.80	$3.70	$7.60	$15.70	$26.90
MREFC:									
Implementation[2]	107.14	99.67	67.12	57.80	48.82	46.34	40.75	5.36	-
Subtotal, MREFC	$107.14	$99.67	$67.12	$57.80	$48.82	$46.34	$40.75	$5.36	-
TOTAL REQUIREMENTS	**$164.27**	**$99.67**	**$67.12**	**$57.80**	**$50.62**	**$50.04**	**$48.35**	**$21.06**	**$26.90**

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

[2] Includes $6.70 million carried forward into FY 2017.



LSST Science Plan

The site at Cerro Pachón, Chile was selected for LSST 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 changing and transient objects within 60 seconds of their discovery. Repeated deep imaging of every part of the accessible sky will turn up explosive events such as cataclysmic variable stars, supernovae, and the optical counterparts of X-ray flashes, as well as finding moving objects and better characterizing those already known. Early estimates of LSST's ability to locate Near Earth Objects (NEO) and Potentially Hazardous Asteroids (PHA) have been refined by LSST Project members, as well as by external studies, including an independent Jet Propulsion Laboratory study supported by NASA's Planetary Defense Coordination Office. Assuming other existing NEO efforts continue, at the end of LSST's 10-year prime mission, the catalog should be ~75

percent complete for NEO (~80 percent for PHA), approximately 15 percent more complete than without LSST.

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 an 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 an MOU signed in July 2012.
- External Structure: The responsible awardee for LSST construction is the Association of Universities for Research in Astronomy, Inc. (AURA), a non-profit science management corporation consisting of 42 U.S. institutional members and five international affiliates. AURA works closely with the 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 construction; 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 NSF and DOE.

Reviews

- Technical Reviews: Reviews were conducted throughout the design and development phase, culminating in NSF's 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.
    - Major reviews held by both NSF and DOE prior to the MREFC award found the Basis of Estimate documentation to be quite adequate, with small improvements requested.
    - On May 7, 2014, the National Science Board (NSB) issued Resolution NSB-14-24, authorizing NSF management to proceed with the construction award, subject to additional cost and management scrutiny. Those reviews were carried out by NSF and allowed the MREFC award to be issued in August 2014.
    - The first annual construction review was scheduled for August-September 2015 but was deferred until February 2016. The review panel made several recommendations to improve project execution. To get back on schedule, the second progress review happened in August 2016 and was also successful, except that the Data Management (DM) systems were undergoing a major replan and could not be fully evaluated. A follow up intensive DM-focused review is being scheduled for July 2017. The next overall progress review is scheduled for September 2017.
    - In conjunction with the first progress review, NSF organized an Earned Value Management (EVM) validation review to consider both the adequacy of the system used for EVM, and the Project staff's ability to use EVM tools and methods. The Project passed with only minor recommendations for small improvements.

  - In January 2017, DOE and NSF held a joint external agency review of the project's plans for commissioning and transition to early operations.
- After 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 2015 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. Since then, the project has worked closely to the planned schedule and cost, with only minor issues covered from the (risk-based) contingency funds and by the use of internal contractor float and project schedule contingency. During FY 2017, the primary telescope building will be substantially completed, as will dome installation. The base facility reconstruction including the LSST Chilean data centers will be well underway, and the calibration telescope will be made ready for installation. NSF- and DOE- supported activities remain tightly coordinated, both at the project level and between agency program officers.

Cost and Schedule

A complete re-estimate of the project occurred 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. NSF carried out some further cost review prior to making the award.

NSF policy changed from a probabilistic contingency estimation based on the Project Management Control System (PMCS) to requiring a joint cost and schedule Monte Carlo (MC) method. The project established the new MC method throughout their PMCS and showed that the computed TPC corresponds to a better than 90 percent chance of coming in and within the cost sum of base plus contingency, and before the planned survey start date (base completion date plus schedule contingency). This result was finalized in April 2015 and incorporated into NSF's award instrument.

NSF has revised its policy on the use and oversight of management fees. AURA and NSF will carry out fee negotiations each fiscal year, and the total will fit under the approved total project cost. Because of these contingency and fee changes, the forward-projected budget profile has been revised.

In addition to NSF's contribution, DOE's baseline for the camera has been fixed at $168.0 million. Construction also includes $38.97 million from non-federal sources, all of which has been expended.

Risks

Technical: Much of the technical risk was retired during design and development. Since full construction began, no new major risks have appeared, and small, realized risks have been mitigated by use of cost and schedule contingency, including float internal to sub-projects. The Data Management construction effort currently is undergoing re-planning, and thus is being carried as a risk.

Environmental and Cultural Compliance: Environmental and cultural impact mitigation continues as planned with no unforeseen issues.

Site: The possible site risk due to local geological anomalies, mentioned in previous requests, was realized early during excavation. Since this risk was localized and anticipated, it was successfully handled. Site disruptions from geological events and extreme weather remain as possible risks with appropriate mitigation plans.

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. Both the summit and base sites have

on-site safety supervisors employed by LSST to monitor contractor and project activities. All safety plans are fully compliant with applicable standards from U.S., Chilean, and participating institutions, and are updated regularly. External reviews have given the Project high marks for its safety culture.

Partnership Risk: The LSST project director and deputy oversee the entire project. A single project manager, agreed to by both NSF and DOE, manages the complete work breakdown structure elements. 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.

Future Operations Costs

Operation costs will be funded out of the Research and Related Activities account. The current estimate for full operations costs was $36.63 million per year (US$ FY 2013) at the time of FDR. The final full operations costs and the amount required from non-federal partners will be determined through a review and approval process scheduled to start in mid-2017 when the project submits a formal proposal for LSST operations jointly to NSF and DOE.

In their joint MOU, NSF and DOE agreed to fund operations, increasing agency support and/or revising the operations plans, as appropriate. MPS/AST has been planning to provide half of the original amount plus early operations support, with the DOE Office of High Energy Physics providing one quarter. The project team has already established firm agreements to fund ~$6.3 million of the estimated $9.0 million annual operating costs allocated for funding by non-federal entities, and negotiations continue with potential partners to find the remaining balance. Should full funding of the operations budgets not be achieved, the project has also prepared de-scope plans that reduce the scope of operations but also inevitably affect some of the science deliverables. Although the possibility of insufficient operational funding is not a risk to the project, it is a significant concern for the agencies and the awardee and is being closely watched.

Construction status on Cerro Pachón, February 2017. *Credit: LSST.*

THE NATIONAL ECOLOGICAL OBSERVATORY NETWORK $0

No MREFC funds are requested for the National Ecological Observatory Network (NEON) in the FY 2018 Request. Construction funding totals an estimated $469.30 million, which reflects a $35.58 million increase in the Total Project Cost (TPC) in conjunction with the change in the managing organization. The increase in the TPC is being funded via transfers of Research and Related Activities (R&RA) funds from the Directorate for Biological Sciences (BIO). Construction is expected to be complete by the spring of 2018. NEON operations and maintenance will be funded through the R&RA account.

Appropriated and Requested MREFC Funds for the National Ecological Observatory Network

(Dollars in Millions)

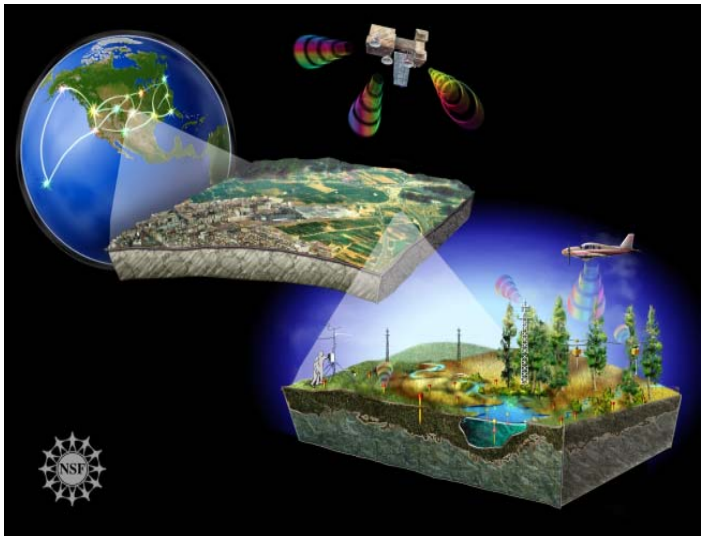
	Prior Years	FY 2012 Actual	FY 2013 Actual	FY 2014 Actual	FY 2015 Actual	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	Total Project Cost[1]
Previous Funding Profile	$12.59	$60.30	$91.00	$93.20	$96.00	$80.64	-	-	$433.72
Revised Funding Profile	12.59	60.30	91.00	93.20	96.00	100.64	15.58	-	469.30
Change from Previous Profile	-	-	-	-	-	*20.00*	*15.58*	-	*35.58*

[1] In June 2016, the National Science Board (NSB) approved an increase in NEON's Total Project Cost from $433.72 million to $469.30 million. The $35.58 million increase is provided through transfers from the R&RA account to the MREFC account of $20.0 million from FY 2016 funds (completed) and up to $15.58 million from FY 2017 funds (expected).

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 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 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 Funding Requirements for NEON

(Dollars in Millions)

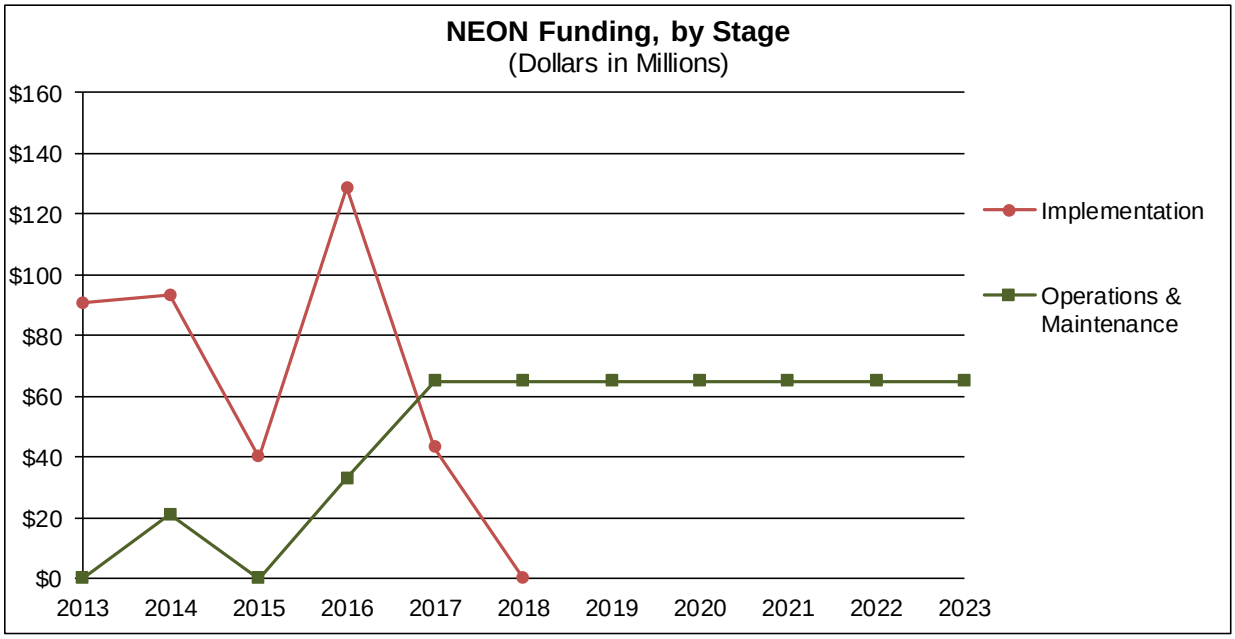
	Prior Years[1]	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	ESTIMATES FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
R&RA:									
Concept & Development	$104.85	-	-	-	-	-	-	-	-
Operations & Maintenance[2,3]	21.00	32.97	65.00	65.00	65.00	65.00	65.00	65.00	65.00
ARRA	9.96	-	-	-	-	-	-	-	-
Subtotal, R&RA	$135.81	$32.97	$65.00	$65.00	$65.00	$65.00	$65.00	$65.00	$65.00
MREFC:									
Implementation[3,4]	296.88	128.51	43.91	-	-	-	-	-	-
TOTAL REQUIREMENTS	**$432.69**	**$161.48**	**$108.91**	**$65.00**	**$65.00**	**$65.00**	**$65.00**	**$65.00**	**$65.00**

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

[2] Funding for O&M is currently capped at $65.0 million per year for planning purposes, pending the results from an initial period of operations under Battelle management. Future O&M requests will be based on a more thorough analysis of science capabilities and affordability.

[3] Consistent with revised TPC plans, $20.0 million of FY 2016 R&RA appropriated funding was transferred to the MREFC account and carried forward into FY 2017. Up to $15.58 million of FY 2017 R&RA requested funding is expected to be transferred into the MREFC account.

[4] $56.0 million of FY 2015 MREFC funding for NEON was carried over into FY 2016. A total of $28.41 million of FY 2016 MREFC funding was carried over into FY 2017 of which $8.40 million is being held as part of NSF's strengthened oversight of budget contingency as well as NSF-held management reserve. These funds will be made available to the project based on bona fide need and recipient performance.



Note: In FY 2016, $20.0 million was transfered from the R&RA account to the MREFC account for NEON Implementation. In FY 2017, a transfer of up to $15.58 million from the R&RA account to the MREFC account is expected.

MREFC Project Plan

NEON is the first research platform and the only national experimental facility specifically designed to collect consistent and standardized sensor and biological measurements across 81 sites nationwide; reduced from 106 sites following NSF's decision in FY 2015 to de-scope the project in order to prevent a potential $80.0 million cost overrun. Measurements will enable 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 continental-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 Battelle Memorial Institute, 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 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 environmental 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 memorandums of understanding 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.

Management and Oversight

- NSF Structure: The NEON program is managed by the Division of Biological Infrastructure (DBI) within BIO. Managing the NEON program in DBI helps foster its associations with other BIO facilities and infrastructure investments and its connections to broader biological and interdisciplinary science activities. Within BIO/DBI, a Science Advisor (working with the Deputy Division Director) provides

[4] Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson (Eds.). (2009). *Global Climate Change Impacts in the United States.* Retrieved from https://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf

[5] The U.S. National Plan, 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.' National Science and Technology Council, Executive Office of the President. (2014). *National Plan for Civil Earth Observations*. (p. 71). Retrieved from www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/2014_national_plan_for_civil_earth_observations.pdf

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

overall programmatic oversight for BIO's mid- and large-scale research infrastructure, while the day-to-day program management is done by dedicated cognizant program officers with assistance from a program manager experienced with other MREFC projects. The cognizant program officers for construction and operations coordinate the direct oversight of NEON construction, operations and maintenance, and science utilization. An NSF Integrated Project Team (IPT) chaired by the NEON program officers, with representatives from the Office of Budget, Finance, and Award Management which includes the Large Facility Office, the Office of Legislative and Public Affairs, the Office of the Director , and program representatives from other NSF large facilities, helps ensure 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.

- External Structure: NEON, Inc., the company previously managing the NEON project, was notified in December 2015 of NSF's intent to transfer responsibility for construction and initial operations to a new management entity. In 2016, NSF used an expedited process to select a new managing entity for the NEON construction and initial observatory operations. As of June 2016, the NEON project is now fully managed by Battelle Memorial Institute, Inc. (Battelle), a non-profit, membership-governed corporation with extensive experience managing large research projects, government contracts, and related activities.

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.
- NSF conducted a Readiness Review to assess Battelle's competence to assume management of the NEON project in June of 2016.
- Construction, Cost, and Schedule reviews:
  - 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 $80.0 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.
  - In July 2015, NSF directed NEON, Inc. to reduce the project scope and deliver revised project documents, construction schedule, and cost proposal to reflect the scope reduction.
  - A revised proposal was submitted December 2015 which indicated the potential for an additional $19 million cost overrun and further schedule slip leading NSF to make its decision to transfer management responsibility.
  - An independent cost estimate (ICE) was obtained by NSF to support its internal cost analysis and award to the new managing organization.
  - In June 2016 NSF conducted a site visit in order to review Battelle's readiness to assume full responsibility for the remaining construction and initial operations of the NEON Observatory.
  - A Construction and Transition to Operations Review will be conducted in 2017.
- National Science Board (NSB) Review: The NSB reviewed and authorized NEON construction in May 2010 and authorized initial NEON Operations and Maintenance (O&M) in February 2013. In

September 2015, it established an ad hoc Task Force on NEON Performance and Plans to review and monitor NSF's oversight of the project. In 2016, after review of a new construction cost proposal (including the ICE), Battelle's successful management of the project to-date, and the remaining project risks, the NSB authorized an increase in the total project cost from $433.72 million to $469.30 million.

- Management, Business, and Operations Reviews:
  - NSF conducted a Business Systems Review 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.
  - Delays in construction have impacted rollout of operations by one year. With the transition to Battelle, an extension of the initial operations award is anticipated to allow the project to stabilize. A focused, external review of annual operations costs is planned for March 2017. A pre-award cost review prior to full observatory operations funding is expected in FY 2018.
  - Annual Operations Reviews will continue once construction is complete.

Project Status

Eighty-five percent of the Observatory research capabilities have been achieved with one hundred percent capability planned to be completed by the spring of 2018. This includes construction for the remaining terrestrial locations, aquatic sites, and airborne observation platforms (AOP).

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. De-scoping decisions were finalized and implemented in late July 2015.

For FY 2017, $65.0 million was requested from the R&RA account to support initial operations and maintenance. This represents the final increment from the original three-year O&M award as well as a partial increment for a proposed two-year extension while future costs are evaluated by NSF. The additional two years in O&M will allow time for a more complete understanding of the science capabilities and costs proposed, identification of management efficiencies under Battelle, 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 cost. 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 AOP.

In FY 2018, NSF will explore options for O&M of the full NEON Observatory after construction. As noted above, NSF expects to extend the initial operations award that began in FY 2014 for 24 months to allow Battelle time to identify project efficiencies, minimize costs, and maximize science delivery. Final costs for observatory O&M will be determined on the basis of these management efforts and analyses.

Cost and Schedule

The original projected length of the construction stage was six fiscal years, with six-months of schedule contingency included. Project performance under NEON, Inc., was running well behind the original plan. Under Battelle's management, the planned project end date has shifted back to mid-FY 2018 and the TPC has been re-established as described above. Roughly 80 percent of the approved project funds for construction have been spent, with Observatory capability at approximately 85 percent complete. Focused management by Battelle and oversight by NSF is now required to remain within budget and on schedule.

Risks

Technical: 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. Technical risk is considered low at this point in construction. The remaining technical hurdle is deployment of the cyber-infrastructure architecture for full integration of the NEON observatory sites and mobile platforms for delivery of data to the science community.

Deployment: Environmental assessment and permitting continues to have a potential impact on schedule. Risk mitigation strategies include the direct contracting of the environmental assessments by NSF, the hiring of experienced, national firms by Battelle for engineering and permitting, and the identification of alternative sites if primary sites still hold significant risk. The selection of alternative sites for other high-risk sites is nearing completion and environmental compliance activities are actively underway.

Management: Management risk has been partially mitigated by NSF based on the decision to replace NEON, Inc. with Battelle. The transition to new management is an inherently risky proposition but was necessary in this case. Battelle continues to work closely with NSF oversight personnel to clearly communicate process, standards, timelines, costs, and expectations.

Future Operations Costs

NEON is the first research observatory that will maintain and operate in-situ instrumentation and conduct biological sampling in 20 domains (81 locations) including three airborne observatories, a central operating facility, and a cyberinfrastructure center. Field 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 activities and associated costs will ramp up as sites are commissioned. Battelle is accelerating the transition of infrastructure to operations whenever possible to appropriately manage construction costs.

A three-year initial award for O&M began September 2014 to allow NEON, Inc. to explore opportunities for schedule and cost efficiencies and provide a basis for funding the full Observatory operations during out-years. The delay in construction has extended this activity from FY 2016 through early FY 2018. An extension of the initial operating period through FY 2019 is now planned under Battelle to allow the project to stabilize. For FY 2018, O&M costs are capped at $65.0 million for planning purposes with final costs to be determined after Battelle's assessment of management efforts and analyses.

REGIONAL CLASS RESEARCH VESSELS $105,000,000

The FY 2018 Request for the Regional Class Research Vessel (RCRV) project is $105.0 million. This represents the second 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[1]

(Dollars in Millions)

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

[1] This table does not reflect final action on FY 2017 appropriations, which were enacted too late to be incorporated in this document. P.L. 115-31 provided funding for an additional RCRV which impacts funding requirements for FY 2017, FY 2019, FY 2020, and the total project cost. There is no impact on the FY 2018 Budget Request.

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*[7], 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).[8] 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

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

[8] National Ocean Council. Federal Oceanographic Fleet Status Report, 2013. https://obamawhitehouse.archives.gov/sites/default/files/federal_oceanographic_fleet_status_report.pdf

construction of RCRVs. Oregon State University (OSU) was selected and received the award in 2013. Input from external review panels, the University-National Oceanographic Laboratory System (UNOLS), and the NAS *Sea Change* report were received during the period 2013 to 2015 which informed the final decision to pursue construction of two RCRVs. In 2015 the National Science Board authorized inclusion of funds to initiate construction of two RCRVs in future budget requests at the NSF Director's discretion. The Final Design Review was conducted in December 2016 and the panel recommended to NSF that the project be advanced to the construction stage.

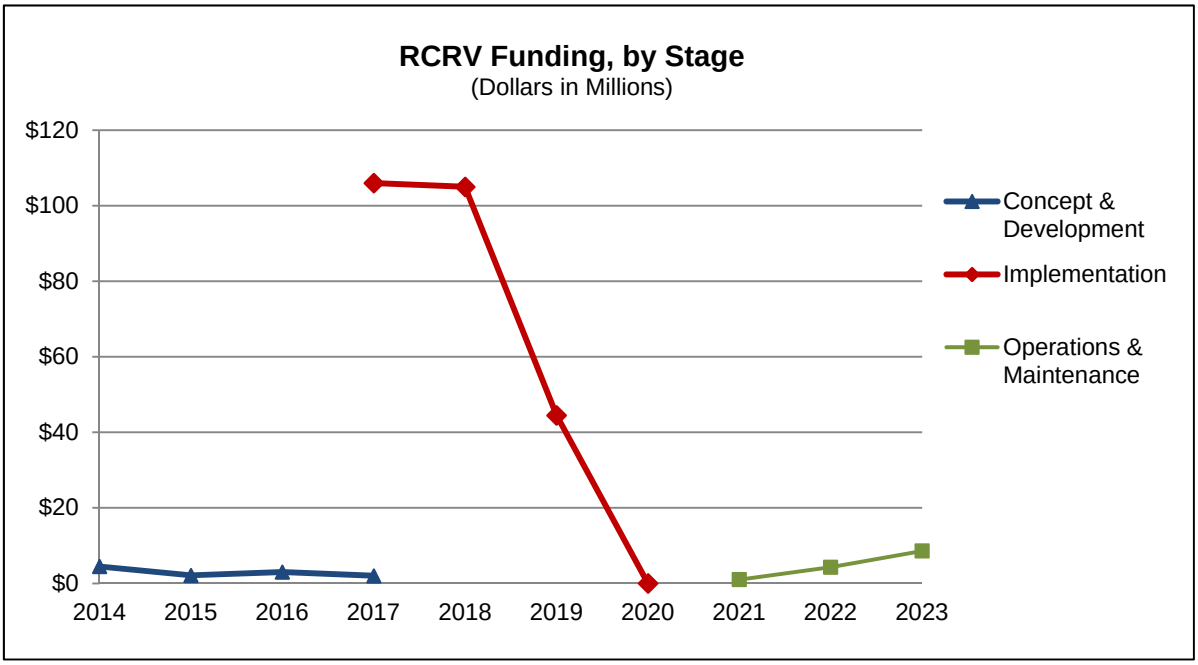
Total Funding Requirements for RCRV[1]

(Dollars in Millions)

	Prior Years[2]	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	ESTIMATES FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
R&RA:									
Concept & Development	$6.62	$3.09	$2.00	-	-	-	-	-	-
Operations & Maintenance	-	-	-	-	-	-	1.00	4.30	8.60
Subtotal, R&RA	$6.62	$3.09	$2.00	-	-	-	$1.00	$4.30	$8.60
MREFC:									
Implementation	-	-	106.00	105.00	44.50	-	-	-	-
Subtotal, MREFC	-	-	$106.00	$105.00	$44.50	-	-	-	-
TOTAL REQUIREMENTS	**$6.62**	**$3.09**	**$108.00**	**$105.00**	**$44.50**	**-**	**$1.00**	**$4.30**	**$8.60**

[1] This table does not reflect final action on FY 2017 appropriations, which were enacted too late to be incorporated in this document. P.L. 115-31 provided funding for an additional RCRV which impacts funding requirements for FY 2017, FY 2019, FY 2020, and the total project cost. There is no impact on the FY 2018 Budget Request.

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



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 administrative 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 (PI) for the award is the project manager (PM), who reports directly to the OSU Dean of the College of Earth, Ocean and Atmospheric Sciences. The PM interacts directly with NSF and manages the RCRV administrative staff. The project scientist (PS) is a co-Principal Investigator (PI) on the award. 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 independent 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. The SOC provides guidance to the OSU RCRV project team through the PM 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 was held in February 2016, at NSF. NSF directed OSU to make minor revisions to the Request for Proposals (RFP) based on the review.
- Interim Design Review (IDR): A second IDR was held 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 was warranted. The review was hosted by the RCRV Project Team in Corvallis, OR, and attended by NSF program staff as well as the RCRV SOC. The SOC provided minor technical improvements to the RCRV, which were incorporated into the RFP package.
- Final Design Review (FDR): The FDR was held in December 2016 to ensure that anticipated project costs remained realistic and that no unforeseen events had arisen prior to the start of construction during FY 2017. Several members of the PDR panel also participated in the FDR. Like CDR and PDR, FDR was conducted in compliance with NSF's Large Facilities Manual. The FDR Panel recommended to NSF that the project be advanced to the Construction Stage.

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 will complete Phase II in CY 2017, during which bids for construction of RCRVs are being solicited and evaluated from U.S. shipyards. Total funding to OSU for RCRV through FY 2017 is expected to be $11.39 million in R&RA funds and $106.0 million in MREFC funds.

Cost and Schedule

The projected length of the project is 10 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.

One significant enhancement to the management of contingency is holding a portion of budget contingency (up to 100 percent) and only allocating to the program, for obligation to the project, based on demonstrated need. This oversight mechanism will generally result in some MREFC carry over each year, however, future obligation is anticipated to manage project risks.

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: The desired low ship self-noise levels may not be initially achieved. Contingency funds are included if a secondary noise mitigation strategy is required to meet the ship specifications. Sonar sensors, science load handling systems, and other vessel sub-systems may also 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. A selected shipyard may 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 funds are 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 (ARF). 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 beginning in 2021 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 $6.10 million to operate in its first year, resulting in a rate of $30,441 per day, including technician support. 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 approximately $4.30 million in FY 2022, which is the first year the lead ship transitions into full operations in the ARF. 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. The second ship would transition to full operations in the ARF in FY 2023.

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