

# Report to Congressional Committees

**July 2022** 

# NATIONAL SCIENCE FOUNDATION

Continued Cost and Schedule Increases for Major Facilities Projects in Construction

Highlights of GAO-22-105550, a report to congressional committees

#### Why GAO Did This Study

NSF supports the design, construction, and operations of science and engineering research infrastructure such as telescopes and research vessels. These projects include major facilities that cost over \$100 million to construct and mid-scale projects. As the COVID-19 pandemic is ongoing, NSF is continuing to respond to the pandemic's effects on cost and schedule performance to further the construction and design of these projects. Prior GAO reports reviewed NSF's oversight of these projects and cost estimating and schedule policies.

Congress included provisions in several congressional reports for GAO to review projects funded from NSF's Major Research Equipment and Facilities Construction account. This report, the fifth, (1) examines the cost and schedule performance of NSF's ongoing research infrastructure projects, (2) evaluates the extent to which NSF followed its guidance to respond to pandemic-related risks for major facilities projects in construction, and (3) describes the extent to which NSF has implemented prior GAO recommendations.

GAO reviewed NSF and award recipient documents, examined policies and procedures to manage and oversee projects, and interviewed NSF officials for clarifying information.

#### What GAO Recommends

NSF agreed with and has taken steps to address the remaining recommendation from GAO's prior report to improve the project management skills of its staff.

View GAO-22-105550. For more information, contact Candice N. Wright at (202) 512-6888 or WrightC@gao.gov.

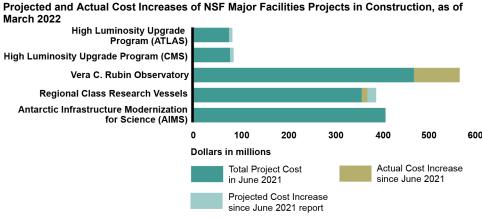
#### **July 202**

#### NATIONAL SCIENCE FOUNDATION

# **Continued Cost and Schedule Increases for Major Facilities Projects in Construction**

#### What GAO Found

Since GAO's June 2021 report on the status of the National Science Foundation's (NSF) major facilities and mid-scale research infrastructure projects, NSF completed construction of the Daniel K. Inouye Solar Telescope. However, NSF continues to face cost increases, schedule delays, or both for the major facilities projects still in construction because of the pandemic and other factors. All major facilities projects in construction will be completely re-baselined by adjusting cost, schedule and scope beyond the original authorized award amounts. For example, NSF approved a re-baseline for the Vera C. Rubin Observatory that resulted in a cost increase of \$98 million, which included approximately \$8.5 million to address new data security requirements. NSF has projected cost increases for four of the remaining projects in construction and chosen to restructure the fifth project, the Antarctic Infrastructure Modernization for Science project. The effects of the pandemic on this project resulted in the decision not to fund certain portions of the project and instead, NSF will consider integrating these portions into a new program.



Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

NSF developed new guidance for how award recipients should respond to cost and schedule increases caused by the pandemic. Specifically, the guidance instructs award recipients to refrain from using contingency funds reserved for foreseen risks identified during the design of a project or de-scoping a project to respond to pandemic-related risks. Instead, award recipients should request NSF-held management reserve, re-plan (adjust cost, schedule, or scope without impacting award amounts), or re-baseline their projects. NSF followed its guidance to respond to the pandemic, such as by using management reserves for the three projects that are farthest along.

NSF has implemented two of the three prior GAO recommendations, including revising policies for developing schedules for major facilities projects and establishing criteria to assess project management expertise of award recipients. NSF took steps to address but has not fully implemented the remaining recommendation to identify and address project management competency gaps of NSF's oversight workforce.

United States Government Accountability Office

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#### **Abbreviations**

AIMS Antarctic Infrastructure Modernization for Science

AIR Antarctic Infrastructure Recapitalization

ARV Antarctic Research Vessel

ATLAS A Toroidal Large Hadron Collider Apparatus

CMS Compact Muon Solenoid

DKIST Daniel K. Inouye Solar Telescope

DOE Department of Energy

GO-BGC Global Ocean Biogeochemistry Array

HL-LHC Large Hadron Collider High Luminosity Upgrade

LCCF Leadership Class Computing Facility

LHC Large Hadron Collider

LSST Large Synoptic Survey Telescope

MREFC Major Research Equipment and Facilities Construction NAN Network for Advanced Nuclear Magnetic Resonance

NSF National Science Foundation
RCRV Regional Class Research Vessels

RDE Research Data Ecosystem

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July 20, 2022

The Honorable Jeanne Shaheen
Chair
The Honorable Jerry Moran
Ranking Member
Subcommittee on Commerce, Justice, Science,
and Related Agencies
Committee on Appropriations
United States Senate

The Honorable Matt Cartwright
Chairman
The Honorable Robert B. Aderholt
Ranking Member
Subcommittee on Commerce, Justice, Science,
and Related Agencies
Committee on Appropriations
House of Representatives

The National Science Foundation (NSF) supports the design, construction, and operations of various research infrastructure projects, which are research tools such as telescopes, research vessels, and distributed observatories. Research infrastructure projects include both major facilities that cost over \$100 million to build and mid-scale research infrastructure projects that cost between \$4 million and \$100 million to build.¹ These projects are designed, constructed, and operated in collaboration with the scientific community. The longevity of these projects—some may operate for 50 years—and complexity of their

For the purposes of our report, we use "mid-scale projects" to refer to research infrastructure projects that have a total project cost between \$20 million and \$100 million and that are funded through the MREFC account, which constitutes NSF's centralized Mid-scale Research Infrastructure Track-2 program.

<sup>&</sup>lt;sup>1</sup>Mid-scale research infrastructure projects are those with a total project cost above the upper limit for NSF's Major Research Instrumentation program and below the threshold for a major facility. American Innovation and Competitiveness Act (AICA), Pub. L. No. 114-329, § 109(b)(4), 130 Stat. 2969, 2988 (2017). Major facilities are those that cost over \$100 million to construct regardless of the funding account. William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, Pub. L. No. 116-283, § 267, 134 Stat. 3388, 3502 (amending section 110 of the AICA).

construction or acquisition necessitate that NSF provide rigorous oversight.

NSF uses cooperative agreements and contracts to fund and oversee the projects throughout their life cycles. Award recipients of cooperative agreements and contracts—which may include universities, nonprofit associations, and companies—manage the projects' day-to-day activities. NSF generally funds these construction efforts through its Major Research Equipment and Facilities Construction (MREFC) account. Over the past 5 fiscal years, NSF has received over \$1 billion in appropriations to this account (see table 1). In fiscal year 2022, Congress appropriated \$249 million for the MREFC account.

Table 1: Appropriations for NSF Major Research Equipment and Facilities Construction

(Dollars in millions)

	Fiscal year				
<del>-</del>	2018	2019	2020	2021	2022
Appropriations	183	296	243	241	249

 $Source: \ National\ Science\ Foundation\ (NSF)\ and\ congressional\ budget\ documents.\ |\ GAO-22-105550$ 

Since 2018, we have issued four reports focused on NSF's oversight of cost and schedule performance of the agency's major facilities construction projects and on NSF's efforts to ensure the project management expertise of NSF oversight staff and award recipients for its major facilities projects. Most recently, we described how the COVID-19 pandemic and other factors resulted in cost and schedule increases for major facilities projects that were in construction. We also previously reported on how NSF shares lessons learned and best practices for the construction of major facilities projects. In two of these prior reports, we made a total of six recommendations to improve NSF's ability to provide oversight over the design and construction of these major facilities projects. NSF concurred with these recommendations and has

<sup>&</sup>lt;sup>2</sup>GAO, National Science Foundation: Revised Policies on Developing Costs and Schedules Could Improve Estimates for Large Facilities, GAO-18-370 (Washington, D.C.: June 1, 2018); GAO, National Science Foundation: Cost and Schedule Performance of Large Facilities Construction Projects and Opportunities to Improve Project Management, GAO-19-227 (Washington, D.C.: Mar. 27, 2019); GAO, National Science Foundation: Cost and Schedule Performance of Major Facilities Construction Projects and Progress on Prior GAO Recommendations, GAO-20-268 (Washington, D.C.: Apr. 3, 2020); GAO, National Science Foundation: COVID-19 Affected Ongoing Construction of Major Facilities Projects, GAO-21-417 (Washington, D.C.: June 8, 2021).

implemented some changes. In April 2020, we reported that NSF had implemented two of the six recommendations—revising policies for estimating the costs of major facilities projects and revising the Vera C. Rubin Observatory's schedule to better meet best practices. In June 2021, we reported that NSF had implemented another recommendation on information sharing among award recipients of major facilities projects and had taken steps to address the remaining three recommendations.

The Consolidated Appropriations Act, 2021, Senate Report 115-275, Senate Report 114-239, and House Report 114-605, included provisions for GAO to review projects within NSF's MREFC account, which includes major facilities and mid-scale projects.<sup>3</sup> This report (1) describes the cost and schedule performance of NSF's ongoing major facilities and mid-scale research infrastructure projects, (2) evaluates the extent to which NSF has followed its policies and guidance to respond to COVID-19 pandemic-related risks for its major facilities projects, and (3) describes the extent to which NSF has implemented prior GAO recommendations related to its management of its research infrastructure projects.

For each of our objectives, we reviewed information pertaining to the major facilities projects that were completed, in construction, or in design at the time of our review, as well as mid-scale research infrastructure projects. We reviewed, for example, cooperative agreements, progress reports, risk reports, and other available documentation that describes cost and schedule performance. In addition, we reviewed NSF policies and other guidance documents to assess the available options NSF and award recipients have to respond to cost and schedule increases related to unforeseen events, such as the pandemic. Finally, we interviewed NSF officials to collect information on progress made to address recommendations from prior GAO reports. For a detailed description of our scope and methodology, see appendix I.

We conducted this performance audit from November 2021 to July 2022 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that

<sup>&</sup>lt;sup>3</sup>The Consolidated Appropriations Act, 2021, makes reference to the explanatory statement containing the mandate, printed in 166 Cong. Rec. H8311 (Dec. 21, 2020). Pub. L. No. 116-260, § 4, 134 Stat. 1182, 1185 (2020).

the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

## Background

# NSF's Research Infrastructure Projects

NSF has twelve research infrastructure projects in construction or design that are either funded or planned for funding out of the MREFC account, as of March 2022. Of these 12, seven projects are major facilities projects and five projects are mid-scale research infrastructure projects (see fig. 1). Once completed, these projects will serve various scientific research goals, from observations of the sea floor environment to the charting of billions of galaxies in space.

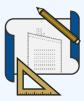
Figure 1: NSF's Research Infrastructure Projects in Construction or Design, as of March 2022

# Major facilities projects in construction



- · Vera C. Rubin Observatory
- · Regional Class Research Vessels
- Antarctic Infrastructure Modernization for Science
- Large Hadron Collider High Luminosity Upgrade Program
  - ATLAS Detector Project
  - o CMS Detector Project

# Major facilities projects in design



- Leadership Class Computing Facility
- Antarctic Research Vessel

# Mid-scale research infrastructure projects



- Distributed Energy Resources Connect
- Global Ocean Biogeochemistry Array
- High Magnetic Field Beamline
- Network for Advanced Nuclear Magnetic Resonance
- Research Data Ecosystem

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

# Stages in the Life Cycles of NSF's Major Facilities Projects

Each major facility and mid-scale research infrastructure project has a sponsoring organization from within NSF's eight research directorates.<sup>4</sup> The sponsoring organization assesses the scientific merit of a potential project, proposes projects for funding through NSF's MREFC account, and is responsible for overseeing the project during its life cycle. For example, the Rubin Observatory is overseen by the mathematical and physical sciences directorate while the Regional Class Research Vessels are overseen by the geosciences directorate. A project typically progresses through the following five stages.

- **Development.** Initial project ideas emerge; and a broad consensus is built within the relevant scientific community for the potential long-term needs, priorities, and general requirements for research infrastructure that NSF may consider funding.
- Design. Entrance into this stage occurs when the NSF Director approves the proposed research infrastructure as a national priority and the sponsoring directorate makes an award (either through a cooperative agreement or contract) for developing detailed project cost, scope, and schedule for possible construction. This stage is divided into conceptual, preliminary, and final design phases. A candidate project will exit the design stage and enter the construction stage after a successful review by the NSF Director and other key stakeholders of its project execution plan and authorization of its not-to-exceed total project cost by the National Science Board, as discussed below.
- **Construction.** The construction stage begins when NSF makes awards to external recipients for acquisition or construction of

<sup>&</sup>lt;sup>4</sup>NSF is divided into the following eight research directorates that support science and engineering research and education: biological sciences; computer and information science and engineering; engineering; geosciences; mathematical and physical sciences; social, behavioral, and economic sciences; education and human resources; and technology, innovation, and partnerships.

research infrastructure.<sup>5</sup> The construction stage ends after final delivery and acceptance of the defined scope of work and facility performance per terms of the award instrument.

- Operations. The operations stage includes the day-to-day work necessary to operate and maintain the research infrastructure (including refurbishment or upgrade activities) and to perform research.
- **Divestment.** Divestment can include the transfer of the research infrastructure to another entity's operational and financial control or the decommissioning of the research infrastructure, including its complete deconstruction and removal. NSF generally decides to divest when the agency or the scientific community determines that the facility is no longer considered an operational priority with regard to advancing science, according to NSF's Research Infrastructure Guide.

NSF funding for the development, design, operations, and divestment stages generally comes from the sponsoring directorate. Funding for the construction stage generally comes from the MREFC account.

## NSF Oversight of Research Infrastructure Projects

NSF has established an oversight structure for major facilities projects that includes organizations from across the agency (see fig. 2). This includes the National Science Board and the NSF Director. NSF's Office of the Director and the National Science Board provide high-level, ongoing oversight of major facilities projects, including the approval of new projects to be included in NSF's annual budget request.

<sup>5</sup>Awards generally take the form of cooperative agreements, although NSF occasionally uses contracts, according to agency officials. The policies and procedures in NSF's Research Infrastructure Guide apply to research infrastructure projects regardless of the award instrument employed. In addition, cooperative agreements with universities, consortia of universities, or nonprofit organizations are governed by the Office of Management and Budget's (OMB) Uniform Administrative Requirements, Cost Principles. and Audit Requirements for Federal Awards (Uniform Guidance). 78 Fed. Reg. 78,590 (Dec. 26, 2013) (codified as amended at 2 C.F.R. pt. 200). In December 2014, NSF and other federal awarding agencies issued a joint interim final rule to implement this Uniform Guidance. 79 Fed. Reg. 75,871 (Dec. 19, 2014). NSF received approval from OMB to implement the Uniform Guidance using a policy rather than a regulation. Acquisitions by contract of supplies or services by and for the use of the federal government are governed by the Federal Acquisition Regulation. See 48 C.F.R. §§ 1.104, 2.101(b); see also chapter 25 of title 48 of the Code of Federal Regulations for NSF-specific provisions. According to NSF's Research Infrastructure Guide, contracts with nonprofit and educational institutions are also governed by the Uniform Guidance.

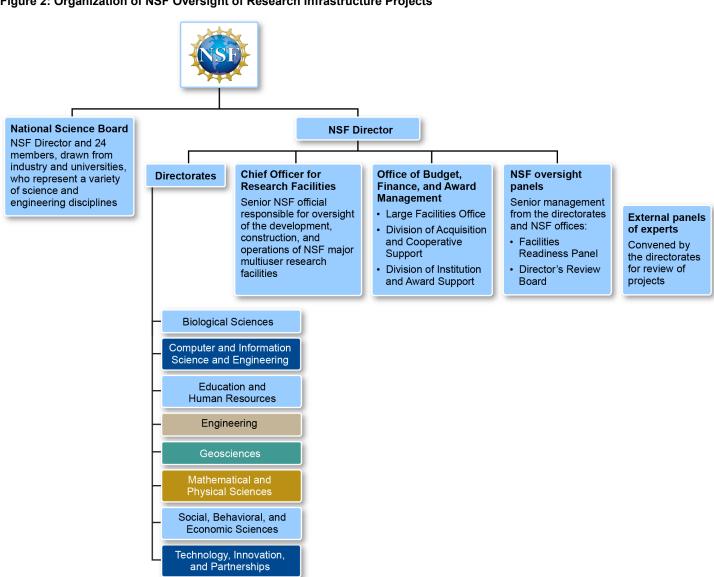


Figure 2: Organization of NSF Oversight of Research Infrastructure Projects

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

Note: Figure does not include all NSF organizations or interactions among them.

The NSF Office of the Director can place research infrastructure projects on its Watch List, which is a management tool to provide specialized oversight and resources to projects navigating critical issues. According to NSF officials, placement on the Watch List is not punitive and is intended only to provide the necessary expertise and bandwidth project

teams need to be successful. NSF decided pandemic-related delays were not sufficient for the agency to place a project on the Director's Watch List because all of the projects in construction would have met that criterion.

Within NSF's Office of Budget, Finance, and Award Management, the Large Facilities Office (1) develops business-related oversight policies for all lifecycle stages, with a focus on the design and construction stages, and (2) provides assistance on nonscientific and nontechnical aspects of project planning, budgeting, implementation, and management. To that end, the office maintains the *Research Infrastructure Guide*, which contains NSF policies for agency staff and award recipients on the planning, management, and oversight of major facilities. The guide also tailors the policies for application to mid-scale research infrastructure projects.

NSF also uses external panels of experts to review projects at several points during their life cycle. An external panel may first review a project proposal during the development stage. Separate panels then review the project at the culmination of each of its design phases. In addition, an external panel periodically reviews each project during both construction and operations; according to NSF officials, those reviews are generally conducted annually.

# Construction Costs and Schedules of Major Facilities Projects

Under NSF's major facilities construction process, the recipients of design awards develop construction cost and schedule estimates for projects and submit them to NSF for review. In particular, after a project's final design review, the National Science Board authorizes a not-to-exceed award amount and duration. The not-to-exceed award amount that the National Science Board authorizes is the amount against which NSF measures cost increases to implement its no cost overrun policy.

NSF's Research Infrastructure Guide defines the following components, which together make up the total project cost and schedule for the construction of major facilities projects. The total project cost awarded in a project's construction agreement may be less than the not-to-exceed cost but it is not to exceed it. These components of the total project cost and schedule include the following:

• Performance measurement baseline. During design, the scope, cost, and schedule are refined and eventually become the project baseline. Once the baseline has been authorized and included in a construction award, it is known as the performance measurement baseline. NSF documents the performance measurement baseline in

the terms and conditions of the award instrument and requires that any changes to it be made through a formal change control process. The performance measurement baseline does not include the project's budget or schedule contingency until a known risk is realized and formal change request is implemented.

**Contingency.** This is an amount of budget or time for covering the cost increases or delays that would result if foreseen project risks were to occur, such as price changes of goods in future years. During development of a total project cost estimate, the timing and effects of such risks are uncertain. As a project progresses, the effects of risks that materialize may exceed the cost or schedule in the performance measurement baseline and lead to use of the project's budget or schedule contingency.6 The amount of contingency needed for a project is typically estimated using statistical analysis or judgment based on past project experience. According to NSF's Standard Operating Guidance on budget contingency, it is likely that no contingency will be left over by the end of a project because all of it will have been used during normal execution of the project to manage known risks and uncertainties. NSF approval is needed when use of contingency exceeds certain project-specific thresholds, which are described in the project's execution plan and codified in the award.

In this report, we identify estimated total project costs for the construction of major facility and mid-scale research infrastructure projects. These costs were developed during the design phase based on the latest estimates available from NSF officials. These estimates are subject to change before construction awards are made. For projects under construction, we identified total project costs based on the amounts awarded in the cooperative support agreements for construction and the not-to-exceed amount authorized by the National Science Board. Only at the end of the project—when construction is complete and the awards have been closed out—will the final total project costs be known.

<sup>&</sup>lt;sup>6</sup>For cooperative agreements, use of budget contingency is governed by OMB's Uniform Guidance. See 2 C.F.R. § 200.433. OMB's Uniform Guidance and NSF's Standard Operating Guidance on budget contingency define contingency as that part of a budget estimate of future costs (typically of large construction projects, information technology systems, or other items as approved by the federal awarding agency) which is associated with possible events or conditions arising from causes the precise outcome of which is indeterminable at the time of estimate, and that experience shows will likely result, in aggregate, in additional costs for the approved activity or project. Amounts for major project scope changes, unforeseen risks, or extraordinary events may not be included.

In addition to the performance measurement baseline and budget contingency, a project's not-to-exceed cost that the National Science Board authorized may include the following:

- **Fee.** NSF may provide recipients the opportunity to earn a fee for major facilities projects.
- Management reserve. NSF, not the award recipient, holds management reserve to manage budget uncertainties, unforeseeable events, and risks not manageable by the recipient (i.e. held by the agency). Management reserves are not a typical cost increase, and the inclusion of these reserves requires authorization from the National Science Board. The National Science Board has the authority to approve the total award amount, including any management reserve, but has currently delegated that authority to the NSF Director for requests up to the lesser of \$10 million or 20 percent of the award amount. Management reserve funds may come from reprogramming of funds within the MREFC account, transfer of funds to the MREFC account, or additional appropriations from Congress. After authorization, NSF does not disburse funds to the recipient until NSF has verified the specific needs for the reserve funding. In July 2020, NSF updated its guidance to add an authorization process for management reserve and clarify applicability of the NSF Director's delegated authority to major facilities.

## NSF's No Cost Overrun Policy for Major Facilities Projects

Since February 2008, NSF has had a policy to manage cost overruns on major facilities projects. <sup>7</sup> Under this policy, the cost estimate developed at the preliminary design review should have adequate contingency to cover all foreseeable risks. <sup>8</sup> Any cost increases not covered by contingency are generally to be accommodated by reductions in scope. <sup>9</sup> Figure 3 provides

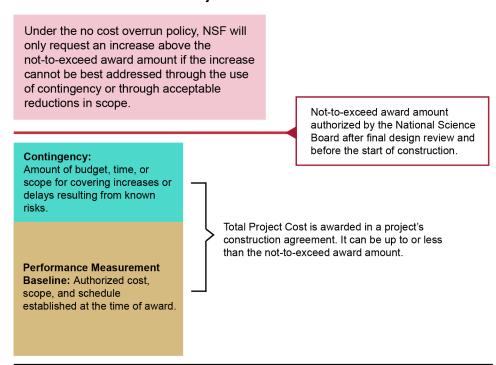
<sup>&</sup>lt;sup>7</sup>See GAO-18-370 for additional details on the history of this policy.

<sup>&</sup>lt;sup>8</sup>According to the September 2019 update to NSF's *Major Facilities Guide* (now the *Research Infrastructure Guide*), while the policy requires that the total project cost estimate established following the preliminary design review have adequate contingency to cover all foreseeable risks, NSF will conduct oversight of major facilities projects against the total project cost authorized by the National Science Board following final design review.

<sup>&</sup>lt;sup>9</sup>Reductions in scope differ from re-planning actions on a project. NSF's *Research Infrastructure Guide* defines re-planning as a normal project management process to modify or re-organize the performance measurement baseline cost or schedule plans for future work without affecting total project cost, project end date, or overall scope objectives or the implementation of approved de-scoping options.

a breakdown of the components that make up the total project cost and its relation to the not-to-exceed award amount.

Figure 3: Components of Total Project Cost in Relation to the Not-To-Exceed Award Amount for NSF Construction Projects



Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

Note: Figure does not include other components of the not-to-exceed award amount that the National Science Board may authorize, such as fees or management reserves.

Delays and Cost Increases Continued for Projects in Construction, but Design and New Project Approvals Were Not Interrupted Since our June 2021 report, NSF has continued construction on five major facilities projects—the Vera C. Rubin Observatory (Rubin Observatory), the Regional Class Research Vessels (RCRV), the Large Hadron Collider High Luminosity Upgrade (HL-LHC) program's ATLAS and CMS detector projects, and the Antarctic Infrastructure Modernization

for Science (AIMS). <sup>10</sup> After a series of delays, NSF also completed construction of a sixth project, the Daniel K. Inouye Solar Telescope (DKIST) (see table 2). <sup>11</sup> Because of the pandemic and other factors, all six projects experienced cost increases and schedule delays, or both. NSF's other research infrastructure projects—the Leadership Class Computing Facility (LCCF) major facilities project in design and all five mid-scale projects—progressed without significant interruption or cost increases. NSF also approved the Antarctic Research Vessel (ARV) major facilities project for entrance into the design stage in 2021, and authorized two new mid-scale projects for award—the Network for Advanced Nuclear Magnetic Resonance Spectroscopy (NAN) and Research Data Ecosystem (RDE).

Table 2: Status of NSF Major Facilities Research Infrastructure Projects in Construction or Recently Completed, as of March 2022

Project name	Percentage complete	Authorized not-to-exceed cost (dollars in millions)	Forecasted or actual construction completion date
Daniel K. Inouye Solar Telescope	100	363.0	November 2021
Vera C. Rubin Observatory	93	571.0	July 2024
Regional Class Research Vessels	46	375.0	July 2025
Antarctic Infrastructure Modernization for Science	31	410.4	January 2028
Large Hadron Collider High Luminosity Upgrade (CMS)	24	78.0	July 2026
Large Hadron Collider High Luminosity Upgrade (ATLAS)	22	75.0	January 2026

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

<sup>&</sup>lt;sup>10</sup>The HL-LHC is a major facilities program composed of two separate upgrade projects, the A Toroidal Large Hadron Collider Apparatus (ATLAS) and Compact Muon Solenoid (CMS) upgrade projects. Each upgrade project has its own total project cost, schedule, and scope that NSF manages and oversees.

<sup>&</sup>lt;sup>11</sup>In November 2021, the DKIST project completed construction 3.9 years (33.1 percent) behind schedule with a total project cost of \$363 million. In 2010, NSF made the original award for construction for a planned completion in December 2017 and a total project cost authorized by the National Science Board of \$297.9 million. In 2013, DKIST experienced a \$46.2 million cost increase, a 2.5-year schedule increase, and a \$5.9 million reduction in scope, due to permitting issues in Hawaii (see GAO-18-370). The final total project cost of \$363 million reflects a 21.9 percent increase of the original award amount.

## Cost or Schedule Increases Continued for Major Facilities in Construction

Factors in Addition to the COVID-19 Pandemic that Contributed to Cost and Schedule Increases in NSF's Major Facilities Projects in Construction

- The Vera C. Rubin Observatory project implemented new data security requirements for U.S. research facilities designed to enhance control of and track access to sensitive information, such as observation data, until it can be fully processed for public release.
- The Regional Class Research Vessels project shipyard had to pause operations for 4 weeks beginning in August 2021 because of the effects of Hurricane Ida, which damaged the shipyard and limited the availability of the local labor pool because of evacuations, among other things.
- The Antarctic Infrastructure Modernization for Science project schedule is limited by complexities with both on-ice construction and the delivery of construction material to the McMurdo Station, which can only occur during certain times because of severe weather conditions experienced during much of the year in the Antarctic.

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

All five of NSF's major facilities projects that were in construction as of March 2022—the Rubin Observatory, RCRV, HL-LHC (ATLAS and CMS), and AIMS—are experiencing cost increases, schedule delays, or both. As a result, all five of these projects will either be completely re-baselined or have their schedules extended and their costs increased. 12 NSF officials told us that the increased costs and delays are primarily because of the pandemic, though other factors have also contributed (see sidebar).

Cost increases for these five major facilities projects range from 7.6 to 21.0 percent of their total project costs since our June 2021 report. For example, the Rubin Observatory added \$98 million to its total project cost after re-baselining, which includes \$20 million in management reserve.

Schedule increases for these five major facilities projects have delayed their estimated completion dates by 10 to 22.4 percent since our June 2021 report, such as the 22-month extension included in the Rubin Observatory's re-baselined project schedule. However, only the Rubin Observatory and RCRV have implemented actual cost and schedule increases as of March 2022. NSF has decided not to fund certain components of the AIMS project and, as of March 2022, construction remains paused and re-baselining had not been completed. The cost and schedule increases for the remaining projects are only estimated at this time because the increases have not been finalized or those projects are undergoing more significant changes (see fig. 4).

<sup>&</sup>lt;sup>12</sup>NSF defines re-planning as a normal project management process to reorganize without affecting the total project cost, schedule or scope, which normally involves external panel review. Re-baselining is a re-planning that results in a change that is outside the terms set forth in the award for either the total project cost, the project duration, or the project scope that is not in the approved options for scope management.

<sup>&</sup>lt;sup>13</sup>According to NSF officials, the decision to not fund certain components of the AIMS project is not considered de-scoping as defined in financial assistance awards, as descoping may imply partial termination on a contract which NSF has not done in the case of AIMS.

2022 High Luminosity Upgrade Program (ATLAS) High Luminosity Upgrade Program (CMS) Vera C. Rubin Observatory Regional Class Research Vessels Antarctic Infrastructure Modernization for Science (AIMS) 100 300 400 500 600 200 Dollars in millions Projected Cost Increase Total Project Cost in June 2021 Actual Cost Increase since June 2021 since June 2021 report<sup>b</sup> High Luminosity Upgrade Program (ATLAS) High Luminosity Upgrade Program (CMS) Vera C. Rubin Observatory Regional Class Research Vessels Antarctic Infrastructure Modernization for Science (AIMS)<sup>a</sup> 25 75 100 125 150 Months Actual Schedule Increase Projected Schedule increase Construction Schedule in June 2021 since June 2021 since June 2021 report<sup>b</sup>

Figure 4: Projected and Actual Cost and Schedule Increases of NSF Major Facilities Projects in Construction, as of March

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

<sup>a</sup>The AIMS project is currently undergoing a re-baseline to continue construction on the two components of the project currently funded. According to NSF officials, the current project cost and schedule will remain the same until the re-baseline is complete.

<sup>b</sup>Estimated delays and cost changes represent NSF projections and are not officially part of the projects' current performance measurement baselines. For the Large Hadron Collider High Luminosity Upgrade program, NSF officials estimate that the change in cost may exceed 10 percent of each detector upgrade's original total project cost.

Actual Cost and Schedule Increases for the Rubin Observatory. As of March 2022, NSF officials had finalized changes to the Rubin Observatory's construction schedule. The National Science Board authorized a schedule extension of 22 months for the Rubin Observatory with an increased award amount of \$98 million (including \$20 million in management reserve), or approximately 21 percent of the total project cost reported in June 2021, primarily to respond to the effects of the pandemic. Although construction delays for the Rubin Observatory have also delayed planned research activities, researchers will still be able to observe major astronomical events, according to NSF officials. NSF

removed the Rubin Observatory from the Office of the Director's Watch List in May 2022.<sup>14</sup>

Planned Cost and Schedule Increases for RCRV and HL-LHC. As of January 2022, the RCRV project team had conducted re-planning in response to the pandemic, including a schedule extension of 9 months to the delivery of all three vessels. However, project re-baselining is not yet complete because the RCRV project team is still assessing the effects of Hurricane Ida at the project's shipyard. NSF removed the RCRV project from the Office of the Director's Watch List in May 2022. 15 Despite planned schedule increases, NSF officials stated that there are no effects to its oceanographic research programs as the agency is still using current vessels in operation for that purpose.

The two HL-LHC project teams (ATLAS and CMS) are in the process of obtaining sufficient cost information to define their re-baseline proposals. NSF officials estimate that the change in costs may exceed 10 percent of each detector upgrade's original total project cost. According to NSF officials, the research schedule for the Large Hadron Collider is driven by decisions at the European Council for Nuclear Research (CERN). Because of delays announced by CERN in January 2022, NSF officials

<sup>&</sup>lt;sup>14</sup>NSF uses the Watch List as a mechanism to provide enhanced oversight to any particular program or project and is not limited to major facilities projects. NSF applies criteria for adding projects to the Watch List, including whether a project (1) is experiencing a credible threat to its ability to meet its baseline cost or schedule, (2) has ongoing performance issues, or (3) constitutes a new, high-risk, large-scale endeavor for the agency. Furthermore, the Watch List is not meant to be punitive; rather it allows the agency to give increased attention to projects and certain events that may occur (e.g., severe adverse weather events or changes in major contractors). According to NSF officials, the agency decided to not include major facilities projects on the Watch List if effects of the pandemic were the only reason for increased oversight, as the agency is already providing oversight in response to the pandemic. We previously reported that NSF added the Rubin Observatory to the Office of the Director's Watch List to closely track updates on the project because of delays related to the telescope's dome enclosure and mount assembly.

<sup>&</sup>lt;sup>15</sup>In March 2020, NSF added RCRV to the Office of the Director's Watch List in response to shipyard performance issues. The project then remained on the Watch List because of a subsequent transition in shipyard ownership and its potential effect on the vessel delivery schedule, including delays and cost overruns for multiple vessels.

said they expect no effect to planned research as a result of pandemic-related delays to the HL-LHC detector upgrade projects.<sup>16</sup>

Planned Restructuring of AIMS. The effects of the pandemic on the AIMS project were significant enough that NSF has decided not to fund certain elements of project scope while maintaining a safe and stable condition at McMurdo Station—the construction site of the AIMS project where other research is ongoing. Effects of the pandemic, combined with complexities associated with the logistics of construction activities in Antarctica, have delayed construction for the AIMS project since March 2020. According to NSF documents, construction will likely not resume until October 2022. As a result, NSF determined that the cost of these delays made pursuing the AIMS project as originally planned untenable.

NSF will continue construction on two of the AIMS project's six components—a lodging facility and vehicle equipment operations center (see fig. 5)—which were funded and in construction prior to the pandemic. The construction award recipient for the AIMS project submitted a rebaseline proposal in July 2021 outlining a new cost and schedule for the project based on the components already funded, as requested by NSF. However, an independent cost and schedule review found that the proposal did not meet GAO best practices for cost and schedule estimating. For example, the project's proposal contained cost estimates that were not appropriately traceable or consistent across its project execution plan, and the review found no evidence to support that the project team considered GAO best practices when developing the project's schedule. As a result, NSF rejected the proposal and asked the award recipient to submit a new proposal, delaying a subsequent external panel review until December 2021. Based on the recommendations from that review, another round of proposals was submitted to NSF for consideration in March 2022. If the revised cost and schedule meet GAO best practices and other NSF requirements, NSF officials expect that award of additional funds could take place in June to support on-ice construction starting in October 2022.

<sup>&</sup>lt;sup>16</sup>In January 2022, CERN officially announced its plan to delay the next shutdown of operations at the LHC facility, Long Shutdown 3, by 1 year to the beginning of 2026 and extend it by 6 months for a total duration of 3 years. CERN approved the schedule extension to allow all project teams, including those not funded by NSF, to absorb pandemic-related schedule delays and complete installation of the ATLAS and CMS upgrades.

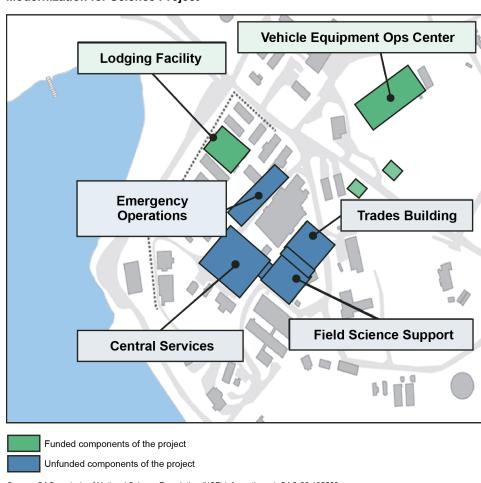


Figure 5: The Original Six Components of NSF's Antarctic Infrastructure Modernization for Science Project

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

According to NSF officials, the agency will consider integrating the remaining components of the project into a new Antarctic Infrastructure Recapitalization (AIR) program, which will provide a long-term funding mechanism for needed infrastructure investments for the U.S. Antarctic Program from NSF's MREFC account. According to NSF officials, the agency will manage the AIR program similar to how it manages the midscale research infrastructure program. NSF is currently developing guidance on how to manage and provide proper oversight for the program once the transition is made. NSF expects to determine the re-baselined cost of AIMS as well as future investments in projects funded through the AIR program in fiscal year 2022 as this transition is made. NSF's Office of

the Director added the AIMS project to its Watch List in May 2022 to support the project as it considers transitioning a majority of its scope to the AIR program and navigates the complex logistics of construction in Antarctica. According to NSF officials, no research projects or plans in Antarctica have been delayed because of the pause in construction of the AIMS project. McMurdo Station has been operating in reduced capacity under COVID-19 precautions. Project summaries for the AIMS project and all the projects in construction can be found in appendix II.

#### Projects in Design Continued and NSF Approved New Projects

Since our June 2021 report, NSF advanced the design of the Leadership Class Computing Facility (LCCF) without pandemic-related interruptions and approved the new Antarctic Research Vessel (ARV) for advancement to the design stage. Under NSF policy, a project's cost, scope, and schedule are not finalized until after the final design review, when the National Science Board authorizes a not-to-exceed cost and award duration. The not-to-exceed cost that the National Science Board eventually authorizes is the amount against which NSF measures cost increases to implement its no cost overrun policy.

NSF's Facilities Readiness Panel recommended that the LCCF project advance to the final design phase and the NSF Director approved that transition in April 2022. After postponing an initial review in October 2021, NSF held the LCCF project's preliminary design review in January 2022. According to NSF officials and project documents, NSF and the award recipient agreed to postpone the review so the project could ensure its cost estimates met GAO best practices and could support an independent cost estimate.

In addition, the NSF Director approved the ARV project to advance from conceptual design to the preliminary design phase in November 2021. The ARV project entered the design stage in June 2021 and its conceptual design review was held in September 2021. The ARV is intended as a replacement for an ice-breaking research vessel approaching retirement and is distinct in its size and capabilities from the three vessels being constructed under the RCRV project (see fig. 6). Further details on the two projects in design are located in appendix III.

Antarctic Research Vessel

Regional Class Research Vessel

Figure 6: Comparison of the Size of NSF's Planned Antarctic Research Vessel to a Regional Class Research Vessel

Source: National Science Foundation (NSF). | GAO-22-105550

Since our June 2021 report, NSF also awarded two new mid-scale projects—the Network for Advanced Nuclear Magnetic Resonance Spectroscopy (NAN) and Research Data Ecosystem (RDE)—from the MREFC account for a total of five active mid-scale projects in implementation (see table 3). The NAN project intends to address a national deficit in high-field nuclear magnetic resonance (NMR) capacity and promote broadened participation in the NMR spectroscopy research community. The RDE project intends to address access and management challenges regarding social and behavioral science data by developing software infrastructure designed to increase accessibility to data and collaboration between researchers. According to NSF officials, these midscale projects are funded through the MREFC account only during implementation, which is analogous to construction and acquisition on major facilities projects. There have been five such mid-scale projects funded so far from NSF's first solicitation. As of March 2022, only one mid-scale project, Distributed Energy Resources Connect, had submitted a supplemental funding request for \$2.4 million of the \$6.5 million NSF reserved from the American Rescue Plan to address pandemic-related effects to its mid-scale projects. Project summaries for the five mid-scale projects can be found in appendix IV.

Table 3: NSF's Mid-scale Research Infrastructure Projects, as of March 2022

Project Name	Awardee	Authorized Award Amount (dollars in millions)		Percentage Complete
Distributed Energy Resources Connect	University of California, San Diego	39.5	October 2025	20
Global Ocean Biogeochemistry Array	Monterey Bay Aquarium Research Institute	52.9	October 2025	10
High Magnetic Field Beamline	Cornell University	32.7	November 2025	15
Network for Advanced Nuclear Magnetic Resonance Spectroscopy	University of Connecticut Health Center	39.7	June 2025	10
Research Data Ecosystem	Regents of the University of Michigan	38.4	January 2027	0

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

In addition to the newly announced projects, NSF issued a solicitation to award a second round of mid-scale projects in December 2020. According to NSF documentation, NSF anticipates awarding two to six mid-scale projects totaling between \$150 million and \$200 million in fiscal year 2023. According to NSF officials, the pandemic has not delayed NSF's schedule for authorizing the next round of mid-scale awards.

NSF Developed and Followed Guidance for Responding to Pandemic-related Effects for Its Major Facilities Projects NSF developed guidance for how award recipients should respond to cost and schedule increases due to the pandemic. Since the start of the pandemic, major facilities projects in construction have faced work stoppages, delays in the delivery of material, and work inefficiencies because of COVID-19 safety protocols. All of these conditions contributed to cost and schedule increases. For example, the AIMS project has paused construction at the McMurdo Station in Antarctica since the pandemic began in March 2020 because of the complexities of the logistical chain and to prevent COVID-19 from spreading to the continent. NSF refers to unforeseen events, such as the pandemic, as "unknown unknowns," and risks related to those events are held by the agency since they could not have been identified during the design of each project.

NSF's existing policies identify five methods for addressing any potential cost increases during the construction of major facilities projects:<sup>17</sup>

- Re-planning. Re-planning is a process to modify cost and schedule plans for future work without affecting the authorized total project cost, duration, or overall scope objectives.<sup>18</sup>
- Use of contingency. Contingency is an amount of budget added to a
  project's cost estimate to allow for items, conditions, or events that
  experience shows will likely result in a cost increase. These events
  are typically known risks and uncertainties that projects may
  anticipate or identify as potential risks during the design stage.
- Use of management reserve. Management reserve is an amount of money authorized by NSF to address unforeseen events or uncertainties that are beyond the control of an award recipient or NSF. Management reserve is not for typical cost increases, and its use requires authorization from the National Science Board if the amount exceeds the NSF Director's delegated authority. After authorization and identification of a funding source, NSF does not disburse funds to the recipient until NSF has verified the specific needs for the reserve funding.
- De-scoping. De-scoping is the process of removing elements or objectives of a major facilities project. Prior to the construction of a major facilities project, the project team develops a scope management plan to identify potential elements or objectives that can be removed in a manner that minimizes negative effects to the project.
- Re-baselining. Re-baselining is a modification to the project cost, duration, or scope that results in a change beyond the amounts defined in the construction award or contract. Re-baselining generally requires NSF approval or National Science Board authorization and

<sup>&</sup>lt;sup>17</sup>According to NSF's *Research Infrastructure Guide*, the options to address cost increases are ranked in order of precedence and assume appropriate use in accordance with NSF's policy and practice.

<sup>&</sup>lt;sup>18</sup>Under NSF's no-cost overrun policy, the cost estimate developed during the preliminary design review should have adequate contingency to cover all foreseeable risks. Any cost increases not covered by contingency are to be accommodated by reductions in scope.

<sup>&</sup>lt;sup>19</sup>According to NSF officials, once management reserve is authorized, the value of the amount approved becomes a part of the total project cost, and may be obligated to the award as either baseline funding, budget contingency, or fee. The NSF Director may authorize management reserve up to his or her delegated authority of \$10 million or 20 percent, whichever is less.

can be used for other purposes, such as introducing new requirements or scope.

In new guidance developed in November 2020, NSF directed award recipients away from using budget contingency or reducing the scope of major facilities projects in construction to address cost and schedule increases related to the pandemic. NSF issued this guidance because these two options are typically used in response to known risks and uncertainties. For example, the Rubin Observatory used a portion of its budget contingency to address contaminated refrigeration lines on the telescope mount assembly. According to NSF officials, the agency did not want to de-scope major facilities projects to address cost and schedule increases related to the pandemic, as doing so would have negatively affected the scientific research potential for all the major facilities in construction.

Instead, NSF instructed award recipients to document the cumulative costs of risks realized because of the pandemic separately and use funds already obligated to the project to address those costs until NSF could identify supplemental funding or approve the use of other existing tools to respond to these unforeseen events. If a project cannot cover existing cost increases because of the pandemic with its current funding, NSF instructed award recipients to submit a supplemental funding request once they had sufficient information to support a cost analysis, which may include an expert panel review. Typically, these actions should only be used in rare circumstances and situations where such risks could not have been identified prior to construction. According to NSF officials, the agency had determined that the pandemic meets the definition of an unforeseen event.

NSF's new guidance directs award recipients to the use of management reserve, re-planning (re-budgeting), or re-baselining to address pandemic-related cost and schedule increases for the major facilities projects and ensure those projects can continue activities without using budget contingency or reducing scope. According to NSF officials, NSF and the award recipients followed this new guidance to respond to pandemic-related risks based on several factors, including a project's completion percentage, the availability of information for pandemic-related costs, and potential future effects of the pandemic on remaining construction activities. In some cases, NSF exercised multiple options to respond to these risks.

Management Reserves Used for DKIST, RCRV, and Rubin Observatory. NSF followed its guidance to authorize the use of management reserve for three projects. For example, the DKIST project team requested use of management reserve to respond to pandemic-related risks. At the start of the pandemic, the DKIST project was nearly complete with an expected completion date of June 2020. However, work stoppages resulting from the pandemic prevented the DKIST project team from completing remaining construction activities. NSF approved and the National Science Board authorized supplemental funding requests for the use of management reserve totaling \$9.5 million in February 2021 and \$9.4 million in June 2020. The project team made these separate requests to continue funding subcontracts necessary to complete the remaining construction activities, such as the instrumentation calibration.

NSF reprogrammed funds from the AIMS project to fulfill the management reserve needs for the DKIST project. According to NSF officials, the use of management reserve for the DKIST project was more appropriate than other available options because of the level of certainty regarding the project's pandemic-related costs and its proximity to completion. For example, the DKIST project's pandemic-related costs were primarily to extend subcontracts to support the remaining construction activities and salaries for support staff.

In December 2020, the NSF Director authorized \$14.1 million in management reserve for the RCRV project to respond to pandemic-related risks. In its request for supplemental funding, the RCRV project team identified several factors affected by the pandemic, including increased labor and materials costs for the construction of all three vessels totaling \$4.6 million and \$1.3 million, respectively. According to NSF officials, NSF applied funds appropriated by Congress from the American Rescue Plan to the management reserve authorized for the RCRV project. In addition to the request for funding submitted in 2020 to respond to the pandemic, the project team submitted an initial estimate of \$18.9 million to respond to the effects of Hurricane Ida. As of April 2022, NSF obligated the \$14.1 million for pandemic effects, but is still assessing the estimates related to effects of the Hurricane Ida.

Similar to the prior two projects, NSF authorized the use of \$42 million in management reserve for the Rubin Observatory to respond to pandemic-related and other risks (see table 4). Specifically, in fiscal year 2021, NSF authorized the use of management reserve for unforeseen risks attributed to the pandemic, such as the protection of equipment at the construction site and potential damage to the unfinished dome resulting from winter

storms. In December 2021, the National Science Board authorized additional management reserve for remaining pandemic risks as part of the re-baseline of the project. According to NSF officials, NSF reprogrammed \$10 million from the AIMS project to the Rubin Observatory for management reserve, with the remaining management reserve sourced from American Rescue Plan funds distributed to the agency's MREFC account.

Table 4: Management Reserves Authorized and Obligated to Major Facilities Projects, as of March 2022

Major facilities project	Amount of management reserve authorized (dollars in millions)	Amount of management reserve obligated to award recipients (dollars in millions)
Daniel K. Inouye Solar Telescope <sup>a</sup>	18.9	18.3
Regional Class Research Vessels	14.1	14.1
Vera C. Rubin Observatory	42.0	2.4

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

Re-planning Used for RCRV. The RCRV project's award recipient has re-planned the project to respond to both the pandemic and change in ownership of the shipyard where construction is taking place. According to NSF officials, the re-planning has resulted in a total schedule increase of 9 months. However, the project is still assessing the schedule increase resulting from the halted construction that lasted four weeks because of Hurricane Ida. According to NSF officials, the RCRV project did not require a re-baseline review to respond to pandemic-related cost increases because the increases were discrete, quantifiable, and able to be handled through a series of obligations as opposed to a reevaluation of the baseline.

**Re-baselining Used for Rubin Observatory and AIMS.** As of April 2022, NSF has required two projects to be re-baselined in accordance with the agency's guidance for responding to the pandemic. According to NSF documentation, the National Science Board approved a re-baselined total project cost for the Rubin Observatory project in December 2021, resulting in a \$78 million increase to the project's authorized award amount and an additional \$20 million in authorized management reserve. The re-baselined cost also includes a 22-month extension for the project's

<sup>&</sup>lt;sup>a</sup>NSF completed construction in November 2021 and does not expect to obligate additional management reserves.

construction schedule. As stated above, the National Science Board authorized a total of \$42 million in supplemental funding from NSF management reserve for the Rubin Observatory project to address immediate pandemic-related cost increases and support the project through the re-baselining review and authorization process. According to NSF documentation, the award recipient had since obtained sufficient cost information to estimate risks associated with the pandemic and submit a re-baseline proposal for the Rubin Observatory project.

The Rubin Observatory project's re-baselined total project cost also incorporated new security requirements for the site's observation data that were established after the National Science Board had authorized the original award amount. According to NSF officials, these new requirements alone would have required a supplemental funding request to address since NSF would not have reduced the scope of the Rubin Observatory to fund the new requirements, nor would the use of budget contingency have been appropriate.

In addition, according to NSF officials, the agency is in the process of rebaselining the AIMS project to include only the construction on the two components of the project started prior to the pandemic. The AIMS project team has paused construction activities at the McMurdo Station in Antarctica because of the pandemic to prevent COVID-19 exposure to the current research activities in progress at the station. Because of both the pandemic and the complex logistics needed to support construction, NSF decided that a long-term plan composed of smaller construction activities is more suitable for the U.S. Antarctic Program. 20 Since the total project cost and project schedule authorized by the National Science Board represents all the original components of the AIMS project, NSF requested that the AIMS project team submit a proposal to re-baseline the project with the new scope. However, re-baselining has taken additional time because of independent reviews conducted in October and December 2021 that found that the project team's cost and schedule estimates were insufficient and did not meet GAO's best practices.21 In

<sup>&</sup>lt;sup>20</sup>The other components not yet started under AIMS will be considered for inclusion in NSF's new Antarctic Infrastructure Recapitalization (AIR) program, which will be a separate program within the MREFC account to fund future construction work for the U.S. Antarctic Program.

<sup>&</sup>lt;sup>21</sup>We previously reported that NSF's procedures for overseeing major facilities projects did not fully or substantially meet all 12 best practices in GAO's cost estimating guide and recommended that NSF revise its policies to better incorporate those best practices, which NSF implemented in 2020.

March, NSF received a new re-baseline proposal from the AIMS project team and expects to continue with its review and potential approval of the re-baseline in June 2022, according to NSF officials.

# NSF Implemented Two Recommendations on Revising Its Guidance Documents and Took Steps to Address Another

Since our June 2021 report, NSF has taken steps to address the three remaining recommendations from our June 2018 and March 2019 reports on the management of its major facilities projects. Specifically, NSF has revised its guidance to include information on using best practices to develop project schedules and criteria for assessing the project management expertise of award recipients. These actions address two of our prior recommendations. In addition, NSF has taken further steps to address, but has not fully implemented, an additional recommendation related to project management competencies for its workforce.

NSF Revised Its Policies for Developing Schedules and for Project Management Expertise for Award Recipients

NSF revised its policies and guidance for developing project schedules and for establishing criteria against which the agency can assess project management expertise of its award recipients for major facilities projects.

**Policies for developing schedules.** In December 2021, NSF revised the *Research Infrastructure Guide*, the agency's main guidance document for oversight, to include a new section on developing schedules that incorporates best practices in GAO's schedule guide.<sup>22</sup> In addition, NSF updated internal guidance requiring the agency to analyze proposed schedules. These actions address a recommendation from our June 2018 report. In that report, we found that NSF substantially met one of the 10 best practices for developing project schedules, partially or minimally met six best practices, and did not meet three best practices. We recommended that NSF revise its policies for developing project schedules for major facilities projects, and for reviewing those schedules, to better incorporate best practices in GAO's schedule guide.<sup>23</sup>

In our current assessment of the revised guidance and policy documents, we found that NSF substantially met the nine best practices for developing project schedules that we previously found that NSF partially

<sup>&</sup>lt;sup>22</sup>GAO, Schedule Assessment Guide: Best Practices for Project Schedules, GAO-16-89G (Washington, D.C.: December 2015).

<sup>&</sup>lt;sup>23</sup>GAO-18-370.

met, minimally met, or did not meet (see table 5).<sup>24</sup> For example, in 2018 we found that NSF partially met the best practice of capturing all activities because its policies and procedures describe some best practices for capturing all activities. Our updated analysis shows that NSF now substantially meets the best practice since the *Research Infrastructure Guide* requires that a schedule must include all the activities to complete the full scope of the project.

Table 5: Updates to GAO's Assessment of the National Science Foundation's (NSF) Policies Against Best Practices for Developing Project Schedules

Best practices	Original assessment (June 2018) <sup>a</sup>	Current assessment, as of March 2022
Capturing all activities	Partially met	Substantially met
Sequencing all activities	Minimally met	Substantially met
Assigning resources to all activities	Partially met	Substantially met
Establishing the durations of all activities	Not met	Substantially met
Verifying that the schedule can be traced horizontally and vertically	Minimally met	Substantially met
Confirming that the critical path is valid	Not met	Substantially met
Ensuring reasonable float	Not met	Substantially met
Conducting a schedule risk analysis	Substantially met	Not assessed
Updating the schedule using actual progress and logic	Minimally met	Substantially met
Maintaining a baseline schedule	Partially met	Substantially met

Source: GAO analysis of NSF information | GAO-22-105550

Note: Fully met: NSF provided complete evidence that satisfies the elements of the best practice; Substantially met: NSF provided evidence that satisfies a large portion of the elements of the best practice; Partially met: NSF provided evidence that satisfies about half of the elements of the best practice; Minimally met: NSF provided evidence that satisfies a small portion of the elements of the best practice; Not met: NSF did not provide any evidence that satisfies the elements of the best practice.

We did not address the best practice on conducting a schedule risk analysis since NSF substantially met the best practice in 2018.

<sup>a</sup>Assessment based on GAO, *National Science Foundation: Revised Policies on Developing Costs and Schedules Could Improve Estimates for Large Facilities*, GAO-18-370 (Washington, D.C.: June 1, 2018).

Project management expertise of award recipients for major facilities projects. NSF has taken several actions to ensure project management expertise among award recipients of major facilities projects. In 2019, we found that while NSF had some procedures in place

<sup>&</sup>lt;sup>24</sup>We did not address the best practice on conducting a risk analysis since NSF substantially met this practice in 2018.

to ensure award recipients of major facilities projects have project management expertise, NSF did not establish criteria for project management expertise needed by recipients or how they should demonstrate it.<sup>25</sup> We recommended that NSF should establish criteria for project management expertise of award recipients and incorporate the criteria in project requirements and external panel reviews.

NSF has taken appropriate steps to address our recommendation and ensure project management expertise of award recipients of major facilities projects. For example, NSF's updated Research Infrastructure Guide includes a new section on project management expertise of award recipients. The new guidance issued in December 2021 identifies key personnel and competency requirements for management of major facilities projects, along with descriptions of each type of personnel and competency. For example, the guidance identifies project management, program management, earned value management, and risk management as several key competencies required for award recipients. In addition, NSF issued internal guidance in June 2022 that requires external panel reviews to assess project management expertise of award recipients in the areas identified by the Research Infrastructure Guide. According to NSF officials, NSF had been informally using these requirements. For example, the review of the re-baseline for the AIMS project and the preliminary design review for the LCCF project both included an analysis of project management expertise for their respective recipients. The agency's actions demonstrates sufficient actions to implement this recommendation.

NSF Has Taken Additional Steps to Address the Remaining Recommendation on Major Facilities Projects

NSF has taken additional steps to evaluate the project management competencies of its oversight staff. In our 2019 report, we found that NSF identified project management competencies for key positions of its oversight staff, but the agency had not yet assessed any potential competency gaps among its staff or established a timeframe for doing so. We recommended that NSF assess the agency's oversight workforce to identify any competency gaps, develop a plan to address them and timeframes for doing so, and monitor progress in closing them.

Since then, NSF has taken some steps to identify, address, and monitor competency gaps but has not yet fully addressed the recommendation. For example, in April 2020 we reported that NSF hired a contractor to

<sup>&</sup>lt;sup>25</sup>GAO-19-227.

develop a competency model and identify competency gaps through a proficiency assessment and workforce gap analysis. 26 While the analysis found certain individuals had gaps in certain areas such as award management, project management, and risk management, among others, the results showed that the NSF's project teams as a single group possessed the competencies expected. According to NSF officials, NSF is using the results of the analysis to address these gaps by developing a course curriculum tool that generates individual training plans for its major facilities oversight staff. The competency model will be used as a basis for monitoring project management competencies of oversight staff during individual assessments. In addition, NSF has also revised standard operating guidance that defines the minimum core competencies for oversight of major facilities projects to incorporate the competency model. According to NSF officials, the course curriculum tool has been tested and will be available for use by NSF staff in the third quarter of fiscal year 2022. We will continue to review NSF's progress for this recommendation.

## **Agency Comments**

We provided a draft of this report to NSF for review and comment. NSF provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Director of the National Science Foundation, and other interested parties. In addition, the report is available at no charge on the GAO website at <a href="https://www.gao.gov">https://www.gao.gov</a>.

If you or your staff have any questions about this report, please contact me at (202) 512-6888 or WrightC@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs May be found on

<sup>&</sup>lt;sup>26</sup>NSF is taking these actions to concurrently implement the Program Management Improvement Accountability Act, Pub. L. No. 114-264, § 2(b)(1), 130 Stat. 1371, 1372-74 (2016) (codified as amended at 31 U.S.C. § 1126).

the last page of this report. GAO staff who made key contributions to this report are listed in Appendix V.

Candice N. Wright

Director, Science, Technology Assessment, and Analytics

Candice N. Weight

# Appendix I: Objectives, Scope, and Methodology

The Consolidated Appropriations Act, 2021, Senate Report 115-275, Senate Report 114-239, and House Report 114-605, included provisions for GAO to review projects within NSF's MREFC account, which includes major facilities and mid-scale projects. This report (1) describes the cost and schedule performance of the National Science Foundation's (NSF) ongoing major facilities and mid-scale research infrastructure projects, (2) evaluates the extent to which NSF has followed its policies and guidance to respond to COVID-19 pandemic-related risks for its major facilities projects, and (3) describes the extent to which NSF has implemented prior GAO recommendations related to its management of its research infrastructure projects.

To describe the cost and schedule performance of NSF's major facilities research infrastructure projects since our 2021 report, we reviewed project documents and NSF's written responses to our questions about projects which were under construction and in design. We reviewed, for example, cooperative agreements, progress reports, risk reports and risk registers, documentation on available scope reduction options, and other NSF, award recipient, and external panel project documents, as applicable, related to project cost, schedule, scope, and risks. The construction projects include the Daniel K. Inouye Solar Telescope (DKIST), the Vera C. Rubin Observatory (Rubin Observatory), the Regional Class Research Vessels (RCRV), the Antarctic Infrastructure Modernization for Science (AIMS), and the Large Hadron Collider High Luminosity Upgrade (HL-LHC) program's ATLAS and CMS detectors. The two projects in design at the time of our review included the Leadership Class Computing Facility (LCCF) and Antarctic Research Vessel (ARV).

To describe the cost and schedule performance of NSF's MREFC-funded mid-scale research infrastructure projects since our 2021 report, we also reviewed NSF and award recipient documents that detailed project cost, schedule, and risks for each of those projects. These mid-scale projects include the Distributed Energy Resources Connect (DERConnect), the Global Ocean Biogeochemistry Array (GO-BGC), the High Magnetic Field (HMF) Beamline, the Network For Advanced Nuclear Magnetic Resonance (NAN), and the Research Data Ecosystem (RDE).

<sup>&</sup>lt;sup>1</sup>The Consolidated Appropriations Act, 2021, makes reference to the explanatory statement containing the mandate, printed in 166 Cong. Rec. H8311 (Dec. 21, 2020). Pub. L. No. 116-260, § 4, 134 Stat. 1182, 1185 (2020).

We assessed the reliability of project data by obtaining supporting documentation when possible, conducting routine checks for consistency with other information contained in the documentation provided by NSF, and clarifying any discrepancies with NSF project officials. Through this process, we determined that the project data were sufficiently reliable for our purpose of describing information available on the projects' cost and schedule performance and current status.

To evaluate the extent to which NSF has followed its policies and guidance to respond to COVID-19 pandemic-related risks for its major facilities projects, we reviewed NSF's policies and procedures for managing and providing oversight for major facilities projects to identify available options NSF has to respond to unforeseen events, such as the COVID-19 pandemic. In addition, we reviewed new guidance that NSF developed specifically to respond to the COVID-19 pandemic. We then reviewed NSF project documentation, such as monthly progress reports and project memos, to identify the actions NSF and the award recipient took to respond to the COVID-19 pandemic. Specifically, we reviewed the documentation to determine how (1) NSF followed the available options identified in policies and guidance, such as the use of management reserves; and (2) how NSF and the award recipients followed NSF policies and procedures for managing and providing oversight.

To describe the extent to which NSF has implemented the three recommendations from two prior GAO reports on NSF major facilities that have not been implemented as of June 2021, we reviewed NSF policies and procedures and other relevant documentation related to the actions the agency took to implement these recommendations.<sup>2</sup> For our recommendation on revising policies for project schedules of major facilities to incorporate best practices in GAO's schedule guide, GAO staff with project scheduling expertise compared the updated procedures documented in NSF's policies with the best practices.<sup>3</sup> In comparing NSF's procedures to best practices in GAO's schedule guide, we used the following ratings:

• "Fully met" means there was complete evidence that satisfied the entire best practice.

<sup>&</sup>lt;sup>2</sup>GAO-18-370 and GAO-19-227.

<sup>&</sup>lt;sup>3</sup>GAO-16-89G.

Appendix I: Objectives, Scope, and Methodology

- "Substantially met" means there was evidence that satisfied a large portion of the best practice.
- "Partially met" means there was evidence that satisfied about half of the best practice.
- "Minimally met" means there was evidence that satisfied a small portion of the best practice.
- "Not met" means there was no evidence that satisfied any of the elements of the best practice.

We took additional steps to assess NSF's implementation of a recommendation on project management competencies of NSF staff. We also interviewed NSF officials to discuss NSF's ability to implement the remaining recommendation, as well as their estimated timeframe for completion.

## Appendix II: Summaries of the National Science Foundation's Major Facilities Projects under Construction

This appendix provides individual summaries of the National Science Foundation's (NSF) four major facilities projects that are under construction: (1) the Vera C. Rubin Observatory, (2) the Regional Class Research Vessels, (3) the Antarctic Infrastructure Modernization for Science, and (4) the Large Hadron Collider High Luminosity Upgrade Program.

Each project's summary is based on project documents and other information that NSF officials provided and includes the following:

- an overview of the project and its purpose;
- a timeline identifying key project dates, including the date of the original construction award, which we report as the start of construction;<sup>1</sup>
- project information, such as the project's scheduled completion date for construction (including schedule contingency), the type and latest amounts of the awards for construction, the responsible NSF directorate; project partners; and expected duration of operations;
- table summarizing the project's current status and its cost and any cost<sup>2</sup> or schedule<sup>3</sup> increases or scope reductions made under NSF's no cost overrun policy and changes since our June 2021 report;<sup>4</sup>
- a summary of the project's cost and schedule performance history; and
- information on remaining project risks and potential for cost or schedule increases, including the amount of remaining contingency and scope reduction options.<sup>5</sup>

<sup>&</sup>lt;sup>1</sup>Costs are reported in then-year dollars, which means that NSF or the recipient converted base-year dollars by applying an inflation index. According to NSF policy, inflation is a part of NSF's budgeting and project planning.

<sup>&</sup>lt;sup>2</sup>NSF measures cost increases against the not-to-exceed cost that the National Science Board authorized under the agency's no cost overrun policy. Therefore, we define cost increases since starting construction as increases to the not-to-exceed cost that the Board authorized.

<sup>&</sup>lt;sup>3</sup>We identified schedule increases by comparing the project's scheduled completion date in the construction award as of December 2021 with the scheduled completion date in the original construction award. When a project's scheduled completion date was not identified in the award, we used the expiration date of the award.

<sup>&</sup>lt;sup>4</sup>GAO, *National Science Foundation: COVID-19 Affected Ongoing Construction of Major Facilities Projects*, GAO-21-417 (Washington D.C.: June 8, 2021).

<sup>&</sup>lt;sup>5</sup>We report each project's estimate of remaining risk exposure as weighted by the recipients for the probability of the risks occurring. According to NSF's *Research Infrastructure Guide*, risk exposure is the quantitative effect of risks. We report the risk exposure as determined by the Monte Carlo method when available.

#### VERA C. RUBIN OBSERVATORY

The National Science Foundation's (NSF) Vera C. Rubin Observatory (Rubin), an 8.4-meter, wide-field optical telescope, will initially be used to image the entire visible southern sky—every 3 days for a decade—using the world's largest digital camera (3 billion pixels). Built on a mountaintop in Chile, a location with pristine skies, the telescope will collect data and images to chart billions of galaxies and increase knowledge about potentially hazardous asteroids, dark matter, and energy. Rubin has the potential to advance every field of astronomical study, from the inner solar system to the large-scale structure of the universe. Its former name was the Large Synoptic Survey Telescope (LSST).



	Design	<b>&gt;</b>	Construction		Operations	
2003	2013	2014	2018	2025	2070s	
Start of	Final design	Construction	Operations	End of construction/	End of	
design	review	award	award	start of full operations	operations	
Source: GAO analysis of National Science Foundation (NSF) information,   GAO-22-105550						



Source: National Science Foundation (NSF). | GAO-22-105550

## **∳**√x

#### Responsible NSF directorate:

• Mathematical and Physical Sciences.



#### Construction award:

 Cooperative support agreements with the Association of Universities for Research in Astronomy, Inc., consisting of 42 U.S. institutional members and three international affiliates.



#### Project partners:

• The LSST Corporation, Department of Energy.



Expected construction completion date, including schedule contingency:

• July 2024.



#### Expected duration of operations:

• 30+ years.

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

#### **Project Status**

As of March 2022, the Rubin project was 93 percent complete and in its eighth year of construction. Although improved COVID-19 pandemic conditions enabled the project to advance construction on the telescope mount assembly since our June 2021 report, the recent Omicron variant has affected productivity at the construction site and contributed to additional delays. However, now that construction has progressed and pandemic-related risks for the Rubin project are better understood, NSF has approved a re-baselined project schedule with an extension of 22 months, which includes 7 months as schedule contingency. The rebaseline approval also added \$98 million to the total project cost, which includes \$20 million in management reserve to address future unknown risks associated with the pandemic. According to NSF officials, the Rubin project now expects to complete construction by July 2024 with 90 percent confidence. In addition to addressing pandemic-related effects, the rebaseline also addressed new data security requirements for overseas infrastructure to protect data transmitted from the site's location in Chile.

Construction Status of the Vera C. Rubin Observatory, as of January 2022				
Percentage complete		93		
		<b>Dollars in millions</b>		
Not-to-exceed cost that the National So	cience Board authorized	571.0		
Total project cost in latest construction	awards	551ª		
National Science Foundation (NSF) fur	nding obligated to date	461.8		
Changes in Cost, Schedule, and	Scope			
Dollars in millions				
	Cumulative changes since original construction award	Changes since June 2021		
Not-to-exceed cost that the National	+98 ▲	+88 🔺		
Science Board authorized				
Total project cost <sup>b</sup>	+83.2 ▲	+79.8 🔺		
Scope <sup>c</sup>	-1.2 ▼	+8.3 ▲		
Scheduled Completion date (months)	+22 ▲	+22 ▲		

Legend: ▲ = cost or schedule increase; ▼= scope reduction.

Source: GAO analysis of NSF documents and information from NSF officials. | GAO-22-105550

<sup>a</sup>Excludes the \$20 million in management reserve authorized, but not yet obligated, in the Rubin project's re-baselined total project cost.

<sup>b</sup>This change reflects the project's 2021 re-baseline, less the \$20 million in authorized management reserve, and includes a prior change made after the original construction award.

°Scope changes included are reductions in response to NSF's policy on no cost overruns at initial award or to increase the available budget contingency, as well as the incorporation of new data security requirements.

#### **VERA C. RUBIN OBSERVATORY (CONT.)**

#### **Latest Construction Award**

Total project cost, in millions, as of January 2022



Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

Notes: Excludes fee of \$1.1 million provided to the recipient to stimulate efficient performance.

## Remaining Contingency and Scope Reduction Options

As of March 2022.

#### **NSF Management Reserve:**

\$42 million, prior to re-baseline.

#### **Budget contingency:**

\$21.5 million (\$500 thousand less than the probability-weighted risk exposure of \$22 million).

#### Schedule contingency:

7.25 months.

### Estimated value of remaining scope reduction options:

\$4 million.

Source: NSF documents and officials. | GAO-22-105550

## NSF Breakdown of the Costs Included in the Rubin Project's Re-baseline Proposal

Value (dollars in n	Value (dollars in millions)	
Original not-to-exceed cost authorized by the National Science Board	473.0	
COVID-19: Additional Baseline	60.7	
COVID-19: Additional Contingency	8.2	
COVID-19: Additional Fee	0.6	
Data Security: Additional Baseline	8.5	
Subtotal	551.0	
Future NSF-held Risks: Management Reserve	20.0	
Revised total project cost	571.0	

Source: National Science Foundation (NSF) documents and officials. | GAO-22-105550

#### Contributions of Project Partners

The U.S. Department of Energy (DOE), a cosponsor of the Vera C. Rubin Observatory is responsible for delivering the camera at a cost of \$168 million. SLAC National Accelerator Laboratory manages a collaboration of DOE national laboratories and universities to develop, fabricate, and deliver the camera. The COVID-19 pandemic also affected camera fabrication. The camera had 2 months of schedule float as of December 2021, but the Rubin project's mitigation plan will potentially add 3 to 5 months, delaying the project's critical path by 2 months.

Source: GAO analysis of NSF and DOE information. | GAO-22-105550

#### **Cost and Schedule Performance History**

In December 2021, the National Science Board authorized a cost increase of \$98 million for the Rubin project, which includes an additional \$20 million in management reserve for future pandemic-related costs. The new total project cost of \$571 million authorized by the National Science Board through the project's re-baseline will address pandemic-related effects as well as new data security requirements (see sidebar). According to NSF officials, NSF will fund a portion of the cost increase by using funding appropriated by Congress to the agency through the American Rescue Plan Act of 2021. As of our review, NSF anticipates awarding the project to reflect the new total project cost in April 2022 and is currently conducting a cost analysis of the revised re-baseline proposal. Prior to the award, NSF will obligate supplemental funding to the project from previously authorized management reserves to address immediate needs and support the project through the re-baselining process.

In addition, the Rubin project will use approximately \$8.5 million to address new data security requirements instituted after the Rubin project completed its design stage. According to NSF officials, these data security requirements would strengthen the security of observation data transmitted from the telescope's location in Chile. Thus, the project team could not implement these requirements without reducing the scope of the project. However, since these requirements constitute an unforeseen risk for the project team, NSF officials said the agency decided to incorporate the data security requirements as part of the re-baseline rather than asking the project to de-scope or use budget contingency.

#### Remaining Project Risks and Potential for Cost or Schedule Increases

As of February 2022, the project had an estimated remaining risk exposure of \$31.6 million for non-pandemic-related risks, which is \$10.1 million more than the remaining budget contingency of \$21.5 million. According to project documents, factoring in actions to mitigate these risks lowers the expected risk exposure to \$22 million. NSF will address any future pandemic-related costs through the \$20 million in newly-authorized management reserve, which requires NSF approval for use. The largest non-pandemic-related risks include delays to subsystem integration and late delivery of the DOE-funded camera.

In accordance with NSF policy, the project maintains a list of scope reduction options. As of March 2022, there was approximately \$4 million in total possible project scope reduction options remaining. As the project moves toward completion, fewer scope reduction options will be available. The Rubin project was removed from the NSF Office of the Director's Watch List in May 2022.

#### REGIONAL CLASS RESEARCH VESSELS

The National Science Foundation's (NSF) Regional Class Research Vessels (RCRV) project will construct three 199-foot vessels to support the nation's ability to conduct fundamental scientific research in the coastal zone and continental shelf, including from the ocean's surface through the water column to the sea floor and subsea floor environment. These vessels will provide enhanced capabilities beyond those of the retiring vessels they will replace. The three vessels' research locations will depend on where the science demand is greatest, but the vessels will have home ports in Oregon, Rhode Island, and Louisiana now that the operating institutions have been selected.



De	sign	<b>&gt;</b>	Co	nstruction		perations
	<b>A</b>					
2012	2016	2017	Sept 2019	Jan 2021	2025	2050s
Start of design	Final design review	Construction award	Start of construction for second ship	Start of construction for third ship	End of construction for all three ships and start of full operations	End of operations
Source: GAO analysis of N	ational Science Foundation	n (NSF) information	.   GAO-22-105550			



Source: Artist Rendering by Glosten. | GAO-22-105550

#### **Project Status**

As of January 2022, construction of NSF's RCRV project was 46 percent complete and the project was in its fifth year of construction. Since our June 2021 report, the RCRV project has continued to experience delays because of the COVID-19 pandemic and a change in shipyard ownership. As a result, the project recently underwent re-planning, resulting in a total delay of 9 months to the project and obligation of an additional \$14.1 million in funding from NSF-held management reserve. According to NSF officials, the RCRV project will be further re-planned to account for the effects of Hurricane Ida, which disrupted operations at the shipyard in August 2021 and adversely affected the regional labor pool.



#### Responsible NSF directorate:

Geosciences.

#### Construction award:

 Cooperative support agreement with Oregon State University, which contracted with Gulf Island Shipyards, LLC, that was acquired by Bollinger Houma Shipyards, LLC.



 The U.S. Navy supported initial design oversight for the vessels.

Scheduled construction completion date, including schedule contingency:

• July 2025 for three vessels.

Expected duration of operations:

30 years.

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

<b>Construction Status of the Regio</b>	nal Class Research Vessels	project, as of
March 2022		
Percentage complete		46
		Oollars in millions
Not-to-exceed cost that the National Sc	cience Board authorized	375.0
Total project cost in latest construction	awards	371.4
National Science Foundation (NSF) fun	iding obligated to date	368.0
Changes in Cost, Schedule, and	Scope	
Dollars in millions	•	
	Cumulative changes since	Changes since
	original construction award	June 2021
Not-to-exceed cost that the National	+10 ▲	None
Science Board authorized		
Total project cost	+17.4 ▲	+11.9 🔺
Scope <sup>a</sup>	None	None
Scheduled Completion date (months)	+9 ▲	+3 🛕

Legend: ▲ = cost or schedule increase.

Source: GAO analysis of NSF documents and information from NSF officials. I GAO-22-105550

<sup>&</sup>lt;sup>a</sup>Scope changes included are reductions in response to NSF's policy on cost overruns or as part of a cost increase.

#### **Latest Construction Award**

Total project cost, in millions, as of March 2022



Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

Note: Percentages do not sum to 100 percent because of rounding.

## Remaining Contingency and Scope Reduction Options

As of January 2022 with construction 46 percent complete.

#### **NSF Management Reserve:**

\$14.1 million.

#### **Budget contingency:**

\$22.1 million (\$8.3 million more than the probability-weighted risk exposure of \$13.8 million).

#### Schedule contingency:

3.1 months.

## Estimated value of remaining scope reduction options:

\$4.9 million.

Source: NSF documents and officials. | GAO-22-105550

#### **Cost and Schedule Performance History**

In January 2022, the RCRV project completed initial re-planning efforts in response to the pandemic and change in shipyard ownership, which together have extended the scheduled delivery date by 10 months for vessels 1 and 2, and 9 months for vessel 3. As a result, the project's overall construction schedule increased by 9 months. According to NSF officials, the pandemic has caused worksite inefficiencies and led to delays in developing schedule plans and technical drawings used by the shipyard. We reported in June 2021 that NSF authorized \$14.1 million in management reserves for the RCRV project to address pandemic-related costs. According to NSF documents, the project completed negotiations between the shipyard and award recipient in January 2022 and submitted a supplemental funding request for almost all of its authorized management reserves to cover pandemic-related costs. The \$14.1 million in supplemental funding was awarded in March 2022.

The RCRV project is also considering additional re-planning to respond to effects of Hurricane Ida. On August 29, 2021, the category 4 hurricane shut down operations at the Bollinger Houma Shipyard for 4 weeks and devastated the local area which created a severe labor shortage in the region around the shipyard. As of January 2022, NSF was analyzing the RCRV project team's estimates for the effects for Hurricane Ida on the project's cost and schedule. The project team estimated a cost increase of \$18.9 million and schedule delay of 6 months, but the actual cost and schedule effects of Hurricane Ida may increase because of the protracted labor shortage. According to NSF officials, the agency expects the replanning process to continue into mid-2022.

Including estimated delays because of Hurricane Ida, vessel delivery has slipped from September 2022 to August 2023 for the first vessel; from March 2023 to February 2024 for the second vessel; and from August 2023 to July 2024 for the third vessel.

#### Remaining Project Risks and Potential for Cost or Schedule Increases

Unlike other major facilities projects, which are typically funded incrementally across several years, the total requested funds for RCRV were provided at the beginning of construction. According to NSF officials, this has provided the project with the necessary funding to deal with the initial contract modifications and other actions to continue construction without the need for additional obligations. In addition, a re-baseline review has not been necessary because pandemic-related cost increases have been handled through discrete obligations from NSF-held management reserve. However, with all available management reserve expended under the Director's delegated authority, NSF officials said the National Science Board will need to be engaged for increases to RCRV's total project cost resulting from Hurricane Ida.

As of January 2022, the project had an estimated remaining risk exposure of \$13.8 million for non-pandemic-related risks and a remaining contingency of \$22.1 million. Because of the project team's re-planning efforts with the new shipyard owner, the risks associated with shipyard performance have decreased. Nonetheless, potential issues with the transition to operations remain a risk to completing the project on time and budget. As of November 2021, the RCRV project had implemented one scope reduction option, leaving 15 remaining scope reduction options.

#### ANTARCTIC INFRASTRUCTURE MODERNIZATION FOR SCIENCE

The National Science Foundation's (NSF) Antarctic Infrastructure Modernization for Science (AIMS) project will modernize the core infrastructure of McMurdo Station in Antarctica, the largest of three stations operated by NSF's United States Antarctic Program and used by multiple agencies. McMurdo Station serves as a logistics hub for remote field sites and for the Amundsen-Scott South Pole Station. The AIMS project is expected to make environmental and safety upgrades to McMurdo Station and redevelop it into a more compact, operationally and energy-efficient core facility to support research. The planned core facility will consolidate critical buildings, such as medical facilities and field science support.



	Design			Construction			Operations
		<b>A</b>					
2014	2	018 2	2019	2022-2026		2028	2063 - 2078
Start of design		design Cons view av	struction wards	Phased start of operations	cc	End of onstruction	End of operations

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550



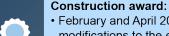
Source: Leidos. | GAO-22-105550

Note: Rendering of McMurdo Station's core facility.



#### Responsible NSF directorate:

Geosciences.



 February and April 2019 modifications to the existing Antarctic support contract with Leidos Innovations Corporation.



#### Project stakeholders:

 Other federal agencies—such as the National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and the Department of Energy.



**Expected construction completion** date, including schedule contingency:

· January 2028.



#### **Expected duration of operations:**

35 to 50 years.

Source: GAO analysis of National Science Foundation (NSF) information.

#### **Project Status**

Construction of the AIMS project was about 31 percent complete as of February 2022. Although some domestic construction activities have continued, the COVID-19 pandemic caused a delay in on-ice construction at McMurdo Station from March 2020 through October 2022. Because of these delays, NSF decided to continue construction on two of the components (a lodging facility and vehicle equipment operations center) and potentially fund the other four components through a new program the Antarctic Infrastructure Recapitalization (AIR) program—proposed under NSF's Major Research Equipment and Facilities Construction (MREFC) account. NSF received the contractor's re-baseline proposal to reflect these decisions in March 2022. According to NSF officials, until the re-baseline process is completed the cost and schedule for the AIMS project will be based on the original project scope. The AIMS project was added to the NSF Office of the Director's Watch List in May 2022.

Construction Status of the Antarctic Infrastructure Modernization for Science, as of February 2022				
Percentage complete	31			
-	Dollars in millions			
Not-to-exceed cost that the National Science Board authorized	410.4			
Total project cost in latest construction awards	389.6			
National Science Foundation (NSF) funding obligated to date 155.5				
Source: GAO analysis of NSF information.   GAO-22-105550				

#### **Latest Construction Award**

Total project cost, in millions, as of February 2022



Source: GAO analysis of National Science Foundation (NSF) information. I GAO-22-105550

Notes: The baseline includes fees and on-site oversight costs.

#### Independent Cost Estimate

In November 2018, the U.S. Army Corps of Engineers completed an independent cost estimate (ICE) report for the AIMS project. According to NSF officials, the ICE was critical in helping the agency determine the reasonableness of the contractor's proposed cost estimate and schedule for the project and associated risks. According to NSF officials, NSF and the contractor resolved all recommendations from the ICE report to NSF's satisfaction prior to setting the not-to-exceed cost.

Source: GAO analysis of NSF information. | GAO-22-105550

## Remaining Contingency and Scope Reduction Options

As of February 2022 with construction about 31 percent complete.

#### **Budget contingency:**

\$58.5 million (\$6.4 million more than the probability-weighted risk exposure of \$52.1 million).

#### Schedule contingency:

15.2 months (included in the 2028 scheduled completion date).

Source: NSF documents and officials. | GAO-22-105550

#### **Cost and Schedule Performance History**

Although domestic production of AIMS components was able to continue, the project remains behind schedule with all construction work at McMurdo Station paused because of the pandemic. After the loss of a second construction season, NSF and the contractor are re-baselining the AIMS project to include only the two components that were funded at the start of the pandemic. As of February 2022, pandemic-related cost and schedule increases were not yet reflected as formal changes to the project's performance management baseline because the re-baseline process was ongoing. Thus, the project's not-to-exceed cost remains at \$410.4 million, which included \$67.2 million in budget contingency, the amount authorized by the National Science Board in February 2019. The AIMS project team expects to submit its request for authorization of the new project baseline in May 2022.

NSF is considering construction of the remaining four components of the AIMS project separately under the new AIR program. After the COVID-19 pandemic caused significant delays and uncertainty for the AIMS project, NSF determined that discrete recapitalization on existing infrastructure, rather than a combined major construction project, was better suited for NSF's long-term Antarctic research goals and the logistical challenges of on-ice construction. According to NSF officials, the agency expects to determine the re-baselined cost of AIMS, as well as initial investments in projects funded through the AIR program, in fiscal year 2022.

#### Remaining Project Risks and Potential for Cost or Schedule Increases

As of February 2022, the AIMS project had a risk exposure of \$52.1 million and \$58.5 million in remaining contingency, and 15.2 months of schedule contingency remained available. The project had cumulatively used \$8.7 million in budget contingency. Of this amount, \$7.3 million was used for contract modifications for initial construction, with the remainder used for other realized risks, including additional equipment purchases and leases. Because NSF will be funding less than half of the planned components, the project's risk exposure will likely be reduced once re-baselining is complete.

As of February 2022, the AIMS project was monitoring \$17 million in major risks. Given the level of uncertainty and high potential impact on Antarctic operations associated with the pandemic, a meaningful risk profile will not be available until the project is re-baselined. The AIMS project continues to monitor other known risks, including engineering delays and proposals exceeding cost estimates, with estimated values of \$1.4 million and \$15.2 million, respectively. However, their associated effects have been overtaken by the pandemic and will be reevaluated as part of the rebaseline.

#### Large Hadron Collider High Luminosity Upgrade Program

The Large Hadron Collider (LHC) is the world's most powerful particle accelerator. The facility's four detectors observe new particles that are produced when high-energy protons are accelerated and collided, providing insight into fundamental forces of nature and the condition of the early universe. Through the National Science Foundation's (NSF) Large Hadron Collider High Luminosity Upgrade (HL-LHC) program, the agency will fund a portion of a larger international effort to upgrade two of the facility's detectors. Specifically, NSF plans to fund the design and implementation of certain parts of the upgrades as two separate projects for the facility's detectors, the A Toroidal LHC Apparatus (ATLAS) and Compact Muon Solenoid (CMS) detectors. The Department of Energy (DOE) is also contributing to upgrades to the LHC's accelerator and to the ATLAS and CMS detectors.



Source: GAO. | GAO-22-105550

Design				Constru	ıction	Operations	
	<b>A</b>	<b>A</b>	<b>A</b>	<u> </u>			
Nov. 2015 Start of design	<b>Mar. 2016</b> Conceptual design review	<b>Dec. 2017</b> CMS preliminary design review	Jan. 2018 ATLAS preliminary design review	Sept. 2019 Final design review	April 2020 Construction award	2026 End of construction/Start of full operations	<b>2038</b> End of operations

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550



Source: © 2008 CERN. | GAO-22-105550

Note: photograph above depicts the A Toroidal Large Hadron Collider Apparatus (ATLAS) detector.



#### Responsible NSF directorate:

· Mathematical and Physical Sciences.



#### Construction award:

 Cooperative agreements with Columbia University (ATLAS detector) and Cornell University (CMS detector).



#### Project partners:

 European Organization for Nuclear Research (CERN) and the Department of Energy.



Expected construction completion date, including schedule contingency:

· December 2026.



#### **Expected duration of operations:**

12 years.

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

#### **Project Status**

As of February 2022, NSF's HL-LHC program was in its second year of construction. In August 2021, external panels for both upgrade projects found that the project teams are appropriately mitigating the effects of the COVID-19 pandemic. However, they recommended resolving pandemic-related uncertainties before conducting a re-baseline review. As of March 2022, both upgrade projects were implementing baseline changes in response to the pandemic, which has delayed construction by an estimated 18 months for ATLAS and 13 months for CMS. According to NSF officials, the agency anticipates both projects' cost increases to be greater than 10 percent of their total project costs. However, a scheduled delay to the next planned shutdown at LHC announced by the European Council for Nuclear Research (CERN) may offset effects that the ATLAS and CMS projects' pandemic-related schedule delays may have had on scientific research that would have otherwise occurred absent construction delays.

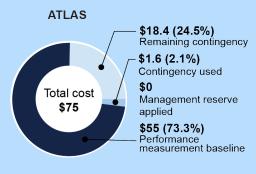
## Construction Status of the Large Hadron Collider High Luminosity Upgrade, as of February 2022

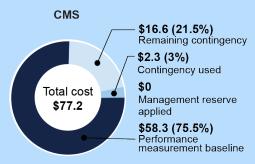
Dollars in millions			
	ATLAS	CMS	Program Total
Percentage complete	21	22	Not applicable
Not-to-exceed cost that the National Science Board authorized	75	78	153
Total project cost in latest construction awards	75	77.2	152.2
National Science Foundation (NSF) funding obligated to date	27.9	33.9	61.8

Source: GAO analysis of NSF information. | GAO-22-105550

#### **Latest Construction Award**

Total project cost, in millions, as of February 2022





Source: GAO analysis of National Science Foundation (NSF) information.  $\mid$  GAO-22-105550

Note: Percentages do not sum to 100 percent for ATLAS because of rounding.

## Remaining Contingency and Scope Reduction Options

As of February 2022.

#### **Budget contingency:**

- \$18.4 million for the ATLAS detector.
- \$17.0 million for the CMS detector.
- \$35.4 million total for the HL-LHC program.

#### Schedule contingency:

- 13.4 months for the ATLAS detector.
- 9.3 months for the CMS detector.

## Estimated value of remaining scope reduction options:

\$13.9 million as follows

- \$8.4 million for the ATLAS detector.
- \$5.5 million for the CMS detector.

Source: GAO analysis of NSF information.  $\mid$  GAO-22-105550

## CERN's Long Shutdown 3 for the LHC was Delayed to 2026

In January 2022, CERN officially announced its plan to extend the timeline for the next shutdown of operations at the LHC facility, Long Shutdown 3. CERN approved the schedule extension to allow the project teams to absorb pandemic-related schedule delays and install the ATLAS and CMS upgrades.

Source: GAO analysis of DOE information. | GAO-22-105550

#### **Cost and Schedule Performance History**

As of February 2022, the total project costs for the ATLAS and CMS projects remained at \$75 million and \$77.2 million, respectively. NSF has obligated \$27.9 million for construction of ATLAS and \$33.9 million for CMS, as of February 2022. According to NSF documentation, remote work conditions and social distancing protocols have caused schedule delays and cost increases for both detectors compared to their baseline schedules and award amounts. In January 2022, NSF notified Congress that the estimated cumulative pandemic-related cost increases for both detector upgrades would exceed 10 percent of the original total project cost for the HL-LHC program. As of March 2022, neither project team had completed re-baselining or re-planning in response to the pandemic. However, both projects are implementing baseline changes, and NSF continues to monitor pandemic-related effects to the costs and schedules of the ATLAS and CMS detector upgrades.

However, the overall effect of schedule delays may be diminished because of the postponement of the planned shutdown by CERN. According to NSF officials, the HL-LHC program's research goals are driven by delays in a separate accelerator upgrade for LHC and by the activities of the ATLAS and CMS projects' international partners. In addition, CERN has officially delayed the start of a planned shutdown for HL-LHC to the beginning of 2026 and extended it by 6 months for a total duration of 3 years. As a result, construction completion for the HL-LHC program is expected to occur well in advance of the required delivery to CERN.

#### Remaining Project Risks and Potential for Cost or Schedule Increases

As of February 2022, NSF had not yet authorized management reserves or additional funding for either project to respond to the effects of the pandemic. Both project teams will develop re-baseline proposals to address the effects of the pandemic on their costs and schedules. According to NSF documentation, the ATLAS and CMS project teams estimated pandemic-related schedule delays to be 18 and 13 months, respectively. According to NSF officials, ATLAS and CMS estimate differing delays because of different assumptions about pandemic-related uncertainties and each project's vendors and dependencies.

As of February 2022, the ATLAS upgrade project had \$18.4 million in budget contingency remaining after using \$1.6 million of its initial \$20 million budget contingency. In July 2021, the ATLAS project team estimated its risk exposure as \$18.6 million. The highest risks managed by the project team included potential cost increases because of delays at CERN, market volatility, and heightened inflation. Risks related to pandemic were not included in the project team's June 2021 risk assessment.

As of February 2022, the CMS upgrade project had \$16.6 million in budget contingency remaining after using \$2.3 million of its initial \$18.9 million contingency fund. In August 2021, the CMS project team estimated its risk exposure was \$17 million. The highest impact risks managed by the project through the use of budget contingency include uncertainty regarding foreign currency exchange rates, uncertainty regarding inflation, and quality problems. Risks related to the pandemic were not included in the project team's August 2021 risk assessment.

# Appendix III: Summaries of the National Science Foundation's Major Facilities Projects in Design

This appendix provides individual summaries of the two National Science Foundation (NSF) major facilities projects that are in design and planned for construction: the Leadership Class Computing Facility and the Antarctic Research Vessel. As of February 2022, no construction funds had been awarded for either project and all cost, schedule, scope, and design information was subject to change.

The project summaries are based on project documents and other information that NSF officials provided and include the following:

- an overview of the project and its purpose;
- a timeline identifying key project dates;
- project information, such as the expected date for completion of construction; the anticipated type of awards for construction; the responsible NSF directorate; project partners; and expected duration of operations;
- a summary of the project's current status;
- a summary of the project's design and construction costs, if available, and the budget account NSF planned to use for construction of the project;<sup>6</sup> and
- information on remaining project risks.

<sup>&</sup>lt;sup>6</sup>Costs are reported in then-year dollars, which means that NSF or the recipient converted base-year dollars by applying an inflation index. According to NSF policy, inflation is a part of NSF's budgeting and project planning.

#### LEADERSHIP CLASS COMPUTING FACILITY

The National Science Foundation's (NSF) Leadership-Class Computing Facility (LCCF) project is intended to provide advanced computational capabilities to enable transformative research in all areas of science and engineering that would not be possible by theory or experiment alone. According to NSF officials, future research using LCCF might include extremely detailed simulations ranging from biological molecules to supernovae and analyses of very large data streams such as satellite images to create high-resolution Earth maps.





Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550



Source: National Science Foundation (NSF). | GAO-22-105550

Note: Photograph above depicts NSF's most advanced computing system currently in operation, known as Frontera.



#### Responsible NSF directorate:

 Computer & Information Science & Engineering.



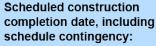
#### Construction award:

· Planned for FY2024.



#### Project partners:

None.



• FY2026.



#### **Expected duration of operations:**

• 10+ years.

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550

#### Project Status

As of January 2022, the LCCF project was in its third year of design. Consequently, all cost, schedule, scope, and design information for the project was subject to change. After postponing an initial review in October 2021, NSF held a preliminary design review in January 2022. NSF and the award recipient had agreed to postpone the review because of a lack of design maturity and sufficient information to support an independent cost estimate, in accordance with GAO best practices. The preliminary design review panel determined that LCCF was ready to enter the final design phase. The panel also endorsed a plan to provide \$7 million for teams of scientists to create a suite of science applications designed to measure the performance improvements of the LCCF system. Including the cost of these science teams, NSF's total obligation for the project as of March 2022 is \$12.4 million, of which \$4.5 million has been expended. The project's next milestone is the National Science Board meeting in August 2022, which is the last opportunity to include LCCF in NSF's budget request for fiscal year 2024 to begin construction as currently planned.

#### **Design and Construction Costs**

As of March 2022, NSF had not yet established the construction cost and scope for the LCCF project. The final cost will be subject to the outcomes of further design reviews, NSF approval, and eventual National Science Board authorization. Since fiscal year 2019, NSF has obligated \$12.4 million from its Research and Related Activities account for the design of LCCF. According to NSF documentation, the estimated total cost of the design stage will be \$15.9 million. NSF officials said the agency is assessing how to complete an early independent cost estimate for LCCF ahead of its final design review tentatively scheduled for fiscal year 2023.

#### **History of the LCCF Project**

The project represents the final phase of a two-phase deployment of high-performance computing systems. The first phase—known as the Frontera project at the Texas Advanced Computing Center at the University of Texas at Austin—was completed in September 2019. According to NSF, at that time, Frontera was the largest high-performance computing system deployed on a U.S. academic campus. The LCCF project will support the design and construction of an upgrade to the Frontera system as well as to the physical facility that will host it.

Source: GAO analysis of NSF information. | GAO-22-105550

The LCCF project's initial solicitation encouraged seeking public-private partnerships to leverage existing data center facilities. According to NSF officials, a commercial data center provider has planned build a 1.5 million square-foot data center approximately 10 miles from the University of Texas at Austin. After considering several alternatives, the project team determined that hosting the LCCF computing system at that data center would have a lower cost and risk profile than the project's original plan of constructing a standalone facility. According to NSF officials, the project may use the cost savings to improve the planned computational power of the LCCF computing system. However, because the project is still in the design stage, the new plan is tentative.

#### **Project Risks**

As of March 2022, the risk register for the LCCF project is still under development because the project is in the design stage. Although the project team had identified 25 discrete risks during conceptual design, such as failing to meet performance specifications, the conceptual design review panel identified immediate, identifiable risks not identified in the design. The panel recommended that the project team expand its assessment of risks early in the preliminary design phase. The project identified additional risks during the preliminary design that are under evaluation by NSF. However, according to NSF officials, the project team was able to reduce its risk exposure in other areas during preliminary design through its proposal to co-locate the LCCF computing system in a commercial data center facility and by entering into agreements with technology companies to ensure the availability of semiconductors during the construction stage.

According to NSF officials, one anticipated challenge for the LCCF project is the rapid pace of technological change in the field of high-performance computing because of external market forces. Conversely, the rapid pace of change can also be an opportunity if the LCCF project can incorporate the latest technological advances. According to NSF officials, taking advantage of such opportunities as late as possible in the design or construction stage will be important for the success of the project. For example, the LCCF project expects acquisition of the computing system to occur when the data center machine room is nearly ready for installation to begin, which allows the acquisition to be as late as possible in the construction schedule.

#### ANTARCTIC RESEARCH VESSEL

The Antarctic Research Vessel (ARV) project is intended to replace the retiring *Nathanial B. Palmer* icebreaking research vessel—which has operational limitations and is reaching the end of its lifetime—with a vessel that has improved capabilities. According to National Science Foundation's (NSF) officials, ARV will be an advanced research vessel for studying Antarctica and its surrounding seas, which could lead to discoveries in fields such as climate change, biology, and oceanography.

Location: Shipyard to be determined.



Design Operations Fiscal Year February Fiscal Year September Fiscal Year 2031 Fiscal Year 2071 2025 2025 2021 2021 2023 End of construction and End of operations Final design Start of Start of Conceptual Preliminary start of operations design design review design review review construction

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-22-105550



Source: National Science Foundation (NSF). | GAO-22-105550 Note: Rendering of the project's conceptual design.

#### Responsible NSF directorate:

 Geosciences, Office of Polar Programs.



#### Construction award:

• FY2025.



#### Project partners:

· None; project is fully NSF-funded.



## Scheduled construction completion date, including schedule contingency:

• FY2031, final acceptance in FY2032.



#### **Expected duration of operations:**

30 to 40 years.

Source: GAO analysis of National Science Foundation (NSF) information.  $\mid$  GAO-22-105550

#### **Project Status**

As of January 2022, the ARV project was in its first year of design. Consequently, all cost, schedule, scope, and design information for the project was subject to change. In June 2021, the NSF Director approved the project to enter the design stage as a candidate major facilities project. NSF conducted a conceptual design review in September 2021, resulting in an external panel recommendation for the project to proceed to the preliminary design phase. According to NSF officials, compared to its predecessor, the ARV icebreaker is planned to have improved capabilities in ice-breaking, mission endurance, and personnel capacity. Those improvements will then be the basis for NSF's performance metrics for the ARV project. More information will be available once the project is closer to its planned preliminary design review in February 2023.

#### **Design and Construction Costs**

NSF has not yet established the construction cost, schedule, or scope for the ARV project. As of January 2022, NSF obligated \$5.6 million to support the project in the design stage. NSF used \$1.5 million to support the conceptual design phase and approximately \$4 million for a contract modification with the initial vessel integrator to evaluate the ARV's capabilities, develop the project execution plan, and perform other steps necessary for the preliminary design phase. NSF estimates that the preliminary design phase will cost a total of \$19.4 million, including \$510,000 expended as of March 2022. NSF officials said the project may benefit from some efficiencies by using the prime contractor for the Antarctic Infrastructure Modernization for Science (AIMS) project as the ARV project's initial vessel integrator. According to NSF officials, the AIMS contractor is familiar with NSF management and oversight policies for major research infrastructure projects. In addition, NSF officials amended an existing Antarctic support contract with the AIMS contractor to include the ARV project, which helped to accelerate the design process. According to NSF officials, the agency also incorporated oversight capabilities that were negotiated as part of that contract.

#### **Project Risks**

As of March 2022, NSF had not yet formally identified risks for the ARV project because the project was early in the design stage. According to NSF officials, the award recipient will use NSF and contractor project management experience with similar vessel projects to develop ARV construction plans and activities. For example, NSF's ARV integrated project team has coordinated with the Regional Class Research Vessels (RCRV) integrated project team to share lessons learned. In addition, the contractor supporting the preliminary design phase for the ARV project consults with a design and engineering firm that worked on RCRV and other research vessel projects.

# Appendix IV: Summaries of the National Science Foundation's Mid-scale Research Infrastructure Projects

This appendix provides individual summaries of the five National Science Foundation (NSF) mid-scale projects that are under construction: (1) the Distributed Energy Resources Connect, (2) the Global Ocean Biogeochemistry Array, (3) the High Magnetic Field Beamline, (4) the Network for Advanced Nuclear Magnetic Resonance Spectroscopy, and (5) the Research Data Ecosystem.

Each project's summary is based on project documents and other information that NSF officials provided and includes the following:

- an overview of the project and its purpose;
- project information, such as the project's scheduled completion date for construction, the type and latest amounts of the awards for construction, and the responsible NSF directorate;
- the project's current status and cost and schedule performance history since our June 2021 report;<sup>7</sup>
- the latest construction award's total project cost for construction, including the performance measurement baseline and budget contingency; and
- information on remaining project risks and potential for cost or schedule increases, if available, including the amount of remaining contingency and scope reduction options.

<sup>&</sup>lt;sup>7</sup>GAO, *National Science Foundation: COVID-19 Affected Ongoing Construction of Major Facilities Projects*, GAO-21-417 (Washington D.C.: June 8, 2021).



Source: University of California, San Diego. | GAO-22-105550

**Award recipient:** University of California, San Diego

Responsible NSF directorate: Engineering

Authorized award amount: \$39.5 million

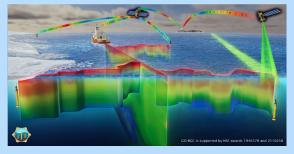
Scheduled completion date: October

2025

Percentage complete: 20

#### DISTRIBUTED ENERGY RESOURCES CONNECT

As of March 2022, the Distributed Energy Resources Connect (DERConnect) project was 20 percent complete with a scheduled completion date of October 2025. To address the long-term challenges of integrating renewable and distributed energy resources into the power grid, the DERConnect project aims to establish a large-scale grid-connected experimental research facility. This testbed will also help to develop a new generation of workforce trained to successfully modernize the power grid. According to project documents, there was no near-term major risk associated with the DERConnect project as of November 2021. However, according to NSF officials, the DERConnect project is the only mid-scale project that has submitted a supplemental funding request because of the COVID-19 pandemic. The DERConnect project requested \$2.4 million of the funding reserved for mid-scale projects by NSF from funding received the American Rescue Plan Act of 2021. Not including this request, which is still under NSF review, the project's cumulative funding obligated as of December 2021 was \$30.6 million.



Source: National Science Foundation (NSF). | GAO-22-105550

**Award recipient:** Monterey Bay Aquarium Research Institute

Responsible NSF directorate: Geosciences

Authorized award amount: \$52.9 million

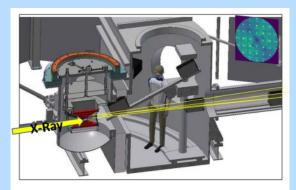
Scheduled completion date: October

2025

Percentage complete: 10

#### **GLOBAL OCEAN BIOGEOCHEMISTRY ARRAY**

As of March 2022, the Global Ocean Biogeochemistry Array (GO-BGC) project was 10 percent complete with a scheduled completion date of October 2025. To better study and monitor the effects of climate change on the oceans, the GO-BGC project plans to construct 500 electronic float devices with oxygen, nitrate, pH, and other sensors to collect chemical and biological ocean data from the surface to a depth of 2000 meters. According to NSF documents, the network will deliver data in real-time to an established global data system, where it would be freely available to researchers at no cost. GO-BGC float devices had completed 782 ocean profiles across 41 active floats as of March 2022. The project team submitted a request to use \$181,000 in budget contingency on unanticipated quality control requirements for some floats being deployed during the first 2 years of the project. In addition, the project team is assessing whether some identified risks can be retired to allow for spending about \$400 thousand in budget contingency on additional sensors. In fiscal years 2021 and 2022, the NSF obligated a total of \$17.2 million to the GO-BGC project.



Source: National Science Foundation (NSF). | GAO-22-105550

Award recipient: Cornell University

Responsible NSF directorate:
Mathematical and Physical Sciences

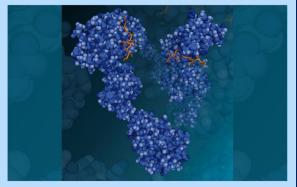
Authorized award amount: \$32.7 million Scheduled completion date: November

2025

Percentage complete: 15

#### HIGH MAGNETIC FIELD BEAMLINE

As of March 2022, the High Magnetic Field (HMF) Beamline project was 15 percent complete with a scheduled completion date of November 2025. To enable new science with X-rays, the HMF Beamline project will establish a first-of-its-kind x-ray facility. Researchers will use the facility to observe the underlying correlations and symmetries of new phases of matter induced by high magnetic fields. That, in turn, could lead to insights into electronic symmetry breaking, unconventional superconductivity, and quantum magnetism. The project's technical teams took advantage of the winter shutdown period at Cornell University in November 2021 and got a head start on demolition and installation work planned for summer 2022. A replanning exercise in December 2021 repurposed a portion of the project's \$1.7 million in cost savings on the budgeted design of the HMF Beamline's 20T magnet. According to project documents, NSF requested that the project review its risk register and contingency activities to prepare for discussions about potentially re-baselining a portion of the project. As of November 2021, the project had \$4.9 million in budget contingency remaining and NSF's total funding obligated to-date was \$8.4 million.



Source: National Science Foundation (NSF). | GAO-22-105550

**Award recipient:** University of Connecticut Health Center

**Responsible NSF directorate:** Biological Sciences

Authorized award amount: \$39.7 million Scheduled completion date: June 2025

Percentage complete: 10

## NETWORK FOR ADVANCED NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY

NSF awarded the Network for Advanced Nuclear Magnetic Resonance Spectroscopy (NAN) project to begin construction in July 2021. As of March 2022, the NAN project was 10 percent complete with a scheduled completion date of June 2025. To support advanced research into molecular structures and dynamics that can help address a wide range of fundamental scientific issues, the NAN project will establish a nuclear magnetic resonance (NMR) spectroscopy research network that can be used by a large community of scientists. The project will also promote broader participation in the NMR research community and address a national deficit in high-field NMR capacity. According to project documents, the project experienced cost savings on personnel and fixed costs in 2021, primarily because of hiring delays, travel restrictions, and a decision to delay certain hardware purchases. NSF obligated \$20.0 million to the NAN project for fiscal year 2021.



Source: National Science Foundation (NSF). | GAO-22-105550

**Award recipient:** Regents of the University of Michigan

Responsible NSF directorate: Social, Behavioral, and Economic Sciences

Authorized award amount: \$38.4 million

Scheduled completion date: January

2027

Percentage complete: 0

#### RESEARCH DATA ECOSYSTEM

NSF awarded the Research Data Ecosystem (RDE) project to begin construction in February 2022. As of March 2022, the RDE project had just begun construction with a scheduled completion date of January 2027. To address access and management challenges associated with social and behavioral science data, the RDE project will develop an integrated suite of software for each stage of the research life cycle. This software infrastructure may improve the quality, integrity, and safety of data while increasing accessibility to data and collaboration between users across the social science and some behavioral science disciplines. NSF's investment in the RDE project directly supports faculty, staff, and graduate students involved in developing the software to access and browse the data archives that will be created by the University of Michigan Institute for Social Research. NSF obligated \$6.7 million to the RDE project for fiscal year 2022.

## Appendix V: GAO Contact and Staff Acknowledgments

#### **GAO Contact**

Candice N. Wright, (202) 512-6888 or WrightC@gao.gov

### Staff Acknowledgments

In addition to the contact named above, Sarah Harvey (Assistant Director), Sean Manzano (Analyst in Charge), and Ian Reed made key contributions to the report. Also contributing were Bethany Benitez, Jenny Chanley, Louise Fickel, Yvette Gutierrez, Ryan Han, Patrick Harner, Jason T. Lee, Donna Morgan, and Jack Wang.

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