United States Government Accountability Office

Report to Congressional Committees

June 2021

NATIONAL SCIENCE FOUNDATION

COVID-19 Affected Ongoing Construction of Major Facilities Projects

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GAO-21-417

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Highlights

Highlights of GAO-21-417, a report to congressional committees

June 2021

NATIONAL SCIENCE FOUNDATION

COVID-19 Affected Ongoing Construction of Major Facilities Projects

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 or acquire, and mid-scale research infrastructure projects. Over the past 5 fiscal years, NSF has received over $1 billion in appropriations for these projects. Prior GAO reports reviewed NSF's oversight of the projects, its cost estimating and schedule policies, and the project management expertise of its oversight workforce.

Senate Report 115-275, Senate Report 114-239, and House Report 114-605 included provisions for GAO to review and report annually on projects funded from NSF's Major Research Equipment and Facilities Construction account. This report, the fourth, examines (1) the cost and schedule performance of NSF's ongoing major facilities and mid-scale research infrastructure projects and (2) the extent to which NSF has implemented prior GAO recommendations related to its management of major facilities. GAO reviewed NSF and award recipient documents for the projects. GAO examined policies and procedures to identify efforts to implement recommendations and interviewed NSF officials for clarifying information.

What GAO Recommends

NSF agreed with and has taken steps to address three remaining recommendations from GAO's prior work to improve the project management skills of its staff and award recipients and to align schedule guidance to GAO's best practices.

View GAO-21-417. For more information, contact Candice Wright at (202) 512-6888 or WrightC@gao.gov.

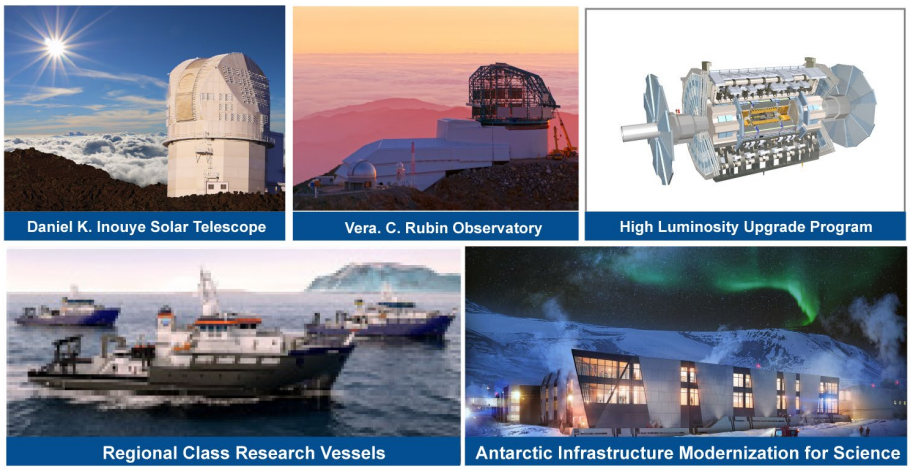
What GAO Found

Since GAO's April 2020 report on the status of the National Science Foundation's (NSF) major facilities projects, the Large Hadron Collider High Luminosity Upgrade program began construction, and it along with the four other major facilities projects in construction (see figure), have weathered schedule delays associated with the COVID-19 pandemic. To partially account for increased costs associated with the pandemic, such as the cost of paying project staff while work is paused, NSF has authorized $38.9 million in total project cost increases to the award recipients constructing three of the five projects:

- $18.9 million for the Daniel K. Inouye Solar Telescope,
- $10.0 million for the Vera C. Rubin Observatory, and
- $10.0 million for Regional Class Research Vessels.

Because the pandemic is ongoing and its full effects are not yet known, NSF expects to make further adjustments to the cost and schedule of all five major projects in construction. Design work on an additional major facility project continued without significant interruption from the pandemic. Further, NSF made awards to begin the agency's first three mid-scale research infrastructure projects.

National Science Foundation Major Facilities Projects in Construction



Sources: Claire Raftery/Association of Universites for Research in Astronomy, Inc./National Solar Observatory (top left); W O'Mullane/ LSST Project/NSF/AURA (top center); 2008 CERN (top right); Artist Rendering by Glosten (bottom left); Leidos (bottom right). | GAO-21-417

NSF has fully implemented GAO's prior recommendation on information sharing among award recipients and has drafted guidance or taken other steps towards addressing GAO's three remaining recommendations. To enhance information sharing among award recipients, NSF added a section to its terms and conditions in its major facilities agreements that encourages awardees to share information among awardees and participate in a knowledge management program.

Contents

Abbreviations

AIMS	Antarctic Infrastructure Modernization for Science
ATLAS	A Toroidal Large Hadron Collider Apparatus
CERN	European Organization for Nuclear Research
CMS	Compact Muon Solenoid
COVID-19	Coronavirus Disease 2019
DKIST	Daniel K. Inouye Solar Telescope
DOE	Department of Energy
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
NSF	National Science Foundation
OMB	Office of Management and Budget
RCRV	Regional Class Research Vessels

GAO@100 U.S. GOVERNMENT ACCOUNTABILITY OFFICE
A Century of Non-Partisan Fact-Based Work

441 G St. N.W.
Washington, DC 20548

June 8, 2021

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 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 and research vessels. 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 construction or acquisition heighten the need for NSF to 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.

[1]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).

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, as shown in table 1. In fiscal year 2021, Congress appropriated $241 million for the MREFC account.

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

Dollars in millions

	Fiscal year				
	2017	**2018**	**2019**	**2020**	**2021**
Appropriations	209	183	296	243	241

Source: National Science Foundation (NSF) and congressional budget documents. | GAO-21-417

Since 2018, we have issued three 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.[2] In addition, we also reported on how NSF shares lessons learned and best practices for the construction of major facilities projects. 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 our recommendations in these past reports. In April 2020, we reported that NSF had implemented two of the six recommendations.

Senate Report 115-275, Senate Report 114-239, and House Report 114-605 included provisions for GAO to review and report on projects funded from the NSF MREFC account. This report, the fourth of our annual reports in response to the Senate and House report provisions, (1) describes the cost and schedule performance of NSF's ongoing major facilities and mid-scale research infrastructure projects and (2) assesses

[2]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.: April 3, 2020).

the extent to which NSF has implemented prior GAO recommendations related to its management of major facilities.

To describe the cost and schedule performance of NSF's major facilities projects, we reviewed NSF and award recipient documents that detailed project cost, schedule, and risks for each major facility. We also reviewed initial documents on NSF's mid-scale research infrastructure projects. Additionally, we interviewed NSF officials to obtain clarifying information about these projects and NSF's oversight.

To assess the extent to which NSF has implemented the four recommendations from two prior GAO reports on NSF major facilities that had not been implemented as of April 2020, we reviewed NSF policies and procedures as well as documentation related to actions the agency took to implement these recommendations.[3] We also interviewed NSF officials to discuss NSF's ability to implement the recommendations, as well as their estimated time frames for implementation.

We conducted this performance audit from September 2020 to June 2021 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 the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Stages in the Life Cycles of NSF's Major Research Equipment and Facilities Projects

Each major facility and mid-scale research infrastructure project has a sponsoring organization from within NSF's seven research directorates.[4] 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 the following five stages of its life cycle.

- **Development.** Initial project ideas emerge; and a broad consensus is built within the relevant scientific community for the potential long-term

[3]GAO-18-370 and GAO-19-227.

[4]NSF is divided into the following seven 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; and education and human resources.

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 research infrastructure.[5] 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

[5]Awards generally take the form of cooperative agreements, although NSF occasionally uses contracts, according to agency officials. The policies and procedures in NSF's *Major Facilities 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 *Major Facilities Guide*, contracts with nonprofit and educational institutions are also governed by the Uniform Guidance.

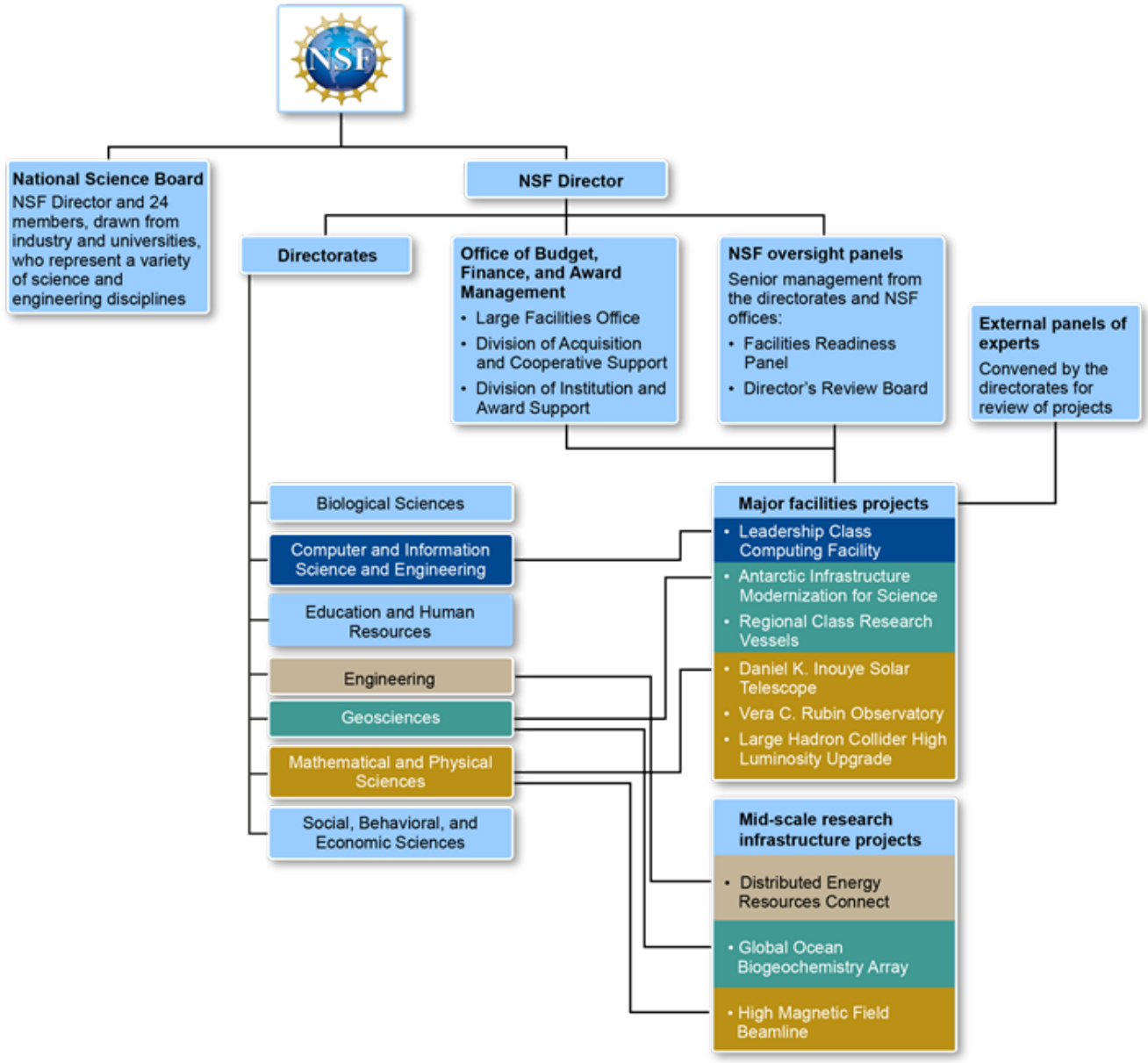
the facility is no longer considered an operational priority with regard to advancing science, according to NSF's *Major Facilities Guide*.

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 Major Research Equipment and Facilities Projects

NSF has established an oversight structure for major facilities projects that includes organizations from across the agency (see fig. 1). This includes the National Science Board, a policy and advisory body that is part of NSF and consists of the NSF Director and 24 members, drawn from industry and universities, who represent a variety of science and engineering disciplines. The NSF 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.

Figure 1: Organization of NSF Oversight of Major Research Equipment and Facilities



Source: GAO analysis of National Science Foundation (NSF) documents. | GAO-21-417

Note: Figure does not include all NSF organizations or interactions between them and includes only the major facilities projects and mid-scale research infrastructure projects in design or construction at the time of GAO's review.

Within NSF's Office of Budget, Finance, and Award Management, the Large Facilities Office (1) develops business-related oversight policies for all life-cycle 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 *Major Facilities Guide*, which contains NSF policies for agency staff and 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 cycles. 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 annual.

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 *Major Facilities 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.

- **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 impacts of such risks are uncertain. As a project progresses, the impacts 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 total project costs for the construction of major facility and mid-scale research infrastructure projects, which were developed during the design phase based on the latest estimates available from NSF officials; those 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.

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.

[6]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.

- **Management reserve.** NSF, not the award recipient, holds management reserve to manage budget uncertainties, unforeseeable events, and risks not manageable by the recipient.

NSF's No Cost Overrun Policy for Major Facilities Projects

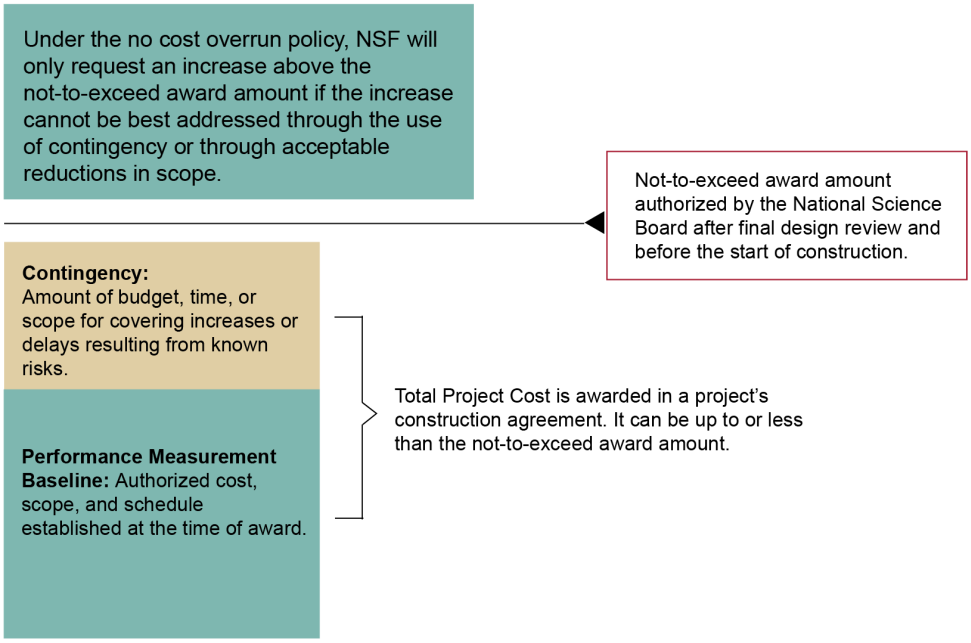
Since February 2008, NSF has had a policy to manage cost overruns on major facilities projects.[7] Under this policy, the cost estimate developed at the preliminary design review should have adequate contingency to cover all foreseeable risks.[8] Any cost increases not covered by contingency are generally to be accommodated by reductions in scope.[9] Figure 2 provides a breakdown of the total project cost and its relation to the not-to-exceed award amount.

[7]See GAO-18-370 for additional details on the history of this policy.

[8]According to the September 2019 update to NSF's *Major Facilities 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 NSB following final design review.

[9]These reductions in scope differ from re-planning actions on a project. NSF's *Major Facilities Guide* defines re-planning as a normal project management process to modify or re-organize the performance measurement baseline cost and/or schedule plans for future work without impacting total project cost, project end date, or overall scope objectives or the implementation of approved de-scoping options.

Figure 2: 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-21-417

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.

NSF Experienced Cost or Schedule Increases on Five of Its Nine Major Projects

Since our April 2020 report, NSF has continued construction on four major facility projects—the Daniel K. Inouye Solar Telescope (DKIST), the Vera C. Rubin Observatory (Rubin Observatory), Regional Class Research Vessels (RCRV), and Antarctic Infrastructure Modernization for Science (AIMS)—and begun construction of a fifth, the Large Hadron Collider High Luminosity Upgrade (HL-LHC) program. The Coronavirus Disease 2019 (COVID-19) pandemic, however, caused unexpected delays to each of the projects in construction. As a result of the pandemic and other factors, all five of these projects have experienced schedule delay and may cost more than initially budgeted. NSF's four other projects, an existing major facility project in design and three newly announced mid-scale projects proceeded without significant interruption.

All Five Projects in Construction Had Schedule Delays and Several Have Requested Additional Funds

Travel and Quarantine Restrictions Enacted Because of the COVID-19 Pandemic Affected Construction of NSF's Major Facilities Projects

Travel restrictions or quarantines caused significant work stoppages at three major facilities projects.

- At Daniel K Inouye Solar Telescope, Hawaii's travel restrictions prevented staff from reaching the telescope for commissioning activities.
- At the Vera C. Rubin Observatory, the Chilean government's quarantine measures resulted in work stoppage between March and September 2020.
- On Antarctic Infrastructure Modernization for Science, NSF suspended work at the project site to avoid the possibility of introducing COVID-19 to Antarctica. This stoppage may continue for another season, effectively halting all construction for two years.

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-21-417

The COVID-19 pandemic has caused unexpected delays to NSF's five projects that are in construction to varying degrees depending on the geographic location, level of completion, and technical nature of the project. NSF considers all five major facility projects that were in construction to be behind schedule and intends to increase authorized not-to-exceed total project costs and supplement awards, or re-evaluate project scope, if necessary, to account for the pandemic's effects. Given the pandemic's on-going domestic and global impacts to personnel and supply chains, NSF officials expect that all of its major facility projects currently in construction will be extensively re-planned or completely re-baselined to account for the effects of the pandemic.[10]

Travel restrictions and social distancing requirements during the pandemic have affected each of the projects in construction (see sidebar). However, these delays have generally not yet been fully incorporated into the projects' performance measurement baselines, because the pandemic is ongoing. As of March 2021, two of the five projects in construction have had their schedules extended (see table 2). NSF officials approved a schedule extension of 18 months for DKIST and a schedule extension of 6 months for RCRV to address COVID-related and other delays. For the three other projects in construction, NSF has not yet adjusted the schedules because these projects are earlier in their construction and not in immediate need of schedule extensions. Officials estimate that the HL-LHC is currently approximately 7 months behind schedule, and the Rubin Observatory is 10 months behind schedule. Having lost a construction season, AIMS is also running behind schedule.

[10]NSF defines re-planning as a normal project management process to re-organize without impacting the total project cost, schedule or scope. 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.

Social Distancing Restrictions Imposed Because of the COVID-19 Pandemic Affected Construction of NSF's Major Facilities Projects

Social distancing requirements, which reduced the number of employees that could work simultaneously, affected four major facilities projects.

- On Regional Class Research Vessels, fewer shipyard workers could be on site to work on the research vessels.
- On the Large Hadron Collider High Luminosity Upgrade, fewer research employees could conduct lab work necessary to advance upgrades to the detector components.
- At the Daniel K Inouye Solar Telescope and the Vera C. Rubin Observatory, social distancing requirements limited the number of individuals on site for construction, integration, and testing.

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-21-417

Table 2: Completion Dates and Additional Estimated Delays to NSF Major Facilities Projects in Construction, as of March 2021

Project Name	Original completion date	Current scheduled completion date	Additional estimated delay[a]
Daniel K Inouye Solar Telescope[b]	December 2017	December 2021	0 months
Vera C. Rubin Observatory[c]	October 2022	October 2022	10 months[c]
Regional Class Research Vessels	July 2024	January 2025	No estimate
Large Hadron Collider High Luminosity Upgrade	December 2026	December 2026	7 months
Antarctic Infrastructure Modernization for Science[c]	January 2028	January 2028	No estimate[c]

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-21-417

[a]Estimated delays are based on NSF projections and are not incorporated into the projects current performance measurement baseline

[b]This project was re-baselined in 2014. Before the Coronavirus Disease 2019 pandemic, its scheduled completion date was June 2020. In May 2021, NSF updated its project schedule to reflect December 2021 as the completion date.

[c]Re-baseline expected in late 2021.

In some cases, NSF officials expect that re-baselining will be necessary to develop a reliable completion schedule for projects in construction. For example, NSF officials expect to re-baseline the Rubin Observatory later in 2021 and develop a new completion date at that time. Shutdown of work at the Rubin Observatory's construction site in Cerro Pachón, Chile, stopped progress on two significant components, the dome that will house the telescope and the telescope mount assembly that moves and stabilizes it. Work at McMurdo Station in Antarctica for the AIMS project was suspended in March 2020 and has not yet resumed. Construction activities in Antarctica are concentrated over the austral summer with work beginning in October and concluding in March. With the pandemic and its effects ongoing, construction work at the site may not resume for the 2021-2022 season, according to NSF officials. A new estimated completion date for AIMS will depend on how the project is re-baselined, including a re-evaluation of the project scope. On April 30, 2021, NSF determined that it would not be funding additional components of AIMS due to the significant impacts of the pandemic. Current components of AIMS include the Vehicle Equipment and Operations Center, the first lodging unit, and associated utilities.

In addition to the pandemic, other factors contributed to schedule delay since our April 2020 report. Major facility projects try to identify foreseeable delays and other schedule risks during design and include

schedule contingency to account for these risks as part of the project management process. For example, the DKIST project site used schedule contingency to account for time lost due to an adverse weather event at its construction site in Hawaii, and the RCRV project site in Houma, Louisiana used scheduled contingency when it experienced shipyard performance challenges. However because the pandemic was unforeseen a project's remaining schedule contingency may not accurately reflect its total schedule risk.

The delays and inefficiencies caused by the pandemic will have cost impacts on the projects under construction as well. Some construction costs, such as those associated with project staff waiting for work to resume, continue to accrue even if no or little construction can be performed. Other costs are new, such as the leasing of additional storage space for materials waiting to be shipped to a project site and time added to tasks as a result of social distancing. For example, on HL-LHC NSF officials estimated that the current cumulative effects of COVID-19 totaled between $2 million and $3 million dollars as of January 2021.

NSF's major facilities projects generally use their budget contingency funds to compensate for changes in expected costs resulting from known project risks. Such contingency is built into the total project cost and is estimated at the start of construction. Consistent with NSF policy, NSF does not plan to use budget contingency to offset cost increases related to the pandemic. For unforeseen events beyond the award recipient's control—like the pandemic—NSF's *Major Facilities Guide* allows for the use of management reserve, which is an authorized amount of money in addition to a project's baseline estimate and contingency to address the additional work associated with unforeseen events.

To address costs associated with the pandemic, NSF has sought authorization through the National Science Board or used delegated authority to create management reserves. Prior to the pandemic, none of the projects under construction had management reserves. As of March 2021, however, three projects were authorized management reserves.[11] To create management reserves, the National Science Board and NSF increased the not-to-exceed amounts cumulatively by $38.9 million. The not-to-exceed cost for DKIST has increased by $18.9 million, and the not-

[11]Since NSF does not normally have management reserves, they must be identified by NSF from available MREFC funds, if needed in the near-term. Long-term additional funds may be appropriated by Congress.

to-exceed costs for both the Rubin Observatory and RCRV have increased by $10 million (see table 3).[12] NSF officials' adjustments to account for the pandemic were ongoing as of March 2021 because the full effects of the pandemic are not yet known. NSF officials told us they expect to seek authorization for additional reserves through the National Science Board to account for the unexpected costs the pandemic has created.

Table 3: Not-to-Exceed Cost Changes for NSF Major Facilities Projects in Construction, March 2021

Dollars in millions

Project name	Original authorized not-to-exceed cost	Increase in not-to-exceed cost as a result of management reserves	Current authorized not-to-exceed cost
Daniel K. Inouye Solar Telescope[a]	297.9	18.9	363.0[a]
Vera C. Rubin Observatory[b]	473.0	10.0	483.0
Regional Class Research Vessels	365.0	10.0	375.0
Large Hadron Collider High Luminosity Upgrade[c]	153.0	0	153.0
Antarctic Infrastructure Modernization for Science[b]	410.4	0	410.4
Total	**1,699.3**	**38.9**	**1,784.4**

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-21-417

[a]DKIST has been re-baselined since its original award, so the original authorized not-to-exceed cost and the increase in not-to-exceed cost as a result of management reserves will not total to the current authorized not-to-exceed cost. Before the Coronavirus Disease 2019 (COVID-19) pandemic, the authorized total project cost was $344.1 million.

[b]NSF officials expect to re-baseline this project in late 2021.

[c]This project is in its first year of construction, so NSF officials may adjust its cost to reflect the effects of the COVID-19 pandemic at a later time.

[12]NSF was able to authorize $14.1 million in additional management reserve for RCRV because the project's construction award was below its not-to-exceed amount. Considering this, total authorized management reserve was about $43 million as of March 2021.

Work Continued on One Project in Design and NSF Announced Three New Projects

A major facility project in design and newly announced mid-scale research infrastructure projects proceeded without significant interruption. The Leadership Class Computing Facility (LCCF), which is the only major facility project in the design stage, underwent conceptual design review in June 2020. LCCF's total project cost is still under development. Under NSF policy, a major facility's total project cost is not final until after the final design review when the National Science Board authorizes a not-to-exceed cost and an award duration for construction.

Additionally, in 2020 the National Science Board authorized the first mid-scale research infrastructure projects from the MREFC account and, following NSF review, awarded funds to three projects. NSF sought proposals for potential projects with total project costs between $20 million and $70 million.[13] The three new projects funded by NSF have a combined total cost of $125.1 million and scheduled completion dates in 2025 (see table 4).

Table 4: NSF Mid-scale Research Infrastructure Projects, March 2021

Project Name	Awardee	Project description	Authorized award amount (dollars in millions)	Scheduled completion date
Distributed Energy Resources Connect (DERConnect)	University of California, San Diego	To address the long-term challenges of integrating renewable and distributed energy resources into the power grid, DERConnect aims to establish a large-scale grid-connected experimental research facility. This testbed will also help to develop a new generation of workforce to successfully modernize the power grid.	39.5	October 2025
Global Ocean Biogeochemistry Array	Monterey Bay Aquarium Research Institute	To better study and monitor the effects of climate change on the oceans, this project aims to construct 500 biogeochemical Argo floats with oxygen, nitrate, pH, and other sensors to be released into the ocean to collect chemical and biological data at depths of over a mile. The network would deliver data in real-time to an established global data system, where it would be freely available at no cost.	52.9	October 2025

[13]Since the initial project solicitation, NSF has increased the upper limit for a mid-scale research infrastructure project to $100 million to align with the definition of a major facility project as amended by the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021. NSF received 48 initial proposals and chose award recipients from 11 full proposals.

Project Name	Awardee	Project description	Authorized award amount (dollars in millions)	Scheduled completion date
High Magnetic Field Beamline	Cornell University	To enable new science with X-rays, this project will establish a High Magnetic Field Beamline. The beamline can be used to observe the underlying correlations and symmetries of new phases of matter induced by high magnetic fields and obtain insights into electronic symmetry breaking, unconventional superconductivity, and quantum magnetism.	32.7	December 2025

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-21-417

NSF Implemented a Recommendation on Information Sharing and Took Steps to Address Others

NSF issued guidance to improve its process for sharing information and best practices among major facilities projects, which fully implements a recommendation we made in March 2019. In addition, NSF has taken preliminary steps such as drafting guidance to address three other recommendations from our June 2018 and March 2019 reports related to its management of its major facilities.[14] Once NSF completes these steps, we will evaluate its actions to determine whether they are sufficient to fully address our recommendations.

NSF Issued Guidance to Improve Information Sharing Among Awardees

NSF has updated the terms and conditions of its major facilities agreements to improve collection and sharing of lessons learned and best practices among major facilities project teams. This action addresses a recommendation in our March 2019 report where we recommended that NSF ensure, through a requirement or other means, that award recipients for major facilities projects provide information to NSF on any lessons learned or best practices.[15] At that time, we found that NSF had a process to share lessons learned but provided inconsistent direction to projects on how to participate in this process. For example, the RCRV project had a requirement in its award terms and conditions to annually share lessons learned, but the Rubin Observatory's award did not.

In our April 2020 report, we found that NSF had drafted preliminary award terms and conditions that would require all recipients to participate in NSF's program and that they planned to finalize and publish this guidance

[14]GAO-18-370, GAO-19-227.

[15]The process for identifying and sharing lessons learned on major facilities projects, which NSF refers to as its Knowledge Management program, was designed to respond to a 2015 recommendation by the National Academy of Public Administration and to the American Innovation and Competitiveness Act's requirements that NSF coordinate the sharing of best management practices and lessons learned from major facilities projects.

in fiscal year 2020.[16] NSF implemented the updated terms and conditions in all its major facilities agreements on October 5, 2020, thereby fully addressing the recommendation. The updated terms encourage all awardees to share information on lessons learned and best practices and participate in NSF's annual Major Facilities Workshop.[17] According to NSF officials, the agency chose not to make this a requirement because other agencies running similar programs found that making participation voluntary yields more meaningful results. The most recent Major Facilities Workshop included representatives from all current major facilities.

NSF Has Taken Additional Steps to Address the Three Remaining Recommendations Related to Its Oversight of Major Facilities

NSF has also taken additional steps since our April 2020 report to address the three remaining recommendations from our June 2018 and March 2019 reports, but has not fully implemented them.[18]

Policies for developing project schedules. NSF is in the process of issuing guidance that could improve the accuracy and reliability of project schedules. In our June 2018 report, we found that the majority of NSF's scheduling policies did not fully align with GAO's best practices for scheduling which could lead to increased costs and schedule delays. We recommended that NSF revise its policies for developing schedules for major facilities projects, and for reviewing those schedules, to better incorporate best practices in GAO's schedule guide.[19]

In April 2020, we reported that NSF had updated internal guidance documents to include an analysis of project schedules by the Large Facilities Office as part of the NSF cost analysis process.[20] In addition, we reported that NSF planned to include additional guidance on scheduling in its *Major Facilities Guide*. The guide contains NSF policy on planning and managing major facilities, including required policies and procedures

[16]GAO-20-268.

[17]NSF hosts its major facilities workshop annually to provide a collaborative forum for continuous learning and information sharing among participants. During the COVID-19 pandemic, NSF transitioned to quarterly virtual webinars. Based on this experience, NSF may use a combination of an in-person workshop and webinars in the future, according to NSF officials.

[18]GAO-18-370, GAO-19-227.

[19]GAO's schedule guide develops the scheduling concepts introduced in our cost estimating guide and presents them as 10 best practices associated with developing and maintaining a reliable, high-quality schedule. See GAO, *Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-16-89G (Washington, D.C.: December 2015).

[20]GAO-20-268.

and related guidance. According to NSF, they revised their pre-award internal guidance to evaluate and document that award recipients develop their schedule estimates in alignment with the four GAO characteristics of a high-quality schedule (comprehensive, well-constructed, credible, and controlled).

In February 2021, NSF released a draft for public comment of the *Major Facilities Guide* that requires award recipients to use GAO's scheduling guide when developing and managing project schedules (a requirement added in 2017) and provides additional guidance for implementation of the GAO guide on NSF-funded projects. According to NSF officials, they expect to issue the updated guide by the end of fiscal year 2021. Once issued, we will review the final version of the guide to determine if the recommendation was met.

Project management competencies of NSF's major facilities oversight workforce. NSF has taken steps to evaluate the project management competencies of its oversight staff and is considering additional actions. The American Innovation and Competitiveness Act directed NSF to determine what project management and financial management expertise NSF staff need to effectively oversee major facilities projects. However, in our March 2019 report, we found that NSF had not assessed NSF major facilities oversight staff for potential competency gaps in these areas of expertise nor taken steps to close any such gaps. We recommended that NSF assess the agency's oversight workforce to identify any competency gaps, develop a plan to address them and time frames for doing so, and monitor progress in closing them.

In April 2020, we reported that NSF had hired a contractor to conduct a proficiency assessment and workforce gap analysis.[21] Since then, the contractor has helped NSF develop a competency model for its staff and complete surveys of NSF staff who oversee major facilities projects to assess their competencies in project management and other professional and technical areas. NSF's contractor used three surveys to identify any competency gaps. Employees rated their own proficiency in competencies, supervisors rated the proficiency of their employees, and supervisors rated the expected minimum proficiency levels for a

[21]In addition to responding to our recommendation, this analysis is part of NSF's implementation of the Program Management Improvement Accountability Act. Pub. L. No. 114-264, § 2(b)(1), 103 Stat.1371, 1372 (2016) (codified as amended at 31 U.S.C. § 1126).

hypothetical, experienced employee. Using data from these surveys, the contractor found that certain individuals had gaps in award management, budget management, financial cost/analysis, project management, and risk and opportunity management, among others. However, they found that NSF's project teams as a single group possessed the competencies expected.[22]

NSF is now planning how to address the identified gaps. According to NSF officials, supervisors have used the survey results to help staff create individualized training plans. In addition, NSF commissioned a study of its training capabilities. In January 2021, the study identified areas where NSF does not provide the training in-house that employees need to reach some mid-level proficiencies and most expert level proficiencies and made recommendations to improve the agency's internal and external training opportunities. For example, according to the study, the agency did not provide sufficient training opportunities in areas such as award management and risk and opportunity management. The study recommended that NSF develop new courses and leverage training resources at other agencies. According to NSF officials, the agency is now taking steps to implement the recommendations and to determine how it will monitor staff competencies, such as by performing regular self-assessment surveys. We will continue to review NSF's actions as it works to identify, address, and monitor competency gaps.

Project management expertise of award recipients for major facilities projects. NSF is in the process of issuing guidance that could improve the project management expertise of its major facilities award recipients. In our 2019 report, we recommended that NSF establish criteria for the project management expertise of major facilities project recipients and incorporate the criteria in project requirements and external panel reviews. In response, NSF identified criteria that award recipients must be able to demonstrate, but these criteria will not be fully integrated into NSF's oversight practices until the end of fiscal year 2021.

As we reported in April 2020, NSF established criteria for expertise in project management, program management, earned value management, risk management, cost estimating, and other areas in draft updates to its *Major Facilities Guide*. As discussed above, the draft guide was released for public comment in February 2021 and NSF expects to issue the guide

[22]NSF's implementation of the Program Management Improvement Accountability Act looks for the three core members of the NSF Integrated Project Team to hold the necessary competencies for award oversight, as opposed to a single individual.

by the end of fiscal year 2021. Further, according to NSF officials, requirements for expert panels to assess recipients' project management expertise will be included in internal guidance they plan to complete in the third quarter of fiscal year 2021. Once issued, we will review the final versions of these documents to determine if the recommendation was met.

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 and the Director of the NSF. In addition, the report is available at no charge on the GAO website at https://www.gao.gov.

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

Candice N. Wright
Acting Director
Science, Technology Assessment, and Analytics

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

This appendix provides individual summaries of the National Science Foundation's (NSF) five major facilities projects under construction: (1) the Daniel K. Inouye Solar Telescope, (2) the Vera C. Rubin Observatory, (3) the Regional Class Research Vessels, (4) the Antarctic Infrastructure Modernization for Science, and (5) 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;
- 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,[1] the responsible NSF directorate, project partners, and expected duration of operations;
- tables summarizing the project's current status and its cost and any cost[2] or schedule[3] increases or scope reductions made under NSF's no cost overrun policy and changes since our April 2020 report;[4]
- a summary of the project's cost and schedule performance history;
- a chart depicting the latest construction award's total project cost for construction, including the performance measurement baseline and budget contingency;

[1]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.

[2]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.

[3]We identified schedule increases by comparing the project's scheduled completion date in the construction award as of December 2020 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.

[4]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.: April 3, 2020).

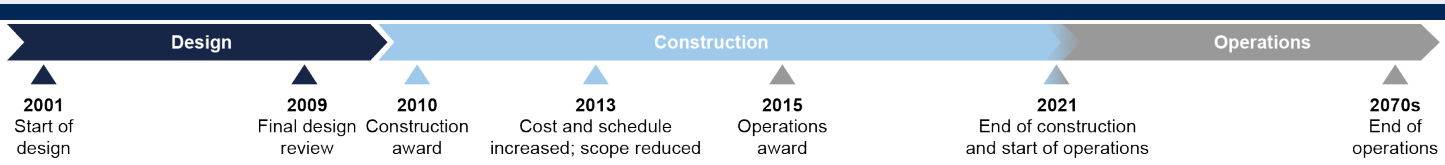
- if applicable, a chart showing the increase in the construction award's total project cost since the original construction award; and
- information on remaining project risks and potential for cost or schedule increases, including the amount of remaining contingency and scope reduction options.[5]

[5]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 *Major Facility Guide*, risk exposure is the quantitative impact of risks. We report the risk exposure as determined by the Monte Carlo method when available.

Source: Claire Raftery/Association of Universities for Research in Astronomy, Inc./National Solar Observatory. | GAO-21-417

DANIEL K. INOUYE SOLAR TELESCOPE

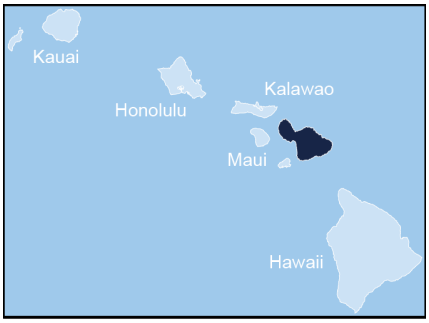
When completed, the National Science Foundation's (NSF) Daniel K. Inouye Solar Telescope (DKIST), formerly named the Advanced Technology Solar Telescope, will be the world's flagship facility for the study of magnetic phenomena in the solar atmosphere. It will help answer fundamental questions in solar physics and enable understanding of solar variability and activity, which can affect Earth through phenomena generally described as space weather.



Source: GAO analysis of NSF information. | GAO-21-417

Project Information

Location: Maui, Hawaii.



Source: GAO. | GAO-21-417

Expected construction completion date, including schedule contingency:

December 2021.

Construction award:

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

Responsible NSF directorate:

Mathematical and Physical Sciences.

Project partners:

More than 20 U.S. and international organizations. Leibniz-Institut für Sonnenphysik (Germany) and Queens University Belfast (Northern Ireland) are supplying additional equipment for the project.

Expected duration of operations:

50 years.

Source: NSF documents and officials. | GAO-21-417

Project Summary

Construction of NSF's DKIST project was 98 percent complete, as of December 2020. The project was in its 11th year of construction and in the process of testing and commissioning the facility. Since our April 2020 report, which included data from September 2019, the project installed and aligned a key component of the telescope's optics. However, the Coronavirus Disease 2019 (COVID-19) pandemic and extreme weather events in Hawaii in early 2020 delayed the project. As of December 2020, the estimated end date for construction was June 2021, but in May 2021 NSF staff said they expect the end of construction in December 2021. As of February 2021, the National Science Board approved a total management reserve of $18.9 million to cover expenses related to the pandemic, such as increased labor due to delays or inefficiencies. NSF applied $6.7 million of this reserve to the project in December 2020 and $2.7 million in March 2021.

Construction Status of the Daniel K. Inouye Solar Telescope, as of March 2021

Percentage complete	98
	Dollars in millions
Not-to-exceed cost that the National Science Board authorized	363.0
Total project cost in latest construction awards[a]	353.4
National Science Foundation (NSF) funding obligated to date	353.4

Changes in Cost, Schedule, and Scope

Dollars in millions

	Cumulative changes since original construction award	Changes since April 2020
Not-to-exceed cost that the National Science Board authorized	+65.1 ▲	+18.9 ▲
Total project cost	+55.5 ▲	+9.3 ▲
Scheduled completion date (months)	+42 ▲	+12 ▲
Scope[b]	-5.9 ▼	None

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

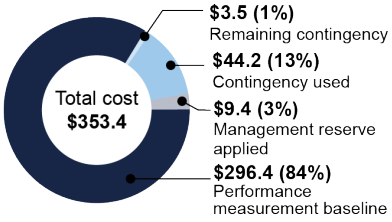
Source: GAO analysis of NSF documents and information from NSF officials. | GAO-21-417

[a]Includes an award funded by appropriations under the American Recovery and Reinvestment Act of 2009 and an award funded by NSF's Major Research Equipment and Facilities Construction account.

[b]Scope changes included are reductions in response to NSF's policy on cost overruns or as part of a cost increase.

Latest Construction Award[a]

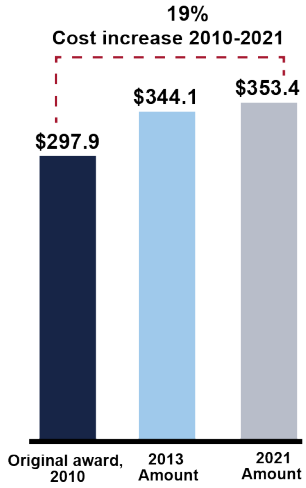
Total Project Cost, in millions, as of March 2021



Note: Percentages do not sum to 100 percent due to rounding.

Increase in Construction Award[a]

Total project cost, in millions, as of March 2021



Source: NSF documents and officals. | GAO 21-417

[a]Includes an award funded by appropriations under the American Recovery and Reinvestment Act of 2009 and an award funded by NSF's Major Research Equipment and Facilities Construction account.

Remaining Contingency and Scope Reduction Options

As of December 2020 with construction 98 percent complete.

NSF Management Reserve:

$18.9 million

Budget contingency:

$3.5 million of budget contingency remaining ($1.1 million more than the estimated remaining risk exposure of about $2.4 million).

Schedule contingency:

One month.

Estimated value of remaining scope reduction options:

$21,000

Source: NSF documents and officials. | GAO-21-417

Cost and Schedule Performance History

DKIST was delayed for pandemic and non-pandemic related reasons. In February 2020, there was an ice storm which caused a power outage at the construction site, and a subsequent 2-week slow down. Then the construction site was shut down again from March 17 to June 4, because of the COVID-19 pandemic. The project began a phased reentry to the site on June 4, 2020. The project requested, and NSF approved, a no cost extension to the project's end date from June 30, 2020 to December 31, 2020. However, the project was unable to meet this deadline because, among other things, personnel needed for testing were located on the U.S. mainland and unable to reach Hawaii until it reopened to travel in October 2020. To address costs and delays related to the pandemic, NSF initially increased the not-to-exceed cost of the project to include a management reserve of $9.4 million using authority delegated to NSF by the National Science Board to adjust costs by up to $10 million. In February 2021, the National Science Board approved an additional increase in management reserve of $9.5 million for a total reserve of $18.9 million. As of March 2021, NSF applied $9.4 million of the reserve to the award and delayed end of construction to June 2021.

Remaining Project Risks and Potential for Cost or Schedule Increases

As of December 2020, the DKIST project had $3.5 million of budget contingency remaining—$1.1 million more than the estimated remaining risk exposure of about $2.4 million when weighted for the risks' probability. The project also had 1 month of schedule contingency remaining to offset any potential delays in completing construction. However, NSF had to extend the award due to commissioning challenges and the pandemic which will require further use of management reserve within the $18.9 million currently authorized.

According to the project documentation, the largest remaining non-pandemic risk category is project completion and closeout, which includes risks related to staff retention and performance and quality issues. As of December 2020, this category included seven risks with about $1.4 million in probability weighted risk exposure. The project maintains a list of scope reduction options, which, as of December 2020, included approximately $21,000 in total possible project scope reduction options. However, the ability of these remaining scope reduction options to reduce costs will continue to decrease as the project approaches completion.

Source: W O'Mullane/LSST Project/ NSF/AURA | GAO-21-417

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).

Source: GAO analysis of NSF information. | GAO-21-417

Project Information

Location: Cerro Pachón, Chile.

Source: GAO. | GAO-21-417

Scheduled construction completion date, including schedule contingency:

October 2022.

Construction award:

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

Responsible NSF directorate:

Mathematical and Physical Sciences.

Project partners:

The LSST Corporation, Department of Energy.

Expected duration of operations:

50 years.

Source: NSF documents and officials. | GAO-21-417

Project Summary

As of December 2020, the Rubin project was 86 percent complete and in its 7th year of construction. Since our April 2020 report, the project made progress on the observatory's dome and telescope mount assembly. However, construction was halted in Chile due to the pandemic in March and the site remained closed until late September 2020. The project is no longer operating on schedule because of pandemic-related delays. NSF expects the end of construction will occur in early 2024, but no formal changes have yet been made to the project schedule. NSF increased the not-to-exceed cost by $10 million to include a management reserve for costs due to the COVID-19 pandemic, such as increased labor due to delays or inefficiencies.

Construction Status of the Vera C. Rubin Observatory, as of December 2020

Percentage complete	86
	Dollars in millions
Not-to-exceed cost that the National Science Board authorized	483.0
Total project cost in latest construction award	471.2[a]
National Science Foundation (NSF) funding obligated to date	459.4

Changes in Cost, Schedule, and Scope

Dollars in millions

	Cumulative changes since original construction award	Changes since April 2020
Not-to-exceed cost that the National Science Board authorized	+10▲	+10▲
Total project cost[b]	+3.4▲	None
Scope[c]	-9.5▼	-8.1▼
Scheduled completion date (months)[d]	None	None

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

Source: GAO analysis of NSF documents and information from NSF officials. | GAO-21-417

[a]Excludes fee of $1.1 million in total provided to date to stimulate efficient performance since award.

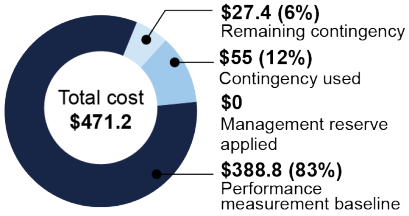
[b]This cost change was anticipated at the time of the original construction award, according to NSF officials, in order to accommodate evolving NSF policies on budget contingency.

[c]Scope changes included are reductions in response to NSF's policy on no cost overruns at initial award ($1.4 million) or to increase the available budget contingency ($8.1 million).

[d]Schedule does not yet incorporate COVID-19 pandemic impacts.

Latest Construction Award

Total project cost, in millions, as of December 2020



Notes: Excludes fee of $1.1 million provided to the recipient to stimulate efficient performance. Percentages do not sum to 100 percent due to rounding.

Remaining Contingency and Scope Reduction Options

As of December 2020 with construction 86 percent complete.

NSF Management Reserve:

$10 million

Budget contingency:

$27.4 million ($2.8 million more than the probability-weighted risk exposure of $24.6 million)

Schedule contingency:

4.8 months.

Estimated value of remaining scope reduction options:

$9 million.

Source: NSF documents and officials. | GAO-21-417

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 impacted camera construction, but as of January 2021 NSF did not expect camera construction would further delay the project.

Source: GAO analysis of NSF and DOE information.

Cost and Schedule Performance History

In June 2020, NSF increased the not-to-exceed cost for Rubin by $10 million to $483 million to include a management reserve to address pandemic-related costs. According to NSF and project documents, the added costs are primarily due to schedule delays as well as direct costs associated with office and construction site closures. As of March 2021, NSF had not yet applied any of this reserve to the award, thus the total project cost has not changed since our April 2020 report. However, NSF and the project anticipate that additional funding beyond the $10 million will be needed for pandemic-related costs. Further, increasing the cost of the project will require authorization from the National Science Board.

The project will not finish by its current construction completion date of October 2022. Prior to the pandemic, the project had experienced delays related to the construction of the dome enclosure and telescope mount assembly. According to NSF, significant progress was made on these items in early 2020. However, they remain unfinished as the project halted construction in March 2020 in response to the COVID-19 pandemic and the Chilean government-imposed quarantine throughout the country in July 2020. Limited construction activities at the site began again in late September 2020. Dome construction resumed in November and mount assembly construction resumed in January 2021. NSF expects a re-baselining of the project in late 2021 to establish a new schedule and total project cost. According to project documents, the pandemic will delay completion by at least 10 months. The project measurement baseline currently has 4.8 months of schedule contingency for non-pandemic-related delays, however pandemic impacts and the planned re-baselining will alter the project's schedule.

Remaining Project Risks and Potential for Cost or Schedule Increases

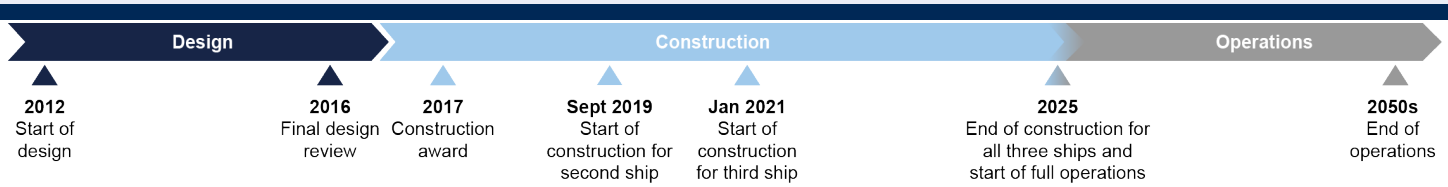
As of December 2020, the project had an estimated remaining risk exposure of $24.6 million for non-pandemic-related risks, which is $2.8 million less than the remaining budget contingency of $27.4 million. According to project documents, factoring in actions to mitigate these risks lowers the expected risk exposure to just $12.4 million. The largest non-pandemic-related risks include late delivery or integration of the dome enclosure or mount assembly and late delivery of the DOE-funded camera.

In accordance with NSF policy, the project maintains a list of scope reduction options. As of December 2020, there was approximately $9 million in total possible project scope reduction options remaining. As the project moves towards completion, fewer scope reduction options will be available.

REGIONAL CLASS RESEARCH VESSELS

Source: Artist Rendering by Glosten. | GAO-GAO-21-417

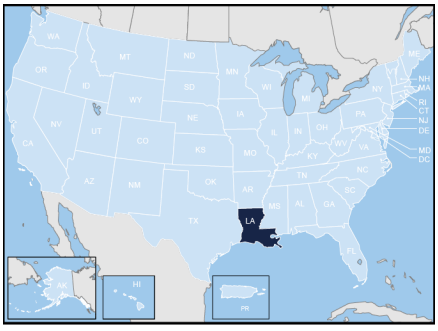
The National Science Foundation's (NSF) Regional Class Research Vessels (RCRV) project will construct three 199-foot vessels to support the nation's ability to conduct fundamental scientific research in the coastal zone and continental shelf, including from the ocean's surface through the water column 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 NSF plans to operate the first vessel along the west coast of the U.S.



Source: GAO analysis of NSF information. | GAO-21-417

Project Information

Location: Construction site is in Louisiana.



Source: GAO. | GAO-21-417

Scheduled construction completion date, including schedule contingency:

January 2025 for three vessels.

Construction award:

Cooperative support agreement with Oregon State University, which contracted with Gulf Island Shipyards, LLC.

Responsible NSF directorate:

Geosciences.

Project partners:

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

Expected duration of operations:

30 years.

Source: NSF documents and officials. | GAO-21-417

Project Summary

As of December 2020, construction of NSF's RCRV project was 35 percent complete and the project was in its 4th year of construction. Since our April 2020 report, the RCRV project has made progress on vessel construction and 3D modeling, but has fallen behind schedule. The project continued construction on vessel 1 and vessel 2. They also performed a keel laying ceremony for vessel 3 in March 2020 but delayed start of construction until January 2021. NSF increased the not-to-exceed cost by $10 million in December 2020 and designated a management reserve of about $14.1 million held by NSF for COVID-19 related costs, such as increased labor costs due to delays or inefficiencies. NSF authorized the project to use $5.5 million of this reserve to address COVID-19 costs to date, but NSF has not yet applied any reserve since the current obligations cover these increases.

Construction Status of the Regional Class Research Vessels, as of March 2021

Percentage complete (based on construction of three vessels)	35
	Dollars in millions
Not-to-exceed cost that the National Science Board authorized	375.0
Total project cost in latest construction award	359.5
National Science Foundation (NSF) funding obligated to date	343.0

Changes in Cost, Schedule, and Scope

Dollars in millions

	Cumulative changes since original construction award	Changes since April 2020 report
Not-to-exceed cost that the National Science Board authorized	+10 ▲	+10 ▲
Total project cost	+5.5 ▲	+5.5 ▲
Scope[a]	None	None
Scheduled completion date (months)	+6 ▲	+6 ▲

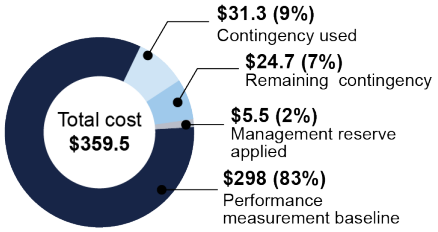
Legend: ▲ = cost or schedule increase.

Source: GAO analysis of NSF documents and information from NSF officials. | GAO-21-417

[a]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 2021



Note: Percentages do not sum to 100 percent due to rounding.

Remaining Contingency and Scope Reduction Options

As of December 2020 with construction of three vessels 35 percent complete.

NSF Management Reserve:

$14.1 million

Budget contingency:

$24.7 million ($4.5 million more than the probability-weighted risk exposure of $20.2 million).

Schedule contingency:

None.

Estimated value of remaining scope reduction options:

$4.9 million

Source: NSF documents and officials. | GAO-21-417

Cost and Schedule Performance History

As of December 2020, the RCRV project had no schedule contingency remaining and NSF anticipated additional schedule delays due to the pandemic. The project also increased its total project cost and delayed project completion, but had not implemented any scope reductions.

The RCRV project has fallen behind schedule, in part due to shipyard delays in developing the 3D models and technical drawings needed for construction. As we reported in April 2020, the project recipient, Oregon State University, had concerns regarding the project management and subcontractors of the Gulf Island Shipyards that led to a partial work suspension in early 2019. In November 2019, Oregon State University implemented the contract's dispute resolution process and assumed responsibility for the project's modelling. In May 2020, the project implemented a change to its baseline to address the impacts of the dispute. This change used $18 million of budget contingency, including a $12.2 million increase in the contract to the shipyard. The change also led to about a 9-month delay in delivery of the three vessels and exhausted the 180 days of schedule contingency available at the time.

In addition, the project has continued to fall behind schedule due to the COVID-19 pandemic. The shipyard lacked sufficient staff to complete RCRV construction as planned and labor inefficiencies led to delays in technical drawings used by the shipyard. In December 2020, NSF authorized about $14.1 million in management reserve to cover costs associated with the pandemic by increasing the project's not-to-exceed cost by $10 million and using additional funds available because the total project cost in the construction award was less than the prior not-to-exceed cost. No additional funds have yet been obligated to the construction award, but NSF subsequently authorized Oregon State University to modify its contract with the shipyard by $5.5 million to address the increased labor costs in 2020. This modification also delayed delivery of the first two vessels by 4 months, delivery of the third vessel by 3 months, and project completion by 6 months.

Since we reported in April 2020, vessel delivery has slipped from August 2021 to September 2022 for the first vessel; from January 2022 to March 2023 for the second vessel; and from July 2022 to August 2023 for the third vessel.

Remaining Project Risks and Potential for Cost or Schedule Increases

As of December 2020, the project had an estimated risk exposure of $20.2 million and a remaining contingency of $24.7 million. Inadequate shipyard performance remains a major risk, but has decreased due to the project's re-planning efforts. Nonetheless, hull delivery delays remain a risk to completing the project on time and budget.

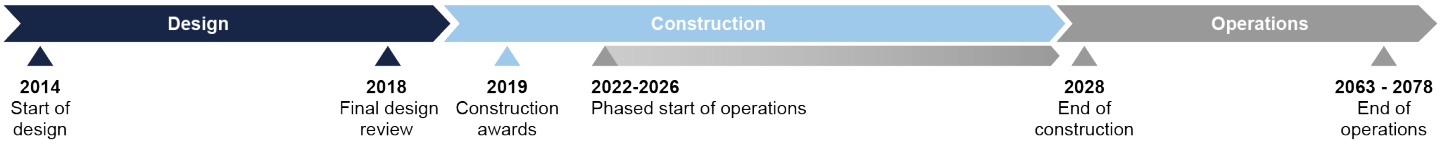
The project has implemented no scope reductions. Fourteen scope reduction options remain totaling $4.9 million in cost reduction. The largest remaining option was to reduce the 18-month timeframe currently devoted to transitioning from construction to full operations. Such a reduction could save $1.5 million in staff costs, but would incur risks to transitioning activities that could impact operations. Other scope reduction options included eliminating certain pieces of equipment, such as the inspection vehicle or cold storage space, to support longer term operations.

Source: Leidos. | GAO-21-417

Note: Rendering of McMurdo Station's core facility.

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.



Source: GAO analysis of NSF information. | GAO-21-417

Project Information

Location: McMurdo Station, Antarctica

Source: GAO. | GAO-21-417

Expected construction completion date, including schedule contingency:

January 2028

Construction award:

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

Responsible NSF directorate:

Geosciences.

Project stakeholders:

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

Expected duration of operations:

35 to 50 years.

Source: GAO analysis of NSF information. | GAO-21-417

Project Status

Construction of the AIMS project was about 24 percent complete as of December 2020. In March 2020, work at the project site was suspended to avoid the possibility of introducing COVID-19 to Antarctica. As of December 2020, AIMS remains behind schedule with all construction work at McMurdo paused. The site has been placed in a safe and stable condition until pandemic and longer-term logistical impacts are better understood. NSF and the awardee continue to discuss how to reprioritize work and maintain forward momentum given the considerable uncertainties of the global logistics chain and construction feasibility due to COVID-19. Materials for the Vehicle Equipment and Operation Center and Lodging facilities are still being procured and delivered to the project's shipping staging site in Port Hueneme, California. Prior to the suspension of work, production of the stone material needed for new structures at the site had begun as had the demolition of retired structures.

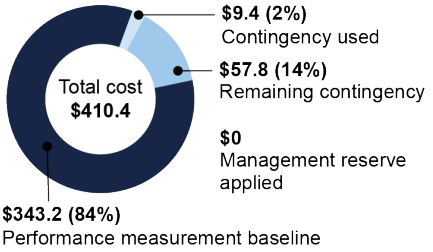
Construction Status of the Antarctic Infrastructure Modernization for Science, as of December 2020

Percentage complete	24
	Dollars in millions
Not-to-exceed cost that the National Science Board authorized	410.4
Total project cost in latest construction awards	410.4
National Science Foundation (NSF) funding obligated to date	151.7

Source: GAO analysis of NSF information. | GAO-21-417

Latest Construction Award

Total project cost, in millions, as of December 2020



Note: .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 for negotiations with the contractor as NSF utilized data within the ICE, such as labor rates and cost of materials, to verify costs. Specifically, the ICE assisted NSF in determining 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.

Remaining Contingency and Scope Reduction Options

As of December 2020 with construction about 24 percent complete.

Budget contingency:

$57.8 million ($5.7 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: GAO analysis of NSF information. | GAO-21-417

Cost and Schedule Performance History

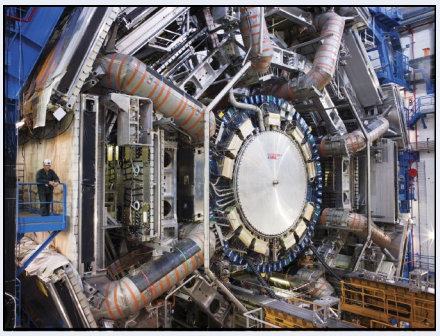
Due to the pandemic, AIMS remains behind schedule with all construction work at McMurdo Station paused. With the loss of a second construction season likely, NSF officials expect that the project will be re-baselined by the end of 2021. In accordance with NSF policy, this could include reductions in project scope, a return to the National Science Board for an increased total project cost, or both. As of December 2020, the impacts of the pandemic were not yet reflected as construction cost increases, formal changes to its scheduled completion date, or scope reductions. The project's not-to-exceed cost of $410.4 million, which included $67.2 million in budget contingency, was set by the National Science Board in February 2019. On April 30, 2021, NSF determined that it would not be funding additional components of AIMS due to the significant impacts of the pandemic. Current components of AIMS include the Vehicle Equipment and Operations Center, the first lodging unit, and associated utilities.

Remaining Project Risks and Potential for Cost or Schedule Increases

As of December 2020, the AIMS project had a risk exposure of $52.1 million and $57.8 million in remaining contingency, and 15.2 months of schedule contingency remained available. The project had cumulatively used $9.4 million in budget contingency. Of this, $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.

As of December 2020, the AIMS project had $17.0 million in major risks monitored by NSF. Given the level of uncertainty and high potential impact on Antarctic operations associated with the COVID-19 pandemic, a meaningful risk profile will not be available until the project is re-baselined. Other major previously-known risks being monitored include proposals exceeding estimates with an estimated value of $15.2 million, and design and value engineering delays with an estimated value of $1.4 million, and their associated impacts have been overtaken by the pandemic. Environmental conditions at McMurdo during the 2020/2021 season prevented the construction of a safe ice pier for cargo unloading, but this did not impact AIMS since no on-site construction was planned due to the pandemic. Domestic production of AIMS components was able to continue.

In accordance with NSF policy, the project maintains a list of scope reduction options, which as of April 2019 included approximately $34.0 million to $43.1 million in total possible project scope reduction options. For example, the largest scope reduction option, with an estimated value of up to $19.1 million, is to remove the new trades shop from the AIMS scope and instead continue to use the current facility. Another option, with an estimated value of up to $4.0 million, is to remove the gymnasium from the emergency operations facility and instead continue to use and maintain the existing gymnasium.



Source: © 2007 CERN. | GAO-21-417

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

LARGE HADRON COLLIDER HIGH LUMINOSITY UPGRADE

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 the facility's accelerator and 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 analysis of NSF information. | GAO-21-417

Project Information

Location: Geneva, Switzerland.

Source: GAO. | GAO-21-417

Expected construction completion date, including schedule contingency:

December 2026.

Construction awards:

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

Responsible NSF directorate:

Mathematical and Physical Sciences.

Project partners:

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

Expected duration of operations:

12 years.

Source: GAO analysis of NSF information. | GAO-21-417

Project Summary

As of December 2020, NSF's HL-LHC program was in its 1st year of construction. In February 2020, the National Science Board authorized an award to Columbia University for the ATLAS detector not to exceed $75 million and a second award to Cornell University for the CMS detector not to exceed $78 million. NSF awarded construction awards to the two universities in March 2020. While the upgrades involve separate cooperative agreements for each detector, NSF considers them one program consisting of two distinct projects. The COVID-19 pandemic has delayed construction of the detectors, including an estimated 7-month delay for ATLAS from its baseline schedule, and impacted other aspects of the LHC upgrade. Excluding impacts of the pandemic, the detectors' baseline schedule estimates end of construction in 2025, not including schedule contingency, or 2026 including it.

Construction Status of the Large Hadron Collider High Luminosity Upgrade, as of December 2020

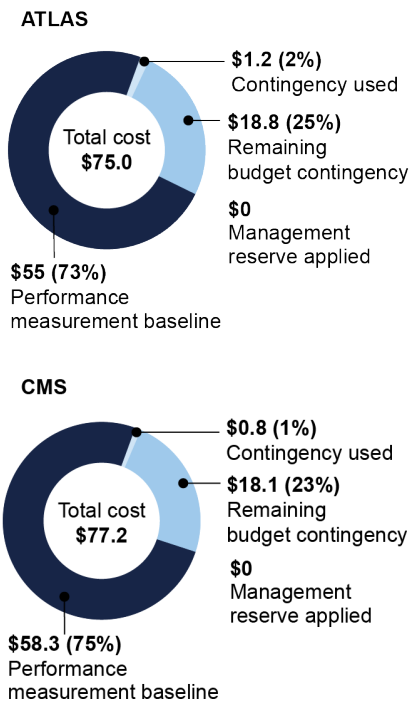
Dollars in millions

	ATLAS	CMS	Program Total
Percentage complete	8.2	9.4	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	22	27.9	49.9

Source: GAO analysis of documents and information from NSF. | GAO-21-417

Latest Construction Award

Total Project Cost, in millions, as of December 2020



Remaining Contingency and Scope Reduction Options

As of December 2020.

Budget contingency:

$36.9 million as follows

- $18.8 million for the ATLAS detector.
- $18.1 million for the CMS detector.

Schedule contingency:

- 13.5 months for the ATLAS detector.
- 10.2 months for the CMS detector.

Estimated value of scope reduction options:

$15.1 million as follows

- $8.4 million for the ATLAS detector.
- $6.7 million for the CMS detector.

Source: GAO analysis of NSF information. | GAO-21-417

DOE's Contributions to Upgrading the Large Hadron Collider

The estimated cost range of DOE's contributions is $149 million to $181 million for the ATLAS detector and $144 million to $183 million for the CMS detector. DOE's work on the detectors is led by the department's national labs, whereas NSF's work is led by university researchers.

Source: DOE fiscal year 2021 budget information. | GAO-21-417

Cost and Schedule Performance History

NSF has obligated $22 million for construction of ATLAS and $27.9 million for CMS, as of December 2020. The project's initial awards estimated total project costs of $75 million for ATLAS and $77.2 million for CMS. The National Science Board's not-to-exceed cost is $75 million for ATLAS and $78 million for CMS. In addition, according to NSF officials, NSF invested a total of $23.7 million for the design of the detector upgrades. Funding for the design came from NSF's Research and Related Activities account. Funding for construction will come from the Major Research Equipment and Facilities Construction account.

Remote work conditions and social distancing protocols due to the COVID-19 pandemic have led to delays to both detectors as compared to the baseline schedule. Both projects are assessing the impacts of the pandemic, and neither has completed changes to their baseline schedules as the impacts of the pandemic are ongoing.

Remaining Project Risks and Potential for Cost or Schedule Increases

Neither the ATLAS team nor the CMS team has fully assessed the impact of COVID-19 on their projects. Both project teams are developing change requests to their baseline to address these impacts. NSF plans to use management reserve, not the projects' contingency, to cover expenses related to the pandemic but has not yet established reserve amounts for these projects. According to NSF, the estimated cumulative costs currently range from $2 million to $3 million, due to labor inefficiencies and re-planning costs, among others. As of December 2020, the project teams estimate schedule delays from the pandemic of 7 and 2 months for ATLAS and CMS, respectively.

According to project documentation, as of December 2020, the ATLAS project team had $18.8 million in budget contingency remaining after using $1.2 million of its initial $20 million contingency fund. The highest impact risks managed by the project team include volatility of commodity prices, delays due to other ongoing projects at CERN, and loss of key personnel. The project team plans to update its risk exposure in late fiscal year 2021.

As of December 2020, the CMS project had $18.1 million in budget contingency remaining after using $840 thousand of its initial $18.9 million contingency budget. In October 2020, the CMS project team estimated its risk exposure was $17.5 million. The highest impact risks managed by the project include uncertainty regarding foreign currency exchange rates, unavailability of scientific labor, and quality problems. Risks regarding COVID-19 were not included in the project team's analysis.

NSF policy also directs a project's design to include prioritized, time-phased options for reducing its scope during construction if needed. As of the final design review, the project teams had identified a total of $15.1 million of potential scope reduction options for the projects, which are subject to change throughout the design and construction of a project.

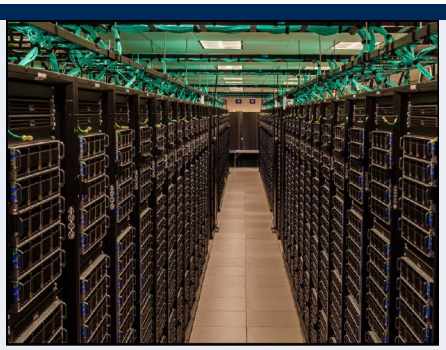
Appendix II: Summary of the National Science Foundation's Future Major Facilities Project in Design

This appendix provides an individual summary of the National Science Foundation (NSF) project that is in design and planned for construction as a major facilities project: the Leadership Class Computing Facility. As of December 2020, no construction funds had been awarded for this project and all cost, schedule, scope, and design information was subject to change.

The 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;
- 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;[1] and
- information on potential project risks.

[1]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.



Source: NSF. | GAO-21-417

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

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 NSF information. | GAO-21-417

Project Information

Location: Texas Advanced Computing Center, University of Texas at Austin

Source: GAO. | GAO-21-417

Expected construction completion date, not including schedule contingency:

Fiscal Year 2026.

Construction award:

Planned for 2024.

Responsible NSF directorate:

Directorate for Computer & Information Science & Engineering.

Project partners:

None.

Expected duration of operations:

10 years.

Source: GAO analysis of NSF information. | GAO-21-417

Project Status

As of December 2020, the LCCF project was in its second year of design; consequently, all cost, schedule, scope, and design information for the project was subject to change. In March 2019, the NSF Director approved the project to enter the design stage as a candidate major facilities project. NSF approved advancing the project to the preliminary design phase in September 2020, following the recommendation of the conceptual design review and facilities readiness panels. A preliminary design phase award of $3.5 million was made on September 17, 2020. 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.

Design and Construction Costs

As of December 2020, 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. In fiscal years 2019 and 2020, NSF obligated $5.5 million from its Research and Related Activities account for the design of LCCF. Based on a recommendation from the Conceptual Design Review Panel, NSF is also planning to fund 15 to 20 science teams ($4.5 million to $6.0 million) in fiscal year 2021 to help define the benchmark suite of science applications that will be used to measure the performance improvements of the LCCF system. According to the project's cooperative agreement, NSF may provide $2.5 million additional funding in fiscal year 2022 to advance the design of LCCF following successful completion of the preliminary design review, subject to availability of appropriations. The preliminary design review is tentatively scheduled for October 2021.

NSF's Support for High-Performance Computing Systems

NSF has supported high-performance computing capabilities for nearly 4 decades. In 2007, NSF awarded $226.6 million for the Blue Waters high-performance computing system through a cooperative agreement to the University of Illinois at Urbana-Champaign. According to NSF, at the time of its deployment in 2013, Blue Waters was one of the most powerful supercomputers in the world and was one of the fastest on a university campus. Scientists and engineers across the country used the computing and data power of Blue Waters to tackle a wide range of problems, including predicting the behavior of complex biological systems and simulating the evolution of the cosmos.

Because of the rapid evolution of computer technology, by 2019, NSF no longer considered Blue Waters to be the leadership computing system for fundamental science and engineering research. Anticipating these technological advances, in August 2018, NSF awarded about $60 million to the University of Texas at Austin for the follow-on project to Blue Waters. Frontera was intended to provide three to five times the computing capability and twice the storage capacity to support the increased computational requirements for science and engineering research. NSF also anticipated that Frontera would help inform science requirements and reduce risks for LCCF, which is planned to provide substantially more computational capabilities than both Blue Waters and Frontera.

Source: GAO analysis of NSF information. | GAO-21-417

Project Risks

As of December 2020, NSF had not yet formally identified risks for the LCCF project because the project is early in the design stage. The project team identified 25 significant risks during the conceptual design, such as failing to meet performance specifications. However, the conceptual design review panel found that there were immediate, identifiable risks that were absent or insufficiently delineated in the design and recommended that the project team expand their consideration of risks early in the preliminary design phase.

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. The officials stated that forecasting the technology marketplace in the future can be challenging as technology can change radically 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 that result in the most advanced computing capabilities. According to NSF officials, taking advantage of such opportunities as late in the design or construction stage as possible will be important for the success of the project.

Appendix III: 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), Paul Kazemersky (Analyst in Charge), Molly Ryan, and Tind Shepper Ryen made key contributions to the report. Also contributing were Cheron Brooks, Louise Fickel, and Patrick Harner.

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