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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

GAO 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.

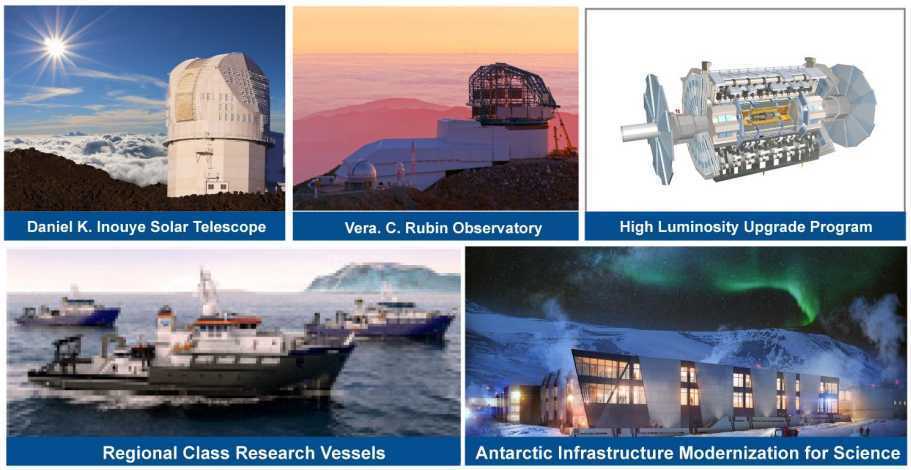
What GAO Found

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.

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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

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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

[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).

associations, and companies—manage the projects' day-to-day activities. NSF generally funds these construction efforts through its Major Research Equipment and Facilities Construction (MREFC) account. Over the past 5 fiscal years, NSF has received over $1 billion in appropriations to this account, 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

Category	2017 (fiscal year)	2018(fiscal year)	2019 (fiscal year)	2020 (fiscal year)	2021 (fiscal year)
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,

[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.

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 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.

[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.

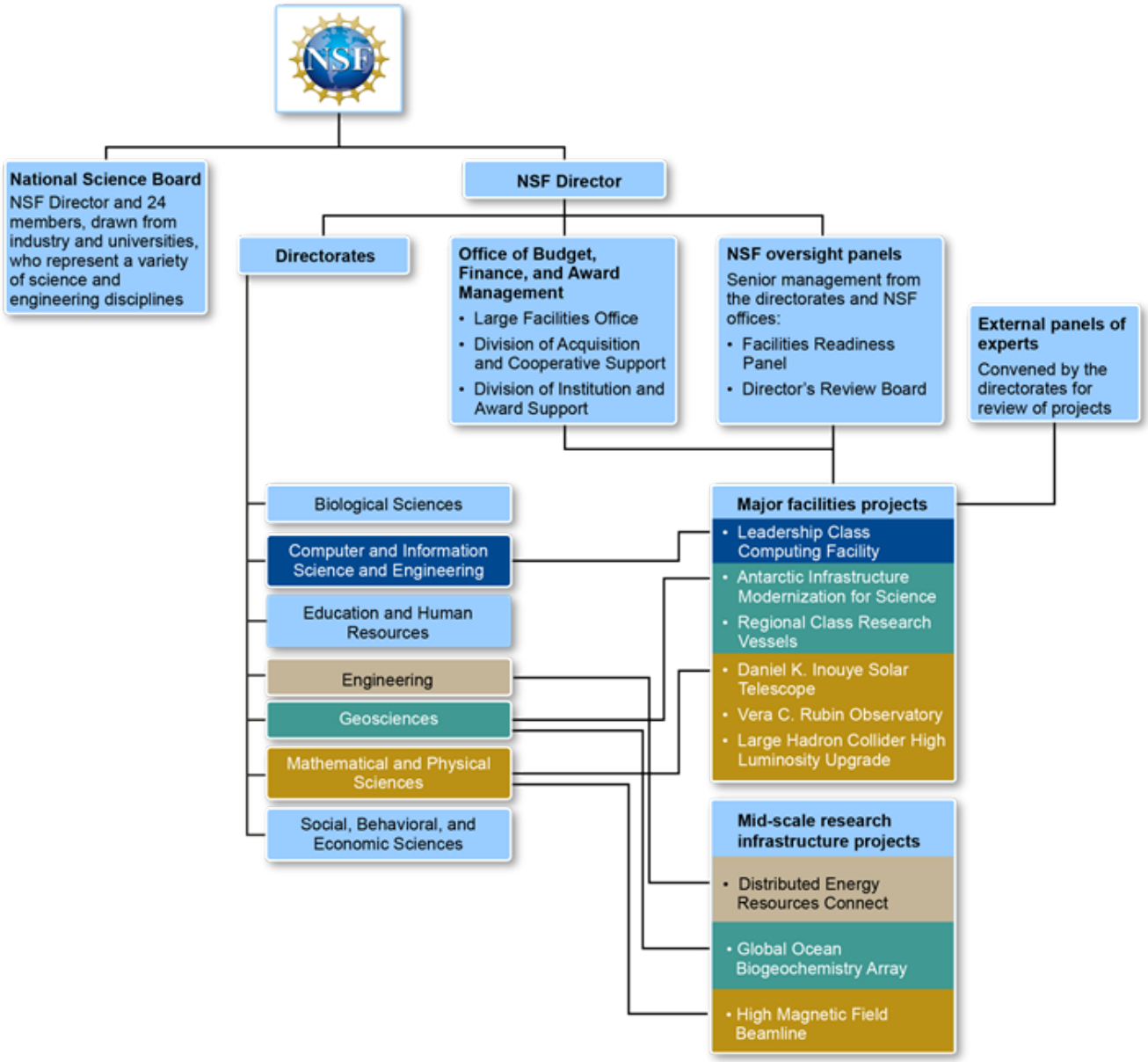
- **Divestment.** Divestment can include the transfer of the research infrastructure to another entity's operational and financial control or the decommissioning of the research infrastructure, including its complete deconstruction and removal. NSF generally decides to divest when the agency or the scientific community determines that the facility is no longer considered an operational priority with regard to advancing science, according to NSF's *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:

[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.

- **Fee.** NSF may provide recipients the opportunity to earn a fee for major facilities projects.
- **Management reserve.** NSF, not the award recipient, holds management reserve to manage budget uncertainties, unforeseeable events, and risks not manageable by the recipient.

NSF's No Cost Overrun Policy for Major Facilities Projects

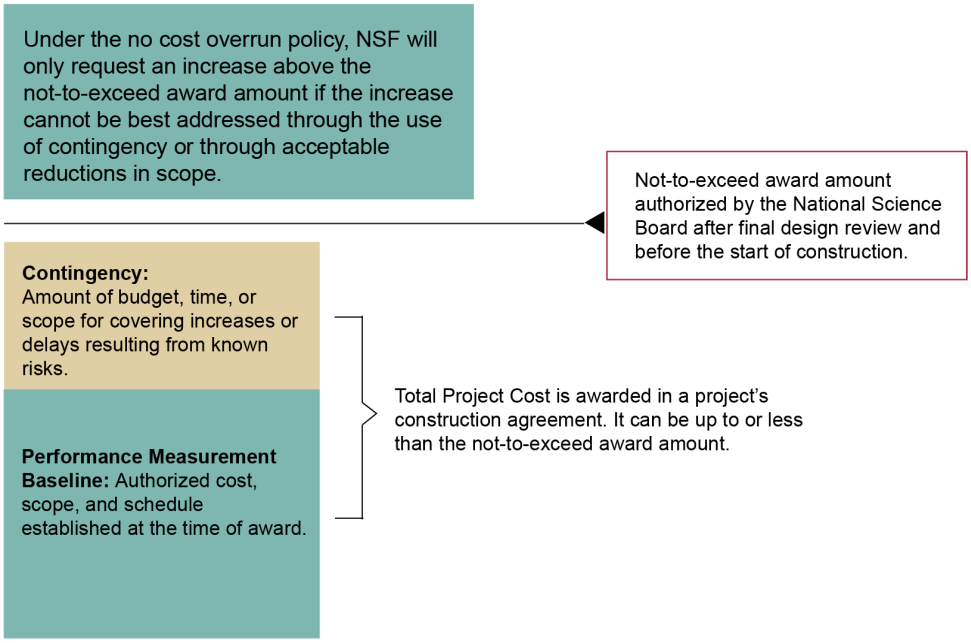
Since February 2008, NSF has had a policy to manage cost overruns on major facilities projects.[7] Under this policy, the cost estimate developed at the preliminary design review should have adequate contingency to cover all foreseeable risks.[8] Any cost increases not covered by contingency are generally 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.

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]

[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

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-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.

[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.

[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.

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.

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).

[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.

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
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,

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

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 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

[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.

[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.

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 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

[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.

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 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

[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).

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 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

[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.

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

(Will be attached)

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

(Will be attached)

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

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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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