United States Government Accountability Office
Report to Congressional Committees

December 2023

NATIONAL SCIENCE FOUNDATION

Additional Steps Would Improve Cost Estimate for Antarctic Research Infrastructure Project

GAO-24-106380

GAO Highlights

Highlights of GAO-24-106380, a report to congressional committees

Why GAO Did This Study

NSF supports the design, construction, and operations of science and engineering research infrastructure such as telescopes and research vessels. These projects include major facilities projects that cost over $100 million. Currently, NSF has five major facilities projects under construction at a combined authorized cost of $1.4 billion and four additional projects in design. Building these on time and within budget helps support the scientific community's ability to conduct research and advance U.S. scientific goals.

The Consolidated Appropriations Act, 2022, includes provisions for GAO to review projects funded from NSF's Major Research Equipment and Facilities Construction account. This report, the sixth, (1) describes the cost and schedule performance of NSF's research infrastructure projects, (2) examines the AIMS project's adoption of cost estimating and schedule development best practices and (3) examines supply chain risk management for NSF's major facilities projects in construction. GAO reviewed NSF and award recipient documents, examined policies and procedures to manage and oversee projects, and interviewed NSF officials.

What GAO Recommends

GAO recommends that NSF ensure the AIMS project meets the well-documented characteristic of a reliable cost estimate. NSF concurred with the recommendation and noted it plans to develop a corrective action plan that will include appropriate measures for revised cost proposals for the project.

View GAO-24-106380. For more information, contact Candice N. Wright at (202) 512-6888 or WrightC@gao.gov.

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Additional Steps Would Improve Cost Estimate for Antarctic Research Infrastructure Project

What GAO Found

Since GAO's July 2022 report, the National Science Foundation (NSF) has finalized the cost and schedule increases that were due to the COVID-19 pandemic and other factors for all five major facilities projects in construction. NSF anticipates additional increases for two of its major facilities projects—the Vera C. Rubin Observatory and the Antarctic Infrastructure Modernization for Science. NSF also advanced the design of two projects and approved the advancement of two new projects to the design stage—the Giant Magellan Telescope, and the Thirty Meter Telescope.

Examples of National Science Foundation Major Facilities Projects

Artist rendering of the Antarctic Infrastructure Modernization for Science project (left) and a picture of the A Toroidal Large Hadron Collider Apparatus Detector (right).

Source: Leidos (artist's rendering, left); 2008 CERN European Organization for Nuclear Research (photograph, right). | GAO-24-106380

NSF's Antarctic Infrastructure Modernization for Science (AIMS) project substantially met three of the four characteristics of a reliable cost estimate and met all the characteristics of a reliable schedule. The AIMS cost estimate was unreliable because it did not substantially or fully meet all four characteristics of a reliable cost estimate, as described in GAO's cost guide. Specifically, the AIMS project partially met the "well-documented" characteristic associated with reliable cost estimates. This was, in part, because the estimate did not specify the source data used and it lacked details to trace technical baselines to cost and other key information for management review. Without good documentation, senior management and others providing oversight will not have confidence that the estimate is reliable. In addition, a reliable cost estimate may help the project to prevent any unnecessary tradeoffs or loss of research capabilities that may result from unexpected cost increases in the future.

NSF guidance requires that project teams identify all known risks and opportunities that may affect the supply chain for their projects in construction. Several projects have experienced unforeseen supply chain related risks due in part to the pandemic and other external factors. For example, the Rubin Observatory reported supply chain issues stemming from the war in Ukraine and the project's inability to receive shipments from that region to support construction. Because of the unforeseen nature of these risks, NSF determined that the agency would provide management reserve funds in response. To manage known supply chain risks, the award recipients may identify specific supplier performance and component availability for projects prior to construction and include in the project's budget contingency to respond to those risks should they occur.

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Abbreviations

AIMS	Antarctic Infrastructure Modernization for Science
AIR	Antarctic Infrastructure Recapitalization
APAR	Airborne Phased Array Radar
ARV	Antarctic Research Vessel
ATLAS	A Toroidal Large Hadron Collider Apparatus
CERN	European Organization for Nuclear Research
CMS	Compact Muon Solenoid
GMT	Giant Magellan Telescope
HL-LHC	Large Hadron Collider High Luminosity Upgrade
LCCF	Leadership Class Computing Facility
LHC	Large Hadron Collider
MREFC	Major Research Equipment and Facilities Construction
NSB	National Science Board
NSF	National Science Foundation
RCRV	Regional Class Research Vessels
TACC	Texas Advanced Computing Center
TMT	Thirty Meter Telescope
US-ELT	U.S. Extremely Large Telescope
VEOC	Vehicle Equipment Operations Center

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December 5, 2023

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 Hal Rogers
Chair
The Honorable Matt Cartwright
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, such as telescopes and research vessels. NSF funds construction, acquisition, and commissioning through its Major Research Equipment and Facilities Construction (MREFC) account. In addition to major facilities projects, NSF expanded its MREFC portfolio in 2020 by awarding mid-scale research infrastructure projects.[1] Together, these research infrastructure projects are designed and constructed to meet the needs of the scientific community and further scientific and engineering research capabilities.

NSF uses cooperative agreements and contracts to fund and oversee the projects throughout their life cycles, including the design, construction, and operations stages. NSF received an MREFC appropriation of $249 million in fiscal year 2022. For fiscal year 2023, NSF received an

[1]For the purposes of this report, the term "research infrastructure projects" refers to the major facilities projects and mid-scale projects that NSF funds from its MREFC account. Major facilities projects have a total project cost of more than $100 million while mid-scale projects funded from the MREFC account have a total project cost between $20 and $100 million. NSF manages another set of mid-scale projects under $20 million that are not funded from the MREFC account.

appropriation of $187 million and requested $305 million in fiscal year 2024 for this account.

In June 2022, we reported that NSF continued to face cost increases, schedule delays, or both, for the major facilities projects still in construction because of the pandemic and other factors. In response to the pandemic, NSF decided to re-baseline all major facilities projects in construction by adjusting cost and schedule beyond the original authorized award amounts. In addition, NSF developed new guidance for how award recipients should respond to cost and schedule increases caused by the pandemic, such as the use of management reserve for three projects in construction. NSF is working to address one remaining recommendation we made in 2019 that focused on NSF's need to identify and address gaps in staff project management expertise.[2]

The Consolidated Appropriations Act 2022 includes provisions for GAO to review projects within NSF's MREFC account, which includes construction of major facilities and implementation of mid-scale projects.[3] This report, the sixth in the series, (1) describes the cost and schedule performance of NSF's ongoing major facilities and mid-scale research infrastructure projects, (2) examines the extent to which the Antarctic Infrastructure Modernization for Science (AIMS) project applied best practices for cost estimating and schedule development, and (3) examines NSF's supply chain risk management process for its major facilities projects in construction.

For each of our objectives, we reviewed information pertaining to the major facilities projects that were under construction or in design at the time of our review, as well as mid-scale research infrastructure projects. We reviewed progress reports and other available documentation that describe cost and schedule performance. We selected the AIMS project for our second objective due to its current construction progress and the recent adjustments made to its cost, schedule, and scope. In addition, we reviewed NSF documents to assess the extent to which NSF identified, assessed, and responded to supply chain related risks for its major

[2]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).

[3]The Consolidated Appropriations Act, 2022, refers to the explanatory statement containing the mandate printed in 168 Cong. Rec. H1709 (2022). Pub. L. 117-103, 136 Stat. 49, 51 (2022).

facilities projects in construction. For a detailed description of our scope and methodology, see appendix I.

We conducted this performance audit from November 2022 to December 2023 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

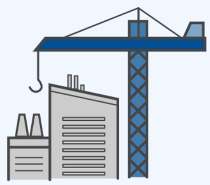
NSF's Research Infrastructure Projects

NSF has 17 research infrastructure projects in design, construction, or implementation that are either funded or planned for funding out of the MREFC account, as of May 2023.[4] Of these 17 projects, nine are major facilities projects and eight are mid-scale research infrastructure projects (see fig. 1). Once completed, these projects will serve various scientific research goals, from observations of the sea floor environment to the charting of billions of galaxies in space.

[4]Major facilities projects typically progress through five stages: development, design, construction, operations, and disposition. According to NSF officials, mid-scale research infrastructure projects are classified as "in implementation" rather than "in construction" given their wide range in technical nature.

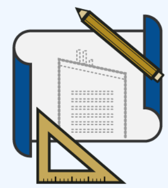
Figure 1: NSF's Research Infrastructure Projects in Construction or Design, as of May 2023

Major facilities projects in construction



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

Major facilities projects in design



- Leadership Class Computing Facility
- Antarctic Research Vessel
- U.S. Extremely Large Telescope Program
    - Thirty Meter Telescope
    - Giant Magellan Telescope

Mid-scale research infrastructure projects

- Distributed Energy Resources Connect
- Global Ocean Biogeochemistry Array
- High Magnetic Field Beamline
- Network for Advanced Nuclear Magnetic Resonance
- Research Data Ecosystem
- Airborne Phased Array Radar
- Advanced Millimeter Survey Instrumentation in Chile
- Compact X-Ray Free-Electron Laser Project

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-106380

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 proposed projects and submit them to NSF for review. After a project's final design review, the NSF authorizes a not-to-exceed award amount and schedule duration. The not-to-exceed amount, which includes budget contingency, is the amount against which NSF measures cost increases to implement its no cost overrun policy. According to NSF policy, any cost increases beyond the not-to-exceed amount should generally be accommodated by reductions in scope.

NSF's current *Research Infrastructure Guide* defines the following components, which together make up the total project cost and schedule for the construction of major facilities projects.[5] 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 be made through a formal change control process.
- **Contingency**. This is the amount of budget or time for covering the cost increases or delays that would result if project risks identified during the design stage were to occur, such as price changes of goods in future years. During development of a total project cost estimate, the timing and effects of such risks are uncertain. As a project progresses, the effects of risks that materialize may exceed the cost or schedule 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 and judgment based on past project experience.

In this report, we identify NSF's estimated total project costs for the construction of major facility and mid-scale research infrastructure projects. For major facilities projects, these costs were developed by the award recipient during the design stage and periodically reviewed by NSF to inform agency decision-making. These estimates are subject to change before construction awards are made. For projects under construction, we

[5]A project's authorized not-to-exceed cost may include a fee or management reserve. NSF may give recipients the opportunity to earn a fee for major facilities projects. NSF, rather than the award recipient, holds management reserve to manage budget uncertainties, unforeseeable events, and risks not manageable by the recipient (i.e. held by the agency). Use of management reserve is not a typical cost increase, and the inclusion in total project costs requires authorization from NSF. National Science Foundation, *Research Infrastructure Guide*, NSF 21-107 (Dec. 2021).

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

identified total project costs based on the amounts awarded in the cooperative support agreements for construction and the not-to-exceed amount authorized by NSF. Only at the end of the project—when construction is complete, and the awards have been closed out—will the final total project costs and actual duration be known.

Methods to Address Cost Increases for Major Facilities Projects

In order to comply with its no cost overrun policy, NSF has five methods for addressing any potential cost increases during the construction of major facilities projects.[7] These methods appear below in order of precedence.

- **Re-planning**. Re-planning is a process to modify cost and schedule plans for future work without affecting the authorized total project cost, duration, or overall scope objectives.
- **Use of contingency**. Contingency is an amount of budget added to a project's cost estimate to allow for items, conditions, or events that experience shows will likely result in a cost increase. These events are typically known risks and uncertainties that projects may anticipate or identify during the design stage.
- **Use of management reserve.** Management reserve is an amount of money authorized by NSF to address unforeseen events or uncertainties that are beyond the control of an award recipient or NSF, such as cost increases associated with extreme events, such as the pandemic or natural disasters. Management reserve is not for typical cost increases, and its use requires authorization from NSF.
- **De-scoping.** De-scoping is the process of removing elements or objectives from a project. Before construction, the project team develops a scope management plan to identify potential elements or objectives that can be removed with minimal negative effects.
- **Re-baselining.** Re-baselining is a modification to the project cost, duration, or scope that results in a change beyond the amounts defined in the construction award or contract.

Risk Management for Major Facilities Projects

To increase the likelihood of a successful construction of a research infrastructure project, NSF requires that projects develop plans to identify, assess, and respond to risks that may occur during construction through a process known as risk management. Risk management allows projects

[7]Under the no cost overrun policy, the cost estimate developed at the preliminary design review is required to have adequate contingency to cover all foreseeable risks. Any cost increases not covered by contingency are generally to be accommodated by reductions in scope.

to forecast effects of a possible event on the total project cost and schedule and to aid the project in prioritizing alternatives to mitigate increases in total project cost and schedule. The *Research Infrastructure Guide* identifies three key products that projects must prepare to support development of the construction total project cost and risk management during construction.

- **Risk Management Plan.** The risk management plan defines how risks will be identified and managed using standard risk management processes and practices.
- **Risk Register.** The risk register documents all identified risks for a project.
- **Quantitative Risk Analysis.** The risk analysis determines risk exposure and the appropriate budget contingency.

NSF Anticipates Cost or Schedule Increases for Two Projects in Construction, While Design and New Project Approvals Continued Uninterrupted

Cost and Schedule Changes to Major Facilities Projects Are Finalized, with Additional Increases Expected for Two Projects

Since our July 2022 report, NSF has finalized cost and schedule increases resulting from the pandemic and other factors for all five major facilities projects in construction (see table 1). However, NSF anticipates additional increases for two of its major facilities projects, the Vera C. Rubin Observatory (Rubin Observatory) and AIMS. In addition, NSF advanced the design of two projects and approved the advancement of two new projects to the design stage, the Giant Magellan Telescope and the Thirty Meter Telescope. As previously reported, NSF planned to adjust the awarded total project cost and schedule of its projects in construction through re-baselines in response to the pandemic. According to NSF officials, NSF decided to re-baseline to prevent projects from using budget contingency for the work stoppages and inefficiencies from the pandemic which would not be an allowable use since budget contingency is intended for known risks. In addition, NSF officials stated that NSF wanted to prevent unplanned major reductions in scientific scope. As of September 2023, NSF has completed re-baselines for all five projects.

Table 1: Most Recent Status of NSF Major Research Infrastructure Facilities Projects in Construction

Project name	Total project cost (in millions)	Percentage complete	Cost change (in millions)	Schedule change (months)
Regional Class Research Vessels[a]	$400	58%	▲ $25.0	▲ 11
Rubin Observatory[a]	$571	94%	-	▲ 5
Antarctic Infrastructure Modernization for Science[b]	$275	58%	▼ $135.4	▲ 13
Large Hadron Collider High Luminosity Upgrade (ATLAS)[b]	$82.8	37%	▲ $ 7.8	▲ 21
Large Hadron Collider High Luminosity Upgrade (CMS)[b]	$88	40%	▲ $10.0	▲ 16
Total	**$1,416.8**			

Legend: ATLAS = A Toroidal Large Hadron Collider Apparatus; CMS = Compact Muon Solenoid

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-106380

[a]Updated as of July 2023

[b]Updated as of August 2023

NSF finalized its re-baseline for the Regional Class Research Vessels (RCRV) project in September 2022. This re-baseline resulted in an increase of $25 million to the total project cost and a schedule increase of 6 months. These increases were mainly due to delays in construction resulting from labor shortages stemming from Hurricane Ida—a category 4 hurricane that heavily damaged the region in August 2021. NSF expects an additional 6-month delay but intends to use available budget and schedule contingency instead of an additional re-baseline, according to NSF officials.

In addition, two projects that recently finalized their re-baselines anticipate additional schedule increases beyond their previously re-established schedule completion dates.

- **Vera C. Rubin Observatory.** NSF anticipates an additional delay of 5 months. A portion of this delay is attributed to an electrical accident at an offsite location where integration work for the observatory's camera is scheduled to take place.[8] The electrical accident—unrelated to the Rubin project—resulted in a 3-month delay from the power outage and temporary stoppage of testing, combined. In November 2022, the project conducted re-planning activities to correct for supply chain issues and schedule conflicts that resulted in the additional 2-month delay. Additionally, management reserve is expected to be used later this year to cover indirect impacts from the war in Ukraine.

- **Antarctic Infrastructure Modernization for Science.** NSF anticipates further cost and schedule increases for the Antarctic Infrastructure Modernization for Science (AIMS) project. In June 2022, NSF originally completed a re-baseline of the project to reflect the reduced scope of the project, bringing the total project cost down from $410 million to $275 million. Although the cost of AIMS has decreased when compared with the original authorization, the re-baseline's reduction in project scope resulted in a higher overall cost for the remaining work. The AIMS project continues to face additional challenges following finalization of the re-baseline in June 2022. NSF identified incorrect design parameters that affect the integrity of building construction and found a number of errors the contractor used to monitor cost and schedule data. Specifically, the wind speed design requires replacement of half of the project's concrete footers and additional structural reinforcement. The approved baseline change request to address these issues utilized $8 million in budget contingency since NSF only approved the additional concrete and steel that would have been needed if the design error had not been made. Schedule impacts are still being evaluated.

The Large Hadron Collider High Luminosity Upgrade (HL-LHC) program's ATLAS and CMS projects finalized their re-baselines in September 2023. The re-baselines resulted in cost increases of $7.8 million and $10.8 million, respectively, with a total project cost of $170.8 million for both projects.

Projects in Design Continued as Planned and NSF Approved New Projects

NSF advanced the design of the Leadership Class Computing Facility (LCCF) and the Antarctic Research Vessel (ARV). NSF conducted a final design review for LCCF in April 2023. The project team provided an updated project execution plan that recommended an option to co-locate

[8]The camera for the Rubin Observatory—funded by the Department of Energy—is being built and tested onsite by the Stanford Linear Accelerator Center.

the data center at a nearby commercial facility.[9] NSF estimated a total project cost of $520 million in their fiscal year 2024 budget request to Congress. The Director plans to consult with the NSB about advancing the Leadership Class Computing Facility (LCCF) to the Construction Stage in November 2023. The fiscal year 2024 MREFC appropriation to support potential construction of LCCF is pending.

NSF conducted the second stage-gate review of the design process—known as preliminary design review—for the ARV project in February 2023 and a subsequent recommendation was made to the NSF Director to proceed to the final design phase. According to NSF officials, the NSF Director approved advancement in September 2023.

In addition, NSF approved two new projects for entry into the design phase: the Giant Magellan Telescope and the Thirty Meter Telescope. Both projects are part of the U.S. Extremely Large Telescope program. Each project underwent a two-stage, preliminary design review: science and technical topics in December 2022 and cost, scope, schedule, and project management plans in February 2023. Each project is projected to cost more than $2 billion, with the requested NSF contribution being over $1 billion for each project. The cost of the final design phase for each project is estimated at $100 million. However, according to NSF officials, NSF has not yet decided whether it will financially support either project in moving forward.

Mid-Scale Projects Continued and NSF Approved New Mid-Scale Projects

Since our last report in 2022, NSF awarded three new mid-scale research infrastructure projects (see table 2). These three new mid-scale projects have a combined total project cost of approximately $235 million. All three projects are expected to finish implementation by 2028.

[9]As discussed in our 2022 report, a commercial data center provider plans to build a new facility in Round Rock, Texas. This facility will be 10 miles from the LCCF project site. The project team determined it would cost significantly less to co-locate planned computational equipment at this facility instead of building a stand-alone facility.

Table 2: NSF Newly Awarded Mid-Scale Infrastructure Projects, as of May 2023

Project name	Awardee	Project description	Authorized award amount (dollars in millions)	Scheduled completion date
Airborne Phased Array Radar (APAR)	University Corporation for Atmospheric Research	To provide significant improvement in storm and climate research, APAR will measure clouds and severe storms worldwide including locations that have previously been unreachable by conventional radar.	$91.8	May 2028
Advanced Millimeter Survey Instrumentation in Chile	The Trustees of the University of Pennsylvania	To take high resolution measurements of the sky with advanced hardware, software, and facility upgrades. The new capability will enable greater measurement accuracy for fundamental physics research.	$52.7	April 2028
Compact X-ray Free-Electron Laser (CXFEL)	Arizona State University	To perform new x-ray measurements that allow for research of material structures in a way that was previously impossible. This device will contribute to research on topics such as biomedical imaging and material and quantum science.	$90.8	March 2028

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-106380

NSF also progressed on the implementation of the five previously awarded mid-scale research infrastructure projects (see table 3). NSF authorized an additional $2.5 million for the Distributed Energy Resources Connect project since our last report. According to NSF officials, this project requested supplemental funding to cover labor and material costs. The total project cost and scheduled completion date for the other mid-scale projects remain the same.

Table 3. Status of NSF Mid-Scale Infrastructure Projects, as of September 2023

Project name	Awardee	Authorized award amount (in millions)	Percent complete	Scheduled completion date
Distributed Energy Resources Connect	University of California, San Diego	$42.0	67%	October 2025
Global Ocean Biogeochemistry Array	Monterey Bay Aquarium Research Institute	$52.9	25%	October 2025
High Magnetic Field Beamline	Cornell University	$32.7	62%	October 2025
Network for Advanced Nuclear Magnetic Resonance Spectroscopy	University of Connecticut Health Center	$39.7	51%	June 2025
Research Data Ecosystem	University of Michigan	$38.4	31%	January 2027

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-106380

Cost Estimate and Schedule Development for the AIMS Project Were Generally Consistent with Best Practices, But Some Information Was Not Documented

AIMS Project Substantially Met Three of Four Characteristics for Reliable Cost Estimate

NSF's AIMS cost estimate substantially met three characteristics of a reliable cost estimate (comprehensive, accurate, and credible), but partially met one (well-documented). Because one characteristic was found to only partially meet best practices, the cost estimate could not be considered reliable.[10] For a summary of our assessment of the project's cost estimate following the June 2022 re-baseline and examples of best practices associated with each characteristic, see table 4.

[10]GAO, *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs*, GAO-20-195G (Washington, D.C.: March 12, 2020). As outlined in the cost guide, we have found that a reliable cost estimate has four characteristics—comprehensive, well-documented, accurate, and credible. If the overall assessment ratings for each of the four characteristics are substantially or fully met, the estimate conformed to leading practices and therefore could be considered reliable. If any of the characteristics are not met, minimally met, or partially met, then the cost estimate does not fully conform to the leading practices and cannot be considered reliable.

Table 4: Assessment of NSF's 2022 Revision of the Antarctic Infrastructure Modernization for Science Project Cost Estimate, Compared to Cost Estimating Best Practices

Characteristic	Examples of a cost estimate reflecting best practices	GAO assessment
Comprehensive	Includes all life cycle costs Is based on a technical baseline description[a] Documents cost-influencing ground rules and assumptions Is based on a product-oriented work breakdown structure[b]	Substantially met
Well-documented	Shows the source data used Describes step by step how the estimate was developed Discusses the technical baseline description Provides evidence that the cost estimate was reviewed and accepted	Partially met
Accurate	Properly adjusts for inflation Is based on a historical record Uses the best methodology from the data collected Contains few, if any, minor mistakes Documents and explains variances Is updated regularly	Substantially met
Credible	Includes a sensitivity analysis[c] Includes a risk and uncertainty analysis[d] Includes cross-checks[e] Is compared to an independent estimate	Substantially met

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-106380

[a]A technical baseline description is a document or set of documents that describe the program's or project's purpose, system, performance characteristics, and system configuration.

[b]A work breakdown structure is a framework for planning and assigning responsibility for work necessary to accomplish a program's objectives. It deconstructs a program's end product into smaller specific elements that are suitable for management control.

[c]A sensitivity analysis is an examination of the effect on program cost of changing one assumption or cost driver at a time while holding all other variables constant.

[d]A risk and uncertainty analysis uses statistical techniques to predict the probability of successfully executing a program within its budget by capturing the cumulative effect of program risks and uncertainty.

[e]Cross-checks—or alternative methodologies—on major cost elements are performed to validate results.

Comprehensive: substantially met. Our analysis found that the project documents included a detailed technical baseline description of the project scope.[11] In addition, the estimate influencing ground rules and

[11]Technical baseline description is a document or set of documents that describe the program or project's purpose, system, performance characteristics, and system configuration.

assumptions were thoroughly described.[12] Further, we found the project estimate used a detailed work breakdown structure (WBS) and WBS dictionary. However, we found some of the life cycle cost estimate data were limited. GAO's cost guide recommends that a life cycle cost estimate encompass all past (or sunk), present, and future costs for every aspect of the program, regardless of funding source.

Well-documented: partially met. According to GAO's cost guide, a cost estimate should be well-documented to ensure an estimate's reliability and support an organization's decision makers. However, our analysis found certain issues related to (1) source data, (2) linkage between the technical baseline and cost estimating methodology, and (3) evidence that the cost estimate was reviewed and accepted.

We found that NSF did not ensure the contractor fully documented the data used for significant portions of the estimate. For example, project documentation that outlined the basis of estimates for individual tasks did not contain the source data used to generate estimates. Further, we found that key data elements were either (1) not captured in the estimate or (2) were not captured in a way that would allow for easy updates to the estimate. Estimates may need to be updated as the project incurs actual costs or if the project executes scope changes. For example, much of the estimate uses numerical values rather than the equations used to calculate the values. In addition, key data were stored in separate files rather than in the estimate itself. GAO's cost guide recommends that cost estimates should be detailed enough to provide an accurate assessment of the cost estimate's quality. Without good documentation, management and those providing oversight will not be convinced that the estimate is reliable.

We also found that the cost estimate and accompanying documentation lack the detail required to trace technical baseline requirements to cost. For example, the proposal data used to support much of the estimate provides only vague descriptions of the data and methods used to develop the estimates. As an example, in one case the provided documentation states that "proposed hours are estimated based on the scope of work, deliverables, the knowledge of the estimators and the

[12]Ground rules are often grouped together with assumptions, ground rules represent a common set of agreed-to estimating standards that provide guidance and minimize conflicts in definitions.

team involved." This provides insufficient detail to determine whether the data and methods used to generate the cost estimates are reliable.

Moreover, we found there is little evidence provided of the cost estimate specifically being reviewed and approved by NSF management. NSF provided a memo from June 2022 that acknowledges several events. For example, the memo documents a number of things, such as negotiation between NSF and the prime contractor to accept the re-baseline of the AIMS additional costs associated with the re-baseline and renegotiate the incentive fee structure. However, it is not a comprehensive discussion of the cost estimate for the purposes of gaining management approval. Additional documentation contained reviews that included discussions of cost, but no comprehensive management review of the cost estimate.

NSF officials provided several documents as sources of information in response to our assessment. Although these documents provided details on how costs were calculated, they lack sufficient information on the methods and data used to generate labor and material quantity estimates from the technical specifications of the project.

Accurate: substantially met. Our analysis found the estimate is based on broadly accepted methodologies, with minimal use of subject matter expert judgment. The estimate is largely reliant on engineering build-up estimates, and these are backed-up with significant detail regarding labor hours and labor rates (including subcontractor effort), materials lists, and materials costs. Further, we found that their estimate and documentation are largely mistake-free despite some minor discrepancies between some of the supporting documents.[13]

The estimate is updated frequently as the scope changes. Variances are tracked through earned value management data. However, there have

[13]One example of a minor discrepancy was that the quantitative risk analysis had different values compared to other project documentation such as the project execution plan and cost book. For example, the base cost before fee is $213.2 million and the total project cost is $271.4 million. However, the quantitative risk analysis documentation uses values of $213.7 million and $268.9 million for the base cost before fee and the total project cost, respectively.

been recent concerns surrounding the validity of this data.[14] Finally, we found evidence the estimate is based on historical data, but the specific data used is not well-documented, nor is there discussion of the reliability and applicability of the data. GAO's cost guide recommends there be enough knowledge about the data source to determine if the data can be used to estimate accurate costs for the program.

Credible: substantially met. Our analysis found that the project developed a detailed cost risk and uncertainty analysis. Further, we found an independent cost estimate (ICE) was conducted and documented and an independent cost assessment related to the most recent scope changes was performed.[15] Moreover, cross-checks were performed on much of the estimate. The project conducted a detailed sensitivity analysis of all the cost elements. However, in many cases, the variations were based on subjective judgment or assumptions. We also found the sensitivity analysis had not been updated since 2019, despite numerous updates to the scope of the project and the accompanying cost estimate in that time. GAO's cost guide recommends carefully assessing the underlying risks and supporting data, and documenting the sources of variation, for a sensitivity analysis to be useful in making informed decisions.

[14]NSF reviewed the project's earned value management system (EVMS) and found several issues, including problems with the baseline budget, integration of cost and schedule data, processes, and management reporting. As a result, NSF will not be able to accept the project's EVMS and has reduced its confidence in the project's earned value management data until the project makes necessary adjustments to meet the agency's guidelines. NSF officials said the agency will provide the contractor time to correct these issues before its next review.

[15]An independent cost assessment is a non-advocate's evaluation of a cost estimate's quality and accuracy, looking specifically at a program's technical approach, risk, and acquisition strategy to ensure that the program's cost estimate captures all requirements. An independent cost estimate is conducted by an organization outside the acquisition chain, using the same detailed technical information as the program estimate, an ICE serves as a comparison with the program estimate to determine whether the program estimate is accurate and realistic.

AIMS Fully or Substantially Met All Four Characteristics of a Reliable Schedule

NSF's AIMS project schedule is reliable because the project fully or substantially met all four characteristics of a reliable schedule.[16] For a summary of our assessment and examples of leading practices associated with each characteristic, see table 5.

Table 5: Assessment of NSF's 2022 Revision of the Schedule for the Antarctic Infrastructure Modernization for Science Project, Compared to Best Practices

Characteristic	Examples of a schedule estimate reflecting best practices	GAO assessment
Comprehensive	Capturing all activities Assigning resources to all activities Establishing the durations of all activities	Substantially met
Well-constructed	Sequencing all activities Confirming that the critical path is valid[a] Ensuring reasonable total float[b]	Substantially met
Credible	Verifying that the schedule can be traced horizontally and vertically Conducting a schedule risk analysis[c]	Substantially met
Controlled	Updating the schedule using actual progress and logic Maintaining a baseline schedule[d]	Fully met

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-106380

[a]A critical path is the longest continuous sequence of activities in a schedule. Defines the program's earliest completion date or minimum duration.

[b]Total float is the amount of time an activity can be delayed or extended before delay affects the program's finish date.

[c]A schedule risk analysis is an examination on uncertainty and key risks and how they affect the schedule's activity durations.

[d]A baseline schedule is the original configuration of the program plan and signifies the consensus of all stakeholders regarding the required sequence of events, resource assignments, and acceptable dates for key deliverables.

Comprehensive: substantially met. Our analysis found that the schedule captures all activities and assigns durations to all activities. The Integrated Master Schedule (IMS) captures relevant contractor and subcontractor effort and reflects the contractor work breakdown

[16]GAO, *Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-16-89G (Washington, D.C.: Dec. 22, 2015). As outlined in the schedule guide, we have found that a reliable schedule has four characteristics—comprehensive, well-constructed, credible, and controlled. If the overall assessment ratings for each of the four characteristics are substantially or fully met, the estimate conformed to leading practices and therefore could be considered reliable. If any of the characteristics are not met, minimally met, or partially met, then the cost estimate does not fully conform to the leading practices and cannot be considered reliable.

structure.[17] Key milestones are identified and activities in the schedule are traceable to key management documents. Activity names are unique and descriptive, and level-of-effort activities are clearly marked. The schedule contains labor, material, and non-labor resources, however it is not clear at what level they are specified. Labor resources do not appear to have realistic unit counts or availability and labor resource assignments are not complete.

Well-constructed: substantially met. Our analysis found the majority of the activities in the schedule are scheduled using intuitive finish-to-start logic.[18] We found no instances of missing or anomalous logic and the majority of date constraints used in the schedule are documented and justified. In addition, we found the critical path is continuous and is not hindered by unjustified date constraints or other logic issues. NSF management uses the critical path to focus on activities that will detrimentally affect key program milestones and deliveries if they slip, and the project team is aware of key delayed activities. Further, we found reasonable amounts of total float values in the project schedule, with large values justified in program documentation. However, we found minor anomalies in the total float values. Specifically, one activity and one milestone appear to be able to slip more days than there are remaining on the project.

Credible: substantially met. Our analysis found that NSF conducted a quantitative risk analysis for the re-baselined AIMS project in May 2022 to determine a probabilistic finish date and associated contingency. The program documentation details the overall methodological approach, risk data collection, and risk and uncertainty ranges. We also found schedule logic is in place and the technical content has been validated. The schedule is horizontally traceable, meaning it links products and outcomes associated with other sequenced activities. We found the schedule to be vertically traceable. For example, the schedule allows for lower-level activities to roll up into higher WBS levels and we were able to map key major milestones between the schedule and management

[17]The integrated master schedule is a program schedule that includes the entire required scope of effort, including the effort necessary from all government, contractor, and other key parties for a program's successful execution from start to finish. The IMS should consist of logically related activities whose forecasted dates are automatically recalculated when activities change. The IMS includes summary, intermediate, and detail-level schedules.

[18]Finish-to-start logic is a logic relationship that dictates that a successor activity cannot start until the predecessor activity finishes.

documents and presentations. We found some inconsistencies in activity names between documents; names should be consistent to allow for total schedule integrity and to enable different teams to work towards the same schedule expectations.

Controlled: fully met. We found that the schedule is updated periodically, and progress is archived monthly. In addition, the program has a schedule basis document that defines ground rules and assumptions, calendars, and other schedule parameters. In addition, the project monitors performance against an approved baseline and tracks schedule contingency.

NSF Has Processes in Place to Manage Supply Chain Risks

NSF Has Processes to Assess and Respond to Unforeseen Global Supply Chain Risks

Several major facilities projects have experienced unforeseen supply chain related risks that have led to unexpected cost and schedule increases. According to NSF officials, these risks are primarily related to global supply chain issues that emerged during the pandemic and the war in Ukraine. For example, the Rubin Observatory project reported that supply chain issues from the war in Ukraine have affected the project's ability to receive shipments to support construction. Specifically, manufacturers for the Rubin Observatory's dome faced availability issues regarding metal sourced from Ukraine. In addition, the two detector upgrade projects for HL-LHC have identified issues related to availability of both construction materials and programmatic scientific equipment as an ongoing issue since the start of construction.

NSF classifies unforeseen risks as those that major facilities projects could not have anticipated that may affect the project's cost and schedule. These differ from the known risks that may occur during construction that project teams typically identify during the design stage of the project and include in their budget contingency estimates. Other recent examples of unforeseen risks include a severe hurricane in 2021 that affected construction for the RCRV project and an electrical incident at the site where camera integration efforts are taking place for the Rubin Observatory. Because of the unknown nature of the likelihood and potential severity of these types of risks, NSF has decided that it would assume responsibility for unforeseen events, rather than having the project use budget contingency to respond to them. According to NSF officials, NSF's approach aligns with the definition of budget contingency in both the Uniform Guidance and the Federal Acquisition Regulation, which states it should be used to address known risks.

According to NSF officials, NSF has considered revisions to its practices for assessing and responding to unforeseen supply chain risks and other unforeseen events. For example, NSF deliberated on providing management reserve in addition to the contracted award amount for projects as they begin construction, given the global supply chain issues affecting multiple projects. However, based on an analysis of industry and other agency practices for project management, NSF believes its current process of using management reserve held by NSF and awarding as needed is sufficient.

NSF is responding to supply chain risks through the use of management reserve, similar to how the agency has responded to pandemic related risks. As previously reported, NSF has developed guidance for project teams to submit requests for supplemental funding to respond to unforeseen risks resulting from the pandemic.[19] For example, a supplemental funding request is expected for the Rubin Observatory for the use of management reserve previously authorized as part of the 2021 re-baseline. This funding request will be used to respond to the unforeseen supply chain risks stemming from residual pandemic impacts and the war in Ukraine. In addition, according to NSF officials, the project teams for the ATLAS and CMS detector upgrade projects updated the design to ensure a more timely delivery of parts to meet revised schedules. NSF took these actions in order to address unforeseen supply chain issues and the lack of material available affecting construction.

NSF May Identify Specific Supplier Performance and Component Availability Issues during the Design Stage

According to NSF officials, project teams, at their discretion, may identify specific known risks at the time of estimate related to supplier performance or component availability as part of the project's overall risk management. Project teams can use quantitative risk analysis to determine the effect of a risk on the project's completion date and cost. NSF guidance requires that project teams identify all known risks and

[19]GAO, *National Science Foundation: COVID-19 Affected Ongoing Construction of Major Facilities Projects*, GAO-22-105550 (Washington, D.C.: July 20, 2022). This guidance requires project teams to submit information to NSF that shows the unexpected cost increases and how those cost increases were related to unforeseen events. According to NSF officials, this will prevent projects from requesting management reserve as a means to respond to known risks, given that such "reserves" are prohibited under the Office of Management and Budget's (OMB) Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards (commonly referred to as "Uniform Guidance").

opportunities that may affect the supply chain for their projects in construction. Development of the risk management plan occurs as part of the project execution plan submitted in the design stage, well before construction takes place. In addition, the guidance requires that project teams perform quantitative risk analyses to determine the appropriate amount of budget contingency to respond to known risks. During design review phases, NSF will assess the project team's risk management plan and analyses and may request revisions.

Specifically, project teams may identify supplier performance or component availability risks that projects may anticipate due to issues with a specific vendor, or a particular industrial sector, in relation to a particular component, or the criticality of a particular component. For example, the RCRV project has identified supplier failure as a risk that accounts for inability of specific suppliers to provide materials in a timely manner. Additionally, the ATLAS detector upgrade project of the HL-LHC program maintains a supply chain risk register that identifies risks for specific parts and equipment for various components. These types of supplier performance or material availability issues differ from the global supply chain issues that have affected global commodities, partly as a result of the pandemic. Having project teams identify known risks as part of the risk management plan helps ensure that project teams will use budget contingency, not supplemental management reserve provided by NSF, to respond to these known risks if realized.

Conclusions

NSF's research infrastructure projects are essential for advancing the research capabilities of the U.S. science community. These projects provide the necessary equipment to conduct groundbreaking research across many fields of science, from astronomy to geophysics. Because of their importance, it is critical for NSF to construct these research infrastructure projects on budget and in a timely manner.

Having a cost estimate that is comprehensive, well-documented, credible, and accurate would help ensure that the cost estimate is of high quality and reliable. NSF and Congress could have greater confidence in the project's cost estimate if the AIMS project is detailed enough to accurately assess the cost estimate's quality. Having a high-quality cost estimate supports management's future budgetary decisions about the project's construction. Moreover, a reliable cost estimate may help NSF and awardees avoid having to make unnecessary tradeoffs or reduce the research capabilities on their projects that could result from unexpected cost increases in the future.

Recommendation for Executive Action

The Director of NSF should ensure that the Antarctic Infrastructure Modernization for Science cost estimate meets the well-documented characteristic of a reliable cost estimate, as defined in GAO's cost guide. (Recommendation 1)

Agency Comments

We provided a draft of this report to NSF for review and comment. In its comments, reproduced in appendix IV, NSF concurred with our recommendation, stating that it would develop a corrective action plan that will include appropriate measures for revised cost proposals for the project. NSF also provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Director of the National Science Foundation, and other interested parties. In addition, the report is available at no charge on the GAO website at 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 V.

Candice N. Wright

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

Appendix I: Objectives, Scope, and Methodology

The Consolidated Appropriations Act, 2022 includes provisions for GAO to review projects within NSF's Major Research Equipment and Facilities Construction (MREFC) account.[1] This report (1) describes the cost and schedule performance of NSF's ongoing major facilities and mid-scale research infrastructure projects, (2) examines the extent to which a selected major facilities project—the Antarctic Infrastructure Modernization for Science project—applied best practices for cost estimating and schedule development and (3) evaluates the extent to which NSF has identified, assessed, and responded to risks related to the supply chain for its major facilities projects in construction.

To describe the cost and schedule performance of NSF's research infrastructure projects since our 2022 report, we reviewed project documents and NSF's written responses to our questions about projects that were under construction and in design. We reviewed, for example, progress reports; risk reports and risk registers; documentation on available scope reduction options; and other NSF documents. The major facilities projects under construction were the Vera C. Rubin Observatory, the Regional Class Research Vessels, the Antarctic Infrastructure Modernization for Science, and the Large Hadron Collider High Luminosity Upgrade. The major facility projects in design at the time of our review were the Leadership Class Computing Facility, Antarctic Research Vessel, the Giant Magellan Telescope, and the Thirty Meter Telescope.

To describe the current status of NSF's MREFC-funded mid-scale research infrastructure projects since our 2022 report, we also reviewed documents that detailed project cost and schedule. These mid-scale projects were the Distributed Energy Resources Connect, the Global Ocean Biogeochemistry Array, the High Magnetic Field Beamline, the Network for Advanced Nuclear Magnetic Resonance, and the Research Data Ecosystem. In addition, three new mid-scale research infrastructure projects were awarded during our review: the Airborne Phased Array Radar, the Advanced Millimeter Survey Instrumentation in Chile, and the Compact X-ray Free-Electron Laser.

To examine the extent to which NSF's AIMS project applied best practices for cost estimate and program schedule, experts from our Engineering Sciences group completed two separate analyses of the

[1]The Consolidated Appropriations Act, 2022, makes reference to the explanatory statement containing the mandate printed in 168 Cong. Rec. H1709 (2022). Pub. L. 117-103, 136 Stat. 49, 51 (2022).

Antarctic Project. We selected this project because it had been under construction long enough to allow our analysis but had enough time remaining in construction to allow for changes, if necessary.

We chose to examine cost estimate and scheduling because

- Developing reliable cost estimates is crucial for realistic program planning, budgeting and management. Without a reliable cost estimate, projects are at risk of experiencing cost overruns, missed deadlines, and performance shortfalls; and
- A well-planned schedule is another fundamental management tool that provides a road map for systematic execution of a project as well as a means to gauge progress, identify and address potential problems, and promote accountability.

We (1) compared the AIMS project's cost estimates to best practices in GAO's cost guide and (2) compared the project's construction schedule to best practices in GAO's schedule guide. Specifically, we reviewed agency policies—such as NSF's Research Infrastructure Guide and a standard operating guidance document on cost estimates—and project documents—such as the AIMS project's integrated master schedule, work breakdown structure, risk management plan and risk registers. We provided our criteria and draft analyses to NSF for review and incorporated their technical comments as appropriate.

To evaluate the extent to which NSF has identified, assessed, and responded to risks related to the supply chain for its major facilities projects in construction, we reviewed key documents outlining NSF's plans, including risk management plans and risk registers. In addition, we reviewed monthly and bi-monthly status reports to determine when supply chain risks were realized. Furthermore, we interviewed NSF officials to understand how NSF assessed and responded to those risks affecting the supply chain that had occurred. Finally, we compared those actions to guidance for risk management maintained in NSF's Research Infrastructure Guide to determine whether those risks were assessed and responded to according to policy.

Appendix II: Summary of the National Science Foundation's Major Facilities Projects in Construction

This appendix provides individual summaries of the National Science Foundation's (NSF) major facilities projects that are under construction: the Vera C. Rubin Observatory, the Regional Class Research Vessels, the Antarctic Infrastructure Modernization for Science, and the Large Hadron Collider High Luminosity Upgrade Program, which consists of the A Toroidal Large Hadron Collider Apparatus (ATLAS) and Compact Muon Solenoid (CMS) detector upgrade projects.

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;
- table summarizing the project's current status and its cost and any cost[2] or schedule[3] increases since our July 2022 report;[4]
- a summary of the project's cost and schedule performance history; and

[1]Costs are reported in then-year dollars, which means that NSF or the recipient converted base-year dollars by appropriate escalation rates, including 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 NSF 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 is authorized.

[3]We identified schedule increases by comparing the project's scheduled completion date in available NSF documentation with the scheduled completion date we reported in our July 2022 report.

[4]GAO, *National Science Foundation: Continued Cost and Schedule Increases for Major Facilities Projects in Construction*, GAO-22-105550 (Washington, D.C.: July 20, 2022).

- information on remaining project risks and potential for cost or schedule increases, including the amount of remaining contingency and scope reduction options.[5]

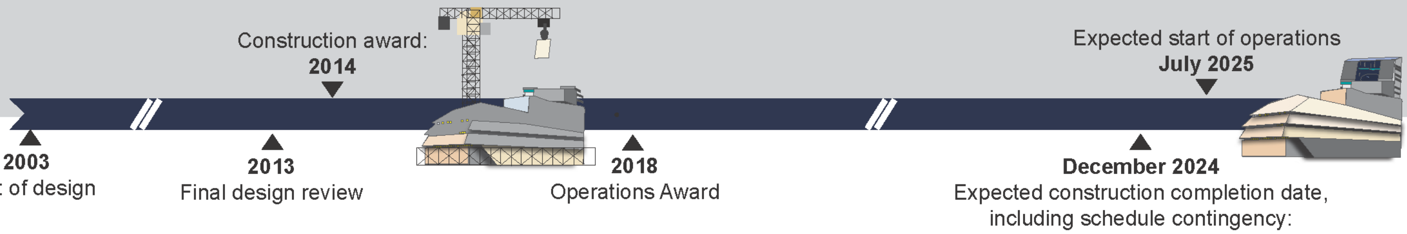
[5]We report each project's estimate of remaining risk exposure as weighted by the recipients for the probability of the risks occurring. According to NSF's Research Infrastructure Guide, risk exposure is the quantitative effect of risks. We report the risk exposure as determined by the Monte Carlo method when available.

VERA C. RUBIN OBSERVATORY

Location: Cerro Pachón, Chile

Source: GAO | GAO-24-106380

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 the first decade—using the world's largest digital camera (3 billion pixels and provided by the Department of Energy). 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 National Science Foundation (NSF) information; Rubin/NSF/Association of Universities for Research in Astronomy (B. Stalder) (icons). | GAO-24-106380

Source: Rubin Obs/NSF/AURA (B. Stalder). | GAO-24-106380

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

Responsible NSF directorate:
Mathematical and Physical Sciences

Project partners:
Department of Energy (DOE), The LSST Corporation (Early contributer)

Expected duration of operations:
30+ years

Source: GAO analysis of National Science Foundation (NSF) information; GAO (icons). | GAO-24-106380

PROJECT STATUS

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-106380

As of July 2023, the Rubin project was 94 percent complete and in its ninth year of construction. Since our July 2022 report, the project has continued to make progress despite setbacks resulting from an electrical accident at an offsite testing facility not operated by the project team and supply-chain disruptions. Material shortages and shipping delays in Italy resulted in dome fabrication delays that led to a nearly six-month schedule delay beyond the previous completion date of July 2024. As a result, the project team held a workshop in April 2023 to review project plans and understand the effects of the electrical accident on future schedule risks. The Rubin project now expects to complete construction by July 2025 with a 90 percent confidence level.

Construction Status as of February 2023	
Dollars in millions	
Not-to-exceed NSF authorized cost	$571.0
Current estimated total project cost	$551.0
NSF funding obligation to date	$532.5

Source: GAO analysis of NSF information. | GAO-24-106380

REMAINING CONTINGENCY AND SCOPE REDUCTION OPTIONS

As of July 2023 with construction 94 percent complete

NSF management reserve:
$20 million

Budget contingency:
$23.6 million

Schedule contingency:
11 months

Source: NSF documents and officials. | GAO-24-106380

SUPPLEMENTAL FUNDING REQUESTS

Following the NSF Director and NSB authorization of the new total project cost, NSF awarded a portion of the increase early through Supplemental Funding Requests (SFR) using previously held management reserve. To date, the project team submitted five SFRs to cover several unanticipated costs to the project related to a variety of issues such as the pandemic and new federal data security requirements. For example, NSF obligated $3.4 million across three SFRs to respond to pandemic related costs. NSF is anticipating a sixth SFR to respond to additional pandemic costs and supply chain issues.

Source: GAO analysis of NSF information. | GAO-24-106380

Source: Rubin Obs/NSF/AURA (B. Stalder). | GAO-24-106380

COST AND SCHEDULE PERFORMANCE HISTORY

While no additional cost increase has been requested since the total project cost re-baseline, several incidents and schedule slippages have caused the overall project schedule to increase. The project's previously authorized $22 million of management reserve was used to respond to immediate cost related to the pandemic prior to the 2021 re-baseline (see SFR sidebar). Part of the re-baseline authorized $20 million in NSF-held management reserve, for a new total project management reserve of $42 million. NSF is anticipating an additional supplemental funding request of $7 million from the newly authorized management reserve to cover indirect supply chain costs as a result of the war in Ukraine.

In December 2022, an electrical accident—unrelated to the Rubin project—occurred at a facility where integration work for the Rubin camera was scheduled to take place. The subsequent power outage at the facility resulted in a three-month work stoppage for integration activities. Shipping delays and material shortages are being closely monitored and prioritized. Due to several technical challenges, the camera development work could add an additional two-month schedule increase. In April 2023, the project convened a workshop originally intended to review and discuss the progress of the schedule following the 2021 re-baseline. Instead, the workshop reviewed the schedule impact due to the electrical accident and telescope mount delay. A completion date has been increased by six months to July 2025 with an expected mid-summer 2025 start of operations.

Increases to not-to-exceed NSF authorized cost	Increases to total project cost	Increases to scheduled completion date
Since July 2022: 0	**Since July 2022:** 0	**Since July 2022:** ▲+5 months
Since construction started: ▲+98 million	**Since construction started:** ▲+83.2 million	**Since construction started:** ▲+27 months

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-106380

REMAINING PROJECT RISKS AND POTENTIAL FOR COST OR SCHEDULE INCREASES

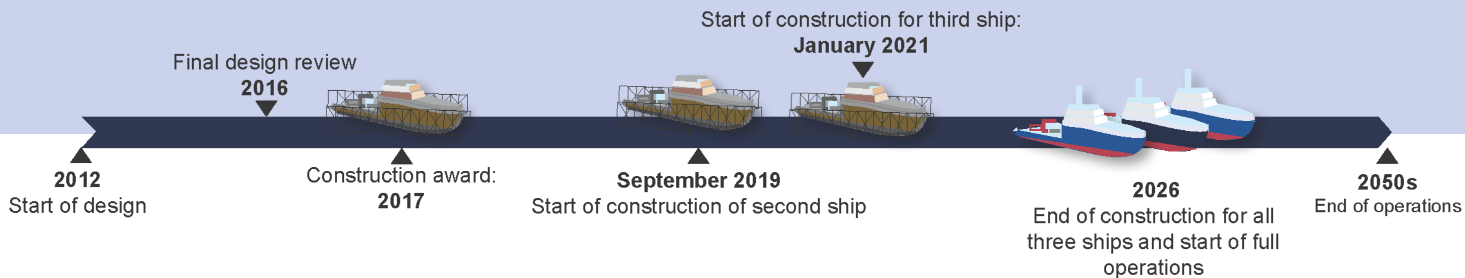
The project maintains 15 scope reduction options with an estimated value of $3.0 million. The use of these scope reduction options is unlikely due to the project being at a 94 percent completion and the remaining major components being completely built or near completion. A current $12.6 million risk exposure remains based on the top ten known risks, but once additional mitigations are implemented this risk will reduce to $7.7 million. All risks will be continuously evaluated against the re-baseline contingency budget.

REGIONAL CLASS RESEARCH VESSELS

The National Science Foundation's (NSF) Regional Class Research Vessels (RCRV) project will construct three 199-foot vessels to support the nation's ability to conduct fundamental scientific research in the coastal zone and continental shelf, including from the ocean's surface through the water column to the sea floor and subsea floor environment. These vessels will provide enhanced capabilities beyond those of the retiring vessels they will replace. The three vessels' research locations will depend on where the science demand is greatest, but NSF plans for operation of the first vessel along the west coast of the U.S.

Location: Construction site is in Louisiana.

Source: GAO | GAO-24-106380



Source: GAO analysis of National Science Foundation (NSF) information; NSF (icons). | GAO-24-106380

Source: National Science Foundation (NSF). | GAO-24-106380

FEB.2026

Scheduled construction completion date, including schedule contingency:
June 2026 for three vessels

Construction award:
Cooperative support agreement with Oregon State University, with subcontract to Bollinger Houma Shipyards, LLC

Responsible NSF directorate:
Geosciences

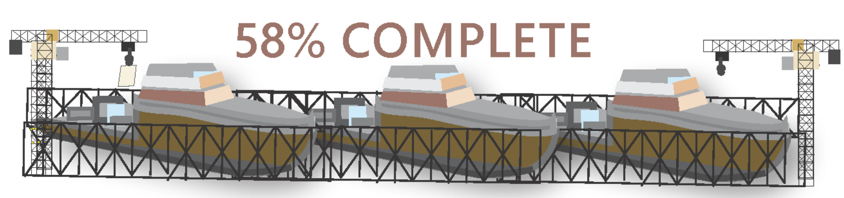
Project partners:
The U.S. Navy supported initial design oversight for the vessels

Expected duration of operations:
30 years

Source: GAO analysis of NSF documents and information from NSF officials; GAO (icons). | GAO-24-106380

PROJECT STATUS

As of July 2023, construction of NSF's RCRV project was 58 percent complete and the project was in its sixth year of construction. Since our July 2022 report, NSF conducted a re-baseline for the RCRV project, increasing the project's total project cost by $25 million. According to NSF officials, the re-baseline will address the effects of both the pandemic and Hurricane Ida. In May 2023, the project team launched the first vessel, R/V Taani, but according to NSF officials, significant work remains before commissioning and delivery to the vessel's operator, Oregon State University.



Source: GAO Analysis of National Science Foundation (NSF) information; NSF (icons). | GAO-24-106380

Construction Status of the Regional Class Research Vessels, as of June 2023

Dollars in millions	
Not-to-exceed NSF authorized cost	$400.0
Current estimated total project cost	$391.5
NSF funding obligation to date (MREFC)	$391.5

Source: GAO analysis of NSF information. | GAO-24-106380

REMAINING CONTINGENCY AND SCOPE REDUCTION OPTIONS

As of July 2023 with construction 58 percent complete

NSF management reserve:
$8.5 million

Budget contingency:
$23.3 million

Schedule contingency:
8.0 months

Estimated value of remaining scope reduction options:
$4.9 million

Source: NSF documents and officials. | GAO-24-106380

COST AND SCHEDULE PERFORMANCE HISTORY

In August 2022, a new total project cost was authorized by NSF as a re-baseline for the RCRV project, resulting in an increase of $25 million to the total project cost and an increase to the project schedule of six months. This re-baseline addressed the remaining effects of Hurricane Ida, the category 4 hurricane that hit the region in August 2021. In September 2022, NSF provided $23.4 million in supplemental funding to the project to address these risks.

In addition to the remaining challenges as a result of the hurricane, the RCRV project is also facing some shipyard production issues caused by the complexities with the vessel design and labor challenges. Currently, vessel delivery for all three vessels has slipped since our last report. The first vessel is estimated to be delivered in December 2023, the second vessel in June 2024, and the third vessel in November 2024. Last year, we reported that deliveries would occur in August 2023, February 2024, and July 2024, respectively.

Increases to not-to-exceed NSF authorized cost	Increases to total project cost	Increases to scheduled completion date
Since July 2022: ▲+25 million	**Since July 2022:** ▲+23.5 million	**Since July 2022:** ▲+11 months
Since construction started: ▲+35 million	**Since construction started:** ▲+37.5 million	**Since construction started:** ▲+20 months

Source: GAO analysis of NSF information. | GAO-24-106380

Source: National Science Foundation (NSF). | GAO-24-106380

REMAINING PROJECT RISKS AND POTENTIAL FOR COST OR SCHEDULE INCREASES

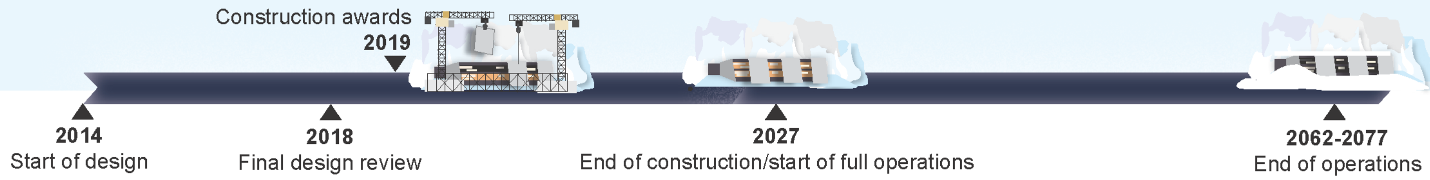
With construction of one vessel complete and expected deliveries of the remaining vessels in 2024, the project will have more risks associated with the testing of the vessels that will occur in the transition to operations phase. NSF continues to monitor the most significant risks to the project: inadequate shipyard performance, transition to operations issues, and requirements changes. For example, NSF has increased a risk associated with issues that may occur during the transition to operations phase to respond to unanticipated logistical costs and transition support contracts. As of March 2023, the project had an estimated remaining risk exposure of $11.8 million for non-pandemic-related risks and a remaining contingency of $23.3 million. In addition, scope reduction options associated with vessel construction will be retired after the vessels have been delivered. Currently, eight scope reductions options remain totaling $4.9 million.

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 operated by the United States Antarctic Program which is funded primarily by NSF 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 upgrades for near term needs of the McMurdo Station and enhance operational support for science by improving operations efficiency, containing operating costs, and enhancing safety. The currently funded upgrades include a new Vehicle Equipment and Operations Center (VEOC) for maintenance on light and heavy equipment along with a new lodging facility to ensure adequate bed space to support the station workforce, and scientists and construction workers. Currently, the AIMS project is pursuing only two of the project's original six components following a restructure of the AIMS project because of the construction pause from the pandemic.

Location: McMurdo Station, Antarctica.

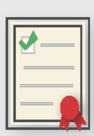
Source: GAO. | GAO-24-106380



Source: GAO analysis of National Science Foundation (NSF) information; Leidos (icons). | GAO-24-106380

Source: Leidos. | GAO-24-106380
Note: Rendering of McMurdo Station's core facility.

Expected construction completion date, including schedule contingency:
January 2027



Construction award:
February and April 2019 modifications to the existing Antarctic support contract with Leidos Innovations Corporation

Responsible NSF directorate:
Geosciences

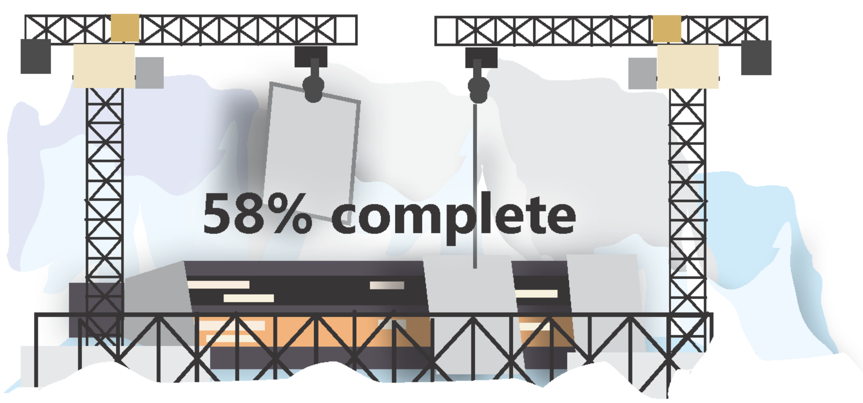
Project stakeholders:
Other federal agencies—such as the National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and the Department of Energy

Expected duration of operations:
35 to 50 years

Source: GAO analysis of NSF documents and information from NSF officials; GAO (icons). | GAO-24-106380

PROJECT STATUS

As of August 2023, construction of the AIMS project is 58 percent complete and the project was in its fifth year of construction. After the pause in construction due to the pandemic in March 2020, construction resumed at McMurdo Station in late September 2022. In March 2023, NSF conducted its annual construction review and a surveillance review of its earned value management system that tracks progress against the project plan. The reviews highlighted issues the AIMS project needs to address, including errors in design parameters for the VEOC and adjustments to its earned value management system.



Source: GAO Analysis of National Science Foundation (NSF) information; Leidos. (icons). | GAO-24-106380

Construction Status of the Antarctic Infrastructure Modernization for Science, as of August 2023

Dollars in millions

Not-to-exceed NSF authorized cost	$410.4
Total project cost in latest construction awards	$275.0
National Science Foundation (NSF) funding obligated to date	$155.5

Source: GAO analysis of NSF information. | GAO-24-106380

REMAINING CONTINGENCY AND SCOPE REDUCTION OPTIONS

As of August 2023 with construction about 58 percent complete

Budget contingency:
$38.8 million

Schedule contingency:
10.9 months

Estimated value of scope reduction options:
$2.5 million

Source: NSF documents and officials. | GAO-24-106380

REMAINING PROJECT RISKS AND POTENTIAL FOR COST OR SCHEDULE INCREASES

As of March 2023, the AIMS project team had a risk exposure of $60.0 million and $38.8 million in remaining contingency, and 10.9 months of schedule contingency remained available. Leidos has been awarded approximately $8.5 million of budget contingency to manage known risks.

As of May 2023, the AIMS project had $20.6 million in major risks being monitored by NSF. One of the highest risks is the wind design error that require replacing footers and adding structural steel with an estimated cost of $8 to 10 million and a delay of one year. The other known risks the AIMS project continues to monitor include material delays due to vessel capacity, support for packing with materials into shipping containers, and labor availability.

COST AND SCHEDULE PERFORMANCE HISTORY

In June 2022, the AIMS project completed a re-baseline with a revised total project cost of $275 million and a budget contingency of $38.9 million. As previously reported, the AIMS project was originally comprised of six components totaling $389.6 million. Effects of the pandemic, combined with complexities associated with the logistics of construction activities in Antarctica, delayed construction activities on-ice between from March 2020 to September 2022. These factors led to NSF to restructure AIMS by funding only two of the project's original six components. NSF will evaluate and consider including the four unfunded components in the Antarctic Infrastructure Recapitalization (AIR) program.

Construction resumed at McMurdo Station in September 2022 following the pause due to the pandemic. However, the AIMS project continues to face additional challenges. In particular, the wind design error requires replacement of approximately half of the 50 reinforced concrete footers and adding structural components. The baseline change request estimates the cost of the wind design error to exceed $8 million and 1 year to address. The delay will likely push the completion date further beyond the period of performance on the current Leidos contract. According to NSF officials, the agency is considering options to best support the AIMS project as part of the contract transition.

In addition, NSF reported multiple issues with the project's earned value management system. Specifically, NSF found problems with cost and schedule data, and management reporting and as a result, NSF cannot accept Leidos' earned value management system and has reduced confidence in the project's earned value management metrics, including cost and schedule data. According to NSF officials, NSF received a corrective action plan from Leidos in July 2023 to remediate issues with the system by December 2023.

CONSTRUCTION SEASON
(SEPTEMBER 2022- MARCH 2023)

Construction for the AIMS project is limited to several months of the year, typically during the spring and summer months in the Southern Hemisphere. NSF needs to manage a number of issues for the construction season to be successful. For example, NSF coordinates shipments of construction materials to Port Hueneme, California, through the Antarctic Support Contract, which are then loaded for shipment along with other equipment and goods for the U.S. Antarctic Program. Timely delivery to Port Hueneme is essential as shipments require an icebreaking ship to clear a path to McMurdo Station. Other issues include unpredictably severe weather conditions, and the ability to hire and transport skilled laborers from the McMurdo Station to support construction.

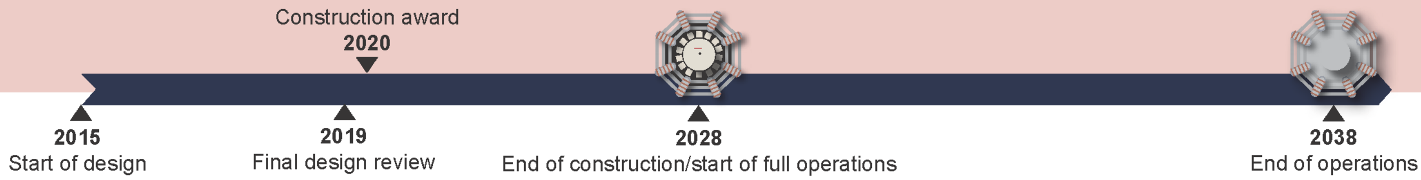
Source: Leidos. | GAO-24-106380

LARGE HADRON COLLIDER HIGH LUMINOSITY UPGRADE PROGRAM

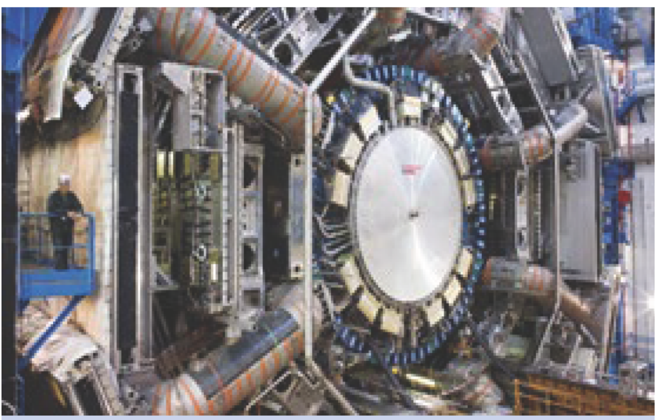
The Large Hadron Collider (LHC) is the world's most powerful particle accelerator. The facility's four detectors observe new particles that are produced when high-energy protons are accelerated and collided, providing insight into fundamental forces of nature and the condition of the early universe.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

Location: Geneva, Switzerland.

Source: GAO | GAO-24-106380



Source: GAO Analysis of National Science Foundation (NSF) information; GAO (icons). | GAO-24-106380



Source: 2008 CERN European Organization for Nuclear Research. | GAO-24-106380

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

Expected construction completion date, including schedule contingency:
August 2028 (ATLAS); June 2028 (CMS)

Construction award:
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 documents and information from NSF officials; GAO (icons). | GAO-24-106380

PROJECT STATUS

As of April 2023, NSF's HL-LHC program was in its third year of construction. The impact of the COVID-19 pandemic has stabilized sufficiently to allow NSF to start the re-baselining effort. ATLAS completed its external panel review in April 2023. CMS finished its external panel review in May 2023 after reconvening to make two changes to the revised baseline. The scope of these external reviews covered NSF's plans to re-baseline both detector upgrade projects due to COVID impacts and the schedule revisions in response to the CERN planned shutdown of operations for the LHC. Both detector upgrades have initiated baseline changes in response to the pandemic, supply chain issues, inflation and market uncertainties, and the war in Ukraine. In September 2023, ATLAS and CMS completed their re-baselines.

Construction Status of the Large Hadron Collider High Luminosity Upgrade, as of August 2023

Dollars in millions

	ATLAS	CMS	Program Total
Percentage complete	37	40	Not applicable
Not-to-exceed NSF authorized cost	$82.8	$88.0	$170.8
Total project cost in latest construction awards	$75.0	$77.2	$152.2
National Science Foundation (NSF) funding obligated to date	$39.0	$56.9	$95.9

Increases to not-to-exceed NSF authorized cost	Increases to scheduled completion date
Since construction started: ▲ +7.8 million (ATLAS) ▲ +10 million (CMS)	**Since construction started:** ▲ +21 months (ATLAS) ▲ +16 months (CMS)

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-106380

REMAINING CONTINGENCY AND SCOPE REDUCTION OPTIONS

as of August 2023

Budget contingency:
$31.7 million as follows:

- $19.3 million for the ATLAS detector
- $12.4 million for the CMS detector

Schedule contingency:

- 21.2 months for the ATLAS detector
- 11.2 months for the CMS detector

Estimated value of scope reduction options:
$10.4 million as follows:

- $5.4 million for the ATLAS detector
- $5 million for the CMS detector

Source: GAO analysis of NSF information. | GAO-24-106380

Source: 2008 CERN: European Organization for Nuclear Research.
| GAO-24-106380

COST AND SCHEDULE PERFORMANCE HISTORY

As of August 2023, the total program cost for HL-LHC (CMS and ATLAS combined) is $170.8 million, as NSF has finalized re-baselines for both projects in response to the pandemic and other factors. The pandemic has resulted in schedule delays, cost increases, and work stoppage, which have factored into NSF's decision to wait until 2023 to complete the re-baselines. Both projects have realized so far a relatively small cost increase of approximately $2 million because many initial project activities, coinciding with the early stage of the pandemic, involved detailed production design work, procurements, and software development activities that could be accomplished through remote telework. In addition, the effects of supply chain delays and inflation still pose risks.

The current forecasted construction delays for both projects are 21 months for ATLAS and 16 months for CMS. According to NSF officials, both detector upgrades are expected to see cost increases greater than 10 percent. According to NSF officials, NSF has estimated that the re-baselines for ATLAS and CMS projects led to cost increases of $7.8 million and $10.8 million, respectively. However, a scheduled delay to the next planned shutdown at LHC announced by CERN may offset effects that the ATLAS and CMS projects' pandemic-related schedule delays may have had on scientific research that would have otherwise been conducted.

REMAINING PROJECT RISKS AND POTENTIAL FOR COST OR SCHEDULE INCREASES

Both project teams have finalized their re-baseline proposals to address the effects of the COVID-19 pandemic and other factors on the cost for constructing the detectors. The current forecasted construction delays for both projects is 21 and 16 months. As of August 2023, the ATLAS project team had $19.3 million in budget contingency. The project team estimates its risk exposure at $21.4 million. The highest impact risks managed by the project team include delays at CERN, cost variances due to market volatility, and international partners not providing key components. As of August 2023, the CMS project had $12.4 million in budget contingency. The project team estimates its risk exposure was $17 million. The highest impact risks managed by the project include uncertainty regarding foreign currency exchange rates, uncertainty regarding inflation, and component capabilities.

INTERNATIONAL PARTNERS FOR THE HL-LHC

The European Organization for Nuclear Research (CERN) is the world's leading laboratory for particle physics. CERN has 23 Member States, with other nations from around the globe contributing to and participating in its research programs. CERN oversees the HL-LHC program while NSF oversees the institutes who are building components for the HL-LHC program.

In June 2022, CERN announced its intention not to renew its joint agreement with Russia (in December 2024) and Belarus (in June 2024) after the current agreement expires at the end of 2024. The decision to not renew the agreement is a result of the war in Ukraine. NSF has begun to take steps to address potential increases if the agreement goes into effect. The cost and schedule impacts of CERN's decision have been determined to be approximately $1.6 million and were factored into the re-baseline.

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

This appendix provides individual summaries of the four National Science Foundation (NSF) projects that are in the design stage as potential major facilities projects: the Leadership Class Computing Facility, the Antarctic Research Vessel, and the U.S. Extremely Large Telescope program, which consists of the Giant Magellan Telescope and the Thirty Meter Telescope. As of November 2023, no construction funds had been awarded for these projects and all cost, schedule, scope, and design information was subject to change.

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

- an overview of the project and its purpose;
- a timeline identifying key project dates;
- project information, such as the expected date for completion of construction; the 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.

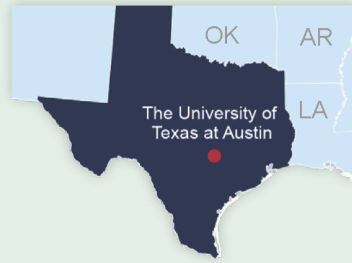
[1]Costs are reported in then-year dollars, which means that NSF or the recipient converted base-year dollars by applying appropriate escalation rates, including inflation. According to NSF policy, escalation is a part of NSF's budgeting and project planning.

LEADERSHIP CLASS COMPUTING FACILITY

The National Science Foundation's (NSF) Leadership-Class Computing Facility (LCCF) project is intended to provide advanced computational capabilities to enable transformative research in all areas of science and engineering that would not be possible by theory or experiment alone.

According to NSF officials, future research using LCCF might include extremely detailed simulations ranging from biological molecules to supernovae and analyses of very large data streams such as satellite images to create high-resolution Earth maps.

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



Source: GAO | GAO-24-106380

Source: GAO analysis of National Science Foundation (NSF) information; GAO (icons). | GAO-24-106380

Source: National Science Foundation (NSF). | GAO-24-106380

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

Location:
Texas Advanced Computing Center (TACC), University of Texas at Austin

Final design review:
April 2023

Construction award:
Planned for March 2024

Expected construction completion date, not including schedule contingency:
Fiscal year 2027

Responsible NSF directorate:
Directorate for Computer & Information Science & Engineering

Project partners:
None

Expected duration of operations:
10+ years

Source: GAO analysis of NSF documents and information from NSF officials; GAO (icons). | GAO-24-106380

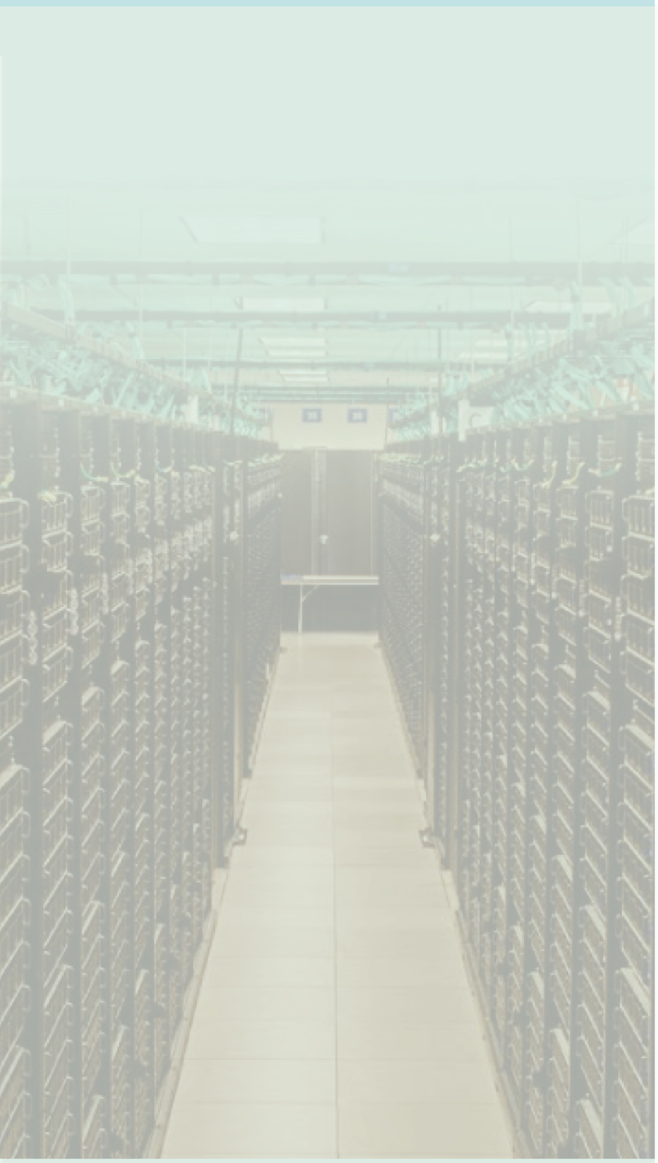
PROJECT STATUS

As of March 2023, the LCCF project was in its fourth year of design; consequently, all cost, schedule, scope, and design information for the project was subject to change. Following the preliminary design review held in 2022, NSF authorized inclusion of LCCF in a future budget request in August 2022. In addition, the LCCF project team revised its project execution plan to reflect the decision to co-locate the project's data center at a nearby existing commercial facility with a proposed total project cost of $506 million. According to NSF officials, this option has a potential savings of $100 million, as it would eliminate the need to construct an onsite data center and acquire auxiliary equipment. NSF held a final design review in April 2023, with the panel recommending the project advance to the construction stage. The NSF Director approved advancement in September 2023 and engagement with the NSB is planned in November to support the start of construction in March 2024, contingent on availability of sufficient appropriations for fiscal year 2024.

HISTORY OF THE LCCF PROJECT

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

Source: GAO analysis of NSF information. | GAO-24-106380



Source: National Science Foundation (NSF). | GAO-24-106380

PROJECT RISKS

According to NSF officials, the project team submitted a preliminary risk management plan to NSF for preliminary design review. The risk management plan included a risk assessment matrix that assessed the likelihood and effect of each identified risk to cost, schedule, and technical performance. According to NSF officials, the external review panel, independent contractor, and NSF all evaluated the risk management plan at preliminary design review and found the plan to be sound and well-documented. Finally, according to NSF officials, NSF and the external panel found the project's risk register to be complete for the purposes of the preliminary design review. The risk register will be revised as part of the construction proposal package for the final design review.

As we previously reported, one anticipated challenge for the LCCF project is the rapid pace of technological change in the field of high-performance computing. According to NSF officials, LCCF will likely reach comparative obsolescence halfway through its initial 10 years of operations. However, NSF believes that LCCF will continue to be high-performing and useful. In addition, the project team may pursue a technology refresh of the computing system in its fifth year of operations. According to NSF officials, such a refresh would be considered separate from the LCCF project.

DESIGN AND CONSTRUCTION COSTS

As of March 2023, the project team estimates a total project cost of $506 million for the LCCF project. NSF's fiscal year 2024 budget request to Congress included a risk-adjusted total project cost between $520 million and $620 million. NSF will conduct an additional independent cost estimate based on additional inputs by the project team prior to a construction stage award. NSF has provided guidance to the project team on how to further improve its project execution plan, specifically related to its cost estimate and risk management, among other areas. Since fiscal year 2019, NSF obligated $15.9 million from its Research and Related Activities account for the design of LCCF and, as of May 2023, has expended $7.4 million for design.

Since our last report, NSF decided to co-locate the project's data center at a nearby commercial facility, which has a potential savings of $100 million to the overall total project cost. According to NSF officials, NSF and the project team assessed technical and legal factors to support the decision. For example, NSF reviewed terms and conditions of the agreement between TACC and the data center provider and the project team evaluated options to ensure continuity of operations should any interruption in business operations occur within the commercial facility.

In addition, the project team continues to refine and update all components of the LCCF project. As we reported in July 2022, NSF established characteristic science application teams to create a suite of science applications to measure performance improvements for LCCF. According to NSF officials, the project team has partnered with these teams to assist in deciding optimal technology choices for the LCCF computing system. In addition, the project team met with potential vendors to inform the architecture of the computing system, which will help to refine the estimated cost and schedule. Finally, according to NSF officials, in order to ensure that the LCCF project will use the latest available computing technology, the project team will schedule acquisition of the computing system as late as possible in the project schedule.

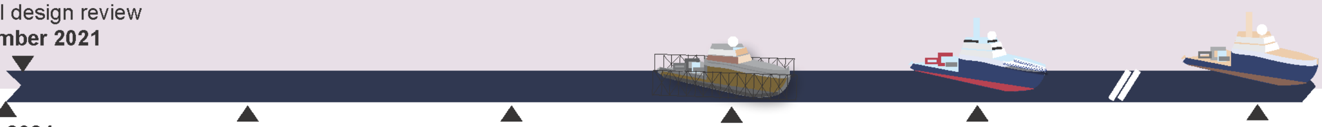
ANTARCTIC RESEARCH VESSEL

The National Science Foundation's (NSF) Antarctic Research Vessel (ARV) project is intended to replace the retiring research vessel icebreaker *Nathaniel B. Palmer*, which has operational limitations and is reaching the end of its lifetime. The ARV will ensure uninterrupted science operation in the Southern Ocean and the Antarctic for several decades. In addition, the ARV will meet NSF's science mission goals by increasing access to difficult to reach areas, allow for longer missions, and delivering more scientists and equipment to the Antarctic.

The starts of construction and operations shown below are notional and subject to change. According to NSF officials, the schedule is dependent on a successful final design review, authorization for a future budget request, authorization to proceed to construction, and appropriations of funds.

Location: Shipyard to be determined

Source: GAO. | GAO-24-106380



Source: GAO analysis of National Science Foundation (NSF) information; NSF (icons). | GAO-24-106380

Source: National Science Foundation (NSF). | GAO-24-106380
Note: Rendering of the project's conceptual design.

Location:
U.S. shipyard to be determined

Expected construction completion date, not including schedule contingency:
Fiscal year 2030, final acceptance in fiscal year 2031

Construction award:
Fiscal year 2026

Responsible NSF directorate:
Directorate for Geosciences, Office of Polar Programs

Project partners:
None; project is fully NSF-funded

Expected duration of operations:
40 years

Source: GAO analysis of NSF documents and information from NSF officials; NSF (vessel icon), GAO (icons). | GAO-24-106380

PROJECT STATUS

As of November 2023, the ARV project was in its second year of design; consequently, all cost, schedule, scope and design information for the project was subject to change. NSF convened an external panel in February 2023 to conduct a preliminary design review, which recommended that the project advance to the final design phase. Along with its recommendation to advance the project, the panel also recommended that the project assess technical aspects of vessel design and strengthen the science advisory subcommittee membership selection and approvals on technical change, among others. The NSF Director approved advancement to the final design phase in September 2023, but NSF authorization for inclusion in a future budget request is still pending. Furthermore, the award may not occur until summer 2024 as NSF is soliciting a vessel integrator for final design and construction. NSF previously awarded a contract to Leidos to serve as the vessel integrator through the preliminary design phase. NSF held an industry day in July and released a draft request for proposal in late September 2023 for comment by all interested parties.

PROJECT RISKS

According to NSF officials, the project submitted a risk register as part of its project execution plan, as required for preliminary design review. The project team continues to refine the risk register as the project matures. Following preliminary design review, the external panel made recommendations to NSF and the project team to assess risks and designate responsibility—either NSF or the project—should these risks occur. These risks include the selection and a potential transition of vessel integrator from Leidos to the final vessel integrator, the selection of a shipyard to construct the vessel, and overall project management.

DESIGN AND CONSTRUCTION COSTS

As of our review, NSF had not yet established the construction cost, schedule, or scope for the ARV project. According to NSF officials, NSF is planning to leverage an inter-agency agreement with Naval Sea Systems Command (NAVSEA) to conduct an independent cost estimate which will help inform a potential fiscal year 2026 budget request. NSF estimates a total cost of $19.4 million for preliminary design. As of May 2023, the project has obligated $16.4 million for the design stage and was approved to use an additional $2 million in contingency funding for additional design work and construction and testing of a model vessel. NSF issued a letter in May 2022 to solicit interest in construction and operation of the ARV, and is planning to provide separate awards for a vessel integrator starting at the final design phase and a vessel operator. The vessel operator would be determined in the final design phase or early in the construction stage.

During the design stage, NSF is considering how the vessel will meet key performance parameters and the effects of any adjustments will have on construction costs. For example, the project is currently using a model test basin in Hamburg, Germany to develop models and conduct tests of the different hull forms, including ice breaking, sea keeping, fuel efficiency, and sonar performance. According to NSF officials, this site is only one of two commercial test basins in the world capable of performing ice-breaking model testing. The test facility in Germany is the same one the U.S. Coast Guard used for their new Polar Security Cutter program. NSF is assessing these design changes and their potential effects on the cost estimates for construction and operations of the vessel. In addition, NSF is soliciting input from internal experts and the scientific community for their input on the design. For example, NSF held four interim design reviews that resulted in feedback on ship design and lab layout.

Source: National Science Foundation (NSF). | GAO-24-106380

U.S. EXTREMELY LARGE TELESCOPE PROGRAM

The National Science Foundation's (NSF) U.S. Extremely Large Telescope (US-ELT) Program is currently proposed as two projects, the Thirty Meter Telescope (TMT) and the Giant Magellan Telescope (GMT). If both projects were funded, the combined collecting area of the two-telescope system would exceed that of any other large telescope for at least the next two to three decades, with the added advantage of providing all sky coverage (Northern and Southern Hemispheres) and longitudinally staggered, allowing for opportunistic observation of transient celestial events. The US-ELT Program will leverage current ground-based optical and radio astronomy facilities and will obtain high-fidelity observations of rare objects, such as nearby habitable exoplanets and rare classes of transient events. The US-ELT Program will also provide critical follow-up of NASA missions, such as the James Webb Space Telescope, at higher resolutions as well as support a range of science including particle physics, gravitational wave sources, and searches for biosignatures to better understand the evolution of life. The starts of construction and operations shown below are notional and subject to change given that approval to advance to the final design phase and other strategic agency decisions are still pending as discussed below.

November 2022 Start of design

February 2023 Preliminary design review

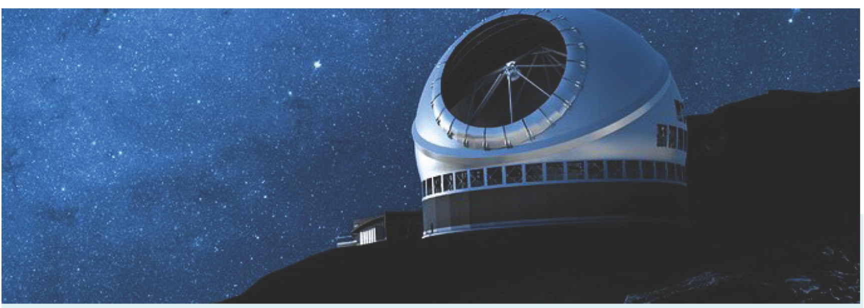
March 2025 Final design Review

April 2026 Start of construction

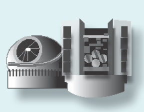
2035 End of construction and start of operations

2065 End of operations

Source: GAO analysis of National Science Foundation (NSF) information; Thirty Meter Telescope International Observatory (icons). Adapted from Courtesy Thirty Meter Telescope International Observatory and "Creative Commons Giant Magellan Telescope" by Giant Magellan Telescope Organization Corporation which is licensed by CC BY-SA 4.0 CC BY-SA 4.0 Deed | Attribution-ShareAlike 4.0 International | Creative Commons (icons). | GAO-24-106380



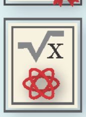
Source: Courtesy of Thirty Meter Telescope International Observatory. | GAO-24-106380



Location:
GMT will be located on Las Campanas Peak in Chile. TMT is proposed to be located in either Hawaii or the Canary Islands.

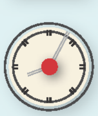
Expected construction completion date, not including schedule contingency: 2035

Construction award: 2026



Responsible NSF directorate:
Directorate for Mathematical and Physical Sciences

Project partners:
Each project is supported by several national and international academic and research institutes



Expected duration of operations:
30 years

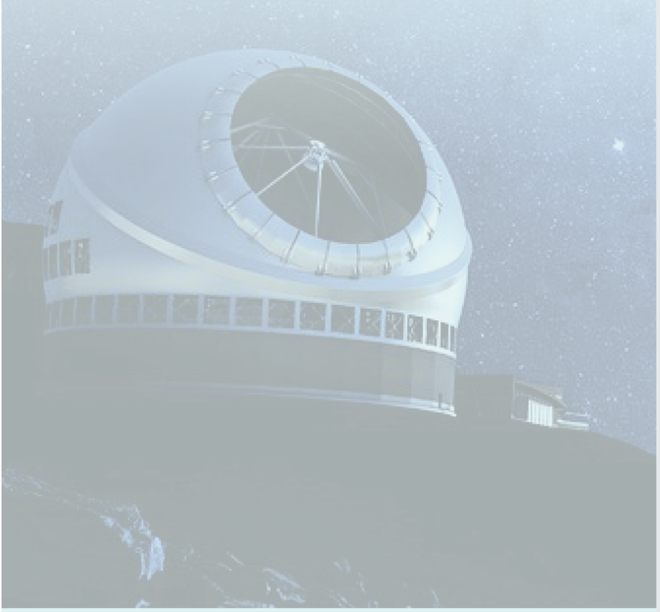
Source: GAO analysis of NSF documents and information from NSF officials; Thirty Meter Telescope International Observatory. Adapted from Courtesy Thirty Meter Telescope International Observatory and "Creative Commons Giant Magellan Telescope" by Giant Magellan Telescope Organization Corporation is licensed by CC BY-SA 4.0 CC BY-SA 4.0 Deed | Attribution-ShareAlike 4.0 International | Creative Commons (Giant Magellan Telescope and Thirty Meter Telescope icon). | GAO-24-106380

PROJECT STATUS

As of March 2023, the US-ELT program was in its first year of NSF's major facility design stage, consequently all cost, schedule, scope, and design information for both projects were subject to change. In December 2022, the NSF Chief Operating Officer approved the program to enter the design stage with two candidate major facilities projects, TMT and GMT. NSF conducted a two-phased preliminary design review. The December 2022 review covered the scientific and technical aspects of both projects, while the review completed in February 2023 covered cost, scope, schedule, and project management details for both. According to NSF officials, if a decision is made to advance one or both projects, NSF would potentially invest approximately $100 million over several years, if appropriated, to advance each project to a final design review. Given the project complexity and potentially significant investment, the Directorate of Mathematical and Physical Sciences established an additional Blue Ribbon Panel of experts to review the Division of Astronomy's plans for potential advancement.

PROJECT RISKS

As of March 2023, NSF has only requested external review of project technical risks during the preliminary design review, which appears robust given the significant previous investments by other partners and the advanced state of technical readiness, according to NSF officials. As previously mentioned, neither project managing organization has been a direct recipient of federal funding. Given the potentially large total costs of both projects, NSF has conducted new performer reviews of financial and other business systems to support potential direct awards in September 2023, according to NSF officials. The Directorate of Mathematical and Physical Sciences convened a Blue Ribbon Panel to help assess strategic risk for the Directorate associated with US-ELT program.

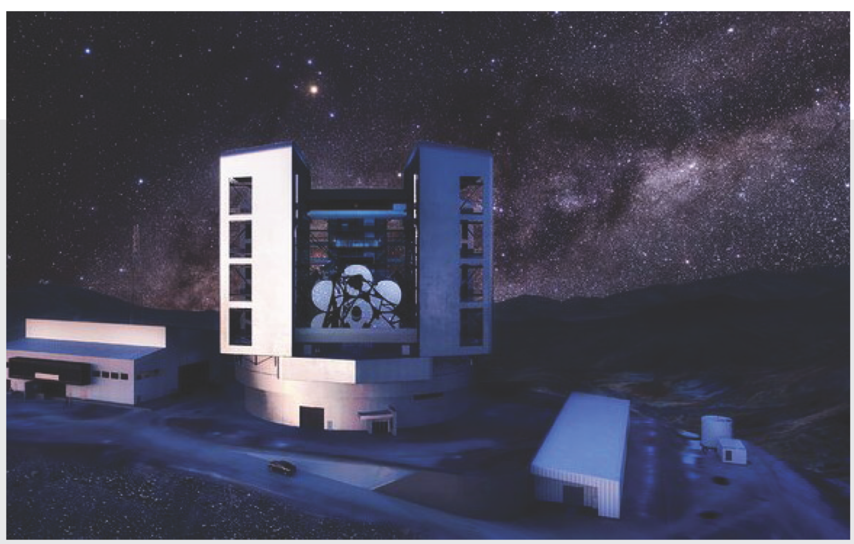


Source: Courtesy of Thirty Meter Telescope International Observatory. | GAO-24-106380

DESIGN AND CONSTRUCTION COSTS

As of this report, NSF has not yet established the construction cost, schedule, or scope for the US-ELT program. Prior to NSF approving both projects to enter the design stage, TMT and GMT began initial design work over a decade ago with funding and other support from national academic and international partners. Since then, both projects have completed significant milestones, such as construction of critical components, site selections, and overall research scope. Additional national and international partners have joined both projects to provide funding, guidance, and design and technical support. At the time of this report, NSF is considering the technical readiness of both projects to advance to the final design phase. NSF authorization for inclusion in a future MREFC budget request will be an agency decision made separately from the decision to advance. NSF is considering how to fund the proposed $100 to $140 million for each project over several years for the final design phase in order to prepare final designs and managements plans for the program.

NSF's portion of the cost for each project is expected to exceed $1 billion per project which is approximately twice the cost of NSF's single largest major facilities project to date. Given that the program is still in the design stage, NSF's actual investment in either project will not be determined until a decision is made to advance one or both of the projects, the projects successfully complete final design reviews, and authorization to proceed to construction is approved, pending sufficient future appropriations. Each project also established its own organization responsible for developing the project, the GMT Observatory Corporation (GMTO) and the TMT International Observatory (TIO) LLC. Aside from a small sub-award to the GMTO for accelerated prototyping and testing of optical and infrared technologies, neither project has received prior federal funding. According to NSF officials, NSF provided additional awards for further development and preliminary design work for both GMT and TMT in September 2023.



Source: Giant Magellan Telescope – GMTO Corporation (CC BY-NC-ND 4.0 Deed | Attribution-Non-Commercial-NoDerivs 4.0 International | Creative Commons). | GAO-24-106380

Appendix IV: Comments from the National Science Foundation

National Science Foundation
Office of the Director

November 9, 2023

Candice N. Wright
Director
Science, Technology Assessment, and Analytics
U.S. Government Accountability Office
441 G Street, NW
Washington, D.C. 20548

Dear Ms. Wright:

The National Science Foundation (NSF) appreciates the opportunity to review and provide comments on the Government Accountability Office (GAO) draft report, *National Science Foundation: Additional Steps Would Improve Cost Estimate for Antarctic Research Infrastructure Project* (GAO-24-106380). This report provides NSF with a valuable, independent assessment of our oversight of major facility projects in design and construction as well as our stewardship of the Major Research Equipment and Facilities Construction (MREFC) account. NSF's investment in research infrastructure remains critical to the progress of science and effective agency oversight helps protect those investments.

While we are proud of our progress with implementing GAO good practices around project cost and schedule over the last five years, we recognize there is always room for improvement. We will use this year's recommendation and the details provided in the report to take appropriate measures on the Antarctic Infrastructure Modernization for Science (AIMS) project, including strengthening any revised cost proposals. Our approach will be outlined in our Corrective Action Plan. These future enhancements notwithstanding, NSF is confident that the latest contract modifications associated with AIMS were fully compliant with the requirements of the federal acquisition framework.

On behalf of the NSF staff participating in the latest GAO review, I would like to acknowledge the members of the GAO team for their professionalism, diligence, and commitment to strengthening government oversight. Please contact Veronica Shelley at (703) 292-4384 if you have any questions or require additional information.

Sincerely,

Sethuraman Panchanathan
Director

2415 Eisenhower Avenue | Alexandria, VA 22314

Appendix V: GAO Contact and Staff Acknowledgments

GAO Contact

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

Staff Acknowledgements

In addition to the contact named above, Sarah Harvey (Assistant Director), Sean Manzano (Analyst in Charge), Darren Grant, Scott Henderson, William Laing IV, and Juaná Collymore made key contributions to the report. Also contributing were Michael Armes, John Bauckman, Ryan Han, Louise Fickel, Jason T. Lee, Curtis Martin, Carl Ramirez, and Ashley Stewart.

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