



June 2024

# NATIONAL SCIENCE FOUNDATION

## Five Major Facilities Projects Experienced Delays

# GAO Highlights

Highlights of [GAO-24-107044](#), a report to congressional committees

## Why GAO Did This Study

NSF supports the design, construction, and operations of various research infrastructure projects, such as telescopes and research vessels. These projects include major facilities that cost over \$100 million to construct and mid-scale projects that cost from \$20 million to \$100 million. NSF funds construction, acquisition, and commissioning of major facilities and mid-scale research infrastructure projects through its Major Research Equipment and Facilities Construction account.

As of March 2024, NSF has 18 research infrastructure projects in design, construction, or implementation that are either funded or proposed for funding from the major research facilities account. Building these projects 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 2023 includes provisions for GAO to review projects funded from NSF's major research facilities account. This report, the seventh in a series, describes the cost and schedule performance of NSF's research infrastructure projects. To do this study, GAO reviewed NSF documents, examined NSF policies to manage and oversee projects, and interviewed NSF officials.

View [GAO-24-107044](#). For more information, contact Candice N. Wright at (202) 512-6888 or [WrightC@gao.gov](mailto:WrightC@gao.gov).

JUNE 2024

## NATIONAL SCIENCE FOUNDATION

### Five Major Facilities Projects Experienced Delays

## What GAO Found

The National Science Foundation (NSF) continues to make progress on its major facilities projects in construction, major facilities projects in design, and mid-scale research infrastructure projects. However, NSF's project management data show schedule increases for all major facilities projects in construction relative to estimates from June 2023. NSF officials also anticipate additional increases in schedule for both the Rubin Observatory and Antarctic Infrastructure Modernization for Science (AIMS), but estimates will not be available until NSF completes a Rubin Observatory supplemental funding request in late Spring 2024 and an AIMS construction review in July 2024. Additionally, NSF completed the re-baseline for both Large Hadron Collider High Luminosity Upgrade projects in August 2023, which formalized the cost and schedule increases that resulted from prior events, such as the pandemic.

#### Examples of National Science Foundation Major Facilities Projects



The Rubin Observatory (left), a Regional Class Research Vessel (middle), and the Antarctic Infrastructure Modernization for Science's Vehicle Equipment and Operations Center (right).

Source: Rubin Obs/NSF/AURA (B. Stalder, left); National Science Foundation (middle); National Science Foundation (right). | GAO-24-107044

Both the Regional Class Research Vessels (RCRV) and AIMS have reported staffing shortages, each with unique causes, that are resulting in ongoing construction delays. NSF officials said that a lack of skilled labor is affecting the RCRV project at the shipyard in Louisiana. Workforce recovery after Hurricane Ida has been hindered by scarce housing, and reconstruction remains a challenge. In contrast, NSF officials said the shortage of skilled labor for the AIMS project, based in Antarctica, is due to U.S. demand for construction workers and heavy equipment operators. The lower availability of domestic labor has increased reliance on non-American workers, and the process for obtaining background checks for these workers is causing delays. The contractor is working with its primary subcontractor to develop a mitigation plan to hire and onboard the necessary staff.

For the major facilities projects in design, two of the five progressed through their respective design phases and are nearing entry into the construction stage. A third project recently entered the design stage, and two other projects are awaiting NSF decisions to advance to later design phases. Finally, NSF has progressed on the implementation of the eight previously awarded mid-scale projects.

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## Abbreviations

AIMS	Antarctic Infrastructure Modernization for Science
ARV	Antarctic Research Vessel
ATLAS	A Toroidal Large Hadron Collider Apparatus
CMS	Compact Muon Solenoid
ELT	U.S. Extremely Large Telescope Program
LHC	Large Hadron Collider
MREFC	Major Research Equipment and Facilities Construction
ngVLA	Next-Generation Very Large Array
NSF	National Science Foundation
RCRV	Regional Class Research Vessels
Rubin	Vera C. Rubin Observatory

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June 12, 2024

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 some mid-scale research infrastructure projects from that budget account.<sup>1</sup> 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. For fiscal year 2024, the NSF MREFC account received an appropriation of \$234 million; NSF requested \$300 million in fiscal year 2025.

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<sup>1</sup>NSF manages another set of mid-scale projects with total project costs under \$20 million that are not funded from the MREFC account.

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The Consolidated Appropriations Act 2023 includes provisions for GAO to review projects within NSF's MREFC account.<sup>2</sup> In December 2023, we reported that NSF had finalized cost and schedule increases for all five major facilities projects in construction. These increases were caused by the pandemic and other factors. We also reported that NSF's Antarctic Infrastructure Modernization for Science (AIMS) project only met three of the four characteristics of a reliable cost estimate. Therefore, we recommended that NSF take steps to ensure the project meets the well-documented characteristic of a reliable cost estimate. NSF officials said that the agency is working to address this recommendation.

This report, the seventh in the series, provides the cost and schedule performance updates reported by NSF for the 9-month period from June 1, 2023, to March 1, 2024, the most recent and complete data available. We reviewed NSF project progress reports and other available documentation that describes cost and schedule performance for the major facilities projects and mid-scale research infrastructure projects that were under construction or in design at the time of our review. We also interviewed NSF officials about the projects. For a detailed description of our scope and methodology, see appendix I.

We conducted this performance audit from September 2023 to June 2024 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.

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## Background

### Current MREFC Projects

As of March 2024, NSF has 18 research infrastructure projects in design, construction, or implementation that are either funded or proposed for funding from the MREFC account (see fig. 1).<sup>3</sup> Of these 18 projects, five are major facilities projects in the construction stage, five are major facilities projects in the design stage, and eight are mid-scale projects in

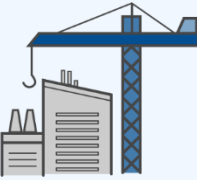


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<sup>2</sup>The mandate is contained within the explanatory statement printed at 168 Cong. Rec. S7819, referenced by the Consolidated Appropriations Act, 2023, Pub. L. No. 117-328, § 4, 136 Stat. 4459, 4462 (2022).

<sup>3</sup>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.

implementation. Major facilities projects each have a total project cost of more than \$100 million, while mid-scale projects funded from the MREFC account each have a total project cost from \$20 million to \$100 million.<sup>4</sup>

**Figure 1: NSF’s Major and Mid-Scale Research Infrastructure Projects, as of March 2024**

<p><b>Major facilities projects in construction</b></p> 	<p><b>Major facilities projects in design</b></p> 	<p><b>Mid-Scale research infrastructure projects</b></p> 
<ul style="list-style-type: none"> <li>• Vera C. Rubin Observatory</li> <li>• Regional Class Research Vessels</li> <li>• Antarctic Infrastructure Modernization for Science</li> <li>• Large Hadron Collider High Luminosity Upgrade Program               <ul style="list-style-type: none"> <li>○ ATLAS Detector</li> <li>○ CMS Detector</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Leadership Class Computing Facility</li> <li>• Antarctic Research Vessel</li> <li>• U.S. Extremely Large Telescope Program               <ul style="list-style-type: none"> <li>○ Thirty Meter Telescope</li> <li>○ Giant Magellan Telescope</li> </ul> </li> <li>• Next-Generation Very Large Array</li> </ul>	<ul style="list-style-type: none"> <li>• Advanced Millimeter Survey Instrumentation in Chile</li> <li>• Airborne Phased Array Radar</li> <li>• Compact X-Ray Free-Electron Laser</li> <li>• Distributed Energy Resources Connect</li> <li>• Global Ocean Biogeochemistry Array</li> <li>• High Magnetic Field Beamline</li> <li>• Network for Advanced Nuclear Magnetic Resonance Spectroscopy</li> <li>• Research Data Ecosystem</li> </ul>

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-107044

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

<sup>4</sup>NSF also funds the Antarctic Recapitalization Program—a portfolio of investments in facilities and infrastructure across U.S. Antarctic Program—through the MREFC Account, according to officials. In June 2022, NSF completed a re-baseline of the project to reflect the reduced scope of the AIMS project which now funds only two of the original six components. NSF officials added that the previously unfunded portions of AIMS will be considered within the broader the Antarctic Recapitalization Program and may transition to stand-alone mid-scale research infrastructure projects in the future. We reported on the planned restructuring of the AIMS project in July 2022, see GAO, *National Science Foundation: Continued Cost and Schedule Increases for Major Facilities Projects in Construction*. [GAO-22-105550](#). (Washington, D.C.: July 20, 2022).

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## Stages in the Life Cycles of NSF's Research Infrastructure Projects

Each research infrastructure project has a sponsoring organization from within NSF's eight research directorates. For major facilities projects, the sponsoring organization assesses the scientific merit of a potential project, proposes a project for funding through NSF's MREFC account, and is responsible for overseeing the project during the five stages of its life cycle, described below. The mid-scale projects are proposed by the research community in response to a program solicitation. NSF funding for the development, design, operations, and divestment generally comes from the Research and Related Activities account via the sponsoring directorate. Funding for the construction stage generally comes from the MREFC account.

- **Development.** Initial project ideas emerge. A broad consensus is built within the relevant scientific community on the potential long-term needs, priorities, and general requirements for research infrastructure that NSF may consider funding.
- **Design.** Entrance into this stage occurs when the NSF Director approves the proposed research infrastructure as a national priority and the sponsoring directorate makes an award (either through a cooperative agreement or contract) for developing detailed project scope, cost, and schedule for possible construction.<sup>5</sup> This stage is divided into conceptual, preliminary, and final design phases. A project exits the design stage and enters the construction stage after a successful review by the NSF director and other key stakeholders of its project execution plan and authorization of its not-to-exceed total project cost by the National Science Board.
- **Construction.** The construction stage begins when NSF makes award to external awardees to acquire or construct research infrastructure. The construction stage ends after final delivery and acceptance of the facility as defined in the scope of work and facility performance per terms of the award instrument. Because of the broader technical nature of mid-scale projects and different NSF oversight processes, NSF labels some mid-scale projects as in implementation rather than in the construction stage.
- **Operations.** The operations stage includes the day-to-day work necessary to operate and maintain the research infrastructure (including refurbishment or upgrade activities) and to support research.

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<sup>5</sup>Awards generally take the form of cooperative agreements, although NSF occasionally uses contracts, according to agency officials.



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- **Divestment.** Divestment involves the transfer of the research infrastructure to another entity’s operational and financial control or the decommissioning of the research infrastructure, including its complete deconstruction and removal. NSF generally decides to divest of research infrastructure when the agency or the scientific community determines that the facility is no longer considered a priority to advance science, according to NSF’s Research Infrastructure Guide.<sup>6</sup>

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## Most Projects Remain on Schedule and within Budget; Five Projects in Construction Experienced Delays

NSF continues to make progress with its major facilities projects in construction, major facilities projects in design, and mid-scale research infrastructure projects funded from the MREFC account. All five major facilities projects in construction have reported schedule increases relative to their June 2023 estimates, and additional delays are expected but not finalized for two of these five. Two major facilities projects in design progressed through their respective design phases, while an additional project was added to the design stage and two other projects are awaiting NSF decisions to advance to later design phases. Finally, NSF has progressed on the implementation of the eight previously awarded mid-scale projects.

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## All Five Major Facilities Projects in Construction Experienced Delays

All five major facilities projects in construction experienced delays to construction completion. NSF’s project management data show schedule increases relative to their estimates from June 2023 for the Rubin Observatory (Rubin), Regional Class Research Vessels (RCRV), Antarctic Infrastructure Modernization for Science (AIMS), and both Large Hadron Collider (LHC) High Luminosity Upgrade projects: the ATLAS (A Toroidal LHC Apparatus) and CMS (Compact Muon Solenoid) detectors.<sup>7</sup> NSF officials anticipate additional increases in schedule for both Rubin and AIMS, although estimates will not be available until NSF completes and approves the Rubin supplemental funding request in late Spring 2024 and the AIMS construction review in July 2024.

NSF completed the re-baseline for ATLAS and CMS in August 2023, which formalized increases in the authorized total project cost that resulted from prior events, such as the pandemic. The new authorized

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<sup>6</sup>According to officials, NSF expects the 2025 revision of the Research Infrastructure Guide will rename the divestment stage as disposition, to better capture the options available to NSF.

<sup>7</sup>We have calculated changes to project cost and schedule using the Earned Value Management System. According to NSF’s Research Infrastructure Guide, the progress of all major facilities projects during the construction stage is tracked and measured using this system.

cost for ATLAS is \$82.8 million, representing a \$7.8 million increase, and the new authorized cost for CMS is \$88 million, representing a \$10 million increase. In addition, NSF officials anticipate a \$15 million increase in the estimated total project cost to Rubin that will be finalized supplemental funding request in late Spring 2024. This will increase the estimated total project cost to approximately \$565 million, which is below the \$571 million currently authorized. Cost and schedule are inextricably linked; therefore, the schedule delays experienced across all five major projects may result in increased costs in the future.

Table 1 provides an overview of the reported status of each major facilities project in construction, as of March 2024.

**Table 1: Status of NSF Major Research Infrastructure Facilities Projects in Construction, as of March 2024**

Project name	NSF-authorized total project cost <sup>a</sup>	Cost change since June 2023	Expected construction completion date <sup>b</sup>	Schedule change since June 2023
Rubin Observatory	\$571.0 million	No change <sup>c</sup>	March 2025	▲ 3 months <sup>c</sup>
Regional Class Research Vessels	\$400.0 million	No change	January 2027	▲ 7 months
Antarctic Infrastructure Modernization for Science	\$275.0 million <sup>d</sup>	No change <sup>e</sup>	January 2027	▲ 1 month <sup>e</sup>
Large Hadron Collider High Luminosity Upgrade Program	\$82.8 million	▲\$7.8 million	July 2028	▲ 11 months
ATLAS detector	\$88.0 million	▲\$10.0 million	July 2028	▲ 1 month
CMS detector				
<b>Total</b>	<b>\$1,416.8 million</b>			

Legend: ATLAS = A Toroidal Large Hadron Collider Apparatus; CMS = Compact Muon Solenoid; ▲ = cost or schedule increase

Source: GAO analysis of National Science Foundation (NSF) information | GAO-24-107044

<sup>a</sup>Total project cost is determined by the NSF authorized not-to-exceed cost. This value is not the same as the current estimated total project cost based on NSF’s Earned Value Management System calculations. The total project cost does not include design costs, which generally do not come from the Major Research Equipment and Facilities Construction (MREFC) account.

<sup>b</sup>Expected construction completion is determined by adding the remaining schedule contingency to the current forecasted construction completion date based on NSF’s Earned Value Management System calculations in comparison to the performance measurement baseline.

<sup>c</sup>NSF officials will update cost and schedule estimates for the Rubin Observatory once it approves a supplemental funding request, currently estimated at \$15 million and scheduled for late Spring 2024.

<sup>d</sup>Total project cost for the Antarctic Infrastructure Modernization for Science project is determined by current estimated total project cost based on NSF’s Earned Value Management System calculations. During NSF’s re-baselining to account for delays due to the pandemic, the NSF authorized total project cost was not changed from \$410.4 million. Therefore, the current estimated total project cost better reflects the current cost status.

<sup>e</sup>NSF officials will update cost and schedule estimates for the Antarctic Infrastructure Modernization for Science at its construction review in July 2024.

There are a variety of factors contributing to the anticipated schedule increases for RCRV and AIMS, which may also result in cost increases. Specifically, both RCRV and AIMS have reported staffing shortages, each with unique causes, that are resulting in ongoing construction delays. NSF officials said that a shortage of skilled labor is an issue for the entire shipbuilding industry, particularly in Louisiana, home of the RCRV shipyard. For example, workforce recovery after Hurricane Ida has been further hindered by scarce housing, and reconstruction remains an ongoing challenge. In contrast, NSF officials said the shortage of skilled labor for the AIMS project is due to domestic U.S. demand for construction workers and heavy equipment operators. The lower availability of domestic labor has increased reliance on non-American workers, and the process for obtaining background checks for these workers is taking longer than the expected four-week period. The contractor is working with its primary subcontractor to develop a mitigation plan to hire and onboard the necessary staff.

Table 2 highlights significant, recent events that may cause cost or schedule increases for these projects.

**Table 2: Significant Events Occurring from June 2023 to March 2024 that May Affect Cost or Schedule for Major Facilities Projects in Construction**

Project name	Significant events
Regional Class Research Vessels	<ul style="list-style-type: none"> <li>• Shipyard missed the delivery date of September 22, 2023, for Vessel 1, and the awardee is withholding financial penalties in accordance with the shipyard contract.</li> <li>• Further delays in delivery for all three vessels are anticipated due to staffing shortages with shipyard employees, subcontractors, and vendors.</li> <li>• The awardee’s project team expects additional delays due to the complexity of Vessel 1 and internal space constraints.</li> </ul>
Rubin Observatory	<ul style="list-style-type: none"> <li>• A vacuum leak—now resolved—caused a multi-month delay in the shipment of the camera.</li> <li>• A malfunctioning dome crane, now repaired, caused delays in installing and testing the dome and telescope mount.</li> </ul>

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Antarctic Infrastructure Modernization for Science

- Year-long delays are anticipated for Vehicle Equipment and Operations Center and the Lodging Facility due to construction errors and availability of materials.
- Three of four cranes were out of service at McMurdo in early November 2023 delaying work on Vehicle Equipment and Operations Center and Lodging Facility.
- Inability to enclose the Lodging Facility and the lack of planned winter staff has delayed construction work.

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Source: GAO analysis of National Science Foundation (NSF) information | GAO-24-107044

In the following pages, we provide one-page overviews for each major facilities project in construction.

# VERA C. RUBIN OBSERVATORY

LOCATION: CERRO PACHÓN, CHILE

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), which is provided by the Department of Energy.



Source: Rubin Obs/NSF/AURA (B. Stalder). | GAO-24-107044

## CURRENT SNAPSHOT

The project team continued to make progress in completing various integration and commissioning activities, despite the malfunction and repair of a dome crane. Construction of the commissioning camera was delayed due to a vacuum pump leak but is now complete, and final delivery of the camera is now anticipated for June 2024. A joint status review for construction and commissioning conducted by NSF and the Department of Energy expressed confidence in the project team's ability to complete the project but recognized planning uncertainties that have since been resolved, according to NSF officials.

	Authorized total project cost	Estimated total project cost	Forecasted completion date
Initial	\$473.0M	\$467.8M	August 2022
Current (as of March 2024)	\$571.0M	\$549.6M	March 2025
Total change since construction start	▲ \$98.0M	▲ \$81.8M	▲ 31 months

M = million, ▲ = Increase

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-107044

## MILESTONES

AUTHORIZED PROJECT COST

SCHEDULE

Start of design 2003

Final design review 2013

Construction award 2014

Initial completion date: Aug. 2022

Authorized project costs: **\$473.0M**

NSF increased the authorized, not-to-exceed cost to address pandemic-related costs

JUN. 2020 **+\$10.0M**

National Science Board authorized a cost and schedule increase to address pandemic-related effects and increased data security requirements

DEC. 2021 **+\$88.0M**

**+23 Months**

A Department of Energy off-site power outage and additional technical challenges have caused schedule increases

DEC. 2022 **+5 Months**

Delays due to a dome crane malfunction and leak during commissioning of the camera support system

DEC. 2023 **+3 Months**

Current scheduled completion date

MAR. 2025 Authorized total project cost to date: **\$571.0M**

Increase in authorized total project cost to date: **\$98.0M**

Increase in estimated schedule to date: **31 months**

End of operations 2070s

M = million

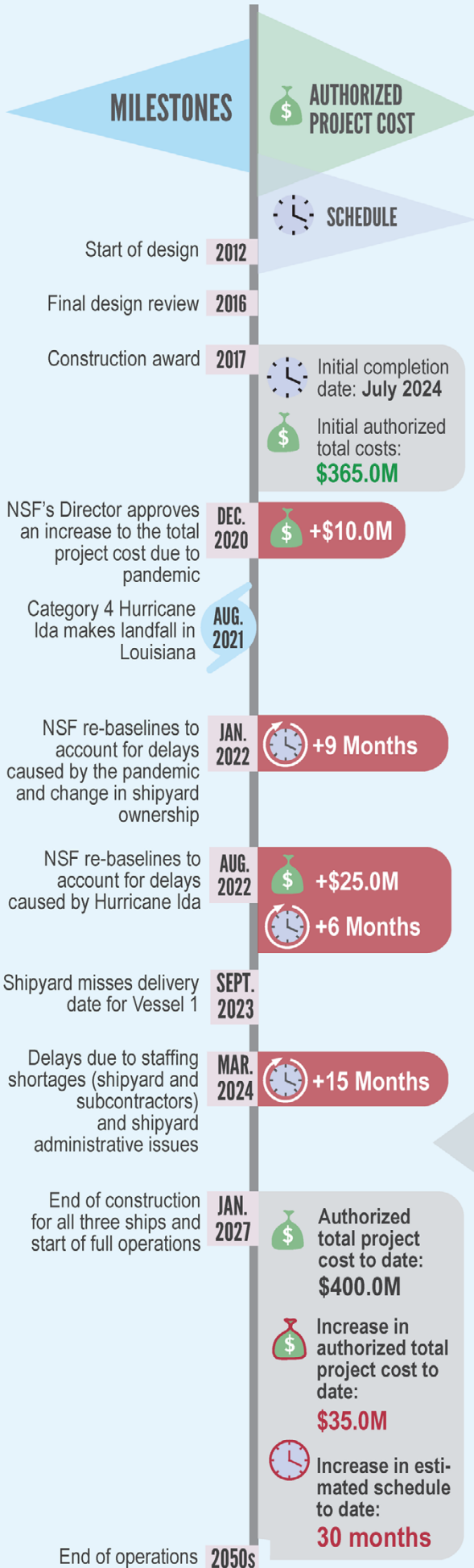
Source: National Science Foundation (NSF); icons (GAO). | GAO-24-107044

## FUTURE RISKS/ANTICIPATED MILESTONES

Delays due to the dome crane malfunction and vacuum pump leak have pushed the project end date to March 2025. However, the upcoming installation of two mirrors, currently scheduled for April 2024 and June 2024, are critical milestones that could impact the overall project schedule, if delayed. A sixth supplemental funding request is currently pending approval by NSF, with a decision estimated for late spring 2024. The request is anticipated to increase the estimated total project cost by approximately \$15 million, which will be within the \$571 million in authorized total project cost.

# REGIONAL CLASS RESEARCH VESSELS

LOCATION: CONSTRUCTION SITE IS IN LOUISIANA



M = million

Source: National Science Foundation (NSF); icons (GAO). | GAO-24-107044

## CURRENT SNAPSHOT



Source: National Science Foundation (NSF). | GAO-24-107044

Progress has been made on all three vessels, but production delays have continued. The shipyard has used lessons learned during its production of Vessel 1 to plan work activities more efficiently, but the overall project schedule continues to slip. The lessons learned from construction of the first vessel concern adapting sequencing of events in what is an exceptionally complex ship with tight conditions for multiple workers and limited space available for discrepancies. The shipyard missed the delivery date of September 22, 2023, for Vessel 1 and is incurring daily financial penalties in accordance with the shipyard contract. Although Vessel 1 has launched, the project team expects additional delays as construction transitions to the most complicated stage—system integration and start-up. Shipyard performance has been an ongoing concern for the project team, and the shipyard has struggled with management and continued skilled labor shortages. For example, staffing shortages have reduced the number of available shipyard employees, subcontractors, and vendors needed to complete work.

	Authorized total project cost	Estimated total project cost	Forecasted completion date
Initial	\$365.0M	\$354.0M	July 2024
Current (as of March 2024)	\$400.0M	\$391.5M	January 2027
Total change since construction start	▲ \$35.0M	▲ \$37.5M	▲ 30 months

M = million, ▲ = Increase

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-107044

## FUTURE RISKS/ANTICIPATED MILESTONES

The remaining two vessels still need to be launched and component installation completed before being delivered. The delivery date for Vessel 1 continues to be delayed as commissioning and outfitting challenges continue. According to NSF officials, the current risks to the project are potentially inadequate shipyard performance (including labor shortage), transition to operations issues, changes in regulatory requirements, and delays in supplier deliveries.

# ANTARCTIC INFRASTRUCTURE MODERNIZATION FOR SCIENCE

LOCATION: MCMURDO STATION, ANTARCTICA

## MILESTONES

ESTIMATED PROJECT COST

SCHEDULE

Start of design 2014

Final design review 2018

Construction award 2019



Initial completion date: Apr. 2028



Initial estimated total costs<sup>a</sup>: \$410.4M

Construction pause due to pandemic

MAR. 2020

NSF re-baselines to account for delays caused by the pandemic. NSF removes four of the six planned components of AIMS and continues with the two of the previously awarded components -- Vehicle Equipment and Operations Center and Lodging.

JUNE 2022



-\$135.4M



-27 Months

Lack of winter staff limits construction

MAR. 2024



+12 Months

NSF construction review to reassess cost and schedule

JULY 2024

Current scheduled completion date

JAN. 2027



Estimated total project cost to date: \$275.0M



Decrease in estimated total project cost to date<sup>a</sup>: \$135.4M



Decrease in estimated schedule to date: 15 months

End of operations 2062-2077

M = million

<sup>a</sup>Total project cost for the Antarctic Infrastructure Modernization for Science project is determined by current forecasted total project cost based on NSF's Earned Value Management System calculations. During NSF's re-baselining to account for delays due to the pandemic, the NSF authorized total project cost was not changed from \$410.4 million. Therefore, the current estimated total project cost better reflects the current cost status.

Source: National Science Foundation (NSF); icons (GAO). | GAO-24-107044

The National Science Foundation's (NSF) Antarctic Infrastructure Modernization for Science (AIMS) project will modernize the core infrastructure of McMurdo Station in Antarctica. The currently funded project at \$275 million includes construction of the Vehicle Equipment and Operations Center for maintenance on light and heavy equipment along with a new lodging facility to ensure adequate bed space to support the station workforce, scientists, and construction workers.

## CURRENT SNAPSHOT



Source: National Science Foundation. | GAO-24-107044

AIMS construction during the 2023/2024 Antarctic season has encountered several challenges. Temporary crane stoppages contributed to a construction delay that, in turn, affected the ability of the contractor to conduct winter work on building interiors. In addition, a lack of planned winter staffing was also a factor for construction delay. A factor for the limited winter staffing is a shortage of skilled labor from the U.S. and the contractor hiring foreign labor that requires a background check. In addition, all insulated structural panels for the lodging building have required replacement because of poor manufacturing discovered after delivery to Antarctica. Although new panels have been shipped to Antarctica, NSF has yet to receive confirmation of compliance with technical specifications.

	Authorized total project cost	Estimated total project cost	Forecasted completion date
Initial	\$410.4M	\$410.4M	April 2028
Current (as of March 2024)	\$410.4M	\$275.0M	January 2027
Total change since construction start	No change	▼ \$135.4M	▼ 15 months

M = million, ▼ = Decrease

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-107044

## FUTURE RISKS/ANTICIPATED MILESTONES

Due to the major interruptions during the past construction season along with other challenges, NSF has decided to move the construction review from March to July 2024. The additional time should allow NSF and contractor the opportunity to assess 2024 construction season on-ice performance, analyze options, and determine next steps. According to NSF officials, the current risks to the project include unavailability of critical equipment, transportation of construction labor to and from McMurdo, background checks for the non-American labor force, and labor availability for future on-ice work. Additionally, NSF will need to consider how to align the previously unfunded portions of the AIMS scope with the recently created Antarctic Infrastructure Recapitalization Program.

# LARGE HADRON COLLIDER HIGH LUMINOSITY UPGRADE PROGRAM: ATLAS (A TOROIDAL LHC APPARATUS) PROJECT

LOCATION: GENEVA, SWITZERLAND

## MILESTONES

 AUTHORIZED PROJECT COST

 SCHEDULE

Start of design 2015

Final design review 2019

Construction award 2020



Initial completion date: **May 2026**



Initial total costs: **\$75.0M**

NSF re-baselines cost and schedule to account for effects of the pandemic, supply chain issues, and the war in Ukraine

AUG. 2023



**+\$7.8M**



**+26 Months**

Current scheduled completion date

JULY 2028



Authorized total project cost to date: **\$82.8M**



Increase in authorized total project cost to date: **\$7.8M**

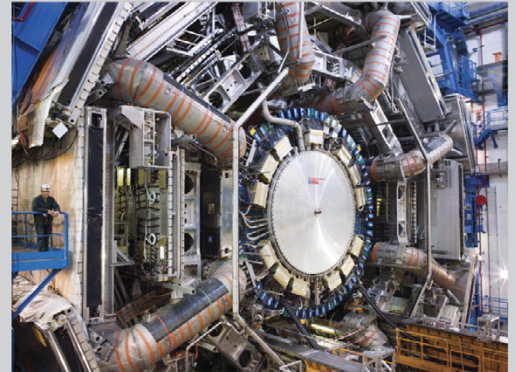


Increase in estimated schedule to date: **26 months**

End of operations 2038

## CURRENT SNAPSHOT

ATLAS finalized its cost and schedule re-baseline in August 2023. Assembly and testing are progressing for several ATLAS components. While some components are slightly behind schedule in their design or production readiness reviews, these delays will have little effect on commissioning schedules.



Source: European Organization for Nuclear Research | GAO-24-107044

	Authorized total project cost	Estimated total project cost	Forecasted completion date
Initial	\$75.0M	\$75.0M	May 2026
Current (as of March 2024)	\$82.8M	\$82.8M	July 2028
Total change since construction start	▲ \$7.8M	▲ \$7.8M	▲ 26 months

M = million, ▲ = Increase

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-107044

## FUTURE RISKS/ANTICIPATED MILESTONES

Although supply chain issues, inflation, and market uncertainties, which have caused prior cost increases, continue to pose potential project risks, NSF has a high level of confidence that the remaining activities can be accomplished within the re-baselines. No critical path milestones are anticipated for the remainder of 2024.

M = million

Source: National Science Foundation (NSF); icons (GAO). | GAO-24-107044



# LARGE HADRON COLLIDER HIGH LUMINOSITY UPGRADE PROGRAM: CMS (COMPACT MUON SOLENOID) PROJECT

LOCATION: GENEVA, SWITZERLAND

## MILESTONES

 AUTHORIZED PROJECT COST

 SCHEDULE

Start of design 2015

Final design review 2019

Construction award 2020



Initial completion date: Aug. 2026



Initial authorized total costs: **\$78.0M**

NSF re-baselines cost and schedule to account for effects of the pandemic, supply chain issues, and the war in Ukraine

AUG. 2023



**+\$10.0M**



**+22 Months**

Current scheduled completion date

JULY 2028



Authorized total project cost to date: **\$88.0M**



Increase in authorized total project cost to date: **\$10.0M**



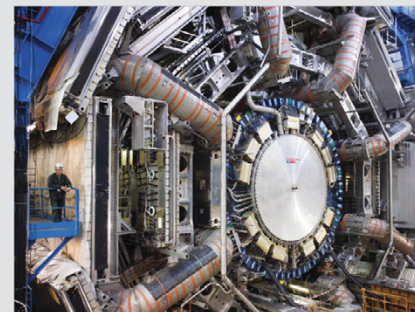
Increase in estimated schedule to date: **22 Months**

End of operations 2038

The Compact Muon Solenoid (CMS) is a general-purpose detector at the Large Hadron Collider (LHC). It has a broad physics program ranging from studying the Standard Model of particle physics to searching for extra dimensions and particles that could make up dark matter. Although it has the same scientific goals as the ATLAS experiment (which stands for A Toroidal LHC Apparatus), it uses different technical solutions and a different magnet-system design.

## CURRENT SNAPSHOT

CMS finalized its cost and schedule re-baseline in August 2023. Some components have since experienced fabrication and testing delays, but the completion of all components is scheduled to meet the European Organization for Nuclear Research's "need-by" date.



Source: European Organization for Nuclear Research | GAO-24-107044

	Authorized total project cost	Estimated total project cost	Forecasted completion date
Initial	\$78.0M	\$77.2M	August 2026
Current (as of March 2024)	\$88.0M	\$88.0M	July 2028
Total change since construction start	▲ \$10.0M	▲ \$10.8M	▲ 22 months

M = million, ▲ = Increase

Source: GAO analysis of National Science Foundation (NSF) information. | GAO-24-107044

## FUTURE RISKS/ANTICIPATED MILESTONES

Supply chain issues related to multiple components could result in increased costs and delivery times that would exceed the current baseline cost and schedule estimates. According to NSF officials, the project team will undertake multiple essential preproduction tasks for a CMS structural component in 2024, including finalizing manufacturing plans, completing quality assurance tests, and receiving all critical materials.

M = million

Source: National Science Foundation (NSF); icons (GAO). | GAO-24-107044

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## Projects in Design Continued with One New Approved Project and Two Pending NSF's Decision to Advance

Since June 2023, two major facilities projects in design progressed through their respective design phases. In addition, two other projects are awaiting NSF decisions to advance to later design phases and a fifth project recently entered the design stage. Specifically:

- The NSF Director approved the advancement of the Antarctic Research Vessel to the final design phase.
- NSF will advance the Leadership Class Computing Facility to the construction stage pending Office of Management and Budget and congressional approval of its fiscal year 2024 spending plan.
- In response to a recommendation from the National Science Board, NSF plans to evaluate whether to advance either of the originally proposed Extremely Large Telescope projects to the Final Design Phase.
- NSF approved one new project into the design stage: the Next-generation Very Large Array.

In the following pages, we provide one-page overviews for each major facilities project in design.



Source: National Science Foundation (NSF).  
| GAO-24-107044

Note: Rendering of the project's conceptual design.

# ANTARCTIC RESEARCH VESSEL

LOCATION: TO BE DETERMINED

## MILESTONES

- JUN. 2021** Start of design
- SEP. 2021** Conceptual design review
- FEB. 2023** Preliminary design review
- FEB. 2026** Final design review
- 2026** Construction award
- 2032** End of construction
- 2070** End of operations

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 approaching the end of its service life. The ARV will meet NSF's science mission goals by increasing access to difficult-to-reach areas, allowing for longer missions, and delivering more scientists and equipment to the Antarctic.

## CURRENT SNAPSHOT

The NSF Director approved the advancement of the ARV project to the final design phase in September 2023. The National Academies released a report in October 2023 that included recommendations that the project team could consider during design, including icebreaking capabilities and underwater vehicles. NSF released the final request for proposal for a vessel integrator in February 2024. The selected integrator will complete the final design phase, select a shipyard, and manage construction of the vessel. According to officials, NSF's decision on including the ARV project in a future budget request is pending.



Cost and schedule estimates will be determined at the construction stage award.



Source: National Science Foundation (NSF); icons (GAO). | GAO-24-107044

## FUTURE RISKS/ANTICIPATED MILESTONES

Ongoing delays in the selection of a vessel integrator and anticipated issues with the availability of shipyard labor will likely delay the timeline for ship delivery to 2032. NSF has asked the U.S. Navy's Naval Sea Systems Command to provide an independent cost estimate, review acquisition plans, help develop contractual requirements, and provide additional program management support.



# LEADERSHIP CLASS COMPUTING FACILITY

LOCATION: AUSTIN, TEXAS

Source: National Science Foundation (NSF). | GAO-24-107044

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

## MILESTONES

- 2019 Start of design
- 2020 Conceptual design review
- JAN. 2022 Preliminary design review
- APR. 2023 Final design review
- JUNE 2024 Construction award
- 2027 End of construction
- 2037 End of operations

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. According to NSF officials, this might include extremely detailed simulations of biological molecules and analyses of very large data streams to create high-resolution Earth maps.

## CURRENT SNAPSHOT

Following final design review in April 2023, the project team is negotiating with a back-up location vendor because the primary vendor's planned space is no longer available. In November 2023, the National Science Board provided input to support a construction stage award, which is delayed due to ongoing finalization of requirements with the new colocation vendor. Construction will begin in summer 2024, pending Office of Management and Budget and congressional approval of NSF's FY24 spending plan. NSF officials are tentatively planning to make a construction award in June 2024.



Cost and schedule estimates will be determined at the construction stage award.



Source: National Science Foundation (NSF); icons (GAO). | GAO-24-107044

## FUTURE RISKS/ANTICIPATED MILESTONES

NSF must resolve several issues, such as reviewing the awardee's acquisition documentation and finalizing terms and conditions for the colocation agreement before authorizing the construction stage award.



Source: Courtesy of Thirty Meter Telescope International Observatory. | GAO-24-107044

# U.S. EXTREMELY LARGE TELESCOPE PROGRAM

LOCATION: TO BE DETERMINED

## MILESTONES

- NOV. 2022 Start of design
- FEB. 2023 Preliminary design review
- TBD Final design review
- TBD Construction award
- TBD End of construction
- TBD End of operations

Source: National Science Foundation (NSF); icons (GAO). | GAO-24-107044

The U.S. Extremely Large Telescope (ELT) Program was originally proposed to include construction of two new telescopes: the Thirty Meter Telescope and the Giant Magellan Telescope. A third potential component consists of the scientific software, community engagement, and user support services to be provided by NSF's National Optical-Infrared Astronomy Research Laboratory. The ELT will leverage current ground-based optical and radio astronomy facilities and will obtain high-fidelity observations of rare objects, such as habitable planets orbiting other stars, and rare classes of transient events. Because of previous investments by non-federal partners, NSF entered the ELT into the major facility design stage ready for an immediate preliminary design review.

## CURRENT SNAPSHOT

The National Science Board released a recommendation in February 2024 that NSF (1) construct only one of the two telescopes and (2) keep the total ELT budget under \$1.6 billion. According to officials, NSF presented its approach for evaluating whether to advance either telescope during the May 2024 National Science Board meeting.



Cost and schedule estimates will be determined at the construction stage award.



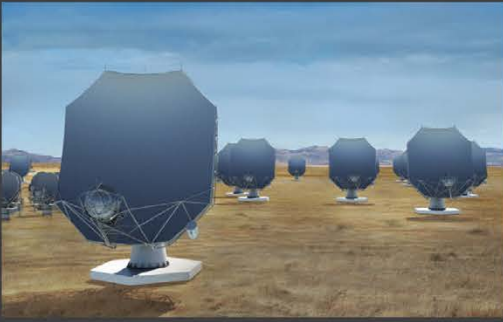
Source: National Science Foundation (NSF); icons (GAO). | GAO-24-107044



Source: Giant Magellan Telescope – GMT Corporation (CC BY-NC-ND 4.0 Deed | Attribution-NonCommercial-NoDerivs 4.0 International | Creative Commons). | GAO-24-107044

## FUTURE RISKS/ANTICIPATED MILESTONES

According to NSF officials, project risks will be refined based on which ELT components are advanced to final design, if any. Known programmatic risks include availability of future appropriations for construction and operations, future commitments from funding partners, and clarifying NSF's role in ELT governance.



Source: Sophia Dagnello/NRAO. | GAO-24-107044

# NEXT-GENERATION VERY LARGE ARRAY

LOCATION: SOCORRO, NEW MEXICO

## MILESTONES

- JULY 2023** Start of design
- SEPT. 2024** Conceptual design review
- TBD** Preliminary design review
- TBD** Final design review
- TBD** Construction award
- TBD** End of construction
- TBD** End of operations

The Next-Generation Very Large Array (ngVLA) project will replace the current Very Large Array and Very Long Baseline Array with a facility capable of achieving a 10-fold increase in sensitivity. The ngVLA will address many of the high-priority goals of modern astrophysics, including the science priorities described in the Astro2020 Decadal Survey.

## CURRENT SNAPSHOT

In July 2023, NSF approved the ngVLA project for entry into the Major Facility Design Stage at the Conceptual Design Phase. NSF created an integrated project team that is preparing the conceptual design review, currently planned for September 2024.



Cost and schedule estimates will be determined at the construction stage award.



Source: National Science Foundation (NSF); icons (GAO). | GAO-24-107044

Source: National Science Foundation (NSF); icons (GAO). | GAO-24-107044

## FUTURE RISKS/ANTICIPATED MILESTONES

The prototype ngVLA antenna is scheduled to arrive at the Very Large Array site near Socorro, New Mexico in June 2024. The mechanical and scientific testing of the prototype antenna is crucial in mitigating technical risk since antenna construction represents a significant portion of the total project cost. Progress on testing will be presented at conceptual design review.



Source: Sophia Dagnello/NRAO. | GAO-24-107044

## Mid-Scale Projects Continued with Minor Adjustments for Two Projects

NSF has made progress with implementing the eight previously awarded mid-scale research infrastructure projects. Table 3 provides an overview of the status of all eight projects as of March 2024. All authorized award amounts remain unchanged since our last report in December 2023. According to NSF, two projects, the Advanced Millimeter Survey Instrumentation in Chile and the High Magnetic Field Beamline, extended their scheduled completion dates—by four months to August 2028 and by two months to December 2025, respectively. According to NSF officials, the schedule extension to the High Magnetic Field Beamline was caused by availability of materials and labor. In contrast, the adjustment to the scheduled completion date for the Advanced Millimeter Survey Instrumentation in Chile was due to a delayed start from the proposed date and not because of any going implementation challenges. Additionally, the Research Data Ecosystem project is currently undergoing re-planning due to inflation and personnel costs. NSF officials told us that cost and schedule changes will likely be available within the next 12 months.

**Table 3: Status of NSF Mid-Scale Infrastructure Projects, as of March 2024**

Project name	Awardee	Current total project cost	Scheduled completion date
Advanced Millimeter Survey Instrumentation in Chile	The Trustees of the University of Pennsylvania	\$52.7 million	August 2028 ▲
Airborne Phased Array Radar	University Corporation for Atmospheric Research	\$91.8 million	May 2028
Compact X-Ray Free-Electron Laser	Arizona State University	\$90.8 million	February 2028
Distributed Energy Resources Connect	University of California, San Diego	\$42.0 million <sup>a</sup>	October 2025
Global Ocean Biogeochemistry Array	Monterey Bay Aquarium Research Institute	\$52.9 million	October 2025
High Magnetic Field Beamline	Cornell University	\$32.7 million	December 2025 ▲
Network for Advanced Nuclear Magnetic Resonance Spectroscopy	University of Connecticut Health Center	\$39.7 million	June 2025
Research Data Ecosystem	University of Michigan	\$38.4 million	January 2027

Legend: ▲ = schedule increase

Source: GAO analysis of National Science Foundation (NSF) information | GAO-24-107044

<sup>a</sup>In addition to the \$42.0 million in MREFC funds, the Distributed Energy Resources Connect project received a \$2.5 million supplement from funding provided to NSF in the American Rescue Plan Act of 2021.

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## Agency Comments

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

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



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



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# Appendix I: Objectives, Scope, and Methodology

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This report describes the cost and schedule performance of the National Science Foundation (NSF) for its ongoing major facilities and mid-scale research infrastructure projects.

To describe the cost and schedule performance of NSF's major facilities projects, we reviewed agency project progress reports for project updates dated from June 1, 2023, to January 31, 2024. To collect the most up-to-date information, we supplemented progress report data with a questionnaire to NSF to update project status, cost, and schedule as of March 1, 2024.

To describe the status of NSF's mid-scale research infrastructure projects funded by the Major Research Equipment and Facilities Construction (MREFC) account, we also reviewed an agency dashboard that detailed project cost and schedule and recent project milestones that were updated as of March 1, 2024.

We further supported our evidence collection with interviews with NSF officials about major projects which were in design or construction. In addition, we reviewed project risk reports and risk registers, documentation on available scope reduction options, and other NSF documents.

We conducted this performance audit from September 2023 to June 2024 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.

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# Appendix II: GAO Contact and Staff Acknowledgments

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**GAO Contact:**

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

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**Staff****Acknowledgments:**

In addition to the contact named above, Sarah Harvey (Assistant Director), Timothy Kinoshita (Analyst in Charge), and Darren Grant made key contributions to this report. Also contributing were Michael Armes, John Bauckman, Louise Fickel, Patrick Harner, Gina Hoover, William Laing, Jason T. Lee, David Marroni, and Curtis Martin.

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# Related GAO Products

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*National Science Foundation: Revised Policies on Developing Costs and Schedules Could Improve Estimates for Large Facilities.* [GAO-18-370](#). Washington, D.C.: June 1, 2018.

*National Science Foundation: Cost and Schedule Performance of Large Facilities Construction Projects and Opportunities to Improve Project Management.* [GAO-19-227](#). Washington, D.C.: March 27, 2019.

*National Science Foundation: Cost and Schedule Performance of Major Facilities Construction Projects and Progress on Prior GAO Recommendations.* [GAO-20-268](#). Washington, D.C.: April 3, 2020.

*National Science Foundation: COVID-19 Affected Ongoing Construction of Major Facilities Projects.* [GAO-21-417](#). Washington, D.C.: June 8, 2021.

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

*National Science Foundation: Additional Steps Would Improve Cost Estimate for Antarctic Research Infrastructure Project.* [GAO-24-106380](#). Washington, D.C.: December 5, 2023.

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