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NASA

Lessons from Ongoing Major Projects Can Inform Management of Future Space Telescopes

Statement of W. William Russell, Director, Contracting and National Security Acquisitions

GAO-22-105555

GAO@100 Highlights

Highlights of GAO-22-105555, a testimony before the Subcommittees on Space and Aeronautics and Research and Technology, Committee on Science, Space, and Technology, House of Representatives

Why GAO Did This Study

The projects in NASA's current portfolio of major space telescopes—JWST, Roman, and SPHEREx—have roots in past decadal surveys on Astronomy and Astrophysics from the National Academies of Sciences, Engineering, and Medicine. NASA is now considering the results of the National Academies' 2020 decadal survey, which may spur new projects in this portfolio.

NASA has made improvements in acquisition management in recent years, but it remains a long-standing challenge for the agency.

This statement reflects GAO's observations on (1) the current status of NASA's major telescope projects, and (2) lessons learned that can be applied to NASA's management of its future telescope projects as it considers the results of this decadal study. This statement is based on ongoing work on the status of NASA's major projects, which is planned to be published in spring 2022, and past GAO reports on JWST and NASA's acquisitions of major projects.

What GAO Recommends

In prior work, GAO has made recommendations to improve NASA's acquisition of major projects. NASA generally agreed with most of those recommendations and implemented changes in response.

As of November 2021, NASA has not fully addressed eight open priority recommendations related to monitoring program costs and execution. Those recommendations were detailed most recently in a report to the NASA Administrator in June 2021.

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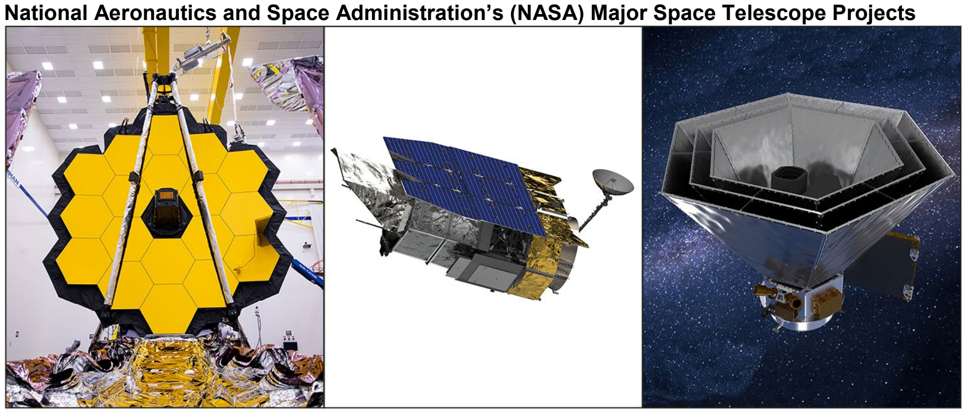
What GAO Found

The National Aeronautics and Space Administration (NASA) relies on complex instruments and spacecraft to accomplish its missions—including to better understand the universe and our place in it. NASA's astrophysics projects currently include three major space telescopes (see figure).

- **James Webb Space Telescope (JWST)** continues to make progress toward its planned launch in December 2021, 90 months later than originally planned.
- **Nancy Grace Roman Space Telescope (Roman)** set cost and schedule baselines in February 2020, but COVID-19 led to cost and schedule growth.
- **Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer (SPHEREx)** set cost and schedule baselines in January 2021. Technical problems pushed the critical design review to January 2022.

National Aeronautics and Space Administration's (NASA) Major Space Telescope Projects



James Webb Space Telescope (JWST) | Nancy Grace Roman Space Telescope (Roman) | Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer (SPHEREx)

Source: NASA (JWST); NASA/Goddard Space Flight Center (Roman); NASA/Jet Propulsion Laboratory-Caltech (SPHEREx). | GAO-22-105555

Three lessons learned from GAO's work, some of which NASA has adopted, provide an opportunity to strengthen management of future space telescopes.

Manage cost and schedule performance for large projects to limit portfolio implications. Increases associated with NASA's most costly and complex missions have cascading effects on the rest of the portfolio, and JWST's cost and schedule increases over the years have had outsized effects.

Minimize risk in program decisions to better position projects for successful execution. GAO has found that major projects often underestimate cost and technical risk, contributing to cost overruns and unstable designs.

Consistently update cost and schedule estimates to provide realistic information to decision makers. NASA now requires major projects to develop and update a joint cost and schedule confidence level—an integrated analysis of a project's cost, schedule, risk, and uncertainty.

Chairs Beyer and Stevens, Ranking Members Babin and Waltz, and Members of the Subcommittees:

I am pleased to be here today to discuss the National Academies of Sciences, Engineering, and Medicine's 2020 decadal survey on Astronomy and Astrophysics (2020 decadal survey). Decadal surveys provide the National Aeronautics and Space Administration (NASA) with the science communities' opinion on mission goals, and are one of the inputs NASA uses to determine when to add new missions. For example, three major telescope projects in NASA's portfolio are derived from past Astrophysics decadal surveys. These telescopes are the key enablers for the agency to achieve its astrophysics science goals, which include seeking to understand the universe and our place in it. NASA's major space telescope projects—those with an estimated life-cycle cost greater than $250 million—include:

- the James Webb Space Telescope (JWST), which is designed to help understand the origin and destiny of the universe, the creation and evolution of the first stars and galaxies, and the formation of stars and planetary systems;
- the Nancy Grace Roman Space Telescope (Roman), which is designed to perform wide-field imaging and survey of the near-infrared sky to answer questions about the structure and evolution of the universe and expand our knowledge of planets beyond our solar system;[1] and
- the Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer (SPHEREx), which will probe the origin and destiny of the universe and create a map of the entire sky to gather data on galaxies and stars in the Milky Way.

In its fiscal year 2022 budget request, NASA requested about $767 million for these telescope projects, which represents almost 50 percent of NASA's budget for astrophysics projects.[2] In total, these projects represent a cumulative total life-cycle cost of approximately $14 billion. As such, while it is important for NASA to continually stretch technological

[1]The Nancy Grace Roman Space Telescope was formerly known as the Wide-Field Infrared Survey Telescope (WFIRST).

[2]In 2017, we found that NASA historically spends 50-70 percent of its astrophysics budget on developing new missions, according to NASA officials. GAO, *NASA: Preliminary Observations on the Management of Space Telescopes,* GAO-18-277T (Washington, D.C.: Dec. 6, 2017).

boundaries to further scientific research, it is also important to manage these projects prudently, with clear accountability and oversight for taxpayer dollars.

The 2020 decadal survey proposes a broad, integrated plan for space- and ground-based astronomy and astrophysics for the next decade. One of the top priorities identified in the survey is a large infrared/optical/ultraviolet (IR/O/UV) space telescope estimated to cost $11 billion. Prior to beginning that mission, the survey also recommends commencing mission and technology maturations programs for key elements, which are estimated to cost $3-5 billion. The proposed telescope effort would be comparable to JWST and Roman.

Acquisition management has been a long-standing challenge at NASA, although we have reported on improvements the agency has made in recent years.[3] We first designated NASA's acquisition management as a high-risk area in 1990 in view of NASA's history of persistent cost growth and schedule slippage in the majority of its major systems. We have identified management weaknesses that have exacerbated the inherent technical and engineering risks faced by NASA's largest projects. NASA has taken steps to improve its management of major projects, but has continued to struggle with major project cost and schedule performance. In our March 2021 High Risk Update, we found that NASA needs to do more to reduce acquisition risk and demonstrate progress, especially with regard to demonstrating sustained improvement in cost and schedule performance for new, large, complex programs entering the portfolio.[4]

My statement today provides our observations on (1) the history of JWST's development challenges, (2) the current status of NASA's major telescope projects, and (3) lessons learned that can be applied to NASA's management of its future telescope projects as it considers the results of this decadal study. This statement is based on our ongoing annual review of the status of all of NASA's major projects for this committee, as well as our May 2021 report on the JWST project, our March 2021 High Risk

[3]GAO, *High-Risk Series: Dedicated Leadership Needed to Address Limited Progress in Most High-Risk Areas*, GAO-21-119SP (Washington, D.C.: Mar. 2, 2021).

[4]GAO-21-119SP.

Update, and other past reports.[5] To assess the cost and schedule performance of JWST, Roman, and SPHEREx, we collected information using data collection instruments and key decision memorandum, and compared current cost and schedule estimates to their original cost and schedule baselines. To assess the status, risk, and challenges for these projects, we collected information on these areas from projects, analyzed monthly status reports, interviewed NASA officials, and reviewed project documentation. To identify lessons learned that can be applied to NASA's management of large complex projects, such as future telescope projects, we examined NASA's efforts to address issues identified in our prior work examining JWST, human space flight, and the major projects portfolio, and our March 2021 High-Risk Update.[6]

We are conducting the work on which this statement is based 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. We plan to issue a final report on our annual assessment of NASA's major projects in spring 2022. NASA provided us technical comments on the telescope projects, which we incorporated as appropriate.

Background

NASA's mission is to drive advances in science, technology, aeronautics, and space exploration, and contribute to education, innovation, our country's economic vitality, and the stewardship of the Earth. To

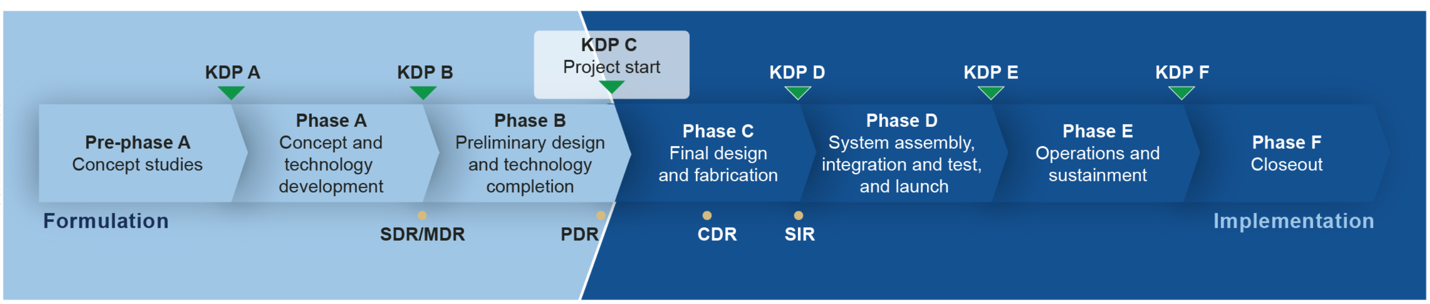
[5]GAO, *James Webb Space Telescope: Project Nearing Completion, but Work to Resolve Challenges Continues*, GAO-21-406 (Washington, D.C.: May 13, 2021); GAO-21-119SP; *NASA: Assessments of Major Projects*, GAO-21-306 (Washington, D.C.: May 20, 2021); *James Webb Space Telescope: Technical Challenges Have Caused Schedule Strain and May Increase Costs*, GAO-20-224 (Washington, D.C.: Jan. 28, 2020); *James Webb Space Telescope: Opportunity Nears to Provide Additional Assurance That Project Can Meet New Cost and Schedule Commitments*, GAO-19-189 (Washington, D.C.: Mar. 26, 2019); and GAO-18-277T.

[6]GAO-21-306; GAO-21-119SP; GAO, *NASA: Assessments of Major Projects*, GAO-20-405 (Washington, D.C.: Apr. 29, 2020); *NASA: Actions Needed to Improve the Management of Human Spaceflight Programs*, GAO-19-716T (Washington, D.C.: Sept. 18, 2019); GAO-19-189;; GAO-18-277T; *NASA: Assessments of Selected Large-Scale Projects*, GAO-13-276SP (Washington, D.C.: Apr. 17, 2013); *James Webb Space Telescope: Actions Needed to Improve Cost Estimate and Oversight of Test and Integration,* GAO-13-4 (Washington, D.C.: Dec. 3, 2012); *NASA: Assessments of Selected Large-Scale Projects,* GAO-09-306SP (Washington, D.C.: Mar. 2, 2009).

accomplish this mission, NASA establishes programs and projects that rely on complex instruments and spacecraft.[7] NASA's projects aim to continue exploring Earth and the solar system, extend human presence beyond low Earth orbit to the lunar surface, and understand climate change, among other things. Some of NASA's projects are expected to incorporate new and sophisticated technologies that must operate in harsh, distant environments.

The life cycle for NASA space flight projects consists of two phases—formulation, which takes a project from concept to preliminary design, and implementation, which includes building, launching, and operating the system, among other activities. Major projects must get approval from senior NASA officials at key decision points before they can enter each new phase. Figure 1 depicts NASA's life cycle for space flight projects.

Figure 1: NASA's Life Cycle of Space Flight Projects



Management decision reviews

KDP = key decision point

Technical reviews

- SDR/MDR = system definition review/mission definition review
- PDR = preliminary design review
- CDR = critical design review
- SIR = system integration review

Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-22-105555

Formulation culminates in a review at key decision point C, known as project confirmation, where cost and schedule baselines are established and documented in a decision memorandum. The cost and schedule baselines represent the agency's baseline commitment. To inform the

[7]We define major projects as those projects or programs with an estimated life-cycle cost of over $250 million.

agency baseline commitment, each project with a life-cycle cost estimated to be greater than $250 million must also develop a joint cost and schedule confidence level (JCL) unless NASA waives the requirement. A JCL is an integrated analysis of a project's cost, schedule, risk, and uncertainty, the result of which indicates a project's likelihood of meeting a given set of cost and schedule targets.[8]

The agency baseline commitment established at key decision point C also includes cost and schedule reserves held at the project—those within the project manager's control—and NASA headquarters level. Cost reserves are for costs that are expected to be incurred—for instance, to address project risks—but are not yet allocated to a specific part of the project. Schedule reserves are extra time in project schedules that can be allocated to specific activities, elements, and major subsystems to mitigate delays or address unforeseen risks.

Many of the government's most costly and complex acquisition programs—such as JWST—require the development of cutting-edge technologies and their integration into large and complex systems. For 2 decades, we have shown that using effective management practices and processes to assess how far a technology has matured and how this has been demonstrated are fundamental to evaluating its readiness to be integrated into a system and managed for risk in the federal government's major acquisitions. Our January 2020 Technology Readiness Assessment Guide established a methodology for evaluating technology maturity based on best practices that can be used across the federal government.[9] It is a companion to our Cost Estimating and Assessment Guide and Schedule Assessment Guide.[10]

[8]National Aeronautics and Space Administration, *NASA Cost Estimating Handbook Version 4.0* (February 2015).

[9]GAO, *Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects* [Reissued with revisions on Feb. 11, 2020.], GAO-20-48G (Washington, D.C.: Jan. 7, 2020).

[10]GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: Mar. 2, 2009); and *GAO Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-16-89G (Washington, D.C.: Dec 22, 2015).

Development Challenges of James Webb Space Telescope

JWST, with a life-cycle cost estimate of almost $10 billion, is one of NASA's most complex projects and top priorities. JWST was identified as a priority in the 2001 Astrophysics Decadal Survey. In the 2020 decadal survey, the National Academies noted that JWST is likely to influence essentially every area of astronomy.

The telescope is designed to help understand the origin and destiny of the universe, the creation and evolution of the first stars and galaxies, and the formation of stars and planetary systems. With a 6.5-meter primary mirror, JWST is expected to operate at about 100 times the sensitivity of the Hubble Space Telescope. JWST's science instruments are to detect very faint infrared sources and, as such, are required to operate at extremely cold temperatures. To help keep these instruments cold, a multi-layered tennis-court-sized sunshield is being developed to protect the mirrors and instruments from the sun's heat.

The JWST project has experienced significant cost increases and schedule delays. Prior to being approved for development, initial cost estimates for JWST ranged from $1 billion to $3.5 billion, with expected launch dates ranging from 2007 to 2011. Due to early technical and management challenges, contractor performance issues, and low levels of cost reserves, the JWST program experienced significant schedule overruns, launch delays, and cost growth.

Since the project's schedule and costs were baselined in 2009, the launch date has been delayed by over 7 years and costs have increased by 95 percent.

- JWST underwent a replan in September 2011 and then a rebaseline.[11]
- In June 2018, after a series of launch delays due to technical and workmanship issues identified during spacecraft element integration, NASA estimated that it would require 29 more months beyond the

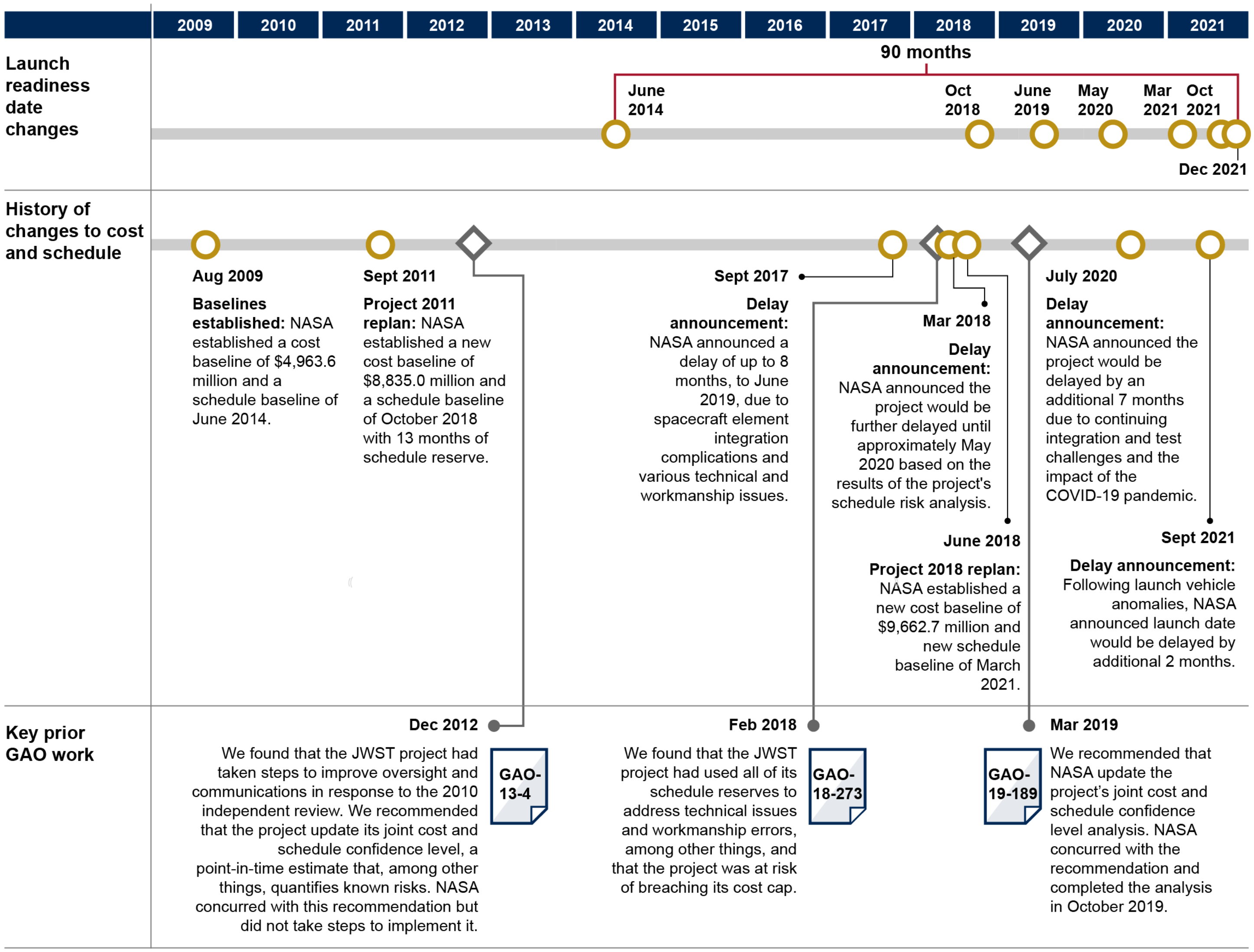
[11]A replan is a process by which a program updates or modifies its plans. It generally is driven by changes in program or project cost parameters, such as if development cost growth is 15 percent or more of the estimate in the baseline report or a major milestone is delayed by 6 months or more from the baseline's date. A replan does not require a new project baseline to be established. Rebaselining is the process that results in a change to the project's Agency Baseline Commitment. A rebaseline is initiated if the estimated development cost exceeds the baseline development cost estimate by 30 percent or more or if the NASA Associate Administrator determines other events make a rebaseline appropriate. NASA NPR 7120.5F, NASA Space Flight Program and Project Management Requirements, Expiration date Aug. 3, 2026, Section 2.4.1.8.

estimates agreed to in the 2011 rebaseline and $828 million in additional resources.

- Additional technical issues, anomalies during launch vehicle missions, and Coronavirus Disease 2019 (COVID-19) all contributed to two additional delays totaling 9 months.

See figure 2 for the history of changes to the project's cost and schedule.

Figure 2: History of Changes to the James Webb Space Telescope (JWST) Project's Cost and Schedule



Source: GAO analysis of National Aeronautics and Space Administration (NASA) documents, external independent review documents, and prior GAO reports. | GAO-22-105555

Note: The JWST project was in formulation from March 1999 through August 2009. This graphic shows only events that occurred after the project entered implementation.

Status of NASA's Major Telescope Projects

NASA's current portfolio of major space telescopes includes three projects—JWST, Roman, and SPHEREx—that vary in cost and complexity. Our past and ongoing work indicates that these projects are each making progress, but also face challenges in execution.[12] Some of these challenges are common among the projects in NASA's portfolio. For example, when projects enter the integration and test phase, unforeseen challenges can arise and affect the cost and schedule for the project. Other challenges stem from the COVID-19 pandemic, or have been exacerbated by the pandemic and the uncertainty surrounding its potential future effects. Table 1 provides more details about the current acquisition phase, cost, and schedule status of NASA's major space telescope projects based on our ongoing work.

Table 1: Phase, Cost, and Schedule Status of NASA's Major Space Telescope Projects as of June 2021

		Life-Cycle Cost Estimate (then-year millions of dollars)			Schedule		
Project	**Acquisition phase**	**Baseline**	**Latest estimate**	**Dollar change**	**Baseline launch readiness date**	**Latest estimated date**	**Change (months)**
JWST	System assembly, integration and test, and launch	4,963.6	9,662.7[a]	4,699.1	June 2014	December 2021[b]	90
Roman	Final design and fabrication	3,934.0	4,316.0	382.0	October 2026	May 2027	7
SPHEREx	Final design and fabrication	451.4	451.4	0.0	April 2025	April 2025	0

Legend: JWST - James Webb Space Telescope; Roman - Nancy Grace Roman Space Telescope; SPHEREx - Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer

Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-22-105555

[a]As of September 2021, project documentation indicates that the project has requested additional resources from NASA headquarters. These changes will be reflected in the project's life-cycle cost estimate after the project's next key decision point review. Until the review is complete, information presented is based on the latest estimates we received from NASA.

[b]JWST's schedule is as of September 2021.

JWST. The JWST project continues to make progress toward its upcoming launch. Over the last 6 months, the project completed final build and testing activities, successfully shipped the observatory to its European Space Agency (ESA)-operated launch location in French Guiana, and completed its operational readiness review. However, the

[12]GAO-21-406; GAO-21-306; and GAO-20-224.

JWST project launch vehicle, Ariane 5, experienced launch vehicle anomalies, which delayed the project's planned launch and ultimately required the JWST project to delay its launch readiness date to December 2021. These delays, as well as COVID-19-related inefficiencies and other program costs, depleted the project's cost reserves. To support the additional development costs associated with a later launch, NASA plans to shift funding planned for JWST operations in fiscal years 2021 and 2022. NASA is staying in close communications with the launch vehicle provider and ESA as they work through the anomaly investigation. In the meantime, the project is currently continuing to prepare for the upcoming launch planned for December 2021.

Roman. This project entered formulation in February 2016, and was the 2010 Astrophysics Decadal Survey's top-ranked large space mission. The latest decadal survey found that Roman remains both powerful and necessary for achieving the scientific goals set by the 2010 survey. The current design includes a 2.4 meter telescope that was built and qualified for another federal agency, and is the same size as the Hubble Space Telescope but with a view 100 times greater.

In 2017, NASA commissioned an independent review to ensure that the mission's scope and required resources were well understood and executable. NASA initiated this review to address the National Academies' concerns that Roman's cost growth could endanger the balance of NASA's astrophysics program and negatively affect other scientific priorities. The review found that the mission scope is understood, but not aligned with the resources provided and concluded that the mission is not executable without adjustments or additional resources. NASA Headquarters agreed with the study team's results and directed the project to reduce the cost and complexity of the design in order to stay within costs. Overall, the project retained its basic architecture, but some design and requirements changes were necessary to reduce costs. For example, the project reduced some of the capabilities of the Wide Field Instrument by eliminating the Integral Field Channel, eliminating estimated costs of $50 million. In addition, to further reduce cost risks, the project's Coronagraph Instrument was designated as a technology demonstration without specific science requirements and is now separately managed from Roman to give the project greater decision-making flexibility and to encourage it to remain within its schedule and cost.

Currently, Roman is in the implementation phase. The project set its cost and schedule baselines in February 2020. According to NASA documentation, soon afterwards, COVID-19 began affecting the project, and the pandemic's effects led Roman to replan its cost and schedule in June 2021, increasing its estimated life-cycle costs by $382 million and delaying launch by 7 months. This replan restored project reserves to pre-pandemic levels, and did not include effects from any technical issues but rather was solely driven by COVID-19.

Despite COVID-19 effects, the project continues to make progress, and completed its critical design review in September 2021.[13] Currently, the project is working within its replanned schedule, but Roman officials acknowledged that they are continuing to see effects in the supply chain stemming from COVID-19. In addition, as of September 2021 the project is reporting project-held cost reserves below Goddard Space Flight Center's required levels for reasons unrelated to COVID-19. Officials said they anticipate reviewing costs following their critical design review. The project's next major milestone is its systems integration review, planned for October 2024.

SPHEREx. The project was selected in February 2019 as part of NASA's Astrophysics Explorers Program, after being chosen as a mission concept in August 2017. The SPHEREx project was derived from the 2010 Astrophysics Decadal Survey. SPHEREx will survey hundreds of millions of galaxies near and far, some so distant their light has taken 10 billion years to reach Earth. In the Milky Way, the mission will search for water and organic molecules—essentials for life, as we know it—in stellar nurseries, regions where stars are born from gas and dust, as well as disks around stars where new planets could be forming. The project will also identify targets for more detailed study by future missions, such as the JWST and Roman.

The project established cost and schedule baselines and entered the implementation phase in January 2021. Prior to entering implementation, the project passed its preliminary design review, and matured its one critical technology to GAO's recommended technology readiness level (TRL). TRLs are a scale of nine levels used to measure a technology's progress, starting with paper studies of a basic concept and ending with a technology that has proven itself in actual usage in the product's operational environment. Maturing technologies by the preliminary design

[13]Critical design review is the time in a project's life cycle when the integrity of the project design and its ability to meet mission requirements are assessed.

review can minimize risks for projects entering product development.[14] Currently, the project is working toward critical design review, which has been delayed to January 2022 due to the redesign of the telescope support structure after an analysis showed the telescope mirrors would break off their mounts. According to project officials, the redesign contributed to the critical design review delay because of the additional design work and associated retesting.

Project officials said the project continues to operate at reduced efficiency due to COVID-19 and related vendor delays, which amplified the schedule delays from the mirror redesign work. Despite these challenges, the SPHEREx project remains within its baseline launch readiness date, although the project plans to incorporate COVID-19 cost and schedule effects following its critical design review.

Lessons Learned from NASA Acquisitions

As Congress, NASA, and the science community consider future telescope efforts, including the IR/O/V space telescope proposed by this decadal study, it will be important to shape and manage new programs in a manner that minimizes cost overruns and schedule delays. NASA's telescope and other science projects will always have inherent technical, design, and integration risks because they are complex, specialized, and often push the state of the art in space technology. But too often, our reports find that management and oversight problems—which can include poor planning, optimistic cost estimating, budgeting gaps, lax oversight, and poor contractor performance, among other issues—are the real drivers behind cost and schedule growth.

In recent years, we have found that the agency's major project portfolio cost and schedule performance have continued to deteriorate.[15] NASA has acknowledged recent challenges in cost and schedule growth and is taking steps to identify and address areas contributing to acquisition risk. For example, in our 2021 High-Risk Assessment, we found that NASA had taken steps to improve transparency and monitoring of cost and schedules, but continued to experience challenges.[16]

Today, I would like to highlight three lessons learned from our reviews of NASA's major projects, including JWST. The extent to which NASA has

[14] GAO-20-48G.

[15] GAO-21-306.

[16] GAO-21-119SP.

adopted some of these practices is mixed. NASA has an opportunity to strengthen its management of major acquisitions, including future space telescopes that it may consider in response to this decadal survey, by doing so.

Manage Cost and Schedule Performance for Large Projects to Limit Implications for Entire Portfolio. In 2013, following JWST's original cost increases and schedule growth, we found that though cost and schedule growth can occur on any project, increases associated with NASA's most costly and complex missions can have cascading effects on the rest of the portfolio.[17] For example, in 2013, we found that the JWST cost growth would have reverberating effects on the portfolio for years to come and required the agency to identify $1.4 billion in additional resources, according to Science Mission Directorate officials. NASA identified approximately half of this required funding from the four science divisions within the Science Mission Directorate account. In essence, NASA had to mortgage future high priority missions and research to address JWST's additional resource needs.

Since that time, JWST has experienced an additional cost growth, more than $800 million, and, in 2021, continues to be one of the main drivers of poor cost and schedule performance in NASA's portfolio of major projects. At the same time JWST was experiencing additional cost and schedule growth, the Roman telescope was struggling to establish itself as a project at NASA. In May 2021, we found for the third year in a row, the President's budget request proposed canceling the Roman project. Improving the cost and schedule performance of its portfolio of major projects is imperative as NASA considers the National Academies' decadal survey recommendations.

Minimize Risk in Programmatic Decisions to Better Position Programs for Successful Execution. Through our reviews of NASA's major projects, we have found that NASA leadership has approved programmatic decisions that compound technical challenges. These decisions include establishing insufficient cost and schedule reserves, approving cost and schedule baselines that do not follow best practices, and proceeding with immature technologies.[18] For example:

[17] GAO-13-276SP.

[18] GAO-19-716T; GAO-18-277T; GAO-13-4; and GAO-09-306SP.

- Twice in the history of the JWST program, independent reviewers found that the program's planned cost reserves were inadequate. First, in April 2006, an independent review team confirmed that the project's technical content was complete and sound, but expressed concern over the project's reserve funding, reporting that it was too low and phased in too late in the development life cycle. The team cautioned that low reserve funding compromised the project's ability to resolve issues, address risk areas, and accommodate unknown problems. In 2010, an independent panel also concluded JWST was executing well from a technical standpoint, but that the baseline cost estimate did not reflect the most probable cost with adequate reserves in each year of project execution, resulting in an unexecutable project.[19]
- In May 2021, we found that 10 of the 14 NASA major projects that reported having critical technologies met GAO's best practice of achieving a TRL 6 by preliminary design review. TRL 6 includes demonstrating a representative prototype of the technology in a relevant environment that simulates the harsh conditions of space. JWST and SPHEREx fully matured their critical technologies, nine and one respectively;[20] however, Roman had only matured four of its nine critical technologies. As I mentioned above, maturing technologies by the preliminary design review can minimize risks for projects entering product development.[21] If a project has a critical technology that has not reached TRL 6 by preliminary design review, then the project does not have a solid technical basis for its design.

Regularly and Consistently Update Project JCLs to Provide Realistic Estimates to Decision Makers. NASA's JCL policy—established in 2009 and updated in 2019—is a positive step to help ensure that cost and schedule estimates are realistic and projects are thoroughly planning for anticipated risks. This will help ensure NASA's most expensive projects update their cost and schedule estimates as risks change. A JCL produces a point-in-time estimate that includes all cost and schedule elements in phases A through D, incorporates and quantifies known risks,

[19]James Webb Space Telescope (JWST) Independent Comprehensive Review Panel (ICRP): Final Report (Oct. 29, 2010).

[20]JWST matured 10 critical technologies by its preliminary design review; however, it cancelled one technology by its key decision point C review. As a result, we only track the remaining nine critical technologies.

[21]GAO-20-48G.

assesses the impacts of cost and schedule to date, and addresses available annual resources, among other things.

NASA originally implemented a JCL policy to help reduce the cost and schedule growth in its portfolio and improve transparency, and increase the probabilities of meeting those expectations. The original policy required that programs and projects with estimated life-cycle costs greater than $250 million develop a JCL prior to key decision point C. In 2019, NASA updated the policy to require projects with life-cycle costs greater than $1 billion to conduct a JCL at key decision points B and C, critical design review, and potentially at key decision point D if development costs are 5 percent or more over the agency baseline commitment. Additionally, NASA requires any project with a life-cycle cost of $250 million or more that rebaselines its cost and schedule to recalculate its JCL.

We have previously made JCL-related recommendations for JWST. In December 2012, we recommended that JWST officials perform an updated integrated cost and schedule risk analysis or JCL analysis in order to provide high-fidelity cost information for monitoring project progress. In March 2019, we recommended that the JWST project office conduct a JCL prior to its system integration review to inform NASA about the probability of meeting its cost and schedule commitments. NASA agreed with both recommendations.[22] While too much time had passed for NASA to take action in response to the first recommendation, in October 2019, JWST completed a JCL analysis prior to the system integration review. This analysis foreshadowed the risk to the March 2021 launch date, which was subsequently delayed to October 2021, less than a year after the JCL was completed. NASA later delayed the launch again to December 2021. It will be important for NASA to fully implement its JCL policy moving forward for major acquisition projects to ensure decision makers have realistic and up-to-date estimates as projects move through their development.

In summary, NASA continues to make progress developing its space telescopes to help understand the universe and our place in it. The most recent decadal survey continues to encourage NASA to pursue transformative capabilities, including a new space telescope. As NASA considers these recommendations from the National Academies' decadal survey, there is an opportunity for NASA to learn from JWST and other

[22]GAO-19-189 and GAO-13-4.

projects that have suffered from cost overruns and schedule delays. Key project management tools and prior GAO recommendations that I highlighted today could help to better position future space telescopes for successful outcomes. We look forward to continuing to work with NASA and this committee in addressing these issues.

Chairs Beyer and Stevens, Ranking Members Babin and Waltz, and Members of the Subcommittees, this completes my prepared statement. I would be pleased to respond to any questions that you may have at this time.

GAO Staff and Acknowledgments

If you or your staff have any questions about this testimony, please contact W. William Russell, Director, Contracting and National Security Acquisitions at (202) 512-4841 or russellw@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this statement. GAO staff who made key contributions to this statement include Kristin Van Wychen, Assistant Director; Juli Steinhouse, Analyst-in-Charge; Pete Anderson; Tina Cota-Robles; Matthew T. Crosby; Alexandra Dew Silva; Lorraine Ettaro; Min-Hei (Michelle) Kim; John Ortiz; Jose A. Ramos; Ashley Rawson; Carrie Rogers; Edward J. SanFilippo; Roxanna T. Sun; Hai Tran; Tom Twambly; and Alyssa Weir.

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