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Report to Congressional Committees

January 2020

JAMES WEBB SPACE TELESCOPE

Technical Challenges Have Caused Schedule Strain and May Increase Costs

GAO-20-224

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GAO Highlights

Highlights of GAO-20-224, a report to congressional committees

Why GAO Did This Study

JWST, a large, deployable telescope, is one of NASA's most complex projects and top priorities. Problems discovered during integration and testing caused multiple delays that led NASA to replan the project in June 2018. Now estimated to cost $9.7 billion, the project's costs have increased by 95 percent and its launch date has been delayed by over 6.5 years since its cost and schedule baselines were established in 2009. Prior to the replanning process, an independent review board assessed the project and made recommendations to improve performance and oversight.

Conference Report No. 112-284 included a provision for GAO to assess the project annually and report on its progress. This is GAO's eighth report. This report assesses the extent to which (1) the project is executing within its revised cost and schedule targets and (2) NASA has implemented and sustained key improvements to performance and oversight established following the June 2018 replan. GAO reviewed relevant NASA policies, analyzed NASA and contractor data, and interviewed NASA and contractor officials.

What GAO Recommends

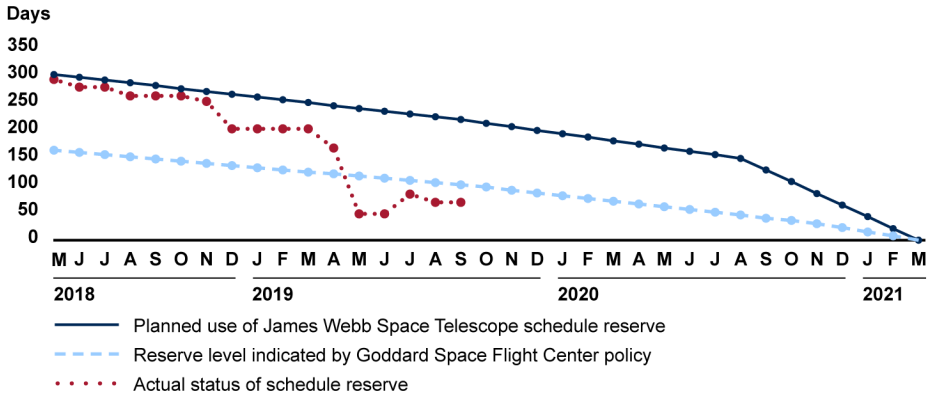
GAO is not making any new recommendations at this time. GAO has made several recommendations to NASA on the management of this project in previous reports and NASA has agreed with and taken action on many of them. Most recently, in March 2019, GAO recommended that NASA complete a joint cost and schedule confidence level analysis for JWST. NASA concurred and completed the analysis in October 2019 to support a key project review.

View GAO-20-224. For more information, contact Cristina T. Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

The National Aeronautics and Space Administration's (NASA) James Webb Space Telescope (JWST) project has made significant progress since GAO's last report in March 2019, such as completing testing of the observatory's individual elements and integrating them together in August 2019. However, new technical challenges have required the project to use more schedule reserve—extra time set aside in the project's schedule to accommodate unforeseen risks or delays—than planned. As of October 2019, the project had used about 76 percent of its available schedule reserve and no longer plans to launch in November 2020 (see figure). The project is now managing to a March 2021 launch date but estimates only a 12 percent likelihood that this date will be achieved. NASA plans to reassess the launch date in the spring of 2020.

Planned and Actual Schedule Reserve for James Webb Space Telescope



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-224

The project used much of the schedule reserve in April 2019 to address issues with two components needed to transmit science data to ground control. The contractor has been able to mitigate some of the schedule loss and continues to look for new efficiencies. Technical challenges also resulted in longer employment of the contractor workforce than planned, which could result in additional cost increases. NASA continues to monitor multiple, other risks that could place further schedule and cost strains on the project.

Since NASA replanned the project again in June 2018, the agency has taken steps meant to improve performance and oversight. NASA has addressed all recommendations from an independent review board, but in doing so sometimes took actions that differed from those outlined in the board's report. NASA has sustained, and in some cases expanded, oversight initiatives following the revised cost and schedule commitments that, in many cases, were designed to enhance communication between the government and the contractor.

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Abbreviations

Goddard	Goddard Space Flight Center
IRB	Independent Review Board
JWST	James Webb Space Telescope
NASA	National Aeronautics and Space Administration

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U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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January 28, 2020

Congressional Committees

The James Webb Space Telescope (JWST) is one of the National Aeronautics and Space Administration's (NASA) most complex projects and top priorities. Its innovative technologies and design are meant to help NASA and others understand the origins of the universe and the creation and evolution of the first stars and galaxies, among its other missions.[1] However, the program has a long history of cost growth and schedule delays driven in part by technical complexity and workmanship issues. In June 2018, NASA established a new cost commitment of $9.7 billion for JWST and a launch readiness date of March 2021, $828 million more and 29 months later than the cost and schedule commitments established in 2011 when the program last revised its cost and schedule estimates through a replan.[2]

In November 2011, Conference Report No. 112-284, which accompanied the Consolidated and Further Continuing Appropriations Act, included a provision for GAO to assess the JWST program annually and to report to the Committees on Appropriations on key issues relating to program and risk management, achievement of schedule and cost goals, program technical status, and oversight mechanisms.[3] This report is our eighth in response to that provision. For this report, we assessed the extent to which (1) the JWST project is executing within the revised schedule and cost targets established in 2018, and (2) NASA implemented and

[1]NASA classifies JWST as a single-project program—those which tend to have long development and operational lifetimes and represent a large investment. The JWST program office is based at NASA headquarters and oversees the project office based at Goddard Space Flight Center responsible for execution of JWST development, integration, and testing. NASA NPR 7120.5E, *NASA Space Flight Program and Project Management Requirements w/ Changes 1-17*, Expiration date August 14, 2020.

[2]A replan is a process generally 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. When the NASA Administrator determines that development cost growth is likely to exceed the development cost estimate by 15 percent or more, or a program milestone is likely to be delayed from the baseline's date by 6 months or more, NASA must submit a report to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate. 51 U.S.C §30104(e)(2)(reporting requirement).

[3]H.R. Conf. Rep. No. 112-284, at 254 (2011).

sustained key improvements to performance and oversight undertaken since 2018.

To assess the extent to which the project is executing within its revised cost and schedule targets, we examined the status of the project's schedule, cost, and technical risks. Specifically, we analyzed monthly JWST status reports provided to NASA management to monitor schedule reserve levels and usage, identify potential risks and technical challenges that may affect the project's schedule, and gain insights on the project's progress. We also reviewed contractor documentation and NASA audit reports for further information on the schedule and cost implications of technical challenges identified by the project. We compared the project's revised cost and schedule baseline to the project's current forecasts to determine what changes have been made, including changes to workforce. We interviewed officials from NASA Headquarters, JWST project officials at Goddard Space Flight Center (Goddard), NASA Independent Verification and Validation officials, and contractors concerning project progress and remaining technology, cost, and schedule risks.

To assess the extent to which NASA has implemented and sustained improvements to performance and oversight, we reviewed prior GAO reports to identify steps the project took to conduct contractor oversight. We interviewed officials and collected relevant documents to identify new steps the project is taking to enhance contractor oversight from these previous initiatives. Further, we collected documentation and interviewed cognizant NASA officials on the status of agency efforts to implement 32 independent review board recommendations developed during the 2018 replan process. We examined award fee documentation related to the JWST development contract letters to examine the relationship between contractor performance and major changes to the project's cost and schedule estimates and to provide an update on the contractor's most recent performance.

We conducted this performance audit from April 2019 to January 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

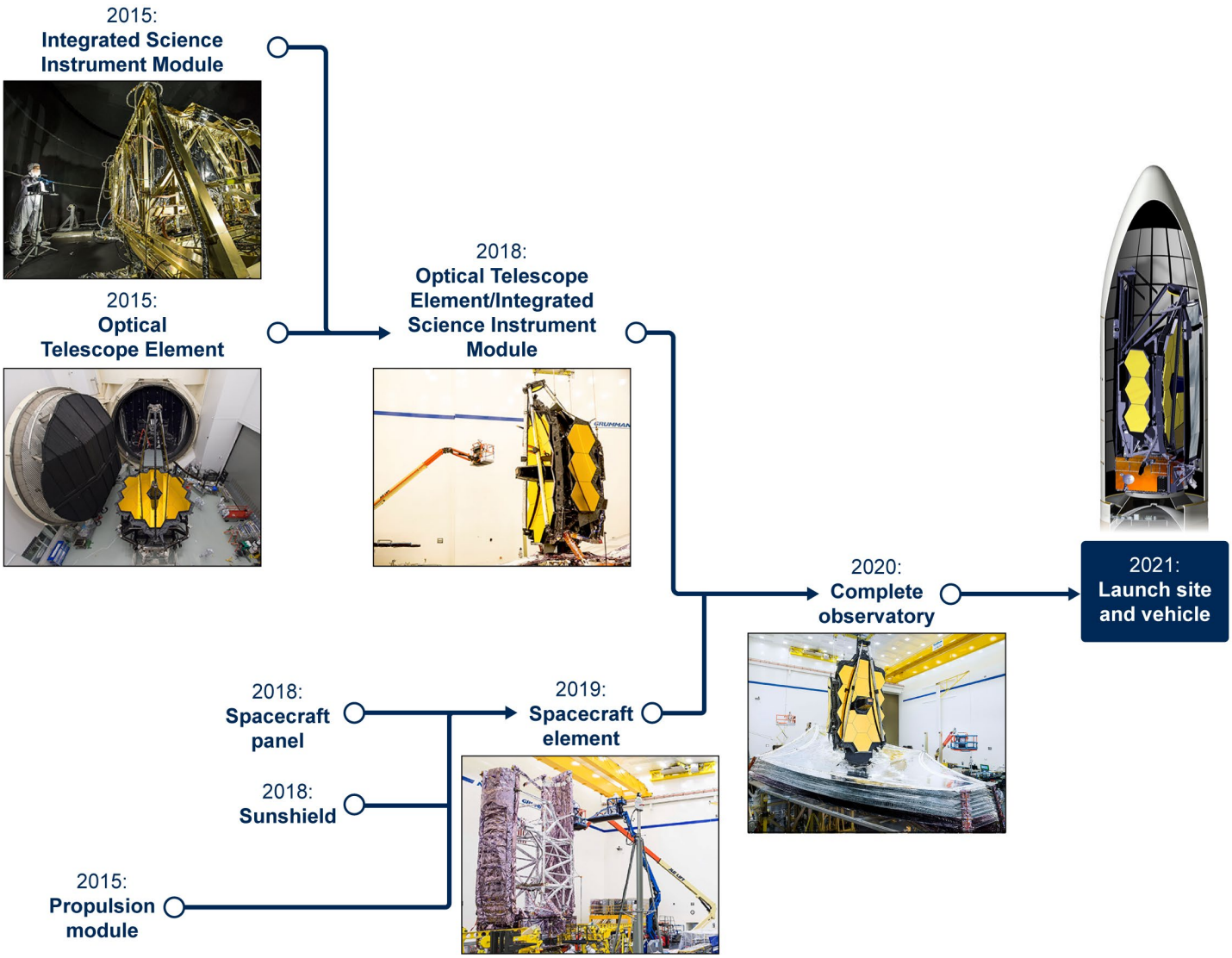
Background

When complete, JWST will be a large, deployable space telescope, optimized for infrared observations. It is the scientific successor to the aging Hubble Space Telescope launched 29 years ago. JWST is being designed for a 5-year mission to find the first stars, study planets in other solar systems, search for the building blocks of life elsewhere in the universe, and trace the evolution of galaxies from their beginning to their current formation. JWST is intended to operate in an orbit approximately 1.5 million kilometers—or 1 million miles—from Earth. With a 6.5-meter (21.3 foot) diameter mirror, JWST is expected to operate at about 100 times the sensitivity of the Hubble Space Telescope. Its science instruments are designed to observe faint infrared sources and therefore are required to operate at extremely cold temperatures. To help keep these instruments cold, the JWST project will rely on a multi-layered, tennis court-sized sunshield to protect the mirrors and instruments from the sun's heat.

The JWST project is divided into three major segments: observatory, ground, and launch. When complete, the observatory segment will include several elements (Optical Telescope Element, Integrated Science Instrument Module, and spacecraft) and major subsystems (sunshield and cryocooler). Additionally, JWST is dependent on software to deploy and control various components of the telescope, and to collect and transmit data back to Earth. The elements, major subsystems, and software are being developed through a mixture of NASA, contractor, and international partner efforts. See figure 1 for the elements and major subsystems of JWST and appendix I for more details, including a description of the elements, major subsystems, and instruments.

JWST depends on more deployment events—steps after launch that configure the observatory for its mission and place it in orbit—than a typical science mission. Due to the observatory's large size, it is nearly impossible to perform deployment tests of the fully assembled observatory in a thermal vacuum chamber to simulate the space environment, so the verification of deployment elements is accomplished by a combination of lower level component tests in flight-simulated environments; ambient deployment tests for subsystem, element, and observatory levels; and detailed analysis and simulations at various levels of assembly. Figure 1 shows the multiple layers of integration and testing for major components of the JWST observatory.

Figure 1: Component and Observatory Test and Integration Activities



Source: GAO analysis of National Aeronautics and Space Administration (NASA) data, photos used with the permission of NASA and are publicly available. | GAO-20-224

For the majority of work remaining, the JWST project is relying on two contractors: Northrop Grumman and the Association of Universities for Research in Astronomy's Space Telescope Science Institute. Northrop Grumman plays the largest role, developing the sunshield, the Optical Telescope Element, the spacecraft, and the Mid-Infrared Instrument's cryocooler, in addition to integrating and testing the observatory. Space Telescope Science Institute's role includes soliciting and evaluating

research proposals from the scientific community, and receiving and storing the scientific data collected, both of which are services that the Institute currently provides for the Hubble Space Telescope. Additionally, the Institute is developing the ground system that manages and controls the telescope's observations and will operate the observatory on behalf of NASA. JWST will be launched on an Ariane 5 rocket, provided by the European Space Agency.

History of Cost Growth and Schedule Delays

The JWST program has a history of significant schedule delays and project cost increases, which resulted in both the 2011 and 2018 replans. Prior to approving the project's development, 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 reserve, the JWST program experienced schedule overruns, launch delays, and cost growth. The program underwent a replan in September 2011 and then a rebaseline; further, Congress placed an $8 billion cap on the formulation and development costs for the project.[4] However, in June 2018, after a series of launch delay announcements due to technical and workmanship issues identified during spacecraft element integration, NASA notified Congress that it had revised the JWST program's cost and schedule estimates again. NASA estimated that it would now require $828 million in additional resources over the program's lifecycle and 29 more months beyond the estimates agreed to in the 2011 rebaseline to complete the project. Since the project's costs and schedule were baselined in 2009, costs have increased by 95 percent and its launch date has been delayed by over 6.5 years.

Prior to this more recent replan, NASA established an Independent Review Board (IRB) in April 2018, comprised of technical experts from outside the JWST program to evaluate all factors that may affect the successful completion of remaining mission steps. The board released its final report in May 2018 in which it made 32 recommendations that address a range of technical, organizational, and other factors. The IRB took into account varying technical and workmanship errors, human mistakes, adequacy of integration and test staff, and other considerations when it analyzed the project's organizational and technical issues. The IRB recommended, among other actions, that the project conduct an

[4]A rebaseline is a process initiated if the NASA Administrator determines the development cost growth is more than 30 percent of the estimate provided in the baseline of the report, or if other events make a rebaseline appropriate. A replan does not require a new project baseline to be established.

audit to identify potential embedded design flaws; establish corrective actions to detect and correct human mistakes during integration and testing; establish a coherent, agreed-upon, and factual narrative on project status and communicate that status regularly across all relevant stakeholders; and, finally, augment integration and test staff to ensure adequate long-term staffing and improve employee morale. These recommendations also included reconsidering the proposed launch date.

In March 2019, we found that NASA had considered many of the program's risks while developing its 2018 replan schedule and cost baseline but recommended that additional analysis be completed to provide NASA and Congress with better insight into project resourcing and affordability.[5] A Joint Cost and Schedule Confidence Level is an integrated analysis of a project's cost, schedule, risk, and uncertainty, the result of which indicates a project's likelihood of meeting cost and schedule targets.[6] The project did not complete such an analysis as part of its second replan. NASA policy says this tool may be used to inform planning. Though not required by NASA policy, we recommended that one be conducted given the long history of program challenges and the significant and complex integration events that still needed to be completed.[7] NASA agreed with our recommendation and completed this analysis in October 2019. GAO plans to conduct a separate, more detailed engagement on this analysis and its findings in the future. See appendix II for more information on this and other GAO recommendations.

Schedule and Cost Reserves for NASA Projects

The JWST project, like other complex development efforts we have reviewed, faces numerous risks and potential unforeseen technical challenges, which often become apparent during integration and testing. To accommodate unanticipated challenges and manage risk, projects include extra time in their schedules, referred to as schedule reserve, and extra funds in their budgets, referred to as cost reserve. Schedule reserve is allocated to specific activities, elements, and major subsystems in the event of delays or to address unforeseen risks. Each JWST element and major subsystem has been allocated schedule reserve. When an element

[5]GAO, James *Webb Space Telescope: Opportunity Nears to Provide Additional Assurance That Project Can Meet New Cost and Schedule Commitments*, GAO-19-189 (Washington, DC, Mar. 26, 2019).

[6]NASA, *NASA Cost Estimating Handbook Version 4.0*, (February 2015).

[7]NASA Procedural Requirement 7120.5E, *NASA Space Flight Program and Project Management Requirements w/ Change 1-16*, (August 14, 2012).

or major subsystem exhausts schedule reserve, it may affect schedule reserve on other elements or major subsystems whose progress is dependent on prior work being finished. Cost reserve is additional funding within the project manager's budget that can be used to address and mitigate unanticipated issues for any element or major subsystem. Goddard—the NASA center with responsibility for managing JWST—issued procedures detailing the cost and schedule reserve requirements for formulating and executing spaceflight programs.[8]

When NASA constructed its 2018 replan for the JWST project, it took into account the remaining integration and test activities planned prior to launch, known technology challenges that presented risks to schedule, as well as potential future risks. The project's replan reflected a planned schedule reserve above the level indicated by Goddard policy, which would have been approximately 5 months at that time. Instead, the new schedule included a total of 293 days or 9.6 months of schedule reserve, with approximately 6 months of this reserve to be managed at the project level and the remainder held by the program at NASA headquarters. Following the replan, the project and the contractor worked toward a launch date in November 2020, which would have required none of the schedule reserve managed at the NASA headquarters level. However, the committed launch date under the replan, where all available schedule reserve is utilized, is now March 2021.

JWST's Use of Award Fees

NASA's cost-plus-award-fee contract with Northrop Grumman has spanned approximately 17 years, during which time there have been significant variances in performance.[9] These types of contracts are suitable when uncertainties in scope of work or cost of services prevent the use of contract types where prices are fixed. Award fee contracts provide contractors the opportunity to obtain additional fee beyond the costs charged to the government for enhanced levels of performance in areas identified in the contract's award fee plan. Award fees may be used when key elements of performance cannot be defined objectively, and, as such, require the project officials' judgment to assess contractor performance. For JWST's contract with Northrop Grumman, these areas

[8]NASA GPR 7120.7, *Schedule and Budget Margins for Flight Projects* (May 4, 2008-May 4, 2015) remains applicable to the JWST program, see NASA, Goddard Procedural Requirements (GPR) 7120.7B, *Schedule and Budget Margins for Flight Projects* (Feb. 28, 2017), Appendix D at pg. 8.

[9]Cost reimbursement contracts provide for payment of allowable incurred costs, to the extent prescribed in the contract. Federal Acquisition Regulation (FAR) 16.301-1.

include cost, schedule, technical, and business management and are established in the contract's award fee plan, which allows for the award of a scaled fee based on assessed performance. This plan has been revised over the life of the contract to incentivize performance in certain areas, but it has always required Northrop Grumman to meet a minimum standard to receive any award fee. Over the course of the JWST contract, nearly $250 million dollars will have been available to Northrop Grumman through this incentive. We have found that when NASA and the contractor have made revisions to fee evaluation criteria to focus on certain aspects of performance, the contractor has been responsive to the new criteria during its work on the JWST project.[10]

Little Margin for Error Remains with Challenging Integration and Test Work Ahead

Though the JWST project has made significant progress since our last report in March 2019, technical challenges have required the use of most of the project's available schedule reserve. According to NASA officials, the contractor has found ways to replenish reserve, but NASA is still reviewing some of these methods and the project continues to work through significant integration and testing events with less than a quarter of the schedule reserve allotted to it in June 2018. The technical challenges have resulted in prolonged employment of the contractor workforce, which is the primary driver for increased costs.

NASA Has Completed Key Testing and Integration Steps and Continues to Address Known Risks

Following the June 2018 replan, the project has achieved a number of integration and testing milestones and has taken steps to address previously identified technical challenges. Since our March 2019 JWST report, the program has completed testing on the individual component elements of the observatory and has integrated them to start observatory level testing, the last of five phases of integration and testing. Leading up to observatory integration, the project completed thermal vacuum testing of the spacecraft element in May 2019. This testing helped to ensure that JWST hardware will function properly in the vacuum of space and withstand significant temperature variations during deployment and operation, and provided data to corroborate modelling on which the observatory's mission is based. Further, the project completed the last major testing milestone for optical telescope and science instrumentation elements—deployment of the secondary mirror assembly—in August 2019. This secondary mirror focuses the light collected by the 18

[10]GAO, *James Webb Space Telescope: Project Facing Increased Schedule Risk with Significant Work Remaining,* GAO-15-100 (Washington, D.C.: Dec. 15, 2014) and *Satellite Acquisitions: Agencies May Recover a Limited Portion of Contract Value When Satellites Fail*, GAO-17-490 (Washington, D.C.: June 9, 2017).

hexagonal primary mirrors of JWST into a beam and directs it toward scientific equipment aboard the observatory. Integration of the observatory components was completed in August 2019, and the program has deployed the sunshield as part of observatory integration and testing.

NASA has also taken steps to address challenges noted in our previous reports. For example,

- In February 2018, we found that Northrop Grumman planned to modify the design of the sunshield's membrane tensioning system in response to a risk of a cable snagging during deployment.[11] NASA approved this redesign in May 2019 and employed a new approach to cable management that involves modification and replacement of certain cable clips and routing cables differently to manage slack that could cause snags.
- We found in March 2019 that the project office identified concerns that trapped air in the folded sunshield membrane could put too much stress on the observatory when the launch vehicle fairing depressurizes—the fairing is the part of the rocket that encapsulates JWST during flight. NASA, Northrop Grumman, European Space Agency, and European vendors responsible for operating and producing the launch vehicle have worked together to study this issue and have designed vents for the fairing that will mitigate the risk of damage to JWST. The new fairing vent design is expected to be tested aboard a rocket planned to launch in the spring of 2020.

Technical Challenges Have Significantly Reduced Schedule Margin, with Considerable Integration and Testing Ahead

Despite the major accomplishments of the past year, the program has identified new technical issues that present risk for meeting the 2018 replan's schedule requirements. Multiple technical issues have contributed to the use of schedule reserve since the June 2018 replan, but two identified in March and April 2019 have had the most significant effect. The program identified two significant anomalies during pre-testing events for the spacecraft element's thermal vacuum testing, which first delayed thermal vacuum testing and then required additional time for investigation and implementation of solutions. Specifically, a traveling wave tube amplifier and a command and telemetry processor had errant powering issues during testing. These are important components of the

[11]GAO, *James Webb Space Telescope: Integration and Test Challenges Have Delayed Launch and Threaten to Push Costs Over Cap,* GAO-18-273 (Washington, D.C.: Feb 28, 2018)

observatory's communication systems that enable JWST to send large amounts of science data and telemetry to the ground segment at high speed.

Though the anomalies occurred at the same time and were both power-related, NASA does not believe they are related and has initiated separate review boards to determine solutions. The amplifier failure is attributed to workmanship issues on the part of a subcontractor. As of October 2019, the exact cause of the processor anomaly remained under investigation, but the electrical problem had been isolated to faults within specific circuit cards. NASA has taken steps to address the risks presented by both anomalies: it has received replacement amplifiers and has upgraded and tested an engineering model processor to replace the faulty one aboard the observatory if necessary.[12]

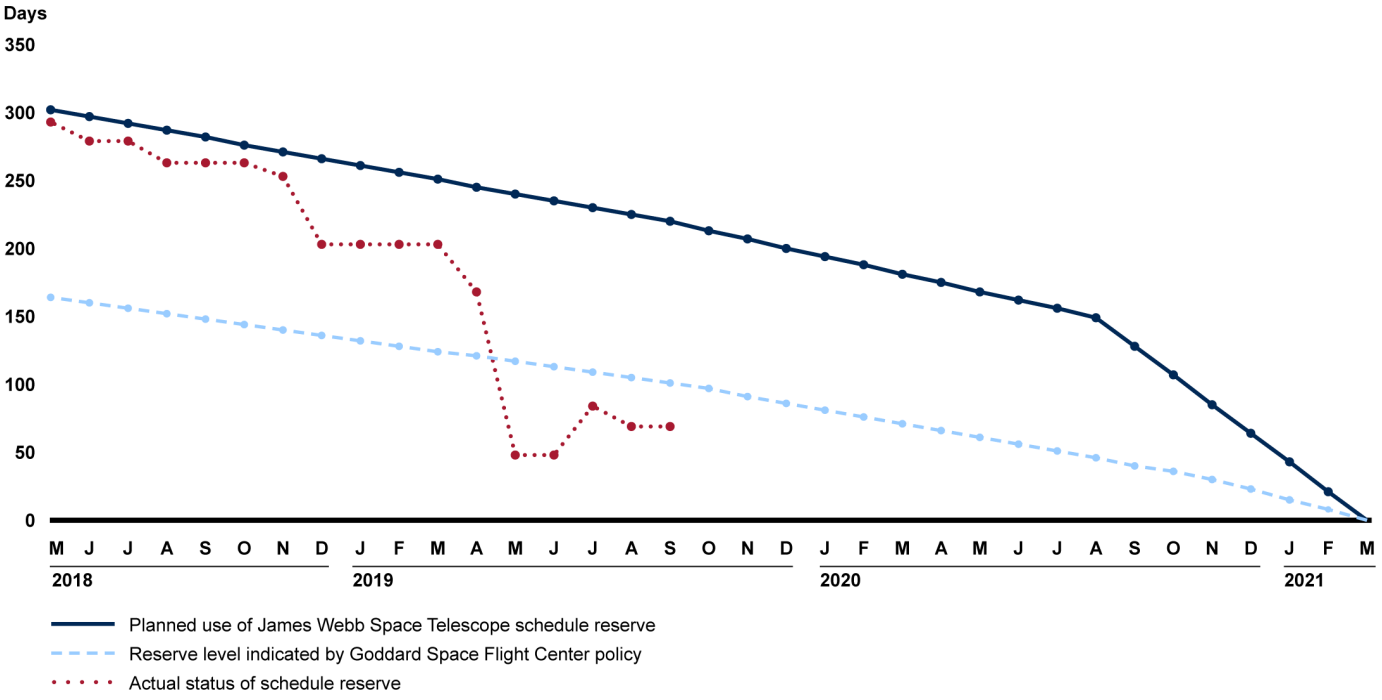
As a result of technical issues discovered since the June 2018 replan, the JWST program has had to use significantly more schedule reserve than it planned to and has been working towards the replan's formally committed launch date of March 2021. As of October 2019, the project had used 224 days of schedule reserve, or about 76 percent of the total project and program-held schedule reserve incorporated into the June 2018 replan. All project-held schedule margin was used by March 2019, a point at which the project would have retained approximately 4 months of reserve according to its original plan. At one point since our March 2019 report, the project had as little as 18 percent of its total schedule reserve left, but contractor-led corrective action plans regained time through found efficiencies. As a result of these challenges, the project's reserve fell below what is indicated by Goddard policy. NASA determined in May 2019 that the November 2020 launch date that the project had hoped to achieve was no longer feasible, and switched focus to meeting the committed launch date of March 2021.[13] Figure 2 shows the level of

[12]An additional 4 days of schedule reserve were used since our last program update in May 2019 to replace a cryocooler refrigerant line to mitigate a risk during element integration and install safety measures.

[13]According to Goddard guidance, a project should plan for at least 1.5 months of funded schedule margin for each 12 months of planned duration between key decision point C approval and the start of integration and testing. Further the project should allocate 2 months of schedule margin for each 12 months of planned duration between integration and testing and delivery to the launch site. Finally, 1 week of schedule margin should be allocated for each month of planned duration from observatory delivery to launch. See NASA GPR 7120.7, Schedule and Budget Margins for Flight Projects (May 4, 2008 – May 4, 2015) remains applicable to the JWST program.

planned reserve for JWST, reserve indicated by Goddard policy, and the project's actual use of schedule reserve.

Figure 2: James Webb Space Telescope Reserve Forecast and Usage



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-224

Since then, however, the JWST project has determined that the March 2021 launch readiness date may not be feasible either, based on a detailed assessment of risks, costs, and schedule. In October 2019, the project completed a joint cost and schedule confidence level analysis in response to a GAO recommendation made in a previous report on the JWST program.[14] Because of schedule delays resulting from technical challenges coupled with remaining risks faced by the project, the analysis assessed only a 12 percent confidence level for the project's ability to meet the March 2021 launch readiness date. NASA typically establishes its cost and schedule baseline commitments at 70 percent confidence level. According to the analysis, this 70 percent baseline confidence level is associated with a July 2021 launch date. The project does not currently intend to change the launch readiness date in response to this analysis

[14] GAO, GAO-19-189

alone, but plans to assess the feasibility of the launch readiness date again in spring 2020 after significant technical tasks are completed.

NASA and Northrop Grumman have a plan to recover schedule reserve but certain portions of the plan remain under technical review. Following the amplifier and processor anomalies, Northrop Grumman developed a corrective action plan to recover schedule reserve, and the contractor and NASA continue to look for ways to gain efficiencies. In June 2019, Northrop Grumman suggested a number of potential schedule optimization steps that were reviewed by NASA management. Northrop Grumman has begun to be implement some of these steps. If all steps are taken, the contractor estimates 65 days of project schedule will be recovered, nearly doubling the amount of reserve available to the project when the anomalies were discovered. Among the efforts described in this corrective action plan are to streamline aspects of vibration testing and to modify build and repair schedules so that a major panel on the spacecraft will only have to be opened once. Combined, these two steps would save an estimated 46 days. However, officials noted that for the plan for a single panel opening to remain viable, corrective actions for the amplifier and processor replacements would need to remain on schedule. The project continues to review some of Northrop Grumman's proposed efficiencies, but more than half of these schedule savings have already been incorporated into the schedule reserve forecast.

The project also continues to identify and monitor risks that could potentially result in further use of schedule margin. As suggested by the IRB, the project has led a number of audits looking for embedded risks. As of November, most of the audits planned have been completed and NASA identified some new risks. The following are some of the risks the project is monitoring that could affect schedule:

- The project found that certain bolts, determined to be deficient on another Northrop Grumman program, were used during the construction of the observatory. A study of this issue found that the bolts used did not meet specifications and could pose a mechanical strength risk. The unused bolts have been identified and isolated, but 501 were installed in the observatory. NASA is performing strength testing to determine if the bolts are strong enough, but some of the deficient bolts may need to be replaced, pending the findings of these tests.
- The project reported in August 2019 that grounding straps on the spacecraft's momentum flap came loose during vibration testing. This flap will act as balance against solar pressure that could cause

unwanted movement of the observatory while in orbit. Observatory-level vibration testing cannot begin until the flap is removed, repaired, and replaced aboard the spacecraft.

- In September 2019, the project found that a non-explosive actuator on one of its membrane retention devices did not fire as planned. These devices, which help to unfurl the sunshield of the spacecraft, are supposed to be electrically redundant, but only one of the two mechanisms used to fire the actuator worked during the test. The program reports that there are approximately 180 actuators on the JWST and the failure of any one of these actuators could result in the total loss of JWST science mission objectives. If the redundancy for the actuators is reduced, it would have a major impact on system reliability.
- The project is evaluating whether it needs to replace certain membrane retention devices that may not be able to withstand the coupled pressure placed upon them by the launch and newly designed fairing ventilation. Testing in the past did not account for all aspects of the pressures placed upon this hardware during launch and spaceflight. The project indicated that it is completing an analysis to determine if stronger devices need to be installed.

The JWST project office reviews and reports on these and other risks monthly. As of October 2019, the project is tracking 50 risks—three more than when we last reported on JWST—of which 12 continue to be assessed as moderate concerns. Of the 50, 23 have been assessed to be at acceptable levels of risk but continue to be monitored should changes affect their status.[15] For example, the risk associated with cabling within the sunshield was elevated in October 2019 when the project found that further testing was needed to ensure slack did not present an unacceptable threat to the spacecraft during deployment. Finally, nine of the 50 risks currently tracked by the project are related to the more than 300 single points of failure aboard the observatory.[16]

The project must conduct significant integration and testing activities in the coming months that could present further challenges. Our previous

[15]NASA risk guidance states that when a risk is accepted, it is typically because the performance risks associated with the performance requirements are all within tolerable levels. NASA Procedural Requirements 8000.4B *Agency Risk Management Procedural Requirements* (Dec. 6, 2017) and NASA Special Publication 2011-3422 *NASA Risk Management Handbook* (Nov. 2011).

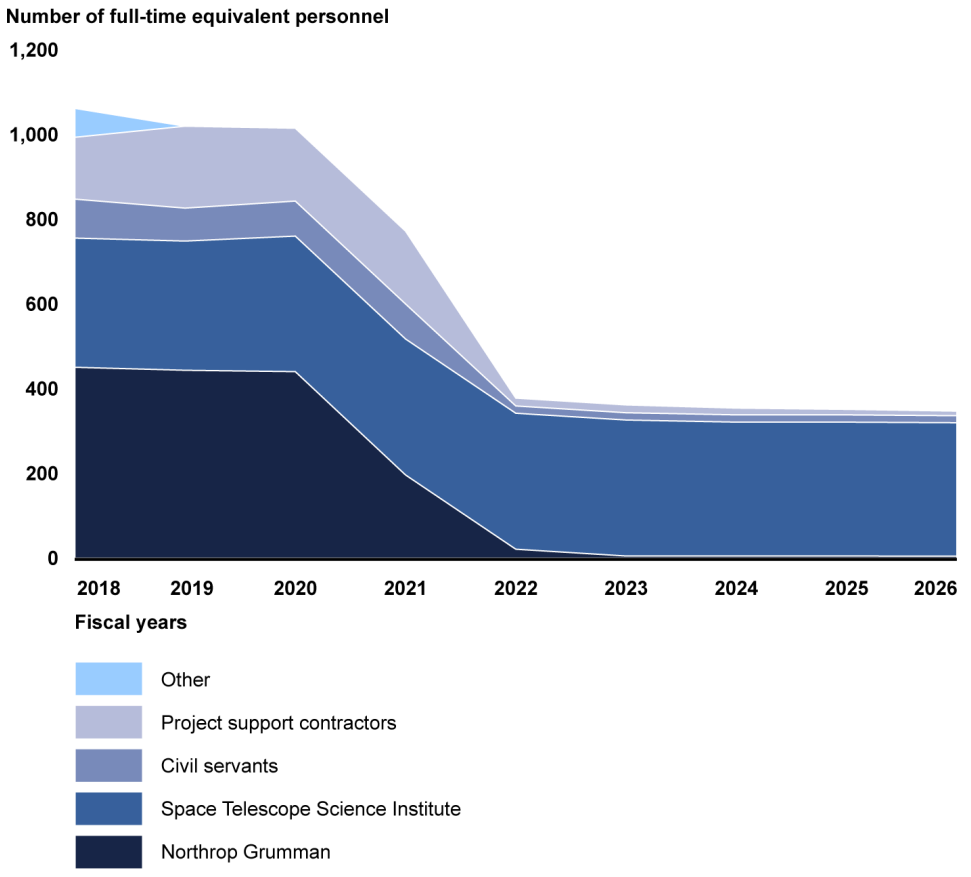
[16]A single point of failure is an independent element of a system, the failure of which would result in loss of objectives or hardware.

work on major NASA acquisition programs found that integration and testing is the phase when challenges are most likely to be found and schedules can slip. The science elements and the spacecraft have only recently been integrated. NASA will have to manage seven top-level integration and testing steps between October 2019 and December 2020 to include observatory-level vibration testing, sunshield deployment and stow, and electrical testing and repairs. Currently, this will all have to be completed with a diminished amount of schedule reserve. Northrop Grumman and NASA officials we interviewed agreed that no other major complication, such as those on the scale of the traveling wave tube amplifier and command and telemetry processor anomalies, can happen without putting the March 2021 launch date in jeopardy.

Technical Challenges May Also Drive Additional Costs for the Project

As we found in March 2019, changes to JWST project's life-cycle cost estimate are principally driven by schedule extension, which requires keeping the contractor's workforce longer than expected to complete integration and testing. We also found that NASA's cost estimate for the 2018 replan was based on a more gradual workforce reduction schedule than previously used by the Northrop Grumman. NASA continues to forecast an overall reduction in contractor and government workforce following the project's launch readiness date with continued, steady support by the Space Telescope Science Institute during remaining development and post-launch phases of the program (see figure 3).

Figure 3: Estimated Full-time Equivalent Personnel Required to Finish Assembling and to Operate James Webb Space Telescope



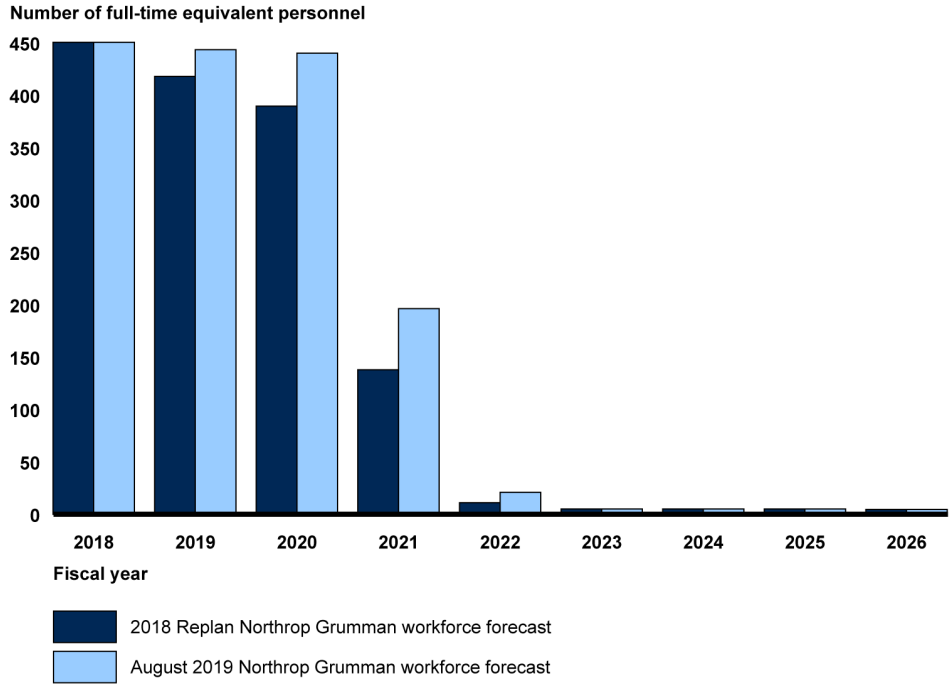
Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-224

The program reports that cost reserve is generally sufficient for planned work but technical challenges could cause workforce costs to increase. The cost and schedule analysis completed by the project in October 2019 indicated that the project will not exceed the cost commitment established in the 2018 replan even if launch is delayed further by a few months. According to officials, funding is sufficient to continue work even if the launch date slips 3-4 months past the March 2021 launch date.[17] However, the technical issues identified during integration and testing

[17]According to project officials, this assumes that the project receives approximately $70 million that NASA planned to reprogram from other Science Directorate projects but has not yet been approved by Congress. According to the program, without this additional funding, the program may not be able to absorb schedule risks that could arise.

activities have required the contractor workforce to remain engaged, instead of drawing down as planned. Rather than see a temporary drop in contractor work hours as hardware deliveries were completed ahead of observatory-level testing and integration activities, the project has maintained contractor workforce levels to address the issues described above. The contractor now forecasts approximately 15 percent more workforce hours between 2019 and 2022, the year following launch (see figure 4). Approximately $133 million in cost reserve funding will be used by the project over the next 2 fiscal years to accommodate increasing workforce retention costs.

Figure 4: Comparison of 2018 and 2019 Northrop Grumman Workforce Forecasts for James Webb Space Telescope Program (Full Time Equivalents)



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-224

NASA Has Addressed Recommendations and Sustained Oversight Improvements Since 2018

Since the June 2018 replan, NASA has taken steps to improve the JWST project by implementing Independent Review Board (IRB) recommendations, pursuing other oversight initiatives, and continuing to incentivize contractor performance through the use of award fees. NASA addressed all IRB recommendations even though the agency did not always agree with the IRB on the specific steps needed to address the recommendations. Further, NASA has sustained, and in some cases expanded, the oversight initiatives that were started prior to our last report. The cost plus award fee contract used for JWST development efforts provides the project with a means to incentivize contractor performance related to cost, schedule, technical, and business management goals. Since the 2018 replan, Northrop Grumman's award fee evaluations have improved but remain below its average for the contract.

NASA Has Completed Its Implementation of IRB Recommendations

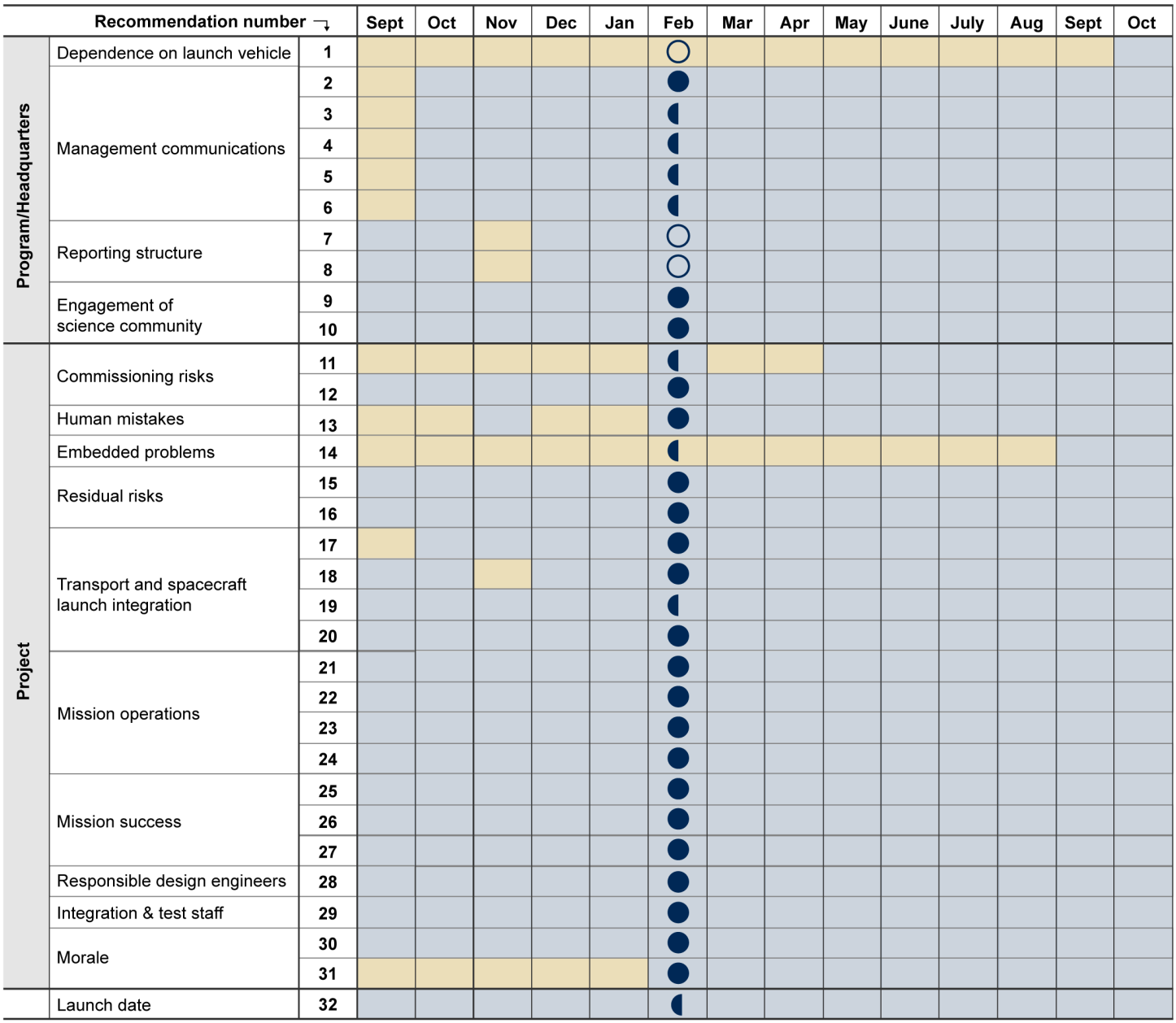
NASA assessed all IRB recommendations as closed in October 2019. The IRB made 32 recommendations covering a range of topics from improving communication with stakeholders to identifying embedded problems.[18] NASA implemented its recommendation to establish March 2021 as the committed launch date for JWST through the June 2018 replan. Responsibility for implementing the remaining 31 recommendations was split among headquarters, the program office, and the project. The 10 headquarters- and program-level recommendations covered high-level recommendations dealing with entities outside of the project or communication between upper-level NASA management and the project. The remaining 21 recommendations were implemented at the project level and included lower-level actions related to assessing, preparing for, and improving day-to-day work.

NASA assessed most recommendations as implemented prior to an IRB follow-up assessment, but the IRB found that more work was required for some to completely align with the board's intent. In February 2019, the IRB found that the steps NASA took for approximately one-third of its recommendations were either inadequate or needed additional work, with the remainder found to be appropriate. Specifically, the IRB categorized 21 of the recommendation responses as appropriate, eight responses as appropriate with additional work needed, and three responses as

[18]For a full list of the recommendations, please see appendix III.

inadequate. The IRB's monitoring of the JWST project ended with the February 2019 follow up (see figure 5).

Figure 5: Status of Independent Review Board (IRB) Recommendations from September 2018 to October 2019



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-224

Though NASA agreed with the intent of all the IRB recommendations, it took a different approach than described in the IRB report when implementing the three recommendations where the agency's response was assessed to be inadequate. NASA conducted additional work for the majority of recommendations assessed by the IRB to be incomplete. However, NASA determined that a few of the IRB recommendations managed at the headquarters level should not be implemented the way they were delineated in the IRB report. Specifically,

- The IRB found that the JWST reporting structure was complex, confusing, and ineffective. The IRB made two recommendations for NASA to update its reporting chain. The IRB believed the Science Mission Directorate Associate Administrator should have responsibility of the entire JWST program and the Goddard Space Flight Center Director should be responsible for all aspects of the JWST project.[19] The IRB asserted that restricting the involvement of the Goddard director will reduce the probability of JWST success. NASA agreed that it is important to have clear organizational roles and responsibilities but had a difference of opinion about the best course of action. In November 2018 and July 2019, NASA announced updates to the JWST reporting structure. However, both times it reduced the role of the Goddard director in favor of more direct line of accountability from the JWST program to the Science Mission Directorate Associate Administrator and the NASA Associate Administrator. NASA asserts that these changes will provide more clear accountability for program performance and allow for expedited decision making.
- The IRB recommended that NASA's Launch Services Program should have accountability for the JWST launch. NASA has taken actions to increase the involvement of the Launch Services Program but NASA maintains that it is not prudent or possible for the Launch Services Program to be accountable for the launch because the European

[19]The Science Mission Directorate is responsible for defining, funding, evaluating, and overseeing implementation of science programs and projects, including JWST. The Science Mission Directorate Associate Administrator is responsible for implementing managing the directorate's program portfolios. This includes defining, funding, evaluating, and overseeing implementation of respective programs and projects, and ensuring outcomes meet schedule and cost constraints. He or she is accountable for cost, schedule, and technical performance, mission safety, and programs and projects success. The Goddard Space Flight Center Director is responsible and accountable for all activities assigned to the center. He or she is responsible for the institutional activities and for ensuring the proper planning for and assuring the proper execution of programs and projects assigned to the center. *NASA Governance and Strategic Management Handbook*, NPD 1000.0B.8.

Space Agency is contributing the launch vehicle and managing the launch. The IRB recognized the unique circumstances of using an international launch vehicle but continued to assert the importance of Launch Services Program accountability. A minority of IRB members were of the opinion that NASA took appropriate action.

NASA Has Sustained Key Oversight Improvements and Made Additional Improvements Since 2018

NASA has sustained increased oversight and involvement with Northrop Grumman following the announcement of an anticipated cost cap breach in March 2018. Previously reported improvements included both the implementation of IRB recommendations and the pursuit of self-initiated activities, like greater NASA on-site coverage and Northrop Grumman's culture change campaign designed to shift focus toward quality assurance. Our March 2019 report, provided examples of these changes and initiatives. Table 1 below provides a summary of our previous report findings and the current status of the changes NASA and Northrop Grumman made in providing oversight and ensuring quality.

Table 1: Current Status of Oversight Changes Begun Following 2018 Schedule Delays

Project	Reported in GAO-19-189	Current status
	National Aeronautics and Space Administration (NASA) implemented an Independent Review Board (IRB) recommendation by selecting a Commissioning Manager to oversee observatory deployment as well as coordinate relevant working groups.	The Commissioning Manager met with teams from the Mars missions at the Jet Propulsion Laboratory to learn about commissioning—the set of activities completed after launch to prepare for science operations. The James Webb Space Telescope project has established 13 phases and activities.
	NASA implemented an IRB recommendation in conjunction with Northrop Grumman to conduct comprehensive audits of designs, processes, and tests to identify areas that may be susceptible to future design problems or workmanship errors.	NASA continued to review audits to uncover embedded problems. In September 2019, the project reported that all of the embedded risk audits had been completed.
	The IRB found that communication channels with the contractor, with the public, and within NASA were uncoordinated and contained conflicting information on the project's status. NASA implemented an IRB recommendation by combining center-level and headquarters review meetings to improve consistency of communication of project status.	In its February 2019 follow-up, the IRB believed that NASA could complete additional work to improve communication. In May 2019, NASA finalized a Communication Plan that provides a strategy for communication with stakeholders and the science community.
Contractor	NASA increased its on-site coverage—continuing permanent technical support, increasing the presence of management staff, and providing regular lead engineer coverage instead of activity-based coverage.	According to the contractor, NASA on-site coverage varies based on the tasks being performed but continues constant on-site monitoring. NASA Mission Assurance Engineers have been added to ensure that engineering and quality best practices are incorporated. NASA currently has five full-time staff on-site as well as a Chief Safety and Mission Assurance officer at the contractor facility 3-weeks per month.

Reported in GAO-19-189	Current status
Management began attending all tabletop meetings—meetings that review integration and test procedures before activities take place—instead of select meetings at the invitation of Northrop Grumman.	Project and contractor officials report NASA attendance at tabletop meetings has been consistent. Attendance at tabletops led to the incorporation of NASA mission assurance recommendations.
Defense Contract Management Agency (DCMA) began to provide full-time instead of part-time oversight of software and quality assurance processes at the Northrop Grumman facility.[a]	Additional DCMA staff has been added. JWST currently has 11 full-time DCMA staff including a lead official with previous experience managing a Department of Defense program.
Northrop Grumman initiated a JWST mission assurance culture change campaign to increase focus on product quality and process compliance. This effort includes having inspectors affirm by signature that they have personally inspected, verified, and confirmed that all aspects of an activity meet quality standards.	Northrop Grumman reports a positive impact from its initiatives—correlated with fewer issues or near misses that impacted people or hardware. Mission assurance culture change includes an initiative that encourages employees to stop processes on the floor if there is a quality assurance concern.

Source: GAO analysis of prior GAO report (GAO-19-189) and National Aeronautics and Space Administration (NASA) documents and interviews with NASA and Northrop Grumman officials. | GAO-20- 224

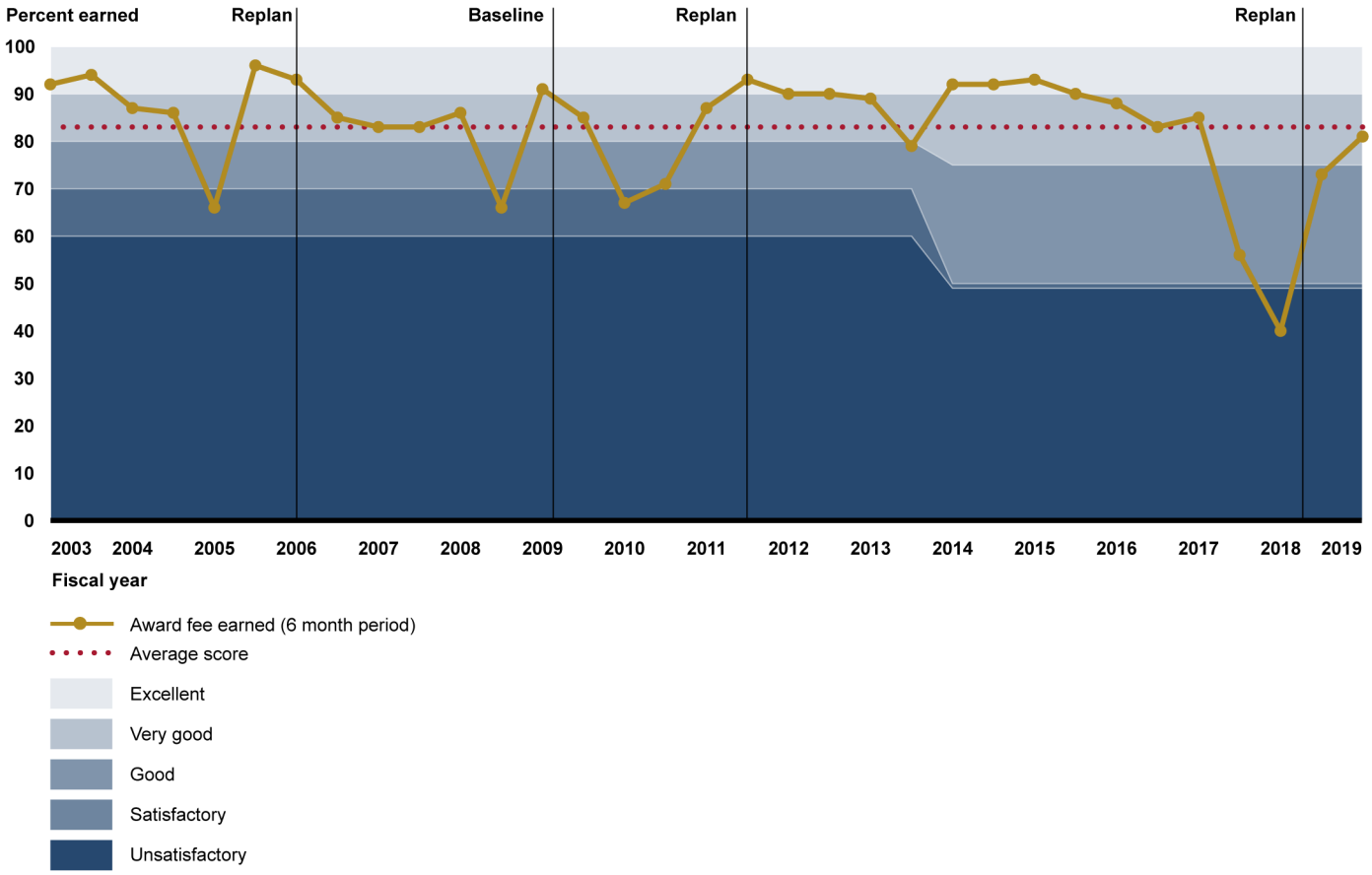
[a] The Defense Contract Management Agency may provide contract administration services in support of NASA programs and projects as specified in an accepted NASA letter of delegation.

Since we last reported in March 2019, NASA has made additional oversight changes to further enhance communication with and oversight of the contractor. Most of these changes emphasize greater involvement of NASA specialists in meetings and reviews. NASA officials reported that its increased presence with the contractor has had positive effects for both ensuring project outcomes and increasing morale of the government and contractor workforce. For example, NASA integration and testing leadership is present and embedded in Northrop Grumman's meetings—directly participating in planning sessions, reporting, and reviews of failures and anomalies. As a result, the project was able to plan for early integration of the observatory and completed key integration activities without being the primary driver of the project's schedule. According to officials, expanded participation has helped to ensure more realistic exercises that include procedural concerns as well as engineering considerations. NASA officials said that the increased participation has allowed NASA input to be incorporated early—potentially reducing issues in the future. Further, NASA officials believe that the consistent presence of NASA personnel has improved morale—an item highlighted by the IRB—and helped foster greater unity of effort between government and contractor workforces.

Contractor Award Fee Has Fluctuated over Time, but Performance Has Improved Recently

NASA has regularly assessed contractor performance through award fee assessments since the beginning of the contract in 2002. Award fee documentation over the course of the Northrop Grumman contract indicates that contractor performance was assessed as below its average before periods of significant cost and schedule growth. On average, Northrop Grumman has been rated as very good with about three-fourths of evaluations assessing its performance as either excellent or very good. For the award fee evaluations that fall below Northrop Grumman's average score, cost performance has contributed to the majority of these dips and schedule performance has contributed to almost half. In particular, schedule performance has reduced the contractor's overall evaluation for all award fee periods since April 2017. The latest dip below the contractor's average preceded lifecycle cost growth of $828 million and schedule growth of nearly 2.5 years (see figure 6).

Figure 6: Government Award Fee Evaluation from October 2002 to March 2019 plus Major Cost and Schedule Changes



Source: GAO analysis of National Aeronautics and Space Administration (NASA) data and James Webb Space Telescope contract. | GAO-20-224

Since our March 2019 report, Northrop Grumman's ratings have improved but remain below its average.[20] For the award fee period from October 2017 through March 2018, Northrop Grumman received an unsatisfactory rating, which resulted in the contractor receiving no award fee for the first and only time in the life of the contract. The unacceptable rating was driven by cost and schedule performance—including the anticipation of breaching the $8 billion congressional cost cap established in response to the 2011 rebaseline. In the following two periods, Northrop Grumman has improved its evaluation, but schedule performance remains a concern. During the last award fee period assessed, NASA was internally managing to a November 2020 launch date. Shortly after the award fee

[20] GAO-19-189

period ended, the project found it could no longer support the November 2020 date and began managing to the March 2021 launch date.

Agency Comments and our Evaluation

We are not making recommendations in this report. We provided a draft of this report to NASA for comment. NASA provided technical comments that, among other things, clarified implementation of schedule recovery steps and updated progress on observatory repairs. We incorporated suggested technical changes as appropriate.

We are sending copies of this report to the appropriate congressional committees, the NASA Administrator, and other interested parties. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions on matters discussed in this report, please contact me at (202) 512-4841 or chaplainc@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 IV.

Cristina T. Chaplain
Director, Contracting and National Security Acquisitions

List of Committees

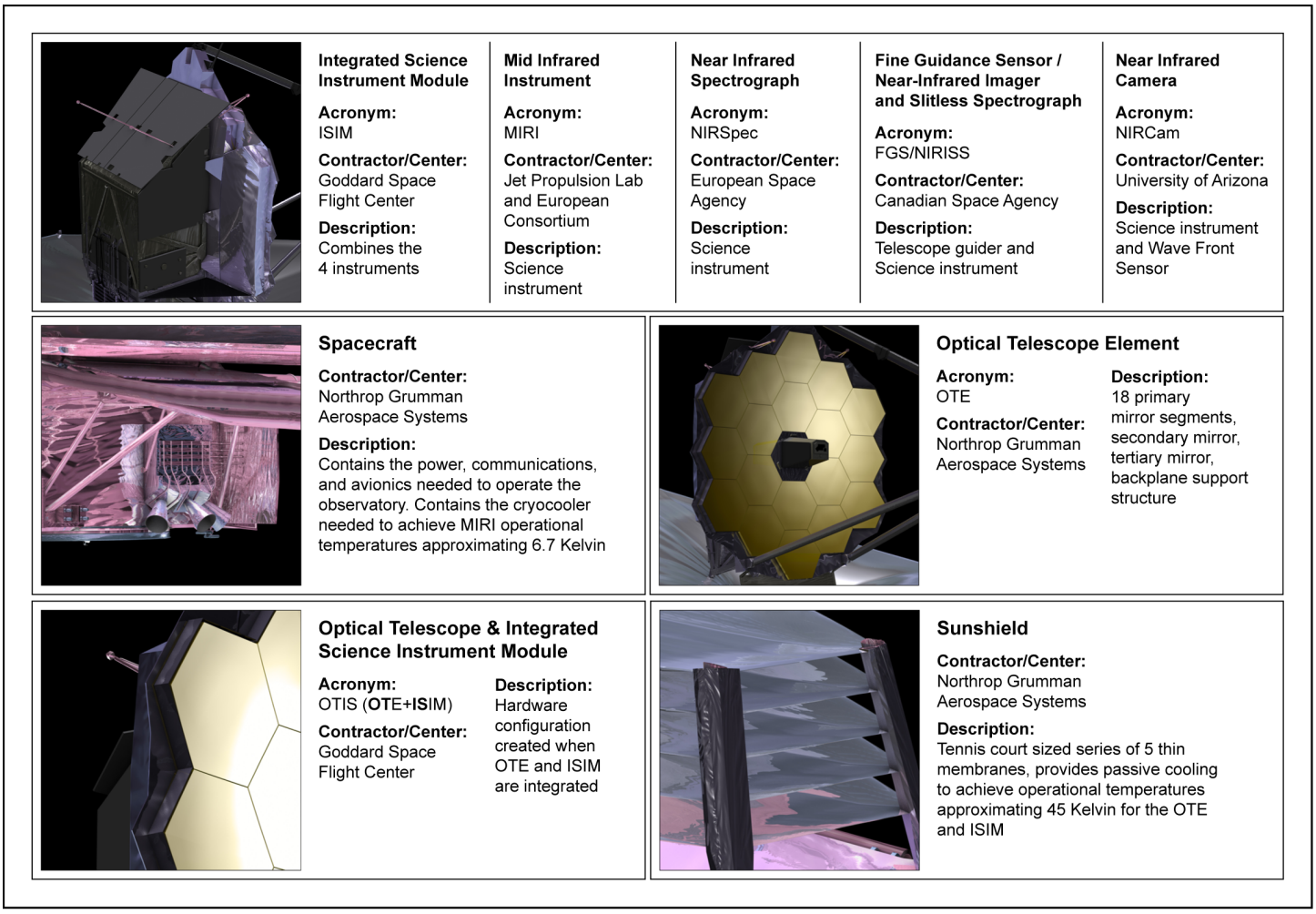
The Honorable Jerry Moran
Chairman
The Honorable Jeanne Shaheen
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
United States Senate

The Honorable José E. Serrano
Chairman
The Honorable Robert B. Aderholt
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
House of Representatives

The Honorable Eddie Bernice Johnson
Chairwoman
The Honorable Frank D. Lucas
Ranking Member
Committee on Science, Space, and Technology
House of Representatives

Appendix I: Elements and Major Subsystems of the James Webb Space Telescope (JWST) Observatory

Figure 7: Elements and Major Subsystems of the James Webb Space Telescope (JWST) Observatory



Sources: GAO (analysis); National Aeronautics and Space Administration (data and images). | GAO-20-224

Appendix II: Status of Previous GAO Recommendations on Management of the James Webb Space Telescope Program

In its previous reports on the James Webb Space Telescope (JWST), the GAO has made several recommendations. These recommendations are listed below. Comments reflect the status of the program at the time GAO closed the recommendation.

Table 2: Recommendations from *James Webb Space Telescope: Actions Needed to Improve Cost Estimate and Oversight of Test and Integration* (GAO-13-4)

	Recommendation	Agency concurrence	Status	Comments
1	To ensure that the JWST life-cycle cost estimate conforms to best practices, and to provide high-fidelity cost information for monitoring project progress, the NASA Administrator should direct JWST officials to improve cost estimate documentation and continually update it to reflect earned value management actual costs and record any reasons for variances.	Partially Concurred	Closed – not implemented (While the intent of the recommendation has not been satisfied, time or circumstances have rendered the recommendation invalid.)	The JWST program has collected earned value management data for its prime contract for several years since a major program replan in 2011, developed an earned value management-like tool for monitoring internal work, and developed supplemental analysis to improve the oversight of its contractors. These actions, however, do not meet the intent of the recommendation because the program has not implemented a mechanism to update the cost estimate by incorporating actual contractor or in-house costs. Over three years have passed since we first made the recommendation and we believe there is no longer sufficient time for the JWST program to take action. The program is scheduled for launch in October 2018, but much of the integration and test activities are scheduled to be completed about a year from now. The program has less than 10 percent of its life cycle cost remaining and the prime contractor has less than 6 percent of its costs remaining; therefore, the program no longer has time to benefit from implementing this recommendation. We still believe NASA should ensure life-cycle cost estimates conform to best practices, including continually updating cost estimates for all its programs, but this program is too close to launch for NASA to invest resources in updating the cost estimate.
2	To ensure that the JWST life-cycle cost estimate conforms to best practices, and to provide high-fidelity cost information for monitoring project progress, the NASA Administrator should direct JWST officials to conduct a sensitivity analysis on the number of staff working on the program to determine how staff variations affect the cost estimate.	Partially Concurred	Closed – not implemented (While the intent of the recommendation has not been satisfied, time or circumstances have rendered the recommendation invalid.)	The JWST project does not expect to perform the workforce sensitivity analysis as recommended by GAO. The JWST project has used a significant portion of its cost reserve to address technical issues, with some of the cost reserve being used to account for an overage in workforce requirements. The prime contractor has carried a significantly higher workforce, much at higher rates of pay such as engineers, than planned. The JWST program manager indicated that the monthly workforce peak for this contractor is close, but when that will happen is unknown at this time

	Recommendation	Agency concurrence	Status	Comments
3	To ensure that the JWST life-cycle cost estimate conforms to best practices, and to provide high-fidelity cost information for monitoring project progress, the NASA Administrator should direct JWST officials to perform an updated integrated cost/schedule risk analysis, or joint cost and schedule confidence level analysis, using a schedule that meets best practices and includes enough detail so that risks can be appropriately mapped to activities and costs; historical, analogous data should be used to support the risk analysis.	Concurred	Closed – not implemented (While the intent of the recommendation has not been satisfied, time or circumstances have rendered the recommendation invalid.)	The agency concurred with this recommendation, but the project has not pulled this information together in an integrated assessment to gain a picture of overall progress, which would be in line with cost and schedule risk analysis best practices. Since so much time has elapsed, the JWST project does not have enough time left in their schedule to perform an updated joint cost/schedule confidence level analysis in time to be of value to the project
4	To ensure that technical risks and challenges are being effectively managed and that sufficient oversight is in place and can be sustained, the NASA Administrator should direct JWST officials to conduct a separate independent review prior to the beginning of the Optical Telescope Element and Integrated Science Instrument Module and spacecraft integration and test efforts to allow the project's independent standing review board the opportunity to evaluate the readiness of the project to move forward, given the lack of schedule flexibility once these efforts are under way.	Concurred	Closed – implemented	The JWST project has now scheduled an independent systems integration review for Optical Telescope Element and Integrated Science Instrument Module (OTIS) in May 2016, prior to the beginning of the OTIS integration and test effort that same month. In addition, the JWST project has scheduled the spacecraft element (SCE) readiness review in March 2016, prior to the beginning of the spacecraft integration and test effort currently scheduled to begin in April 2016.
5	To ensure that technical risks and challenges are being effectively managed and that sufficient oversight is in place and can be sustained, the NASA Administrator should direct JWST officials to schedule the management review and approval to proceed to integration and test (key decision point D or KDP-D) prior to the start of observatory integration and test effort.	Partially Concurred	Closed – implemented	In April 2017, NASA changed the JWST project schedule and will now hold management review (key decision point D or KDP-D) in November 2017 before the start of JWST's integration and test effort in December 2017. KDP-D is when NASA's senior agency decision authority would approve the project to proceed into the system integration and test phase. The change will place the project in compliance NASA policy which states that the key decision point and approval by the NASA Associate Administrator should be held prior to integration and test activities commence.

	Recommendation	Agency concurrence	Status	Comments
6	To ensure that technical risks and challenges are being effectively managed and that sufficient oversight is in place and can be sustained, the NASA Administrator should direct JWST officials to devise an effective, long-term plan for project office oversight of its contractors that takes into consideration the anticipated travel budget reductions.	Concurred	Closed – not implemented (While the intent of the recommendation has not been satisfied, time or circumstances have rendered the recommendation invalid.)	In commenting on this recommendation, the agency concurred but has not taken actions to implement this recommendation. The JWST Program Manager said that the project has not incurred any reductions to its travel budget in fiscal years 2013 and 2014, and will under run its travel budget for 2014 due to efficiencies put in place for its oversight processes and the conclusion of two major contracting efforts. In addition, the project has obtained commitments from the agency that future funding will be in line with baseline projections.

Source: Government Accountability Office | GAO-20-224

Table 3: Recommendations from *James Webb Space Telescope: Project Meeting Commitments but Current Technical, Cost, and Schedule Challenges Could Affect Continued Progress* (GAO-14-72)

	Recommendation	Agency Concurrence	Status	Comments
1	In order to ensure that the JWST project has sufficient available funding to complete its mission and meet its October 2018 launch date and reduce project risk, the NASA Administrator should ensure the JWST project has adequate cost reserve to meet the development needs in each fiscal year, particularly in fiscal year 2014, and report to Congress on steps it is taking to do so.	Concurred	Closed – not implemented (While the intent of the recommendation has not been satisfied, time or circumstances have rendered the recommendation invalid.)	No actions were taken to address this recommendation. JWST Project did not report to Congress on steps it was taking and the JWST project has continued to request budgets consistent with the 2011 replan.

	Recommendation	Agency Concurrence	Status	Comments
2	In order to help ensure that the JWST program and project management has reliable and accurate information that can convey and forecast the impact of potential issues and manage the impacts of changes to the integrated master schedule, the NASA Administrator should perform a schedule risk analysis on the Optical Telescope Element, Integrated Science Instrument Module, and cryocooler schedules, as well as any other subschedules for which a schedule risk analysis was not performed. In accordance with schedule best practices, the JWST project should ensure that the risk analyses are performed on reliable schedules.	Concurred	Closed – not implemented (While the intent of the recommendation has not been satisfied, time or circumstances have rendered the recommendation invalid.)	JWST Project provided both the Optical Telescope Element and Integrated Science Instrument Model schedule risk analyses to GAO. We found these analyses did not meet best practices because they were based on unreliable schedules—counter to the recommendation. The JWST project did not do a cryocooler schedule risk analysis because they had no plans to revise the schedule and with a short period of time remaining on the schedule, we advised the project that the analysis would not be a useful exercise. Since then, events have taken over this recommendation as the contractors have delivered the Optical Telescope Element, Integrated Science Instrument Module, and the cryocooler, and the schedules are no longer relevant.

Source: Government Accountability Office | GAO-20-224

Table 4: Recommendations from *James Webb Space Telescope: Project Facing Increased Schedule Risk with Significant Work Remaining* (GAO-15-100)

	Recommendation	Agency Concurrence	Status	Comments
1	In order to provide additional information and analyses to effectively manage the program and account for new risks identified after the 2011 replan, the NASA Administrator should direct JWST project officials to follow best practices while conducting a cost risk analysis on the prime contract for the work remaining and ensure the analysis is updated as significant risks emerge.	Partially Concurred	Closed – not implemented (While the intent of the recommendation has not been satisfied, time or circumstances have rendered the recommendation invalid.)	JWST did conduct a cost risk analysis and provided the results to GAO. We reported in "James Webb Space Telescope: Project on Track but May Benefit from Improved Contractor Data to Better Understand Costs" (GAO-16-112) that it substantially met best practices. However, the project stated they did not plan to update the analysis as significant risks emerged, which is a key element of the recommendation. Since then, this recommendation has been overcome by events. In June 2018, the program had to rebaseline its cost and schedule estimates and is now conducting new analyses to support upcoming reviews.

	Recommendation	Agency Concurrence	Status	Comments
2	In order to ensure JWST's award fee contracts' final evaluations thoroughly and fairly evaluate contractor performance over the life of the contract and to provide clarity to the process that will be used for the final evaluation, the NASA Administrator should direct JWST project officials, in conjunction with the performance evaluation board for JWST and the Goddard Space Flight Center fee determining official, to modify performance evaluation plans for its award fee contracts to ensure they (a) specify evaluation criteria that reflects total contract performance in advance of the final evaluation, and (b) clearly describe the process the performance evaluation board and fee determining official will use to evaluate contractor performance in the final evaluation.	Concurred	Closed – implemented	In December 2014, GAO reported that the final contractor award fee evaluation plans for the JWST project did not meet NASA award fee guidance or procurement regulations. As a result, GAO recommended that JWST program officials, along with the project's Performance Evaluation Board and the Goddard Space Flight Center Fee Determining Official, modify the performance evaluation plans to reflect the total contract performance of the contractor and clearly describe the final contractor performance evaluation process for its award fee contracts. In response to this recommendation, the JWST project concurred and revised the performance evaluation plans for its two major contractors - Northrop Grumman and Exelis. GAO reviewed the revisions and believes JWST project officials fulfilled the recommendation by specifying the process by which the factors and criteria in the performance evaluation plan will be used in the final evaluation and specifically indicating that the final evaluation will take into account Northrup Grumman's and Exelis' performance over the life the contract.

Source: Government Accountability Office | GAO-20-224

Table 5: Recommendation *from James Webb Space Telescope: Project on Track but May Benefit from Improved Contractor Data to Better Understand Costs* (GAO-16-112)

		Agency Concurrence	Status	Comments
1	To resolve contractor data reliability issues and ensure that the project obtains reliable data to inform its analyses and overall cost position, the NASA Administrator should direct JWST project officials to require the contractors to identify, explain, and document all anomalies in contractor-delivered monthly earned value management reports.	Concurred	Closed – implemented	In February 2016, NASA issued letters to the contractors requiring them to explain all anomalies in the contractor earned value management reports.

Source: Government Accountability Office | GAO-20-224

Table 6: Recommendation from *James Webb Space Telescope: Opportunity Nears to Provide Additional Assurance That Project Can Meet New Cost and Schedule Commitments* (GAO-19-189)

	Recommendation	Agency Concurrence	Status	Comments
1	The NASA Administrator should direct the JWST project office to conduct a Joint Cost and Schedule Confidence Level prior to its system integration review.	Concurred	Closed - implemented	NASA agreed with our recommendation and completed this analysis in October 2019. GAO plans to conduct a separate, more detailed engagement on this review and its findings in the future.

Source: Government Accountability Office | GAO-20-224

Appendix III: List of Independent Review Board (IRB) Recommendations

Table 7: List of 32 IRB Recommendations

Category		Recommendation
Mission Success Dependence on Launch Vehicle	1	The Launch Services Program shall be accountable for James Webb Space Telescope (JWST) launch success at the same level of responsibility they have for U.S. launches, or the National Aeronautics and Space Administration (NASA) should contract with Aerospace Corporation for similar accountability.
Management Communications	2	The Goddard Space Flight Center (Goddard) and Northrop Grumman Project Offices should be established as consistent and factual source of all JWST mission status
	3	Communications of status and details appropriate for stakeholders need to be presented clearly and frequently.
	4	NASA headquarters should be responsible for developing a “communication plan” (messaging strategy) for JWST.
	5	Communicating complexity, risk, and science return for JWST is critically important.
	6	Use the same criticality and assessment charts for all JWST reporting.
JWST Reporting	7	NASA should implement a JWST reporting structure where the Science Mission Directorate Associate Administrator has responsibility for the entire JWST program and the Goddard Space Flight Center Director is responsible for all aspects of the project.
	8	NASA should revise NASA policy directives to be consistent with the recommendation.
Engagement of Science Community	9	Assure consistent, sustained and meaningful engagement of the Science Working Group (SWG).
	10	Appoint an executive committee of NASA-selected members of the SWG to act as conduits to the broader community on mission challenges.
Commissioning Risks	11	NASA should designate a Commission Manager.
	12	NASA should implement sunshield hardware and simulation elements to aid in sunshield anomaly identification and resolution.
Human Mistakes	13	Northrop Grumman should establish corrective actions in1) processes, 2) training, 3) personnel certification, 4) discipline to ensure individual accountability and 5) a failure-proof “safety net” through a robust testing, analysis, and inspection process.
Embedded Problems	14	Goddard and Northrop Grumman should conduct an audit including forensic engineering, hardware pedigree assessment, drawing checks, etc., to identify potential embedded problems.
Residual Risks	15	Goddard should conduct an audit of the JWST project residual risk, reviewing the objective evidence of (a) the completed Test As You Fly and Single Point Failures mitigation plans, and (b) failure corrective action effectiveness to determine the “as built” residual risk.
	16	The project should reconcile the “as built” residual risk with the expected “as designed” residual risk.
Transport and Spacecraft/Launch Integration	17	NASA should define security requirements and plan for JWST transport to launch site.

Category		Recommendation
	18	Develop contingency operations and sparing plan for spacecraft/launch site operations.
	19	Develop “pathfinder” JWST simulator and contamination protection systems for integration “dry runs.”
	20	Assess shipping vessel contamination environment and develop contingency plans for off-nominal shipping operation.
Mission Operations	21	It is critically important that Goddard JWST Project Office maintain responsibility and provide adequate support to ensure Space Telescope Science Institute (STScI) mission operations readiness
	22	The Project should review all simulators/testbeds and required usage against pre-launch tests and rehearsals, post-launch deployment anomaly resolution, fault isolation, and correction.
	23	The Goddard JWST Project Office should develop a staffing plan that meets the needs of integration and test and operational readiness.
	24	The project should develop and approve a transition plan that defines the level of mission operations responsibility for STScI as a function of time with independent gate reviews at transition points.
Mission Success	25	Management should unambiguously emphasize the priority of mission success to “working level” personnel.
	26	Employees must feel empowered to stop or slow down if the pace or procedures can jeopardize mission success.
	27	NASA should assess “top ten” mission success enhancements and implement where appropriate.
Responsible Design Engineer	28	Responsible Design Engineers should be involved and responsible for their element through the successful commissioning of the observatory.
Integration and Test Staff	29	The project should augment integration and test staff; this is critically important to execute the integration and test program.
Morale	30	Augment integration and test staff to achieve more realistic work schedules.
	31	Implement strategies for improving team morale, such as periodic science lectures for Northrop Grumman personnel and families.
Launch Date	32	The Webb IRB recommends the launch date be established as March 2021 (based upon the Project’s 5/18 assessment of the impact of the membrane cover assembly acoustic anomaly).

Source: GAO analysis of National Aeronautics and Space Administration data | GAO-20-224

Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

In addition to the contact named above, Raj Chitikila (Assistant Director), Christina Cota-Robles, Carrie Rogers, Ajani Skeete, Jay Tallon, and Thomas Twambly made key contributions to this report. Assistance was also provided by Hannah Brookhart, Brian Bothwell, Lorraine Ettaro, Emile Ettedgui, Laura Greifner, Kaelin Kuhn, Christine Pecora, Roxanna Sun, and Alyssa Weir.

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