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JAMES WEBB SPACE TELESCOPE

Project Facing Increased Schedule Risk with Significant Work Remaining

Statement of Cristina T. Chaplain, Director, Acquisition and Sourcing Management

GAO-15-483T

GAO Highlights

Highlights of GAO-15-483T, a testimony before the Subcommittee on Space, Committee on Science, Space, and Technology, House of Representatives

Why GAO Did This Study

JWST is one of the National Aeronautics and Space Administration's (NASA) most complex and expensive projects. At an anticipated cost of $8.8 billion, JWST is intended to revolutionize understanding of star and planet formation, advance the search for the origins of the universe, and further the search for earth-like planets. Since entering development in 1999, JWST has experienced significant schedule delays and increases to project costs and was rebaselined in 2011. With significant integration and testing planned during the approximately 3.5 years until the launch date in October 2018, the JWST project will need to address many challenges before NASA can conduct the science the telescope is intended to produce. GAO has reviewed JWST for the last 3 years as part of an annual mandate and for the last 7 years as part of another annual mandate to review all of NASA's major projects. Prior to this, GAO also issued a report on JWST in 2006.

This testimony is based on GAO's third annual report on JWST (GAO-15-100), issued in December 2014, with limited updated information provided where applicable. That report assessed, among other issues, the extent to which (1) technical challenges were impacting the JWST project's ability to stay on schedule and budget, and (2) budget and cost estimates reflected current information about project risks. To conduct that work, GAO reviewed monthly JWST reports, interviewed NASA and contractor officials, reviewed relevant policies, and conducted independent analysis of NASA and contractor data.

View GAO-15-483T. For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

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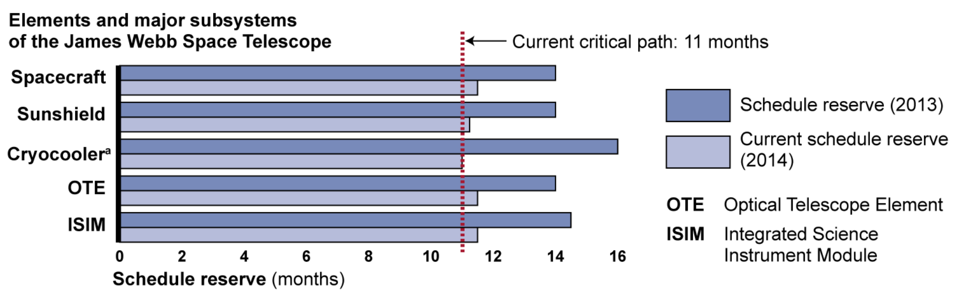
Project Facing Increased Schedule Risk with Significant Work Remaining

What GAO Found

James Webb Space Telescope (JWST) project officials report that the effort remains on track toward the schedule and budget established in 2011. However, the project is now in the early stages of its extensive integration and testing period. Maintaining as much schedule reserve as possible during this phase is critical to resolve challenges that will likely surface and negatively impact the schedule. JWST has begun integration and testing for only two of five elements and major subsystems. While the project has been able to reorganize work when necessary to mitigate schedule slips thus far, this flexibility will diminish as work during integration and testing tends to be more serial, as initiating work is often dependent on the successful and timely completion of the prior work.

Schedule Reserve Changes on the James Webb Space Telescope's Elements and Major Subsystems from 2013 to 2014



Source: GAO analysis of NASA data. | GAO-15-483T

[a]The cryocooler chills an infrared light detector on one of JWST's four scientific instruments.

In December 2014, GAO reported that delays had occurred on every element and major subsystem schedule, each was at risk of driving the overall project schedule, and the project's schedule reserve had decreased from 14 to 11 months. As a result, further delays on any element or major subsystem would increase the overall schedule risk for the project. At the time of the report, challenges with manufacturing of the cryocooler had delayed that effort and it was the driver of the overall project schedule. Since the December report, the project's overall schedule reserve decreased to 10 months as a result of several problems that were identified following a test of the Integrated Science Instrument Module (ISIM), which contains the telescope's scientific instruments. ISIM is now driving the overall project schedule. Furthermore, additional schedule impacts associated with challenges on several other elements and major subsystems are still being assessed.

At the time of the December 2014 report, the JWST project and prime contractor's cost risk analyses used to validate the JWST budget were outdated and did not account for many new risks identified since 2011. GAO best practices for cost estimating call for regularly updating cost risk analyses to validate that reserves are sufficient to account for new risks. GAO recommended, among other actions, that officials follow best practices while conducting a cost risk analysis on the prime contract and update the analysis as significant risks emerged. NASA partially concurred, noting that it has a range of tools in place to assess performance and would update the analysis as required by policy. Since then, officials completed the analysis and GAO is currently examining the results.

Chairman Palazzo, Ranking Member Edwards, and Members of the Subcommittee:

Thank you for inviting me to testify on the current state of the National Aeronautics and Space Administration's (NASA) acquisition of the James Webb Space Telescope (JWST). As you know, JWST is one of NASA's most complex and expensive projects, at an anticipated cost of $8.8 billion. JWST is intended to revolutionize understanding of star and planet formation, advance the search for the origins of the universe, and further the search for earth-like planets. Projects of this scale, complexity, and technological sophistication confront a myriad of unforeseen challenges in their ambitious attempts to expand the limits of scientific accomplishment. With significant integration and testing planned until the scheduled launch in October 2018, the success of JWST hinges on the ability of NASA and its contractors to adjust and respond to these challenges in a timely and cost-effective manner. With future NASA missions and exploration depending on the success of JWST, its ultimate outcome will have effects many years into the future.

We have reviewed JWST for the last 3 years as part of an annual mandate and for the last 7 years as part of our mandate to assess all of NASA's major projects.[1] Prior to this, we also issued a report on JWST in 2006. Information on all of our previous work on JWST is listed in the back of this testimony. Over this time, we have seen much progress and the project has addressed many technical challenges. Significant portions of the telescope are built and being tested or are in manufacturing, including the 18 primary mirrors, four scientific instruments, and parts of the sunshield and spacecraft. Today, I will discuss a portion of our recent work on the acquisition of the JWST. Specifically, I will discuss the extent to which (1) technical challenges are impacting the JWST project's ability to stay on schedule and budget, and (2) budget and cost estimates reflect current information about project risks.

My testimony today is based on our most recent report released in December 2014, some limited updated information since the report was published, and prior reports on JWST for background. For our most recent report, we examined monthly status reports from the project and contractors; conducted an analysis of JWST cost reserves; reviewed best

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

practices for cost risk analyses; and interviewed NASA project, program, and contracting officials, among other actions. Our December report includes a detailed description of our scope and methodology.

All work on which this testimony is based was performed 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.

JWST is defined by three elements: the Integrated Science Instrument Module (ISIM), the Optical Telescope Element (OTE), and the spacecraft and two of its major subsystems—the cryocooler and sunshield. See appendix I for a description of all the elements and major subsystems of JWST. Projects managed out of Goddard Space Flight Center, like JWST, are required to reserve extra time in their schedules—which is referred to as schedule reserve—and extra money in their budgets—which is referred to as cost reserve—to address unforeseen technical challenges or absorb additional costs as the project progresses.[2] For JWST, schedule reserve is held at the overall project level with some reserve allocated to each element and major subsystem. The element or major subsystem with the least amount of schedule reserve determines the project's critical path—the earliest completion date or minimum duration it will take to complete all project activities. Any delay to an activity that is on the critical path will reduce schedule reserve for the whole project, and could ultimately impact the overall project schedule.

Since entering development in 1999, JWST has experienced significant schedule delays and increases to project costs. Prior to being approved for development, cost estimates of the project originally ranged from $1 billion to $3.5 billion with expected launch dates ranging from 2007 to 2011. In March 2005, NASA increased the JWST's life-cycle cost estimate to $4.5 billion and delayed the launch date to 2013. We reported in 2006 that the cost growth was due to a delay in launch vehicle selection, budget limitations in fiscal years 2006 and 2007, requirements changes, and an increase in the project's cost reserves. In April 2006, an

[2] Goddard Space Flight Center, Goddard Procedural Requirements 7120.7 (May 4, 2008).

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 review team reported that for a project as complex as JWST, a 25 to 30 percent total reserve funding was appropriate. The team cautioned that low reserve funding compromised the project's ability to resolve issues, address risk areas, and accommodate unknown problems. The project was baselined in April 2009 with a life-cycle cost estimate of $4.964 billion—including additional cost reserves—and a launch date in June 2014. Shortly after JWST was approved for development and its cost and schedule estimates were baselined, project costs continued to increase and the schedule was extended.

In response to a request in 2010 from the Chair of the of the Senate Subcommittee on Commerce, Justice, Science, and Related Agencies to the NASA Administrator for another independent review of JWST, NASA commissioned the Independent Comprehensive Review Panel (ICRP). In October 2010, the ICRP issued its report and cited several reasons for the project's problems including management, budgeting, oversight, governance and accountability, and communication issues. The panel also identified changes to address root causes to diminish the risk of future cost increases and delays to the launch date. The panel concluded that JWST was executing well from a technical standpoint, but that baseline funding did not reflect the most probable cost with adequate reserves in each year of project execution, resulting in an unexecutable project.[3] Following this review, the JWST program underwent a replan in September 2011. On the basis of the replan, NASA announced that the project would be rebaselined with a life cycle cost of $8.835 billion—a 78 percent increase—and would launch in October 2018—a delay of an additional 52 months. The replan included 13 months of funded schedule reserve and a 66 percent joint cost and schedule confidence level (JCL)

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

for the revised cost and schedule baselines.[4] A JCL is the process that NASA uses to assign a percentage to the probable success of meeting cost and schedule estimates as part of the project's estimating process. Currently, JWST makes up a significant portion—approximately 54 percent, or $6.2 billion—of NASA's 2015 science portfolio's total development cost of $11.5 billion for major projects.

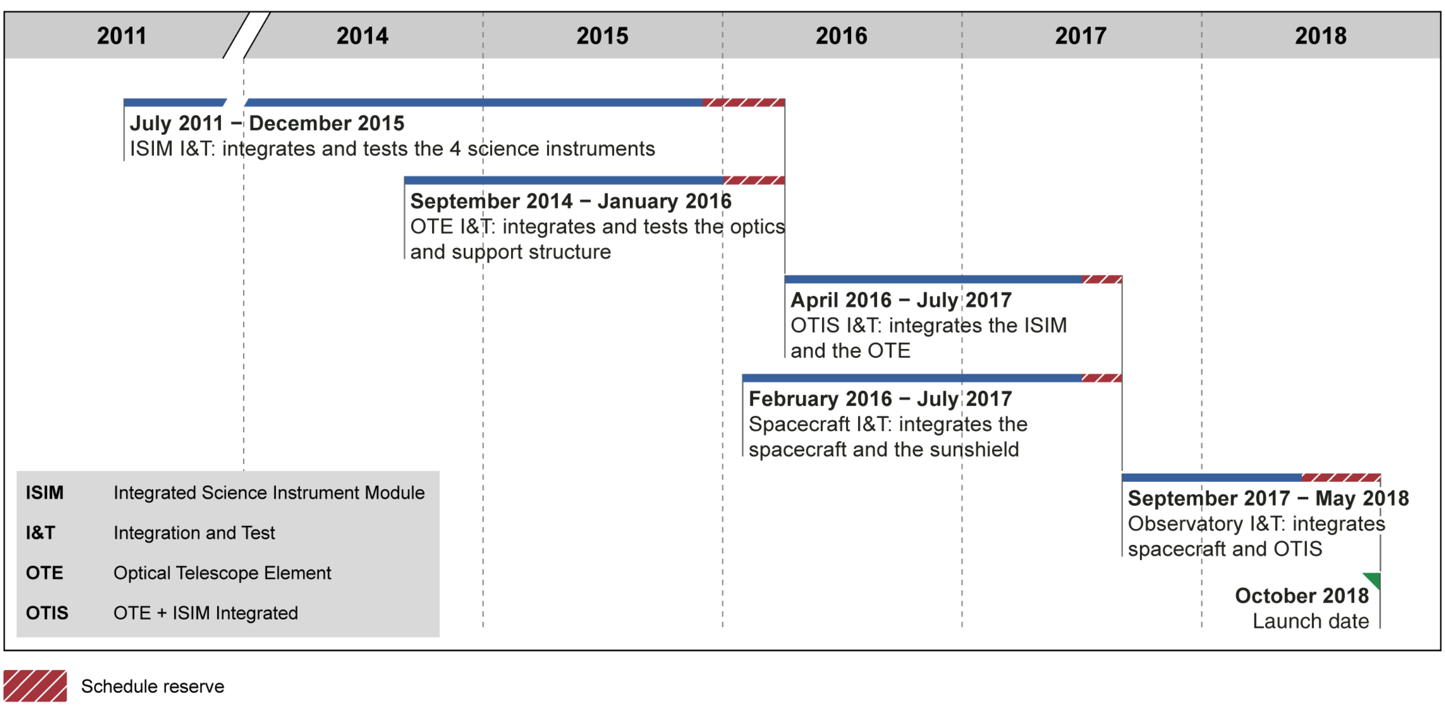
Since 2012, we have reported annually that JWST is on track with respect to its new cost and schedule goals, but have raised questions about the reliability of the project's estimates. In 2012, we reported that the lack of detail in the summary schedule used for JWST's JCL analysis during the 2011 replan prevented us from sufficiently understanding how risks were incorporated, calling into question the results of that analysis and, therefore, the reliability of the replanned cost estimate. We recommended that the JWST project perform an updated JCL analysis. NASA concurred but, to date, has not updated the JCL. In our January 2014 report, our analysis of three subsystem schedules determined that the reliability of the project's integrated master schedule—which is dependent on the reliability of JWST's subsystem schedules—was questionable. We recommended that NASA perform schedule risk analyses on the three specific schedules we examined and any others for which a schedule risk analysis was not performed. NASA concurred and has performed schedule risk analyses on two of the three schedules we examined.

[4] The JCL is a quantitative probability analysis that requires the project to combine its cost, schedule, and risks into a complete quantitative picture to help assess whether the project will be successfully completed within cost and on schedule. NASA introduced the analysis in 2009, and it is among the agency's initiatives to reduce acquisition management risk. The move to probabilistic estimating marks a major departure from NASA's prior practice of establishing a point estimate and adding a percentage on top of that point estimate to provide for contingencies. NASA's procedural requirements state that Mission Directorates should plan and budget programs and projects based on a 70 percent JCL, or at a different level as approved by the Decision Authority of the Agency Program Management Council, and any JCL approved at less than 70 percent must be justified and documented. NASA Procedural Requirements (NPR) 7120.5E, NASA Space Flight Program and Project Management Requirements, paragraph 2.4.4 (Aug. 14, 2012).

Project Risk Heightened Due to Widespread Use of Schedule Reserve to Address Technical Issues

The JWST project continues to report that it remains on schedule and budget with its overall schedule reserve currently above its plan. However, the project is now entering a difficult phase of development—integration and testing—which is expected to take another 3.5 years to complete. Maintaining as much schedule reserve as possible is critical during this phase to resolve known risks and unknown problems that may be discovered. Being one of the most complex projects in NASA's history, significant risks lie ahead for the project, as it is during integration and testing where problems are likely to be found and as a result, schedules tend to slip. As seen in figure 1, only two of five elements and major subsystems—ISIM and OTE—have entered the integration and testing phase. Integration and testing for the spacecraft and sunshield and for the ISIM and OTE when they are integrated together begins in 2016 and the entire observatory will begin this phase in late 2017.

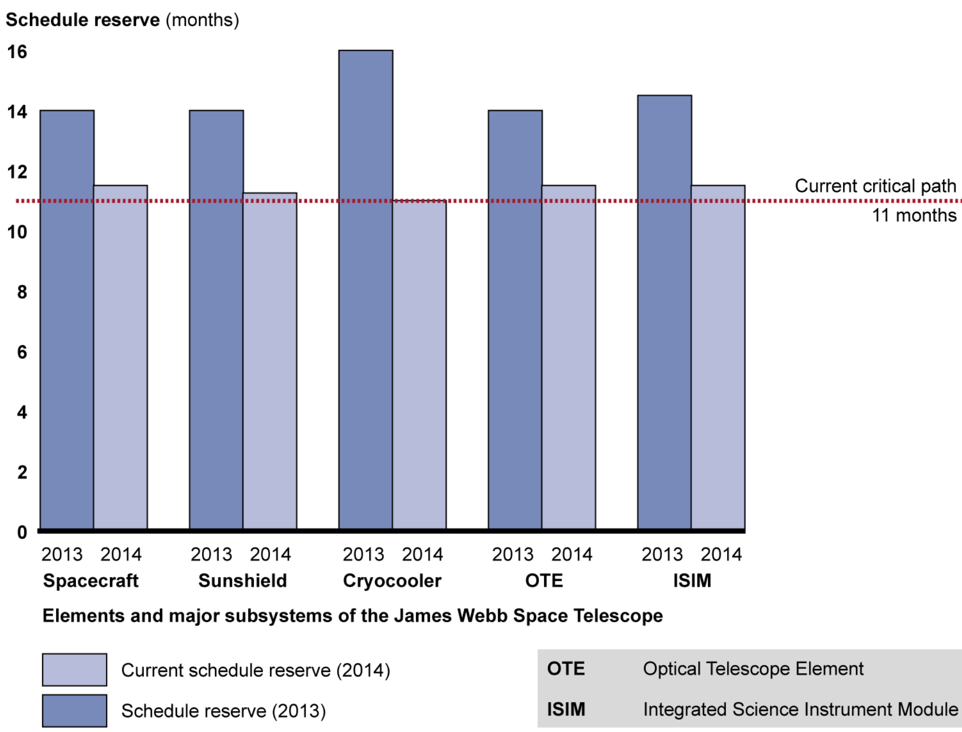
Figure 1: Integration and Test (I&T) Schedule for the James Webb Space Telescope Elements



Source: GAO analysis of NASA data. | GAO-15-483T

In December 2014, we reported that schedule risk was increasing for the project because it had lost schedule reserve across all elements and major subsystems. As a result, all were within weeks of becoming the critical path of the project and driving the project's overall schedule. Figure 2 shows the different amounts of schedule reserve remaining on all elements and major subsystems, their proximity to the critical path, and the total schedule reserve for the critical path at the time of our review.

Figure 2: James Webb Space Telescope Schedule Reserve by Element and Major Subsystem in 2013 and 2014



Source: GAO analysis of NASA data. | GAO-15-483T

The proximity of all the elements and major subsystem schedules to the critical path means that a delay on any of the elements or major subsystems may reduce the overall project schedule reserve further, which could put the overall project schedule at risk. As a result, the project has less flexibility to choose which issues to mitigate. While the project has been able to reorganize work when necessary to mitigate schedule slips thus far, with further progression into subsequent integration and testing periods, flexibility will be diminished because work during integration and testing tends to be more serial, as the initiation of work is often dependent on the successful and timely completion of the prior work. This is particularly the case with JWST given its complexity.

Challenges with the development and manufacturing of the sunshield and the cryocooler were the most significant causes of the decline in schedule reserve that we reported on in December 2014. The sunshield experienced a significant manufacturing problem during the construction of the large composite panel that forms part of the sunshield's primary support structure. The cryocooler compressor assembly—one component of the cryocooler—delivery is a top issue for the project and its development has required a disproportionate amount of cost reserves to fund additional work, caused in part, by issues such as a manufacturing error and manufacturing process mistake that caused delays to the schedule. The development of the cryocooler has been a concern for project officials as far back as 2006. Since that time, the cryocooler has faced a number of technical challenges, including valve leaks and cryocooler underperformance, which required two subcontract modifications and significant cost reserves to fund. The contractor and subcontractor were focused on addressing valve problems, which limited their attention to the cooling underperformance issue. This raised questions about the oversight of the cryocooler and why it did not get more attention sooner before significant delays occurred. In August 2013, the cryocooler subcontract was modified to reflect a 69 percent cost increase and that the workforce dedicated to the cryocooler effort at the subcontractor increased from 40 staff to approximately 110 staff.

Since we issued our December 2014 report, JWST schedule reserve continued to decline: project schedule reserve decreased by 1 month, leaving 10 months of schedule reserve remaining, and the critical path switched from the cryocooler to the ISIM. The project is facing additional challenges with the testing of the ISIM and OTE and the manufacturing of the spacecraft in addition to continuing challenges with the cryocooler compressor assembly that further demonstrates continued schedule risk for the project. For example, after the second test for the ISIM—the element of JWST that contains the telescope's four different scientific instruments—electronic, sensor, and heat strap problems were identified that impact two of the four instruments. Mitigating some of these issues led to a 1.5-month slip to the ISIM schedule and made ISIM the current critical path of the project to allow officials time to replace the unusable and damaged parts. As a result, ISIM's third and final cryovacuum test scheduled to begin in August 2015 has slipped until September 2015.

The OTE and spacecraft efforts are also experiencing challenges that may impact the schedules for those efforts. For example, it was discovered that over 70 harnesses on the OTE potentially had nicks on some wires and the majority will need to be repaired or rebuilt. The effects of these challenges on the project's schedule are still being determined. Finally, the cryocooler compressor assembly has yet to be delivered and will be more than 16 months late if the current delivery date holds. Since our December 2014 report, the cryocooler compressor assembly's delivery slipped almost an additional 2 months due to manufacturing and build issues and for an investigation of a leak to a joint with the pulse tube pre-cooler.[5] Currently, the cryocooler compressor assembly is expected to be delivered in mid-June 2015 and is only 1 week off of the project's critical path.

Entering fiscal year 2015, the JWST project had limited short-term cost reserves to address technical challenges and maintain schedule. We reported the project had committed approximately 40 percent of the fiscal year 2015 cost reserves before the start of the fiscal year. As a result, one of the project's top issues for fiscal year 2015 is its cost reserve posture, which the project reported is less than desired and will require close monitoring. At the end of February, project officials had committed approximately 60 percent of the fiscal year 2015 cost reserves and noted that maintaining fiscal year 2016 reserves needed close watching.

Project Lacked Updated Cost Risk Analysis Despite Significant Changes to Risk

The types of technical problems JWST is experiencing are not unusual for a project that is unique and complex. They are an inherent aspect of pushing technological, design, and engineering boundaries. What is important when managing such a project is having a good picture of risks, which can shift from day to day, and having effective tools for mitigating risks as they surface. Using up-to-date and thorough data on risks is also integral to estimating resources needed to complete the project. Given the cost of JWST, its previous problems with oversight, and the fact that the program is entering its most difficult phases of development, risk analysis and risk management have been a key focus of our work.

[5] The overall schedule reserve was not impacted the full 2 months because the project was able to mitigate the delay, in part, by modifying acceptance testing and by identifying a later delivery date to spacecraft integration and testing.

JWST officials have taken an array of actions following the 2011 replan to enable the program to have better insight into risks and to mitigate them. For instance, we reported in 2012 that the project had implemented a new risk management system after it found the previous system lacked rigor and was ineffective for managing risks. The project instituted meetings at various levels throughout NASA and its contractors and subcontractors to facilitate communication about risks. The project also added personnel at contractor facilities, which allowed for more direct interaction and quicker resolution of issues.

However, we reported in December 2014 that neither NASA nor the prime contractor had updated the cost risk analysis that underpinned the cost and schedule estimates for the 2011 replan. A cost risk analysis quantifies the cost impacts of risks and should be used to develop and update a credible estimate that accounts for all possible risks—technical, programmatic, and those associated with budget and funding. Moreover, conditions have changed significantly since the replan. For example, the delivery of the cryocooler compressor assembly is one of the project's top issues and was not an evident risk when the cost risk analysis was conducted in 2011. On the prime contract, our analysis found that 67 percent of risks tracked by Northrop Grumman in April 2014 at the time of our analysis were not present in September 2011 at the time of the replan.

We determined that a current and independent cost risk analysis was needed to provide Congress with insight into JWST's remaining work on the Northrop Grumman prime contract—the largest (most expensive) portion of work remaining. A key reason for this determination was and continues to be the significant potential impact that any additional cost growth on JWST would have on NASA's broader portfolio of science projects. To provide updated and current insight in to the project's cost status, we took steps to conduct an independent, unbiased analysis.[6] We were, however, unable to conduct the analysis because Northrop Grumman did not allow us to conduct anonymous interviews of technical experts without a manager present. In order to collect unbiased data, interviewees must be assured that their opinions on risks and opportunities remain anonymous. Unbiased data would have allowed us to provide a credible assessment of risks for Northrop Grumman's remaining work.

NASA and the JWST project disagreed that an independent cost risk analysis conducted by an outside organization at this point in the project would be useful. Neither believed that an organization external to NASA could fully comprehend the project's risks. Further, they noted that any such analysis would be overly conservative due to the complexities of the risks and not representative of the real risk posture of the project. GAO's best practices call for cost estimates to be compared to independent cost estimates in addition to being regularly updated. Without an independent and updated analysis, both the committee members' and NASA's oversight and management of JWST will be constrained since the impact of newer risks have not been reflected in key tools, including the cost estimate. Moreover, our methodology would have provided both NASA and Northrop Grumman with several opportunities to address concerns with our findings, including concerns about conservatism.

After we were unable to conduct the cost risk analysis, NASA decided to conduct its own cost risk analysis of the Northrop Grumman remaining work. However, a NASA project official said that they did not plan to use data from the cost risk analysis to manage the project. Instead, they indicated that they planned to use the information to inform committee members of the project's cost risk and would continue to rely on other

[6]As part of the methodology, we had planned to conduct approximately 30 interviews with different personnel working on the Northrop Grumman contract to assess the probability of different risks in their specific area would occur in order to develop probability distributions for the cost or duration of activities. From this data, collected anonymously in the interviews so the data is unbiased, random simulations would be run thousands of times, creating a new program total cost and duration estimate each time. The end product would have been a range of program costs or completion dates along with the probabilities that these costs or dates will occur. While this step was not essential to accomplish the objectives of our review, it would have provided NASA with an updated level of confidence associated with Northrop Grumman meeting its cost estimate and allowed decisionmakers to determine if additional cost reserves were warranted to mitigate future risks.

tools already in place to project the future costs of the project, such as earned value management (EVM) analysis.[7] To maintain quality cost estimates over the life of a project, best practices state that cost risk analyses should be updated regularly to incorporate new risks and be used in conjunction with EVM analysis to validate cost estimates. While EVM is a very useful tool for tracking contractor costs and potential overruns, the analyses are based on past performance that do not reflect the potential impact of future risks. We reported that if the project did not follow best practices in conducting its cost risk analysis or use it to inform project management, the resulting information may be unreliable and may not substantively provide insight into JWST's potential cost to allow either Congress or project officials to take any warranted action. To better ensure NASA's efforts would produce a credible cost risk analysis, in December 2014, we recommended that officials follow best practices while conducting a cost risk analysis on the prime contract for the work remaining and update it as significant risks emerged. Doing so would ensure it provided information to effectively manage the program. NASA partially concurred with our recommendation, again noting that it has a range of tools in place to assess all contractors' performance, the approach the project has in place is consistent with best practices, and officials will update the cost risk analysis again when required by NASA policy. We found that NASA best practices for cost estimating recommend updating the cost risk analysis while a project is being designed, developed, and tested, as changes can impact the estimate and the risk assessment.

Since our report was published, NASA completed its analysis and provided the results to us. We are currently examining the analysis to assess its quality and reliability and the extent to which it was done in accordance with NASA and GAO best practices. Our initial examination indicates the JWST project took the cost risk analysis seriously and took into account best practices in the execution of the analysis. The project has also recently begun conducting a new analysis of EVM data which

[7]Earned value management is a project management tool that integrates the technical scope of work with schedule and cost elements and compares the value of work accomplished in a given period with the value of the work expected in that period. When used properly, earned value management can provide objective assessments of project progress, produce early warning signs of impending schedule delays and cost overruns, and provide unbiased estimates of anticipated costs at completion. As a best practice, the work breakdown structure should match the schedule, cost estimate, and earned value management system at a high level so that it clearly reflects the work to be done.

they term a secondary estimate at completion analysis for two of its largest contractors–Northrop Grumman and Exelis—on work to go. This analysis should provide the project additional insight on the probabilities of outcomes while incorporating current risks against the cost reserves that remain. The initial analysis we have reviewed indicates that both contracts are forecasted to generally cost more at completion than the information produced using EVM analysis alone, but within the JWST life-cycle cost. However, we still have work to do to understand how NASA is analyzing the information and what assumptions it is putting into its analysis.

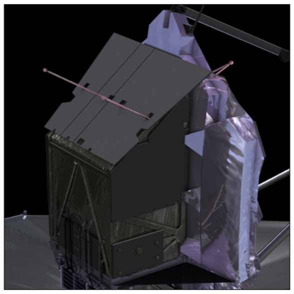
In conclusion, with approximately 3.5 years until launch, project officials have made much progress building and testing significant pieces of hardware and are currently on schedule—achieving important milestones—and on budget. They have also taken important steps to increase their insight and oversight into potential problems. What is important going forward is having good insight into risks and preserving as much schedule reserve as possible—particularly given the complexity of the project, the fact it is entering deeper into its integration and testing cycle, and the fact that it has limited funds available in the short term to preserve schedule. Any cost growth on JWST may have wider implications on NASA's other major programs. While we are concerned about NASA's reluctance to accept an independent cost risk assessment, particularly in light of past problems with oversight, we are also encouraged that NASA took steps to conduct an updated risk analysis of Northrop Grumman's work and that NASA has sustained and enhanced its use of other tools to monitor and manage risk. As we undertake this year's review of JWST, we will continue to focus on risk management, the use of cost reserves, progress with testing, as well as the extent to which its cost risk analysis followed best practices. We look forward to continuing to work with NASA on this important project and reporting to Congress on the results of our work.

Chairman Palazzo, Ranking Member Edwards, and Members of the Subcommittee, this completes my prepared statement. I would be pleased to answer questions related to our work on JWST and acquisition best practices at this time.

GAO Contact and Staff Acknowledgments

For questions about this statement, please contact Cristina Chaplain at (202) 512-4841, or at chaplainc@gao.gov. Contact points for our Offices of Congressional Relationship and Public Affairs may be found on the last page of this statement. Individuals making key contributions to this testimony were Shelby Oakley, Assistant Director; Karen Richey, Assistant Director; Jason Lee, Assistant Director; Patrick Breiding; Laura Greifner; Silvia Porres; Carrie Rogers; Ozzy Trevino; and Sylvia Schatz.

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



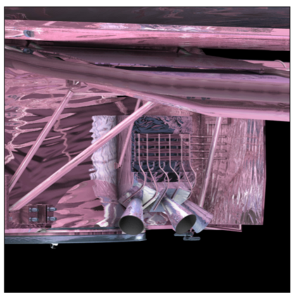
Integrated Science Instrument Module
Acronym: ISIM
Contractor/Center: Goddard Space Flight Center
Description: Combines the 4 instruments

Mid Infrared Instrument
Acronym: MIRI
Contractor/Center: Jet Propulsion Lab and European Consortium
Description: Science instrument

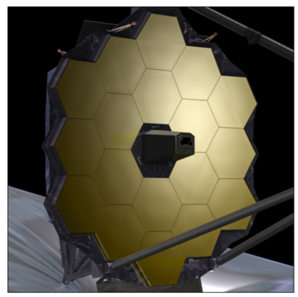
Near Infrared Spectrograph
Acronym: NIRSpec
Contractor/Center: European Space Agency
Description: Science instrument

Fine Guidance Sensor / Near-Infrared Imager and Slitless Spectrograph
Acronym: FGS/NIRISS
Contractor/Center: Canadian Space Agency
Description: Telescope guider and Science instrument

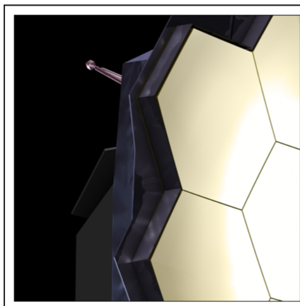
Near Infrared Camera
Acronym: NIRCam
Contractor/Center: University of Arizona
Description: Science instrument and Wave Front Sensor



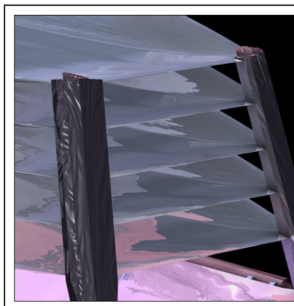
Spacecraft
Contractor/Center: Northrop Grumman Aerospace Systems
Description: Contains the power, communications, and avionics needed to operate the observatory. Contains the cryocooler needed to achieve MIRI operational temperatures approximating 7 Kelvin



Optical Telescope Element
Acronym: OTE
Contractor/Center: Northrop Grumman Aerospace Systems
Description: 18 primary mirror segments, secondary mirror, tertiary mirror, backplane support structure



Optical Telescope & Integrated Science Instrument Module
Acronym: OTIS (**OTE**+**IS**IM)
Contractor/Center: Goddard Space Flight Center
Description: Hardware configuration created when OTE and ISIM are integrated



Sunshield
Contractor/Center: Northrop Grumman Aerospace Systems
Description: Tennis court sized series of 5 thin membranes, provides passive cooling to achieve operational temperatures approximating 45 Kelvin for the OTE and ISIM

Sources: GAO (analysis); NASA (data and images). | GAO-15-483T

Related GAO Products

James Webb Space Telescope: Project Facing Increased Schedule Risk with Significant Work Remaining. GAO-15-100. Washington, D.C.: December 15, 2014.

James Webb Space Telescope: Project Meeting Commitments but Current Technical, Cost, and Schedule Challenges Could Affect Continued Progress. GAO-14-72. Washington, D.C.: January 8, 2014.

James Webb Space Telescope: Actions Needed to Improve Cost Estimate and Oversight of Test and Integration. GAO-13-4. Washington, D.C.: December 3, 2012.

NASA's James Webb Space Telescope: Knowledge-Based Acquisition Approach Key to Addressing Program Challenges. GAO-06-634. Washington, D.C.: July 14, 2006.

NASA: Assessments of Selected Large-Scale Projects. GAO-15-320SP. Washington, D.C.: March 24, 2015.

NASA: Assessments of Selected Large-Scale Projects. GAO-14-338SP. Washington, D.C.: April 15, 2014.

NASA: Assessments of Selected Large-Scale Projects. GAO-13-276SP. Washington, D.C.: April 17, 2013.

NASA: Assessments of Selected Large-Scale Projects. GAO-12-207SP. Washington, D.C.: March 1, 2012.

NASA: Assessments of Selected Large-Scale Projects. GAO-11-239SP. Washington, D.C.: March 3, 2011.

NASA: Assessments of Selected Large-Scale Projects. GAO-10-227SP. Washington, D.C.: February 1, 2010.

NASA: Assessments of Selected Large-Scale Projects. GAO-09-306SP. Washington, D.C.: March 2, 2009.

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