United States Government Accountability Office
Report to Congressional Committees

January 2014

# JAMES WEBB SPACE TELESCOPE

## Project Meeting Commitments but Current Technical, Cost, and Schedule Challenges Could Affect Continued Progress

GAO-14-72

GAO Highlights

Highlights of GAO-14-72, a report to congressional committees

## Why GAO Did This Study

JWST is one of NASA's most complex and costly science projects. Effective execution of the project is critical given the potential effect further cost increases could have on NASA's science portfolio. The project was rebaselined in 2011 with a 78 percent life-cycle cost estimate increase —now $8.8 billion—and a launch delay of 52 months—now October 2018. GAO has made a number of prior recommendations, including that the project perform an updated cost and schedule risk analysis to improve cost estimates. GAO was mandated to assess the program annually and report on its progress. This is the second such report.

This report assesses the (1) extent to which the JWST project is meeting its cost and schedule commitments and maintaining oversight, (2) current major technological challenges facing the project, (3) extent to which cost risks exist that may threaten the project's ability to execute as planned, and (4) extent to which the JWST project schedule is reliable based on scheduling best practices. GAO reviewed relevant NASA and contractor documents, interviewed NASA and contractor officials, and compared the project schedule with best practices criteria.

## What GAO Recommends

Congress should consider directing NASA to perform an updated integrated cost/schedule risk analysis. GAO recommends that NASA address issues related to low cost reserves and perform schedule risk analyses on the three subsystem schedules GAO reviewed. NASA concurred with GAO's recommendations.

View GAO-14-72. For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

January 2014

# JAMES WEBB SPACE TELESCOPE

## Project Meeting Commitments but Current Technical, Cost, and Schedule Challenges Could Affect Continued Progress

## What GAO Found

The James Webb Space Telescope (JWST) project is generally executing to its September 2011 revised cost and schedule baseline; however, several challenges remain that could affect continued progress. The National Aeronautics and Space Administration (NASA) has requested funding that is in line with the rebaseline and the project is maintaining 14 months of schedule reserve prior to its launch date. Performance data from the prime contractor indicate that generally work is being accomplished on schedule and at the cost expected; however, monthly performance declined in fiscal year 2013. Project officials have maintained and enhanced project oversight by, for example, continuing quarterly NASA and contractor management meetings and instituting a tool to update cost estimates for internal efforts. Program officials, however, are not planning to perform an updated integrated cost/schedule risk analysis, as GAO recommended in 2012, stating that the project performs monthly integrated risk analyses they believe are adequate. Updating the more comprehensive analysis with a more refined schedule and current risks, however, would provide management and stakeholders with better information to gauge progress.

The JWST project has made progress addressing some technical challenges that GAO reported in 2012, such as inadequate spacecraft mass margin, but others have persisted, causing subsystem development delays and cost increases. For example, the development and delivery schedule of the cryocooler—which cools one instrument—was deemed unattainable by the subcontractor due to technical issues and its contract was modified in August 2013 for the second time in less than 2 years, leading to a cumulative 120 percent increase in contract costs. While recent modifications have been made, execution of the cryocooler remains a concern given that technical performance and schedule issues persist.

Overall the project is maintaining a significant amount of cost reserves; however, low levels of near-term cost reserves could limit its ability to continue to meet future cost and schedule commitments. Development challenges have required the project to allocate a significant portion of cost reserves in fiscal year 2014. Adequate cost reserves for the prime contractor are also a concern in fiscal years 2014 and 2015 given the rate at which these cost reserves are being used. Limited reserves could require work to be extended or work to address project risks to be deferred—a contributing factor to the project's prior performance issues. Potential sequestration and funding challenges on other major NASA projects could limit the project's ability to address near-term challenges.

GAO's 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—is questionable. GAO's analysis found that the Optical Telescope Element (OTE) schedule was unreliable because it could not adequately identify a critical path—the earliest completion date or minimum duration it will take to complete all project activities, which informs officials of the effects that a slip of one activity may have on other activities. In addition, reliable schedule risk analyses of the OTE, the cryocooler, or the Integrated Science Instrument Module schedules were not performed. A schedule risk analysis is a best practice that gives confidence that estimates are credible based on known risks so the schedule can be relied upon to track progress.

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## Abbreviations

| | |
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| CPI | cost performance index |
| EVM | earned value management |
| FGS | Fine Guidance Sensor |
| I&T | integration and test |
| ICRP | Independent Comprehensive Review Panel |
| ISIM | Integrated Science Instrument Module |
| JCL | Joint Cost and Schedule Confidence Level |
| JPL | Jet Propulsion Laboratory |
| JWST | James Webb Space Telescope |
| K | Kelvin |
| MIRI | Mid-Infrared Instrument |
| NASA | National Aeronautics and Space Administration |
| NIRCam | Near-Infrared Camera |
| NIRISS | Near-Infrared Imager and Slitless Spectrograph |
| NIRSpec | Near-Infrared Spectrograph |
| NPR | NASA Procedural Requirements |
| OTE | Optical Telescope Element |
| OTIS | Optical Telescope Element and Integrated Science Instrument Module |
| SPI | schedule performance index |

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At a current expected cost of approximately $8.8 billion, the James Webb Space Telescope (JWST) is one of the National Aeronautics and Space Administration's (NASA) most complex and costly science projects. Effective execution of the JWST project is critical given the tradeoffs that the agency made to ensure that it was well-funded and the potential impact that any future cost increases or delays could have on the health of NASA's overall science portfolio. Specifically, based on the cost and schedule estimates established in 2011, the cost of the project is almost nine times the cost in its original plan established in 1999, and the impact of funding JWST for more years than originally anticipated has significantly decreased the amount of funds NASA has available to begin work on other major projects. NASA will have the opportunity over the next few years, during the course of several very complex test events, to demonstrate the credibility of the 2011 plan. While additional setbacks are to be expected given the technically challenging and complex nature of the project, much is at stake, including the progress NASA has made in restoring the confidence of Congress and other decision makers in its ability to effectively plan for and execute major acquisitions.

The on-time and on-budget delivery of JWST is a high congressional priority. In November 2011, the conference report for the Consolidated and Further Continuing Appropriations Act, 2012, mandated GAO to assess the program annually and to report to the Committees on Appropriations on key issues relating to program and risk management, achievement of cost and schedule goals, and program technical status.[1] In our first report, issued in 2012, we assessed the reliability of NASA's revised cost estimate based on best practices, the major risks and technological challenges facing the project, and NASA's oversight of the JWST project.[2] This report is our second in response to that mandate. For this report, we assessed (1) the extent to which the JWST project is meeting its cost and schedule commitments and maintaining oversight,

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

[2] GAO, *James Webb Space Telescope: Actions Needed to Improve Cost Estimate and Oversight of Test and Integration*, GAO-13-4 (Washington, D.C.: Dec. 3, 2012).

(2) the current major technological challenges facing the JWST project, (3) the extent to which cost risks exist that may threaten the project's ability to execute as planned, and (4) the extent to which the JWST project schedule is reliable based on scheduling best practices.

Our approach included an examination of the overall cost and schedule progress that NASA has made since our last report in December 2012 and the JWST program changes made in 2011. We examined and analyzed earned value management data; analyzed the progress made and any variances to milestones established during the replan in 2011; and interviewed officials from the JWST program, various contractors, and the Defense Contract Management Agency to determine the extent to which oversight was being conducted. To identify the major technological risks and challenges facing the project, we reviewed the project's risk database, monthly status reviews, and other documentation. We also interviewed project and contractor officials for the major subsystems. To identify the cost risks that may threaten the project's ability to execute as planned, we examined data on JWST's cost reserve posture and reviewed project and contractor documentation on risks to maintaining cost targets and plans to mitigate those risks. We took steps to confirm the accuracy of the data and performed various checks to determine that the data provided was reliable enough for our purposes. To determine the extent to which the JWST project schedule can be relied on to accurately represent the potential impact of schedule risks and technical challenges, we analyzed three subsystem schedules that are used as inputs to the integrated master schedule using scheduling best practices.[3] We also conducted interviews with project and contractor management, schedulers, and analyzed project and contractor documentation concerning scheduling policies and practices. See appendix I for a detailed description of our scope and methodology.

We conducted this performance audit from February 2013 to January 2014 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

[3]GAO, *GAO Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-12-120G (Washington, D.C.: May 30, 2012).

that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

## Background

JWST is a large deployable, infrared-optimized space telescope intended to be the scientific successor to the aging Hubble Space Telescope. JWST is designed for a 5-year mission to find the first stars and trace the evolution of galaxies from their beginning to their current formation, and is intended to operate in an orbit approximately 1.5 million kilometers—or 1 million miles—from the Earth. With its 6.5-meter primary mirror, JWST will be able to operate at 100 times the sensitivity of the Hubble Space Telescope. A tennis-court-sized sunshield will protect the mirrors and instruments from the sun's heat to allow the JWST to look at very faint infrared sources. The Hubble Telescope operates primarily in the visible and ultraviolet regions of the electromagnetic spectrum.[4] The observatory segment of JWST includes several major subsystems.[5] These subsystems are being developed through a mixture of NASA, contractor, and international partner efforts. See figure 1.

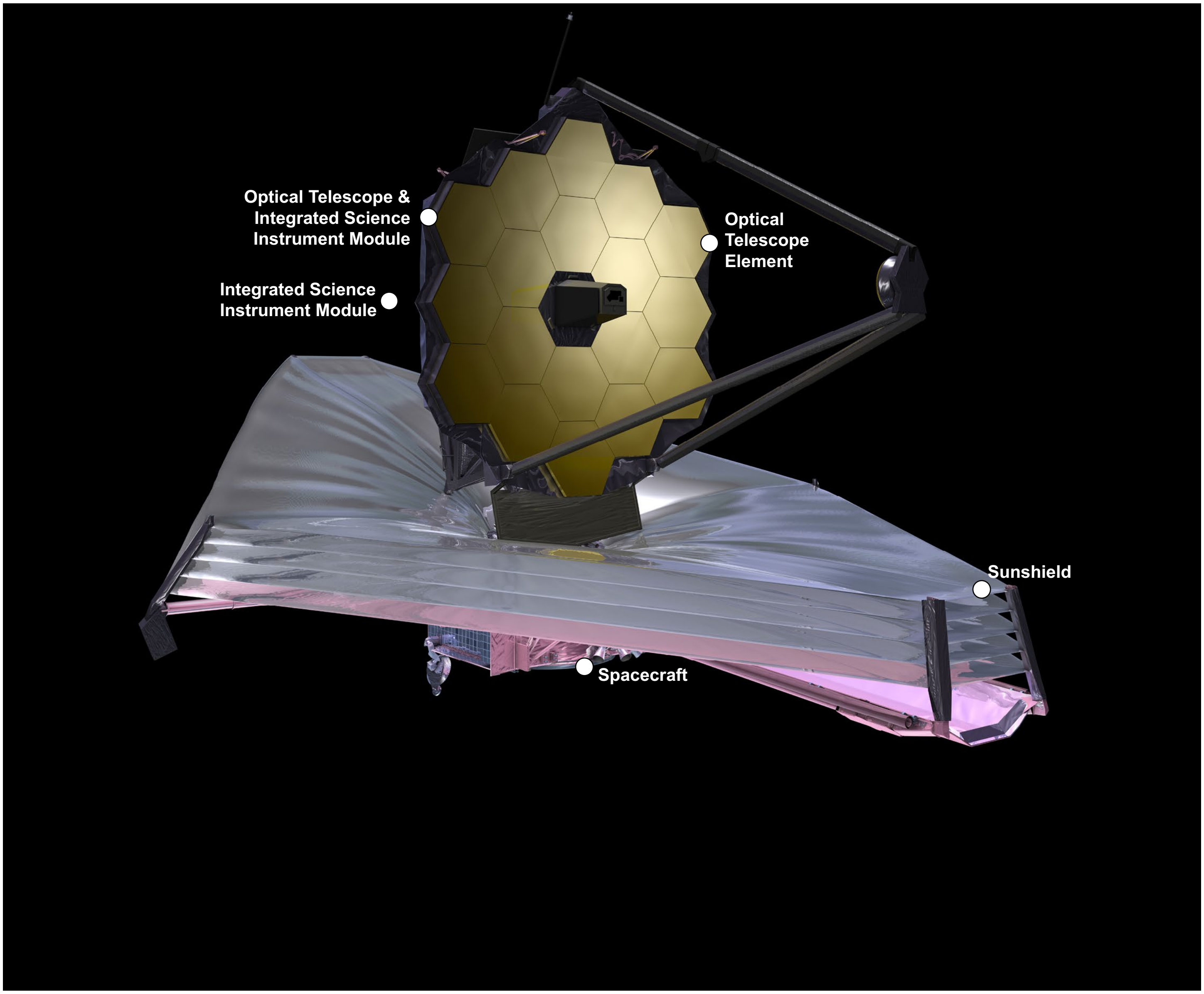
[4]The electromagnetic spectrum consists of the wavelengths of all visible and invisible light. The infrared part of the spectrum, also known as radiant heat, has wavelengths that go from about 0.75 microns to a few hundred microns. The Hubble is designed to operate primarily in the ultraviolet and visible wavelengths of the spectrum from 0.1 to 0.8 microns. Humans cannot see in the ultraviolet region.

[5]The JWST project is divided into three major segments: the launch segment, the ground segment, and the observatory segment. The hardware configuration created when the Optical Telescope Element and the Integrated Science Instrument Module are integrated, referred to as OTIS, is not considered a subsystem by NASA, but we categorize it as such for ease of discussion.

**Figure 1: James Webb Space Telescope**

Interactive Graphic

Rollover the white dots to see description. See appendix II for the non-interactive, printer-friendly version.

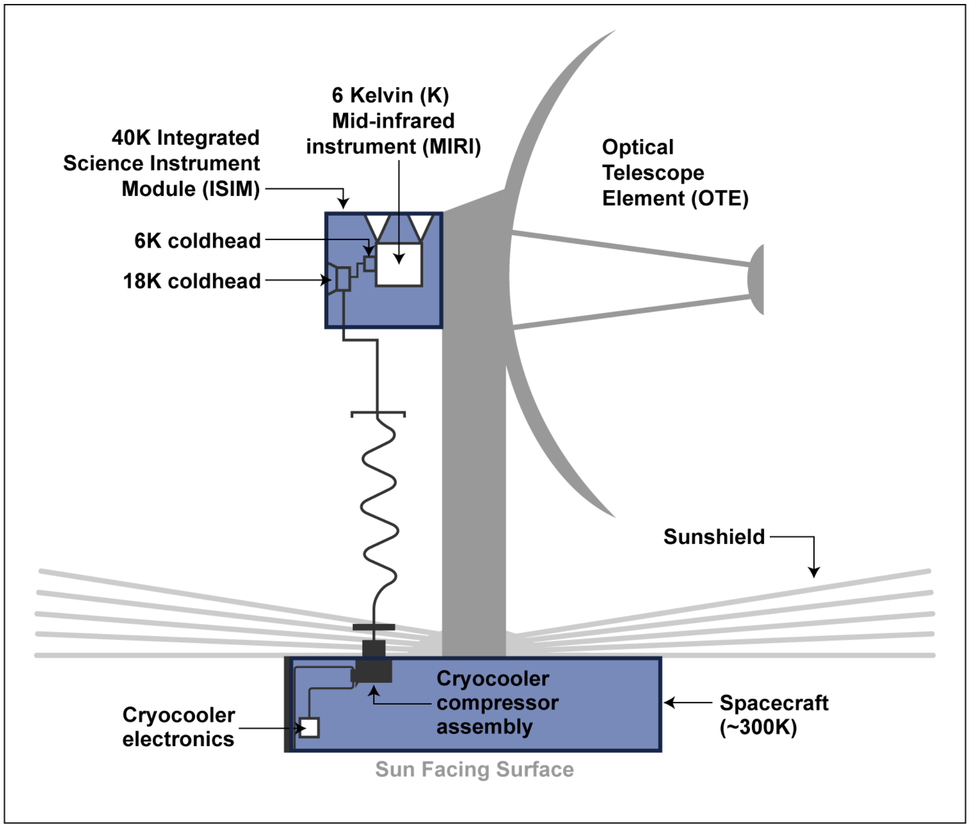



Sources: GAO (analysis); NASA (data and images).

## Optimal Environment for Instrument to Function

The Mid-Infrared Instrument (MIRI)—one of JWST's four instruments in the Integrated Science Instrument Module (ISIM)—requires a dedicated, interdependent two-stage cooler system designed to bring the optics to the required temperature of 6.7 Kelvin (K), just above absolute zero. This system is referred to as a cryocooler. See figure 2 for a depiction of the cooling system on JWST.

**Figure 2: Components of the Mid-Infrared Instrument Cryocooler**




Source: GAO presentation of NASA data.

Note: Not drawn to scale.

The cryocooler moves helium gas through 10 meters (approximately 33 feet) of refrigerant lines from the sun-facing surface of the JWST observatory to the colder shaded side where the ISIM is located. According to NASA officials, a cooler system of this configuration, with so much separation between the beginning and final cooling components, has never been developed or flown in space before. Project officials stated that the MIRI cryocooler is particularly complex and challenging because of this relatively great distance between cooling components located in different temperature regions of the observatory and the need to overcome multiple sources of unwanted heat through the regions before the system can cool MIRI. Specifically, the cooling components span temperatures ranging from approximately 300K (about 80 degrees Fahrenheit, or room temperature) where the spacecraft is located on the sun-facing surface of the telescope to approximately 40K (about -388 degrees Fahrenheit) within the ISIM.

## History of Cost Growth, Low Project Reserves, and Schedule Delays

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 reserve funding—funding used to mitigate issues that arise but which were previously unknown.[6] In April 2006, an Independent Review Team confirmed that the project's technical content was complete and sound, but expressed concern over the project's reserve funding, reporting that it was too low and phased in too late in the development lifecycle. 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.

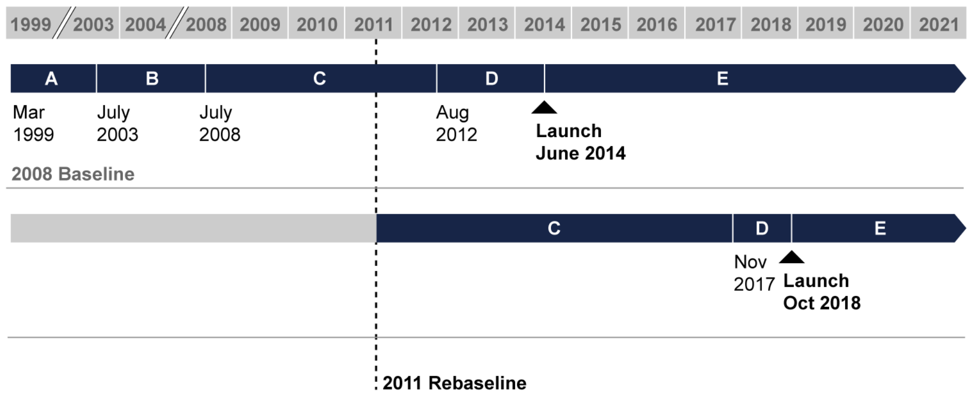
In response to a request from the Chair of the Senate Subcommittee on Commerce, Justice, Science, and Related Agencies to the NASA Administrator for an independent review of JWST—stemming from the

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

project's cost increases and reports that the June 2014 launch date was in jeopardy—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.[7] The panel concluded JWST was executing well from a technical standpoint, but that the baseline funding did not reflect the most probable cost with adequate reserves in each year of project execution, resulting in an unexecutable project. Following this review, the JWST program underwent a replan in September 2011 and was reauthorized by Congress in November 2011, which placed an $8 billion cap on the formulation and development costs for the project. On the basis of the replan, NASA announced that the project would be rebaselined with a life-cycle cost at $8.835 billion—a 78 percent increase—and would launch in October 2018—a delay of 52 months. The revised life-cycle cost estimate included 13 months of funded schedule reserve. In the President's Fiscal Year 2013 budget request, NASA reported a 66 percent joint cost and schedule confidence level associated with these estimates. A joint cost and schedule confidence level, or JCL, is the process NASA uses to assign a percentage to the probable success of meeting cost and schedule targets and is part of the project's estimating process. Figure 3 shows the original baseline schedule and the revised 2011 baseline for JWST.

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

**Figure 3: James Webb Space Telescope 2008 Baseline and Revised 2011 Schedules**




Phase A – Concept development

Phase B – Preliminary design and technology completion

Phace C – Final design and fabrication

Phase D – System assembly, integration and test

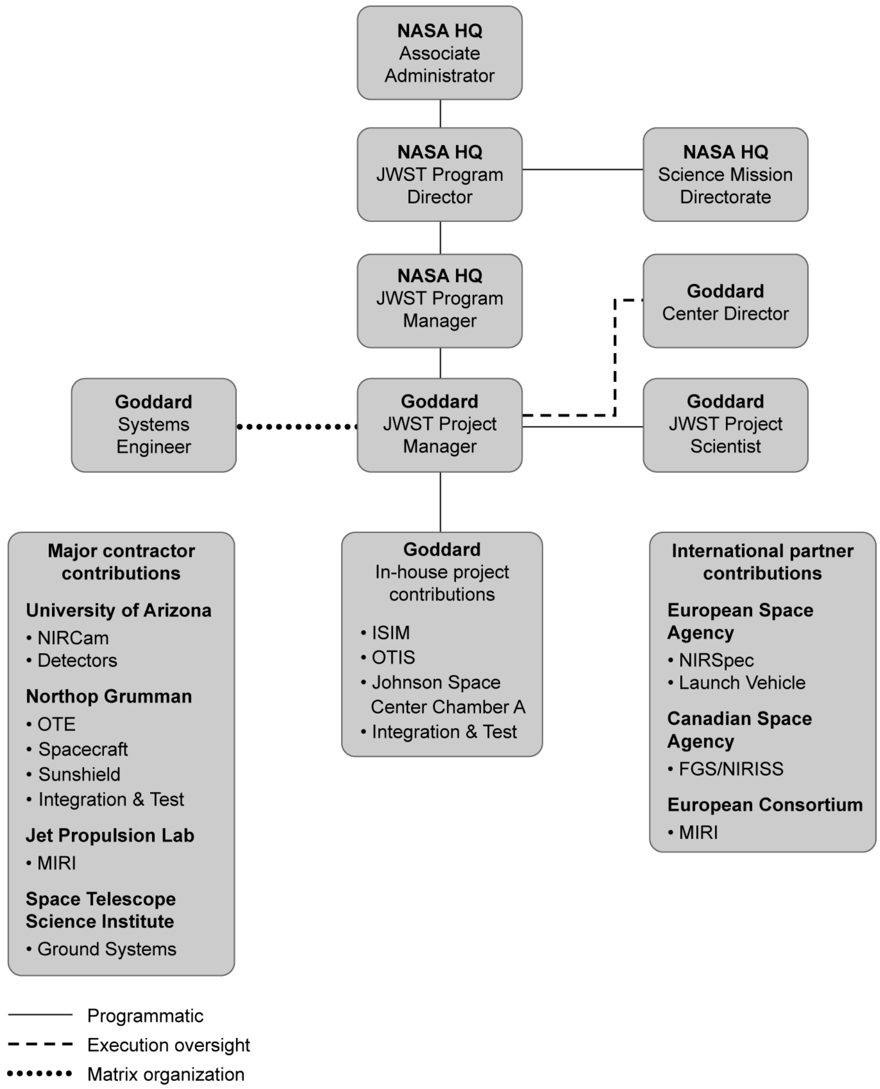
Phase E – Operations and sustainment

Source: GAO analysis of NASA data.

As part of the replan in 2011, JWST was restructured and is now a single project program reporting directly to the NASA Associate Administrator for programmatic oversight and to the Associate Administrator for the Science Mission Directorate for technical and analysis support.[8] Goddard Space Flight Center is the NASA center responsible for the management of JWST. See figure 4 for the current JWST organizational chart.

[8]A project typically reports to a program within a mission directorate, such as the Science Mission Directorate. A similar reporting structure was also instituted in the past with both the Hubble Space Telescope and the Mars Exploration Program when they began experiencing significant cost and schedule issues. For JWST, the change was made in response to recommendations from the ICRP.

**Figure 4: Organizational Chart for the James Webb Space Telescope Program**




Source: GAO analysis of NASA information.

## GAO Reviewed JWST Project in 2012

In 2012, we reported on numerous technical challenges and risks the project was facing.[9] For example, a combination of numerous instrument delays and leaks in the cryocooler's bypass valves resulted in the use of 18 of ISIM's 26 months of schedule reserve and the potential for more schedule reserve to be consumed. Additionally, we identified that the current JWST schedule reserve lacked flexibility for the last three integration and testing events (OTIS, the spacecraft, and observatory), planned for April 2016 through May 2018. While there was a total of 14 months of schedule reserve for all five integration and test events—when problems are more likely to be found—only 7 months were likely to be available for these last three efforts. We also reported that the spacecraft exceeded the mass limit for its launch vehicle and that project officials were concerned about the mass of JWST since the inception of the project because of the telescope's size and limits of the launch vehicle.[10] In addition to these technical challenges, 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.

In our December 2012 report, we made numerous recommendations focused on providing high-fidelity cost information for monitoring project progress and ensuring technical risks and challenges were being effectively managed and sustaining oversight. One recommendation was that the project should perform an updated integrated cost/schedule risk, or JCL, analysis. In addition, we recommended that the JWST project conduct a separate review to determine the readiness to conduct integration and test activities prior to the beginning of the OTIS and spacecraft integration and test efforts. NASA concurred with these two recommendations.

[9] GAO-13-4

[10] Mass is a measurement of how much matter is in an object. It is related to an object's weight, which is mathematically equivalent to mass multiplied by acceleration due to gravity. The project uses mass for JWST because when it goes into space, its weight changes with gravity, but its mass stays the same.

## JWST Project Is Generally Executing to Its 2011 Cost and Schedule Baseline; Recent Performance Has Declined

The JWST project is generally executing to its September 2011 revised cost and schedule baseline. Through the administration's annual budget submissions, NASA has requested funding for JWST that is in line with the rebaseline plan and the project is maintaining 14 months of schedule reserve to its October 2018 launch date. Cumulative performance data from the prime contractor, which is responsible for more than 40 percent of JWST's remaining $2.76 billion in development costs, indicate that work is being accomplished on schedule and at the cost expected. Monthly cost and schedule metrics, however, indicate that this performance has been declining since early 2013. The JWST project is maintaining oversight established as part of the replan, for example, by continuing quarterly NASA and contractor management meetings and instituting a cost and schedule tracking tool for internal efforts. The project, however, is not planning to perform an updated integrated cost and schedule risk analysis, which would provide management and stakeholders with information to continually gauge progress against the baseline estimates.

### Rebaselined Cost Commitments Are Being Met; Recent Work Is Costing More Than Planned

The JWST project is executing to the cost commitment agreed to during the September 2011 rebaseline. Since that time, NASA's funding requests for JWST have been consistent with the budget profile of the new cost rebaseline. For fiscal year 2013, the funding the project received—almost $628 million—matched the agency's budget request. In addition, the project has been able to absorb cost increases on various subsystems through the use of its cost reserves. Project officials remain confident that they can meet their commitments, and stay within an $8 billion development cost cap recommended by congressional conferees, if funding is provided as agreed during the replan.

Performance data from contractors show that planned work was generally being performed within expected costs, but performance has declined over the past year. The project collects earned value management (EVM) cost data from several of its major contractors and subcontractors.[11] EVM

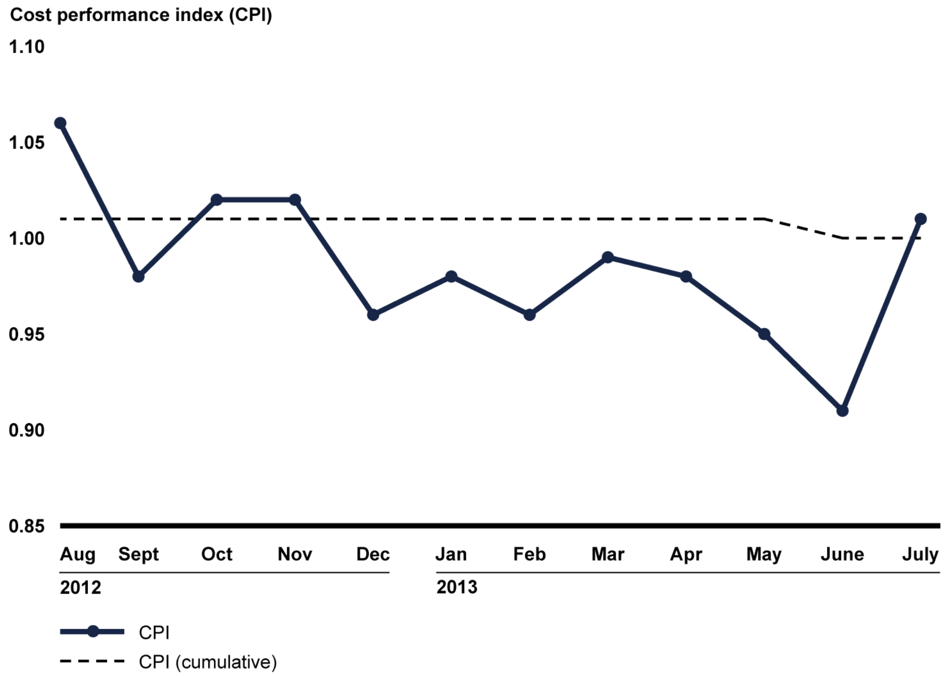
[11]Earned value management is a project management tool that integrates the technical scope of work with schedule and cost elements and compares the value of work accomplished in a given period with the value of the work expected in that period. When used properly, earned value management can provide 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.

data for Northrop Grumman—the project's prime contractor which is responsible for more than 40 percent of the remaining development costs—indicates that cumulatively from May 2011 work planned is being performed at the cost expected.[12] This measure, known as the cumulative cost performance index (CPI), provides an indication of how a contractor has performed over an extended period of time. The CPI indicates that until June 2013 the contractor performed slightly more work for the cost incurred than what was expected.[13] Recent monthly performance, however, has begun to lower the cumulative index. From December 2012 until June 2013, monthly CPI data, which gives an indication of current performance, show that the contractor has been accomplishing less work than planned for the cost incurred. See figure 5.

[12]Project officials state that they reached agreement on a revised cost estimate for the work being performed by Northrop Grumman as part to the replan; however, the contract modification was not signed until December 2013.

[13]Cost performance index (CPI), the ratio of work performed (or earned value) to actual costs for work performed. A CPI less than 1 is unfavorable, because work is being performed less efficiently than planned; a CPI greater than 1 is favorable, implying that work is being performed more efficiently than planned. CPI can be expressed in dollars: 0.9 means that for every dollar spent, the program has received 90 cents worth of completed work. The CPI is calculated both from the monthly EVM data reported and as a cumulative metric from the establishment of the baseline.

**Figure 5: Cumulative and Monthly CPI for the James Webb Space Telescope Prime Contract from August 2012 to July 2013**




Source: GAO analysis of NASA data.

Although several subsystems are experiencing positive performance, cost overruns on spacecraft-related development activities are contributing to this recent trend. For example, Northrop Grumman has reported negative performance within the spacecraft systems engineering and the electrical power subsystems activities for a 6-month period as of the end of June 2013. We calculate that this contract, which is approximately two-thirds complete, could experience a slight cost overrun based on current data. Northrop Grumman is using cost management reserves to offset the decline in performance, but the JWST project reports that Northrop Grumman is consuming cost reserves at a rate faster than planned.

Contractor EVM cost data for ITT/Exelis—which is providing services related to the OTE and OTIS integration and test efforts—also indicate that in recent months the contractor has been accomplishing less work than planned for the cost incurred. ITT/Exelis has experienced cost overruns in each month from March through June 2013, which has lowered the cumulative CPI to 0.98. Project officials told us that the ITT/Exelis has sufficient cost reserves to offset the recent cost overruns and that a cumulative CPI of 0.98 is within the range of acceptable performance. Best practices indicate that a CPI of 1.0 or above is favorable.[14] We found small cost overruns across many elements of the work being performed by ITT/Exelis, similar to the analysis performed by the project. Based on our analysis of EVM data through the end of July 2013, we estimate that this contract could experience a small cost overrun. As of July 2013, ITT/Exelis had completed a little more than one-third of the planned work for this contract and used more than 44 percent of available management reserves from October 2012 to July 2013.

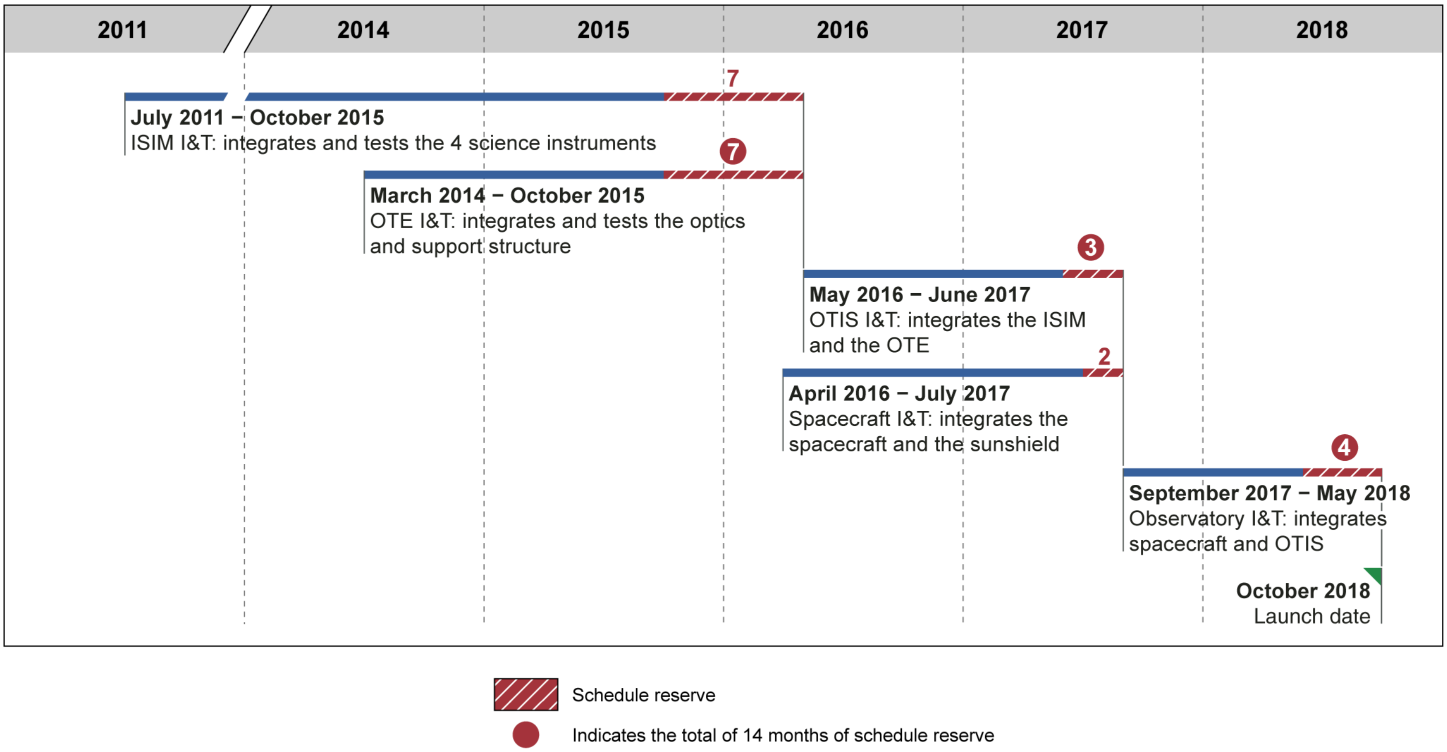
In addition to the work being performed by contractors, the JWST project also performs development work internally at NASA's Goddard Space Flight Center. For example, the project internally manages the ISIM development effort that is expected to cost over $1 billion, which includes the first of five major integration and test efforts. The current estimated cost at completion for ISIM as calculated by the project has risen more than $109 million—a 9.8 percent increase—since the 2011 rebaseline of the project. The cost overrun is primarily because of late instrument deliveries and is being accommodated through the use of project reserves.

## JWST Is Executing to Its Rebaselined Schedule; Recent Work Is Taking Longer Than Planned

The JWST project is executing to the baseline schedule commitment agreed to during the September 2011 rebaseline. The JWST project continues to report 14 months of schedule reserve to its October 2018 launch date, pending a review of the need to use schedule reserve based on the impacts of the government shutdown in October 2013. See figure 6.

[14] GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: Mar. 2, 2009).

**Figure 6: Project Integration and Test (I&T) Timeline**




Source: GAO analysis of NASA data.

We found in 2012 that the 7 months of schedule reserve held by the OTE subsystem will likely be used during its integration and test, prior to delivery to OTIS. If the OTE integration and test effort uses schedule reserve beyond those 7 months, it will reduce the amount of schedule reserve available for the last three integration and test efforts. Northrop Grumman officials said that the OTE integration and test effort is very sequential and does not offer much flexibility to allow for changes to the process flow. The integration and test of OTE must be complete for the OTIS integration effort to begin on schedule. In December 2013, the project indicated that the 14 months of total schedule reserve held by the project was being assessed due to delivery problems with portions of the observatory's sunshield and the impact of the government shutdown.

Because of instrument and hardware delays and non-availability of a test chamber, the project now reports 7 months of schedule reserve associated with the ISIM integration and test effort before it is needed for integration with the OTE subsystem to form OTIS. Previously, the project reported that ISIM had almost 8 months of schedule reserve, which did not account for the delayed start of the first scheduled cryo-vacuum test—in which a test chamber is used to simulate the near-absolute zero temperatures in space. The current 7 months of schedule reserve for the ISIM integrations and test effort does not include the impact of any potential delays due to the government shutdown in October 2013, which was still being determined in mid-December 2013. The first cryo-vacuum test was considered a risk reduction test by the project because it did not include two of the project's four instruments and was to test procedures and the ground support equipment to be used in later cryo-vacuum tests of ISIM. During the replan, this test was scheduled to begin in February 2013, but was delayed until August 2013 because of several issues, including availability of the test chamber and delays in development and delivery of a radiator for the harness that holds electrical wiring. Project officials said they will adjust the ISIM schedule to minimize the schedule impact by performing some activities concurrently, delaying some activities until after the first cryo-vacuum test, and removing some activities. They added that a recently approved September 2013 revision to the ISIM schedule only reduced schedule reserve by 1 week and no additional risk will be incurred based on these changes to the ISIM schedule. The two subsequent cryo-vacuum tests, however, have slipped up to 2 months in the latest revision to the ISIM schedule, although project officials state that the April 2016 completion date for ISIM testing and delivery to the OTIS integration and test effort remains unchanged. According to the JWST program manager, however, the first cryo-vacuum test was in process when the government shutdown happened and, although many of the testing goals were accomplished through prioritization of test activities, the test was terminated once the ISIM staff resumed work and some activities were not accomplished. As a result, he said that the project would incur more risk in the second cryo-vacuum test that is currently scheduled to start in April 2014.

In addition to maintaining up to 14 months of schedule reserve, the project is generally meeting the milestones it reports to Congress and other external entities. See table 1. These milestones include technical reviews prior to the spacecraft critical design review, hardware tests, and the delivery of key pieces of hardware. As shown in the table, the project has completed the majority of its milestones as planned and has deferred six milestones in the past 2 fiscal years. Among the deferred milestones are delays to completion of the first ISIM cryo-vacuum test and delivery of flight hardware for the MIRI instrument cryocooler.

**Table 1: Status of James Webb Space Telescope Top-level Project Milestones**

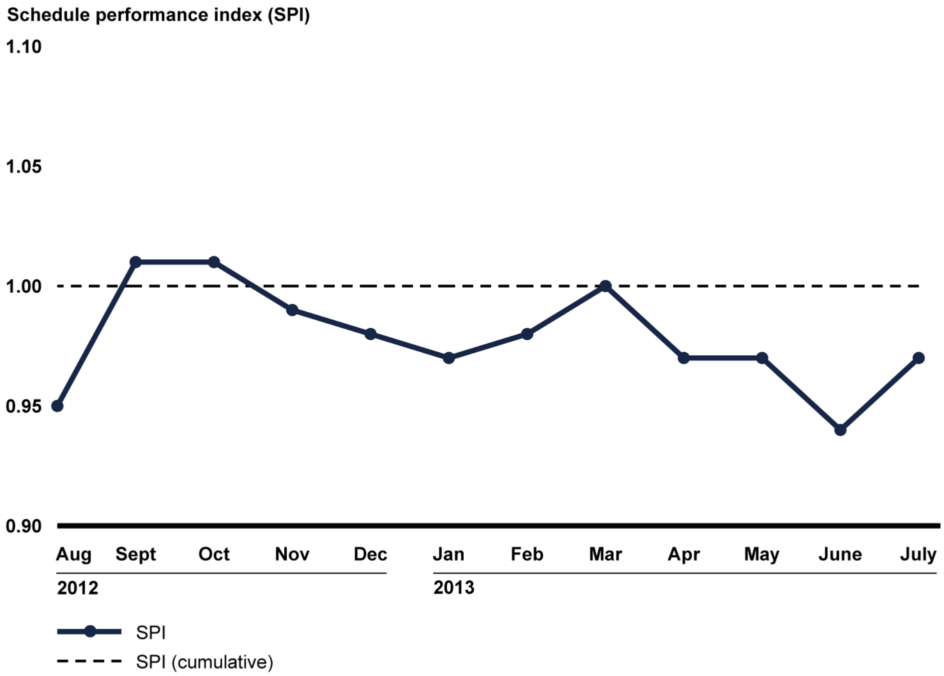
| | Total milestones | Milestones completed | Milestones deferred to future year |
|---|---|---|---|
| Fiscal year 2011 | 21 | 21 | 0 |
| Fiscal year 2012 | 37 | 34 | 3 |
| Fiscal year 2013 | 41 | 38 | 3 |

Source: GAO presentation of NASA data.

EVM schedule data for Northrop Grumman indicates that the cumulative planned work since the new schedule estimate was agreed upon is being performed as expected. This measure, known as the cumulative schedule performance index (SPI), shows consistent performance at the aggregate level for the past year.[15] However, monthly SPI metrics indicate a slight decline in performance in 9 of the 12 months between August 2012 and July 2013. See figure 7.

[15]Schedule performance index (SPI), the ratio of work performed (or earned value) to the initial planned schedule. An SPI less than 1 indicates that work is not being completed as planned and the program may be behind schedule if the incomplete work is on the critical path; an SPI greater than 1 means work has been completed ahead of the plan. An SPI can be thought of as describing work efficiency: 0.9 means that for every dollar planned, the program is accomplishing 90 cents worth of work. The SPI is calculated both from the monthly EVM data reported and as a cumulative metric from the establishment of the baseline.

Figure 7: Cumulative and Monthly SPI for the James Webb Space Telescope Prime Contract from August 2012 to July 2013




Source: GAO analysis of NASA data.

The data from Northrop Grumman in recent months indicates that work is slightly behind schedule for the spacecraft subsystem.

## JWST Project Maintained and Enhanced Oversight Initiatives, but is Not Planning to Perform Updated Cost and Schedule Risk Analysis to Support Monitoring of Project Progress

The JWST project has maintained the oversight activities put in place following the replan and added additional oversight mechanisms. For example, some of the oversight activities implemented as part of the 2011 replan that are still ongoing include

- The JWST Program Director is holding monthly meetings with the NASA Associate Administrator,
- The JWST Program Director is holding quarterly meetings with Northrop Grumman senior management and the Goddard Space Flight Center Director, and
- The JWST Project Spacecraft Manager has relocated to provide an on-site presence at the Northrop Grumman facility.

The project also has implemented some new oversight mechanisms since the time of our last review in 2012, according to JWST officials. For example, the project is implementing a tool to continually update the cost estimate for the internal work on the ISIM development activities. In addition, the project is working with the Space Telescope Science Institute to design a tool, similar to EVM, to monitor progress on ground systems development. The project also has added a financial analyst at the Northrop Grumman facility to provide the spacecraft manager and the project ongoing and increased financial insight of the work being performed by Northrop Grumman and to analyze monthly data prior to the monthly project business meetings with the contractor. In response to our prior recommendation, the project has modified its schedule to add an independent review prior to the beginning of the OTIS and spacecraft integration and test efforts.[16]

Despite these improvements in oversight, JWST project officials said that they are not planning to perform an updated integrated cost/schedule risk analysis—or joint cost and schedule confidence level (JCL) analysis as we recommended in 2012.[17] GAO's cost estimating best practices call for a risk analysis and risk simulation exercise—like the JCL analysis—to be conducted periodically through the life of a program, as risks can materialize or change throughout the life of a project.[18] Unless properly updated on a regular basis, the cost estimate cannot provide decision makers and stakeholders with accurate information to assess the current status of the project. As we recommended in 2012, updating the project's JCL would provide high-fidelity cost information for monitoring project progress. While NASA concurred with our recommendation, project

[16] GAO-13-4.

[17] 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).

[18] GAO-09-3SP.

officials have subsequently stated that they do not plan to conduct an updated JCL. A program official stated that the project performs monthly integrated programmatic and cost/schedule risk analyses using various tools and that the information that these tools provide is adequate for their needs. For example, the JWST project conducts on-going risk identification, assigning probability and dollar values to the risks, tracks actual costs against planned costs to assess the viability of current estimates, uses earned value management, and performs schedule analyses.

Moreover, while the JWST program manager acknowledged that NASA concurred with our recommendation, he said that the agency interpreted that it would be sufficient to do these lower level analyses instead of performing an updated JCL. NASA, however, has not addressed the shortcomings of the schedule that supports the baseline itself. For example, we found that the lack of detail in the summary schedule used for JWST's last JCL in May 2011 prevented us from sufficiently understanding how risks were incorporated, therefore calling into question the results of that analysis. Since the JCL was a key input to the decision process of approving the project's new cost and schedule baseline estimates, we maintain that the JWST project should perform an updated JCL analysis using a schedule that should now be much more refined and accurate and has sufficient detail to map risks to activities and costs in addition to the other analyses they currently perform. Doing so could help increase the reliability of the cost estimate and the confidence level of the JCL. Furthermore, risk management is a continuous process that constantly monitors a project's health. The JWST project is still executing to a plan that was based on the JCL performed in May 2011. The risks the project is currently facing are different than those identified during the JCL process more than 2 years ago, and will likely continue to evolve as JWST is still many years from launch.

## Project Made Progress Addressing Technical Risks; Challenges Persist

The JWST project has made progress in addressing some technical risks; however, other technical challenges exist that have caused development delays and cost increases at the subsystem level. The project and its contractors have nearly addressed a problematic valve issue in the MIRI cryocooler that has been a concern for several years, the OTE and ISIM development efforts have made progress over the past year, and both the project and contractors have remedied the spacecraft mass issue that we reported on last year. The project has other technical issues, however, that still need to be resolved. For example, there is a separate and significant performance issue with the cryocooler and though project officials state that they understand the issue, the subcontractor is still working to validate the changes made to the cryocooler to address the issue. These issues with the cryocooler have led to an increase of about 120 percent in cryocooler contract costs and the execution of the remaining cryocooler effort will be challenging. In addition, the OTE and ISIM efforts are still addressing risks that threaten their schedules.

## Despite Progress, Cryocooler Performance Issues Led to Multiple Replans, Increased Costs, and Schedule Delays

Despite progress in some areas, the cryocooler development effort has been and remains a technical challenge for the project. The cryocooler subcontractor has addressed much of the valve leak issue that we reported on in 2012, and all but the last of the replacement valves, which were produced with new seal materials, have successfully completed testing. While resolution of this issue will be a positive step for the project, other, still unresolved issues with the cryocooler have arisen that have required additional cost and schedule resources to address. Specifically, a key component of the cryocooler underperformed prior tests of this technology by about 30 percent. In addition, both the Jet Propulsion Laboratory (JPL)—which awarded the cryocooler subcontract—and the subcontractor were focused on addressing the valve issue, which limited their attention to the cooling underperformance issue. In late 2012, the cryocooler subcontractor reported that it would be unable to meet the cryocooler schedule. The subcontractor is working toward a revised test schedule, agreed upon in April 2013, which delays acceptance testing and includes concurrent testing of hardware.[19] In August 2013, the cryocooler subcontract was modified to reflect a 69 percent cost increase. Additionally, the number of subcontractor staff assigned to the cryocooler subcontract has increased from 40 to approximately 110, which accounts for a significant portion of the cost increase. This was the second time in less than 2 years that the cryocooler subcontract was modified. Cumulatively, the cryocooler subcontract value has increased by about 120 percent from March 2012.

Various issues may have contributed to the current problems with the cryocooler. For example, according to project and JPL officials they had not verified the cryocooler cost and schedule estimates provided by the subcontractor prior to the project establishing new baseline cost and

[19]Acceptance testing evaluates whether a specific component meets specifications and is suitable for flight.

schedule estimates in 2011. Doing so may have allowed them to ensure adequate resources were accounted for in the new baseline estimates. JPL officials stated that the subcontractor proposal was verified prior to the completion of the March 2012 cryocooler replan. The subcontractor, however, reported that the 2012 replan did not include cost or schedule allowance for rework should additional problems arise, which did happen. In addition, despite erratic and negative EVM data from the subcontractor immediately following the March 2012 cryocooler replan, an in-depth review was not initiated until 9 months later by the cryocooler subcontractor. JPL officials stated that, during this time, they were performing analysis of the EVM data and the technical progress of the subcontractor and provided the results of their analysis to the project. Finally, the project had not followed key best practices since early in development, which left it at an increased risk of cost and schedule delays. For example, best practices call for testing of a model or prototype of a critical technology in its flight-like form, fit, and function and in a simulated realistic or high fidelity lab environment by its preliminary design review. While the subcontractor tested a demonstration model of the cryocooler in such an environment and the project assessed the technology as mature in 2008, a project official acknowledges that the demonstration model's mechanical design was different than what would be used in space and, according to that official, those differences led to the loss of performance between the demonstration model and the current cryocooler. In addition, only 60 percent of the cryocooler's expected design drawings were released as of the mission critical design review—well below the best practice standard of 90 percent drawings released by critical design review—indicating that the project moved forward without a stable cryocooler design as well as an immature cryocooler technology, which increases risk.

The execution of the remaining cryocooler schedule will continue to be challenging as the performance issue is not resolved, the revised schedule is optimistic, the subcontractor has identified significant risks not incorporated in the rebaseline, and there are risks associated with the revised testing approach. The cryocooler subcontractor has developed a separate verification model, which is now being used to validate that the cryocooler redesign will address the underperformance. This step is important because, according to the cryocooler subcontractor program manager, the internal structures of the cryocooler component are intricate and once a unit is completed the internal structure cannot be modified. Thus, when issues arise, such as use of incorrect parts or unexpected underperformance, a new unit must be built rather than simply changing parts on the underperforming cryocooler component. Testing of the verification model, which will give an indication of whether the performance issue has been rectified and a new flight model can be built, was scheduled to be complete in October 2013, but has been delayed. The subcontractor project manager reports that issues were found with processes used to assemble the verification model that must be resolved before testing resumes, which is not expected until at least late December 2013. This delay may reduce the amount of schedule margin available to the overall cryocooler effort.

The cryocooler schedule—agreed upon in April 2013—was optimistic, according to the cryocooler subcontractor program manager. Shortly after the new schedule was put in place, he told us that he had low confidence that the subcontractor would be able to meet this schedule based on the development issues mentioned above. In addition, the JPL scheduler for the cryocooler said that he had only moderate confidence of the subcontractor's ability to meet this schedule. In line with their concerns, the cryocooler subcontractor recently depleted all of its schedule reserve for deliveries to JPL prior to the start of acceptance testing. The cryocooler subcontractor also identified other risks that could impact its execution of the subcontract, but that were not included as part of the rebaseline plan in the modified subcontract. The project retained financial responsibility for addressing those risks, should they arise, at the project level by identifying over $8 million in cost reserves in fiscal years 2014 and 2015. However, some of these risks could require significantly more than $8 million to address. For example, the cryocooler subcontractor program manager stated that some of these risks, if realized, could take a year to mitigate. As of September 2013, delivery dates agreed to in April 2013 for all of the major flight and spare cryocooler components have been delayed, all six weeks of schedule reserve being held at the cryocooler subcontractor had been exhausted, and the start of acceptance testing at JPL has been delayed. Any further delays will have to be accommodated through the use of 12 weeks of schedule reserve held by JPL. The cryocooler subcontractor also recently began reporting EVM data based on the latest cost and schedule estimates and, in line with the delays mentioned above, this data already shows that work is costing more and taking longer than planned. JPL's schedule reserve also has to support any issues that arise during acceptance and end-to-end testing of the cryocooler hardware prior to delivery to the spacecraft integration and test effort.[20]

In an effort to reduce this risk, the project reordered the integration and test schedule. This removed some, but not all, of the cryocooler component testing schedule risk, which may limit the project's ability to address issues that arise during component testing. Specifically, two major spare components of the cryocooler will still be in acceptance testing when spacecraft integration and test begins in April 2016, which is also a risk to the spacecraft integration and test schedule. For example, if a particular cryocooler component fails during one test and a spare component is still undergoing acceptance testing, then the test schedule may be delayed waiting for repairs to be made to the component or for the spare component to be available.

## OTE and ISIM Have Made Progress but Face Risks That May Impact Schedule

Northrop Grumman has made progress on the OTE, but the project expects the contractor to use its current schedule reserve and the OTE is facing risks that may impact the schedule if they are realized. Progress has been made over the past year in fabricating the OTE support structure, which holds the mirrors and ISIM and connects all the pieces of the observatory. Specifically, all of the support structure sections have been completed and fully integrated and the structure has entered cryovacuum testing. The project is tracking an issue with release mechanisms holding the spacecraft and the OTE together while stowed within the launch vehicle and used during the deployment of the telescope after launch. Currently the mechanisms are causing excessive shock vibration when released. According to a NASA official, the project and the contractor are evaluating potential solutions which include changes to the design of the release mechanism, using damping materials to lessen the impact to the spacecraft, and testing to see if the shock requirement can be relaxed. The project has delayed the release mechanism design review until January 2014—after the spacecraft critical design review—while it works to mitigate the issue with contractors. Project officials stated the results of this component level design review will be evaluated prior to a larger mission review to be held later in 2014. In December 2013, the project was also assessing the possibility that

[20]The end-to-end test, which includes representative components to simulate portions of the MIRI, will evaluate the performance of the entire cryocooler rather than individual components.

portions of the observatory's sunshield may be delivered up to 3 months late, which could impact the amount of schedule reserve being held by the project. The project indicates that it is considering options by the contractor to recover some of that potential schedule delay.

The project has made progress on various portions of the ISIM as well. For example, two of the four instruments have been integrated into the ISIM for testing and fabrication of replacement near infrared detectors used in three of the four instruments—which we reported in 2012 may need to be replaced—is ahead of schedule. Prior schedule conflicts with another NASA project, however, delayed the start of the ISIM integration and test effort and instrument and component delays are further threatening the ISIM integration and test schedule which may lead to additional cost increases. The project has already replanned the ISIM schedule flow due, in part, to delays with the Near-Infrared Camera (NIRCam) and Near-Infrared Spectrograph (NIRSpec) instruments. Specifically, the NIRSpec instrument and NIRCam's optics were delivered more than a year behind schedule. NIRSpec completed environmental testing and was delivered to Goddard in late September 2013. An electronics component of the NIRCam instrument, however, failed functional testing following a vibration test possibly due to manufacturing defects. The contractor has developed an approach to screen similar components to verify whether those components have similar anomalies. If the components pass the screening process, then environmental testing will continue with a spare in place of the component that malfunctioned. If all of the components show similar anomalies, they will be restricted from vibration tests and used in other testing until replacement components are ready. This issue may impact the already delayed start of the second and third ISIM cryo-vacuum tests, which would further compress the ISIM integration and test schedule or require the project to use some of ISIM's schedule reserve. Because the ISIM schedule has already been compressed, the project will have less flexibility should any issues or delays arise during this effort. The project is covering the current ISIM-related cost increase—9.8 percent—primarily with funding reserves. Extending the length of time needed to conduct the ISIM integration and test effort, should there be further delays, would require maintaining test personnel and facilities longer than planned, which may lead to further cost increases.

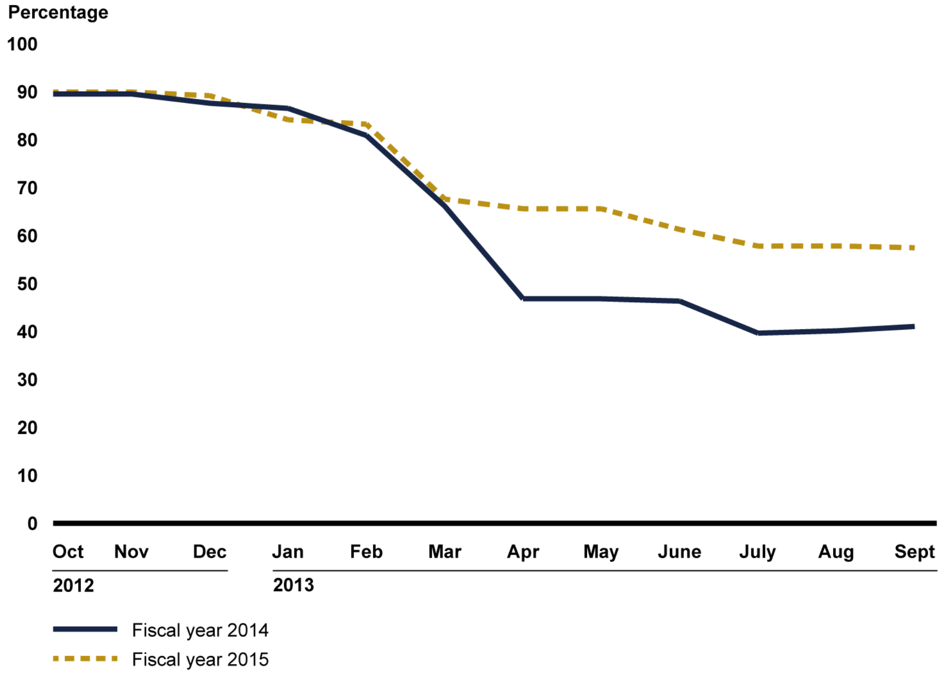
## Northrop Grumman Has Addressed Spacecraft Mass Issues

Northrop Grumman has successfully addressed the spacecraft mass issue that we reported on in 2012 and project officials state that they are comfortable with the observatory mass margin as the project heads into multiple major integration and test efforts, despite the mass margin being lower than Goddard standards. In December 2012, we reported that the spacecraft was more than 200 kilograms over its mass allocation. In November 2013, Northrop Grumman officials stated that the spacecraft was under its mass allocation at that time. Since December 2011, both the contractor and the project made mass reduction a priority and the contractor currently has margin available to address future issues that may require additional mass to solve. The project's current overall mass margin is approximately 7.7 percent, which does not include 90 kilograms of additional mass allocation the project received in 2013 from the launch vehicle provider. This is lower than the Goddard standard of 15 percent mass margin at this phase of development. According to project officials, they applied the Goddard standard at the subsystem level rather than at the observatory level due to JWST's complexity, which allowed them to maintain a lower overall observatory mass margin. They added that the observatory and its component elements have an acceptable amount of mass margin as the project enters its major integration and test efforts and, while they will maintain standard mass controls to avoid unnecessary growth, they do not expect mass margins to be a significant concern going forward. We plan to continue to monitor mass margin in future reviews as the project proceeds through integration and test efforts.

# Near-term Funding Constraints May Limit Project's Ability to Meet Future Commitments

Several current near-term funding constraints such as low cost reserves, a higher-than-expected rate of spending, and potential sequestration impacts are putting at risk NASA's ability to meet its cost and schedule commitments for JWST. In September 2013, project officials reported that while they are making good technical progress, the level of cost reserves held by the project in fiscal year 2014 had become the top issue facing the project and may require them to defer future work. Although not currently identified as an issue by the project, a significant portion of fiscal year 2015 project-held cost reserves have also already been allocated. This does not take into account reserves held by the JWST program at NASA headquarters in fiscal years 2014 and 2015 that can be used to supplement reserves held by the project. However, fiscal year 2014 program reserves are minimal compared to future years. As of September 2013, the project has allocated approximately 60 and 42 percent of its reserves in fiscal years 2014 and 2015, respectively. See figure 8.

Figure 8: James Webb Space Telescope Fiscal Year 2014 and 2015 Project-held Reserves Remaining as of September 2013 Based on Allocations in Fiscal Year 2013




Source: GAO analysis of NASA data.

The need to allocate a significant portion of cost reserves in fiscal year 2014 and 2015 has been driven primarily by the technical issues with the MIRI cryocooler. Specifically, the subcontract modification resulting from the cryocooler replan required the allocation of over $25 million of cost reserves in fiscal year 2014 and 2015. After allocation of these cost reserves, the project began tracking the risk of low fiscal year 2014 cost reserves.

Project officials report that the project’s low reserve posture in fiscal year 2014 may require them to defer work to future years. Specifically, because the project continues to maintain 14 months of funded schedule reserve, it may begin using some of that schedule reserve to conduct work later or allow work to take longer than planned. There are risks associated with this approach, however. For example, prior to the project’s replan in 2011, low cost reserves and technical challenges forced project management to defer planned work into future years. This ultimately led to increased costs for the deferred work and a schedule that was unsustainable. Much of the remaining work on JWST involves the five major integration and test efforts—which began in fiscal year 2011—during which work is often sequential in nature and cost and schedule growth typically occurs. Depleting schedule reserve now could impact project officials' ability to address technical risks or challenges not currently identified or realized, but that will likely arise during this phase. Project officials said that they would like to strike a balance between using remaining cost reserves and having to utilize schedule margin to complete planned work and address currently unknown technical challenges, but their goal is to use as little schedule margin as possible in fiscal year 2014.

Northrop Grumman has also identified issues with the adequacy of its cost management reserves in fiscal year 2014. The project shares this concern given that Northrop Grumman's cost reserves are eroding faster than anticipated. As of October 2012, the contractor held more than $244 million in cost management reserves for the remainder of the contract, but has used almost 24 percent of those management reserves since then. The approximately $185 million in cost management reserves Northrop Grumman has available as of September 2013 represents the total amount of reserves available through the remainder of the contract—almost 6 years—and not how much is available for use specifically for fiscal year 2014. The contract modification for the 2011 replan was signed in December 2013 and, according to the Northrop Grumman program manager, the amount of management reserve available will likely increase by more than $45 million once budget distributions are completed by the end of January 2014. In June 2013, Northrop Grumman had identified up to $80 million in potential risks for fiscal year 2014. Project officials said that Northrop Grumman will sometimes fund new contract requirements for future fiscal years with current year cost reserves. These officials added that they are in the process of determining whether the rate Northrop Grumman is spending cost reserves is a result of additional requirements or because of performance issues. According to JWST project analysts, Northrop Grumman cost management reserves also remain a challenge in fiscal year 2015 when compared to the potential threats. The JWST project manager said that the project could rephase some planned Northrop Grumman cost management reserves from future years to fiscal year 2014 instead, but that would require the project to use some of its fiscal year 2014 cost reserves, which as noted are already constrained. As noted earlier, the JWST Program at NASA headquarters maintains another set of cost reserves that could be used to help in situations such as this, but the bulk of these reserves will not be available until fiscal year 2015.

The project's rate of spending in fiscal year 2013 could also be a significant issue if it continues into fiscal year 2014 and officials have begun tracking the rate of spending as a risk. The project spent approximately $40 million more than planned in fiscal year 2013. According to program officials, the amount of this overage is becoming significant not because of a lack of funds in fiscal year 2013, but because the fiscal year 2014 budget and project cost reserves are constrained. Project officials said that they planned to carry over funding from fiscal year 2013 to support approximately 2½ months of work to help fund contracts and ensure continued operations during a potential continuing resolution or other periods of funding uncertainty. If the project were to receive its full funding allocation for fiscal year 2014 at the level planned, this 2013 money would supplement the money available to the project in 2014. But if the current rate of spending is sustained, the project would only carry over enough 2013 money to fund the project for about 7 to 8 weeks into fiscal year 2014. The lower amount of funding carried over will also cause the project to have less available to supplement shortfalls in future years. For example, the JWST program manager told us that Northrop Grumman has requested more funding in fiscal year 2014 than the amount planned. Program officials noted that if the project continues to spend in fiscal year 2014 at a rate experienced during the latter part of fiscal year 2013, it may not be able to carry any funds into fiscal year 2015 as planned. Project officials, however, indicate that they are confident that they will carryover funds into fiscal year 2015. Our review of the data found that the project's increased spend rate in fiscal year 2013 is due mainly to additional resources necessary for the ISIM due to late hardware deliveries, the cryocooler effort, and the Northrop Grumman effort to prepare for the spacecraft critical design review in January 2014.

NASA's ability to remedy these issues will likely be significantly hindered by the potential impacts from sequestration and competing demands from other major projects. For example, while NASA officials report that the agency was able to absorb the sequestration-related reductions in fiscal year 2013 with relatively no impact on its major projects, including JWST, they indicate that the agency cannot sustain all of its long-term funding commitments at sequester levels in fiscal year 2014 and beyond. Importantly, the JWST project recently began tracking a risk for the budget uncertainty due to sequestration. The risk outlines that there is a potential cut to the JWST budget starting in fiscal year 2014, which could adversely affect the execution of the project's current plan and potentially jeopardize the October 2018 launch date. The program office indicates that NASA headquarters directed JWST to plan for its fiscal year 2014 budget to be consistent with the replan. This direction by NASA could have an impact on other major NASA projects. In interviews for several other major NASA projects, officials informed us that they have less than adequate funding in fiscal year 2014 and some have requested that the agency rephase funds from later years to fiscal year 2014 to address the issue. If additional funds are required and prioritized for JWST, there could be a potentially significant impact on these and other projects within the agency that are already reporting funding issues in fiscal year 2014.

## Selected JWST Schedules Demonstrate Many Best Practices, but Identified Weaknesses Erode Confidence in the Project's Integrated Master Schedule

The reliability of the JWST integrated master schedule is questionable because some of the 23 subordinate schedules synthesized to create it are lacking in one or more characteristics of a reliable schedule. Schedule quality weaknesses in the JWST subsystem schedules transfer to the integrated master schedule. We found a similar result this year consistent with our analysis in 2012 in which weaknesses in the two subsystem schedules we analyzed undermined the reliability of the integrated master schedule.

According to scheduling best practices, the success of a program depends in part on having an integrated and reliable master schedule that defines when work will occur, how long it will take, and how each activity is related to the others that come both before and after it. If the schedule is dynamic, planned activities within the schedule will be affected by changes that may occur during a program's development. For example, if the date of one activity changes, the dates of its related activities will also change in response. The master schedule will be able to identify the consequences of changes and alert managers so they can determine the best response. The government project management office, in this case the JWST project office at Goddard Space Flight Center, is ultimately responsible for the integrated master schedule's development and maintenance.

The quality and reliability of three selected subsystem schedules we examined for this review—ISIM, OTE, and cryocooler—were inconsistent in following the characteristics of high-quality, reliable schedules. Using the 10 best practices for schedules, we individually scored and evaluated the schedules for these subsystems. We then grouped the best practices into one of four characteristics: comprehensive, well-constructed, credible, and controlled. The individual best practice scores within each characteristic were then combined to determine the final score for each characteristic. See appendix III for more detailed information on each characteristic and its corresponding best practices. The ISIM and OTE schedules had more strengths than weaknesses, substantially meeting three of four characteristics of a reliable schedule. The cryocooler schedule demonstrated weaknesses in both of the characteristics we examined.[21] We selected these three subordinate schedules because they represent the significant portion of ongoing work for the project and reflect work by the project, the prime contractor, and a subcontractor. Table 2 identifies the results of each of the selected JWST subordinate schedules and their corresponding best practices sub scores.

[21]We chose the well-constructed and credible characteristics because they represent the basic logic structure of the schedule, which determines the overall ability of the schedules to forecast dates reliably. We did not examine the comprehensive and controlled characteristics of schedule best practices as the cryocooler schedule was rebaselined in August 2013.

**Table 2: Integrated Science Instrument Module (ISIM), Optical Telescope Element (OTE), and Cryocooler Schedule Results for Characteristics and Associated Best Practices of a High-Quality and Reliable Schedule**

| Schedule characteristic or best practice | ISIM | OTE | Cryocooler |
|---|---|---|---|
| *Comprehensive* | ◕ | ● | Not assessed |
| 1. Capturing all activities | ◕ | ● | Not assessed |
| 3. Assigning resources to all activities | ◐ | ◕ | Not assessed |
| 4. Establishing the duration of all activities | ● | ● | Not assessed |
| *Well-constructed* | ◕ | ◐ | ◐ |
| 2. Sequencing all activities | ◕ | ◕ | ◕ |
| 6. Confirming that the critical path is valid | ◕ | ◐ | ◐ |
| 7. Ensuring reasonable total float | ◕ | ◐ | ◐ |
| *Credible* | ◐ | ◕ | ◐ |
| 5. Verifying that the schedule can be traced horizontally and vertically | ◐ | ◕ | ◐ |
| 8. Conducting a schedule risk analysis | ◔ | ◐ | ◔ |
| *Controlled* | ◕ | ◕ | Not assessed |
| 9. Updating the schedule using actual progress and logic | ◕ | ◕ | Not assessed |
| 10. Maintaining a baseline schedule | ◕ | ◕ | Not assessed |

Source: GAO analysis of detailed project level schedules and related documentation for the ISIM, OTE, and cryocooler.

Legend:

● = Met: The program office or contractor provided complete evidence that satisfies the entire criterion.

◕ = Substantially Met: The program office or contractor provided evidence that satisfies a large portion of the criterion.

◐ = Partially Met: The program office or contractor provided evidence that satisfies about half the criterion.

◔ = Minimally Met: The program office or contractor provided evidence that satisfies a small portion of the criterion.

○ = Not Met: The program office or contractor provided no evidence that satisfied any of the criterion.

## Integrated Science Instrument Module

Of the four characteristics of a reliable schedule that we assessed for the ISIM schedule, we found that three substantially met the criteria—comprehensive, well-constructed, and controlled—while the credible characteristic was partially met. The strengths of the ISIM schedule were that it

- captured all activities in manageable durations with their proper sequence,

- identified the longest continuous sequence of activities in the schedule, known as its critical path,[22] and
- estimated reasonable amounts of total float, defined as the time activities can slip before delaying key delivery dates.

NASA also maintains a baseline schedule that is regularly analyzed and updated as progress is made. However, the schedule lacked a schedule risk assessment—a best practice that gives decision makers confidence that the estimates are credible based on known risks and allows management to account for the cost of a schedule slip when developing the life-cycle cost estimate. Without a schedule risk assessment decision makers may not obtain accurate cost impacts when schedule changes occur. Officials noted that while a schedule risk assessment was not performed on the ISIM schedule itself, the schedule was included as a part of the overall JWST JCL analysis, and subsequent cost and schedule estimate, conducted during the project replan in 2011. However, our analysis of the 2011 JCL indicated that the estimate's accuracy, and therefore the confidence level assigned to the estimate, was reduced by the quality of the summary schedule used for the JCL because it did not provide enough detail to determine how risks were applied to critical project activities.

## Optical Telescope Element

Of the four characteristics of a reliable schedule that we assessed for the OTE schedule, we found that the comprehensive characteristic was fully met, credible and controlled characteristics were substantially met, and the well-constructed characteristic was partially met. The strengths of the OTE schedule were that it

- captured all activities in manageable durations with their proper sequence,
- identified the resources needed for each activity,
- linked activities to the final deliverables the work in the schedule is intended to produce, and
- accurately reflected dates presented to management in high-level presentations.

[22] The critical path defines the program's earliest completion date or minimum duration it will take to complete all activities.

Northrop Grumman, the creator and manager of the schedule, also maintains a baseline schedule that is regularly analyzed and updated as progress is recorded by schedule experts. However, while Northrop Grumman has identified a critical path, our analysis was not able to confirm that this path described activities in the schedule that were truly driving the key delivery date for the OTE, which is the delivery of the OTE to the OTIS testing and integration at Goddard Space Flight Center on April 28, 2016. Identifying a valid critical path is essential for management to identify and focus upon activities which will potentially have detrimental effects on key project milestones and deliverables if they slip. In addition, we found that one-third of the remaining activities and milestones had over 200 days of total float. This means that, according to the schedule, these activities could be delayed 9 working months without impacting the key delivery date. Realistic float values allow managers to see the impact of a delayed activity on future work. However, unrealistic estimates of float make it difficult to know the amount of time one event can slip without impacting the project finish date. In addition, incorrect float estimates will result in an invalid critical path. Northrop Grumman officials agreed with our assessment but noted the high values of total float are due to their planning process which only details out the schedule in 6 month increments. Activities beyond the detailed planning window of the schedule have high float and those estimates of float will become more reasonable as the schedule is planned in detail. However, best practices state that all activities in the schedule, even far-term planning packages, should be logically linked in such a way as to portray a complete picture of the program's available float and its critical path. Finally, a schedule risk assessment has not been conducted on the OTE schedule since 2011. Northrop Grumman officials stated that they are not contractually required to periodically conduct a schedule risk assessment. However, as with the ISIM, without a schedule risk assessment decision makers may not have accurate cost impacts when schedule changes occur.

## Cryocooler

Of the two characteristics of a reliable schedule that were assessed for the cryocooler schedule, the well-constructed and credible characteristics were both partially met. The strengths of the cryocooler schedule were that it had

- a logical sequence of activities with few missing logic links, and
- few issues with incorrect logic that might impair the ability of the schedule to forecast dates dynamically.

Despite these strengths, two of the ultimate goals of a reliable schedule—determining a valid critical path and realistic total float—were only partially achieved. Officials stated that the schedule is used to manage critical paths to six major hardware deliveries, or key delivery dates. However, we could not determine how the schedule is used to identify and present those paths to management. In addition, the use of date constraints in 19 activities within the schedule helps determine the remaining total float to some deliveries, but causes an overabundance of activities to appear as critical, which interferes with the identification of the true project-level critical path. We also found that while the schedule accurately reflected some of the delays the project is currently experiencing, its schedule appears to be overly flexible in some cases, such as having activities with over 500 days—or over 2 working years—of total float. Incorrect float estimates may result in an invalid critical path and an inaccurate assessment of project completion dates.

The schedule also lacks a complete and credible schedule risk analysis, without which managers cannot determine the likelihood of the project's completion date, how much total schedule risk reserve funding is needed, risks most likely to delay the project, or how much reserve funding should be included for each individual risk. Northrop Grumman officials, who manage the schedule and the project, stated that a schedule risk analysis was performed in March 2013, but the results were not used by JPL management who oversees the contract. The results of the schedule risk analysis may help JPL determine the probability of meeting key dates or how much schedule contingency is needed.

Officials provided us examples of the schedule risk analysis output, but we were not able to confirm their validity because documentation was not available on the data, risk, or methodologies. In addition to the lack of documentation, because we found the schedule to be only partially well-constructed, we cannot be sure that the results of the schedule risk analysis are valid. Given the weaknesses noted above, if the schedule risk analysis is to be credible, the program must have a quality schedule that reflects reliable logic and clearly identifies the critical path before a schedule risk analysis is conducted. If the schedule does not follow best practices, confidence in the schedule risk analysis results will be lacking. Without the schedule risk analysis, the project office cannot rely on the schedule to provide a high level of confidence in meeting the project's completion date or identify reserve funding for unplanned problems that may occur.

## Conclusions

The JWST project has maintained its cost and schedule commitments since its 2011 replan, has continued to make good technical progress, and has implemented and enhanced efforts to improve oversight. Nevertheless, inherent risks continue to make execution of the JWST project challenging and near-term indicators show that the project is currently facing challenges that need to be addressed primarily by increased reserves and progress tracked using the proper tools. Our report, however, indicates that the project may not have the appropriate resources and high fidelity information to ensure execution as planned and provide realistic information to decision makers and other stakeholders. For example, near-term cost reserves are constrained and the project is spending at a higher rate than planned. Without adequate cost reserves in the near-term and if its increased rate of spending continues, the project may need to defer planned work and delay the resolution of future and yet unknown threats. These actions could put the project on a course to repeat past missteps that led to congressional intervention and the institution of a cap on development costs. In addition, the effect sequestration would have on available funding for the project in fiscal year 2014 and beyond is unknown at this point, but could potentially compound this issue. As a result, NASA may need to make difficult decisions about funding JWST adequately at the expense of other, already cash-strapped projects.

Importantly, JWST project officials may not have the necessary information to determine the impacts of any resource issues because the project currently lacks a reliable integrated master schedule due to weaknesses we found in several subschedules. Without a reliable schedule, project officials cannot accurately manage and forecast the impacts of changes to the schedule that will likely come about during the integration and testing periods. Despite these concerns, the JWST project has declined to take adequate steps to address our recommendation to perform an updated cost and schedule risk analysis—or JCL—that is based on current risks and a reliable schedule. Unless properly updated to include a reliable schedule that incorporates known risks, particularly if NASA is faced with additional resource constraints through the continuation of sequestration, the cost estimate will not provide decision makers with accurate information to assess the current status of the project.

## Matter for Congressional Consideration

To help ensure that NASA officials are making decisions using up to date and reliable information about the JWST project, Congress should consider requiring the NASA Administrator to direct the JWST project to conduct an updated joint cost and schedule confidence level analysis that is based on a reliable schedule and current risks.

## Recommendations for Executive Action

We recommend that the NASA Administrator take the following two actions:

- 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, ensure the JWST project has adequate cost reserves 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, and

- 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, perform a schedule risk analysis on OTE, ISIM, 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.

## Agency Comments and Our Evaluation

NASA provided written comments on a draft of this report. These comments are reprinted in appendix IV.

In responding to a draft of this report, NASA concurred with our two recommendations; however, in some cases it is either not clear what actions NASA plans to take or when they will complete the action to satisfy the intent of the recommendations.

NASA officials concurred with our recommendation to ensure the JWST project has adequate cost reserves 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. In their response, the Acting JWST Program Director cited NASA and the administration's request to Congress to appropriate the full JWST replan level funding for fiscal year 2014, which includes the level of unallocated future expenses, or cost reserves, established in the replan. He also commented that NASA conducts monthly reviews to evaluate risks and associated impacts to funding in order to ensure that adequate cost reserves are available in each fiscal year. We acknowledge in our report that the JWST project has been fully funded at levels commensurate with the 2011 baseline through fiscal year 2013. However, cost reserves approved for the project during the 2011 replan were based on the risks known at that time. The events of fiscal year 2013 have weakened the project's financial posture and flexibility the project has to address any potential technical challenges going forward into fiscal year 2014 and beyond. In addition, NASA's response does not indicate how the agency plans to report to Congress the steps it is taking to ensure that the JWST project has adequate cost reserves to meet its October 2018 launch date. We maintain that NASA should provide more detail to Congress on its plans given the already constrained cost reserve posture the project has early in fiscal year 2014 and past issues with low levels of cost reserves that forced the project to defer work, which led to significant cost increases and schedule delays.

NASA officials concurred with our recommendation to perform a schedule risk analysis on OTE, ISIM, and cryocooler schedules, as well as any other subschedules where a schedule risk analysis was not performed and that, in accordance with schedule best practices, the risk analyses are performed on reliable schedules. The Acting Program Director stated NASA will conduct probability schedule risk analyses on the OTE, ISIM, and cryocooler schedules by the end of calendar 2014 using NASA best practices. This is a positive step, given that our previous work has found that GAO and NASA best practices for scheduling are largely consistent.[23] The Acting Program Director also stated that NASA will conduct the same analyses for other schedules lacking a risk analysis. However, no deadline was mentioned for when these analyses will be accomplished or for how many schedules will be affected. Having reliable schedules sooner will provide management with more timely and accurate information on which to make decisions. If the schedule risk assessments are not completed until after 2014, the project will have less than 4 years until launch to utilize the information these risk analyses can provide. Given that we have found reliability issues with the project's schedules for the second year, improving the current schedules to meet

[23]GAO, *Polar Weather Satellites: NOAA Identified Ways to Mitigate Data Gaps, but Contingency Plans and Schedules Require Further Attention*, GAO-13-676 (Washington, D.C.: Sep. 11, 2013).

best practices is important to provide management with improved tools to better understand the schedule risks and manage the project.

We are sending copies of the report to NASA's Administrator and interested congressional committees. In addition, the report will be available at no charge on GAO's website at http://www.gao.gov.

Should 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 major contributions to this report are listed in appendix V.

Cristina T. Chaplain
Director
Acquisition and Sourcing Management

*List of Committees*

The Honorable Barbara A. Mikulski
Chairwoman
The Honorable Richard C. Shelby
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
United States Senate

The Honorable Frank R. Wolf
Chairman
The Honorable Chaka Fattah
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
House of Representatives

The Honorable Lamar Smith
Chairman
The Honorable Eddie Bernice Johnson
Ranking Member
Committee on Science, Space, and Technology
House of Representatives

# Appendix I: Objectives, Scope, and Methodology

Our objectives were to assess (1) the extent to which the James Webb Space Telescope (JWST) project is meeting its cost and schedule commitments and maintaining oversight established as part of the project's replan, (2) the current major technological challenges facing the JWST project, (3) the extent to which cost risks exist that may threaten the project's ability to execute the project as planned, and (4) the extent to which the JWST project schedule is reliable based on best practices. In assessing earned value management (EVM) data from several contractors and subcontractors and the project's schedule estimate, we performed various checks to determine that the data provided was reliable enough for our purposes.

To assess the extent to which the JWST project is meeting its cost and schedule commitments and maintaining oversight, we reviewed project and contractor documentation, analyzed the progress made and any variances to milestones established during the project's replan in 2011, and held interviews with project, contractor, and Defense Contract Management Agency officials. We reviewed project monthly status reviews, documentation on project risks, and budget documentation. We examined and analyzed EVM data from several contractors and subcontractors. The EVM data reviewed included monthly contractor performance reports and analysis performed by the JWST project on this information. For our analysis, we entered only high-level monthly contractor EVM data into a GAO-developed spreadsheet, which includes checks to ensure the EVM data provided was reliable enough for our purposes. We also reviewed the project's analysis of the estimate at completion for internal work being performed on the Integrated Science Instrument Module. We interviewed program and project officials at NASA headquarters and Goddard Space Flight Center to obtain additional information on the status of the project with regard to progress toward baseline commitments. We periodically attended flight program reviews at NASA headquarters where the current status of the program was briefed to NASA headquarters officials and members of the Standing Review Board. We also interviewed JWST project and contractor officials from the Jet Propulsion Laboratory and Northrop Grumman Aerospace Systems to determine the extent to which oversight was being conducted. In addition, we interviewed officials from the Defense Contract Management Agency to obtain information on oversight activities delegated to it by the JWST project.

To assess the technological challenges and risks facing the project, we reviewed project monthly status reviews, information from the project's risk database, as well as briefings and schedule documentation provided by project and contractor officials. These documents included information on the project's technological challenges and risks, mitigation plans, and timelines for addressing these risks and challenges. We also interviewed program and project officials for each major observatory system to clarify information and to obtain additional information on system and subsystem level risks and technological challenges for each subsystem. Further, we interviewed officials from the Jet Propulsion Laboratory and Northrop Grumman Aerospace Systems concerning risks and challenges on the subsystems, instruments, or components they were developing. We reviewed GAO's prior work on NASA Large Scale Acquisitions; the Goddard Space Flight Center Rules for the Design, Development, Verification, and Operation of Flight Systems technical standards;[1] and NASA's Space Flight Program and Project Management Requirements and Systems Engineering Processes and Requirements policy documents.[2] We compared Goddard standards with data reported by the project to assess the extent to which the JWST project followed NASA policies.

To assess the extent to which cost risks exist that may threaten the project's ability to execute the project as planned, we reviewed project and contractor documentation and held interviews with project and contractor officials. We reviewed project monthly status reviews and NASA headquarters flight program reviews, contractor information on the potential cost to address identified risks, and project analysis of budget-related risks to include the project's cost reserve posture and the impact of sequestration. We interviewed program and project officials at NASA headquarters and Goddard Space Flight Center as well as officials from the Jet Propulsion Laboratory and Northrop Grumman Aerospace Systems to obtain information on risks to maintaining cost targets and plans to mitigate those risks.

To assess the extent to which the JWST project schedule is reliable, we used GAO's Schedule Assessment Guide to assess characteristics of three selected subordinate schedules—the Integrated Science Instrument Module (ISIM), Optical Telescope Element (OTE), and cryocooler—that

[1]GSFC STD 1000, Revision D (June 2, 2008) and GSFC STD 1000, Revision F (Feb. 8, 2013).

[2]NPR 7120.5E (Aug. 14, 2012) and NASA Procedural Requirements 7123.1A, *NASA Systems Engineering Processes and Requirements with Change 1*. (Nov.4, 2009).

are used as inputs to the integrated master schedule.[3] We selected the three schedules above as they reflect a significant portion of the work being conducted within NASA (ISIM), at the contractor level (OTE), and the subcontractor level (cryocooler) during the course of our work. We also analyzed schedule metrics as a part of that analysis to highlight potential areas of strengths and weaknesses against each of our 4 characteristics of a reliable schedule. In order to assess each schedule against the 4 characteristics and their accompanying 10 best practices,[4] we traced and verified underlying support and determined whether the program office or contractor provided sufficient evidence to satisfy the criterion and assigned a score depicting that the practices were not met, minimally met, partially met, substantially met, or fully met. By examining the schedules against our guidance, we conducted a reliability assessment on each of the schedules and incorporated our findings on reliability limitations in the analysis of each subordinate schedule. We also conducted interviews with project and contractor management and schedulers before our analysis was completed and analyzed project and contractor documentation concerning scheduling policies and practices. After conducting our initial analysis, we shared it with the relevant parties to provide an opportunity for them to comment and identify reasons for observed shortfalls in schedule management best practices. We took their comments and any additional information they provided and incorporated it into the assessments to finalize the scores for each characteristic and best practice. We were also able to use the results of the three subordinate schedules to provide insight into the health of the integrated master schedule since the same strengths and weaknesses of the subordinate schedules would transfer to the master schedule. We determined that the schedules were sufficiently reliable for our reporting purposes and our report notes the instances where reliability concerns affect the quality of the schedules.

Our work was performed primarily at NASA headquarters in Washington, D.C. and Goddard Space Flight Center in Greenbelt, Maryland. We also visited the Jet Propulsion Laboratory in Pasadena, California; Northrop Grumman Aerospace Systems in Redondo Beach, California; and the Defense Contract Management Agency in Redondo Beach, California.

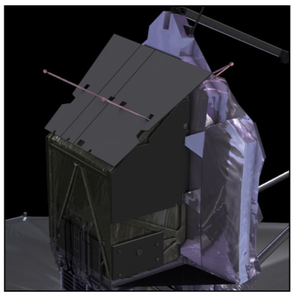
[3]GAO, *GAO Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-12-120G (Washington, D.C.: May 30, 2012).

[4]For the cryocooler schedule, only 2 characteristics were assessed.

We conducted this performance audit from February 2013 to January 2014 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.

# Appendix II: Subsystems of the JWST Observatory

**Figure 9: Subsystems of JWST: Interactive Information**



**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

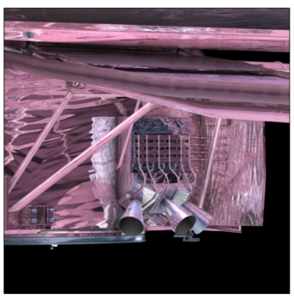
**Description:** Telescope guider and Science instrument

**Near Infrared Camera**

**Acronym:** NIRCam

**Contractor/Center:** University of Arizona

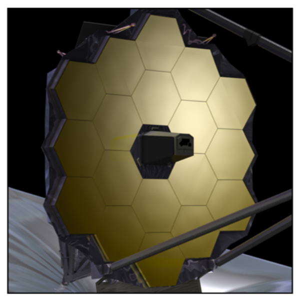
**Description:** Science instrument and Wave Front Sensor



**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

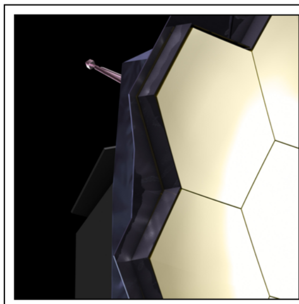


**Optical Telescope Element**

**Acronym:** OTE

**Contractor/Center:** Northrop Grumman Aerospace Systems

**Description:** 18 primary mirror segments, secondary mirror, tertiary mirror, backplane support structure

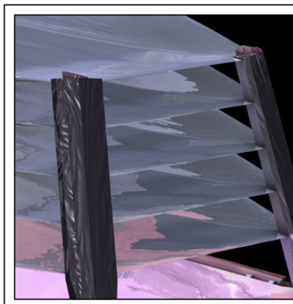


**Optical Telescope & Integrated Science Instrument Module**

**Acronym:** OTIS (**OT**E+**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).

# Appendix III: The Four Characteristics and Ten Best Practices of a High-Quality and Reliable Schedule

| Schedule characteristic | Schedule best practice |
|---|---|
| **Comprehensive**, reflecting<br>• all activities as defined in the project's WBS<br>• the labor, materials, and overhead needed to do the work and whether those resources will be available when needed<br>• how long each activity will take, allowing for discrete progress measurement with specific start and finish dates | 1) Capturing all activities<br>3) Assigning resources to all activities<br>4) Establishing the durations of all activities |
| **Well constructed**, with<br>• all activities logically sequenced with predecessor and successor logic<br>• limited amounts of unusual or complicated logic techniques that are justified in the schedule documentation<br>• a critical path that determines which activities drive the project's earliest completion date<br>• total float that accurately determines the schedule's flexibility | 2) Sequencing all activities<br>6) Confirming that the critical path is valid<br>7) Ensuring reasonable total float |
| **Credible**, reflecting<br>• the order of events necessary to achieve aggregated products or outcomes<br>• varying levels of activities, supporting activities, and subtasks<br>• key dates that can be used to present status updates to management<br>• a level of confidence in meeting a project's completion date based on data about risks and opportunities for the project<br>• necessary schedule contingency and high priority risks based on conducting a robust schedule risk analysis | 5) Verifying that the schedule is traceable horizontally and vertically<br>8) Conducting a schedule risk analysis |
| **Controlled**, being<br>• updated periodically by schedulers trained in critical path method scheduling<br>• statused using actual progress and logic to realistically forecast dates for program activities<br>• compared against a documented baseline schedule to determine variances from the plan<br>• accompanied by a corresponding baseline document that explains the overall approach to the project, defines assumptions, and describes unique features of the schedule<br>• subject to a configuration management control process | 9) Updating the schedule with actual progress and logic<br>10) Maintaining a baseline schedule |

Source: GAO.

# Appendix IV: Comments from the National Aeronautics and Space Administration

National Aeronautics and Space Administration
**Headquarters**
Washington, DC 20546-0001

DEC 11 2013

Reply to Attn of: Science Mission Directorate

Ms. Cristina Chaplain
Director
Acquisition and Sourcing Management
United States Government Accountability Office
Washington, DC 20548

Dear Ms. Chaplain:

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Government Accountability Office (GAO) draft report entitled, "James Webb Space Telescope: Project Meeting Commitments but Current Technical, Cost, and Schedule Challenges Could Affect Continued Progress" (GAO-14-72).

In the draft report, GAO addresses two recommendations to the NASA Administrator intended to address issues related to low cost reserves and performing schedule risk analyses in the Optical Telescope Element (OTE), Integrated Science Instrument Module (ISIM), and cryocooler subsystem schedules that GAO reviewed, specifically:

**Recommendation 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, ensure the JWST project has adequate cost reserves 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.

**Management's Response:** Concur. NASA is committed to assuring sufficient funding levels to support JWST's October 2018 launch date. NASA and the Administration requested that Congress appropriate the full JWST replan funding level for fiscal year 2014, which includes the Unallocated Future Expenses (UFE) level established in the replan for fiscal year 2014. During the current Continuing Resolution period, NASA has funded JWST at the full replan level, including UFE. In addition, NASA conducts monthly reviews to evaluate risks and associated impacts to baselined funding and UFE in order to ensure that adequate UFE is available in each fiscal year including fiscal year 2014.

**Recommendation 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, perform a schedule risk analysis on OTE, ISIM, and cryocooler schedules, as well as any other subschedules where 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.

**Management's Response**: Concur. NASA performs monthly integrated programmatic and cost/schedule risk assessments to forecast and manage impacts to schedules. This assures the continued viability of the JWST development plan. To further enhance this review process, NASA will perform a probabilistic schedule risk analysis of the JWST OTE, ISIM, and cryocooler schedules using schedules that meet NASA best practices, and for other schedules where a risk analysis was not performed, with completion expected by the end of calendar year 2014 for OTE, ISIM, and cryocooler.

Thank you for the opportunity to comment on this draft report. If you have any questions or require additional information, please contact Ray Taylor at 202-358-0766.

Sincerely,

Eric P Smith

Dr. Eric P. Smith
JWST Program Director (Acting)

# Appendix V: GAO Contact and Staff Acknowledgments

## GAO Contact

Cristina Chaplain, (202) 512-4841 or chaplainc@gao.gov

## Staff Acknowledgments

In addition to the contact named above, Shelby S. Oakley, Assistant Director; Karen Richey, Assistant Director; Patrick Breiding; Richard A. Cederholm; Laura Greifner; Keith Hornbacher; David T. Hulett; Jason Lee; Sylvia Schatz; Ryan Stott; and Roxanna T. Sun made key contributions to this report.

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