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NASA MAJOR PROJECTS

Portfolio Is at Risk for Continued Cost Growth and Schedule Delays

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GAO-18-576T

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GAO Highlights

Highlights of GAO-18-576T, a testimony before the Subcommittee on Space, Committee on Science, Space, and Technology, House of Representatives

Why GAO Did This Study

GAO designated NASA's acquisition management as a high-risk area in 1990 after a history of persistent cost growth and schedule slippage in many of NASA's major projects. In more recent years, GAO found that NASA had taken some steps to improve its management, and, in May 2017, GAO found that projects were continuing a generally positive trend of limiting cost and schedule growth. But at the same time, GAO noted that many of these projects, including some of the most expensive ones, were approaching the phase in their life cycles when cost and schedule growth is most likely.

This statement summarizes GAO's 2018 findings from its 10th annual snapshot of how well NASA is planning and executing its major acquisition projects, and describes (1) the cost and schedule performance of NASA's portfolio of major projects and (2) the extent to which NASA faces risks for further cost increases and schedule delays. To conduct its review for the 2018 report, GAO-18-280SP, GAO analyzed cost, schedule, and other data for NASA's 26 major projects, each with a life-cycle cost of over $250 million; reviewed monthly project status reports; and interviewed NASA officials.

What GAO Recommends

GAO is not making any new recommendations in this statement. GAO has made recommendations in prior reports to strengthen NASA's acquisition management of its major projects. NASA generally agreed with these recommendations, but has not fully addressed some of them. GAO continues to believe they should be fully addressed.

View GAO-18-576T. For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

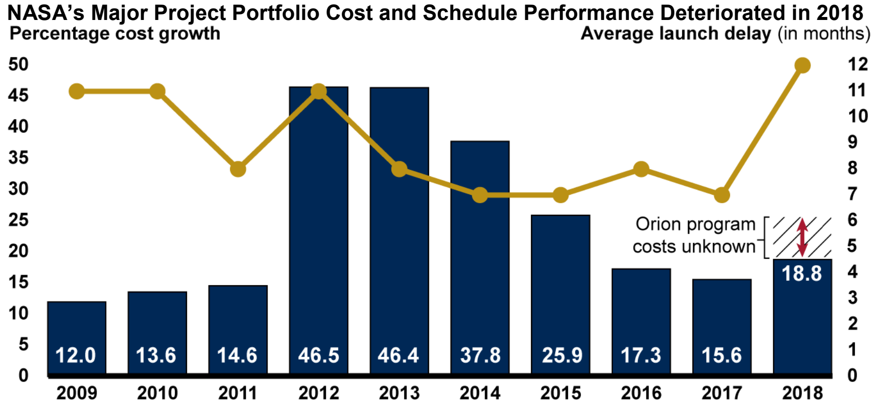
NASA MAJOR PROJECTS

Portfolio Is at Risk for Continued Cost Growth and Schedule Delays

What GAO Found

The cost and schedule performance of the National Aeronautics and Space Administration's (NASA) portfolio of major projects has deteriorated, but the extent of cost performance deterioration is unknown. NASA expects cost growth for the Orion crew capsule—one of the largest projects in the portfolio—but does not have a current cost estimate. In addition, the average launch delay for the portfolio was 12 months, the highest delay GAO has reported in its 10 years of assessing major NASA projects (see figure below).

NASA's Major Project Portfolio Cost and Schedule Performance Deteriorated in 2018



Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-18-576T

The deterioration in portfolio performance was the result of 9 of the 17 projects in development experiencing cost or schedule growth.

- Four projects encountered technical issues that were compounded by risky program management decisions. For example, the Space Launch System and Exploration Ground Systems programs are large-scale, technically complex human spaceflight programs, and NASA managed them to aggressive schedules and with insufficient levels of cost and schedule reserves. This made it more difficult for the programs to operate within their committed baseline cost and schedule estimates.
- Two projects ran into technical challenges that resulted in delays in the integration and test phase. For example, in December 2017, GAO found that the James Webb Space Telescope project encountered delays primarily due to the integration of the various spacecraft elements taking longer than expected, as well as the need to resolve technical issues during testing. GAO has previously found that integration and testing is when projects are most at risk of incurring cost and schedule growth.
- Three projects experienced cost growth or schedule delays due to factors outside of the projects' control, such as delays related to their launch vehicles.

NASA continues to face increased risk of cost and schedule growth in future years due to new, large and complex projects that will enter the portfolio and expensive projects remaining in the portfolio longer than expected.

Chairman Babin, Ranking Member Bera, and Members of the Subcommittee:

Thank you for inviting me to discuss the cost and schedule performance of the National Aeronautics and Space Administration's (NASA) portfolio of major acquisition projects. NASA's major projects are the key enablers for the agency to achieve its vision and its mission. They include NASA's Space Launch System (SLS) and Orion Multi-Purpose Crew Vehicle (Orion), which are the centerpieces of NASA's human exploration plans; Mars 2020 and Europa Clipper, which will further our understanding of the habitability of other planets; and the Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2), which will provide better data on changes in the Earth. In its fiscal year 2019 budget request, NASA requested $19.9 billion, which included about $4.5 billion for its deep space exploration programs and research and about $6 billion for science programs and research. As these projects are complex and specialized, and often push the state of the art in space technology, NASA manages a portfolio that will always have inherent technical, design, and integration risks.

We have been assessing the cost and schedule performance of NASA's major projects—those that have a life-cycle cost over $250 million—annually for 10 years. Over this time, we have seen NASA make progress in reducing acquisition risks, such as by improving cost and schedule estimating tools, and establishing design metrics and tracking projects against the metrics. But our most recent assessment in May 2018 found that the cost and schedule performance of the portfolio deteriorated after several years of following a generally positive trend of limiting cost and schedule growth.[1]

My statement today is based primarily upon our May 2018 report. Specifically, I will discuss (1) the cost and schedule performance of NASA's portfolio of major projects and (2) the extent to which NASA faces risks for continued cost increases and schedule delays. To conduct this work, we collected cost and schedule information from NASA's major projects using a data collection instrument, analyzed projects' monthly status reports, interviewed NASA project and headquarters officials, and reviewed project documentation. At the time of our review, there were 26 major projects in total, but the information available depended on where a

[1]GAO, *NASA: Assessments of Major Projects*, GAO-18-280SP (Washington, D.C.: May 1, 2018).

project was in its life cycle.[2] For the 17 projects that were in the implementation phase, we compared current cost and schedule estimates to their original cost and schedule baselines. We reviewed historical data on cost and schedule performance for major projects from our prior reports and compared them to the performance of NASA's current portfolio of major projects. More detailed information on our objectives, scope, and methodology for that work can be found in our May 2018 report. In addition, we requested and received an update from NASA in early June 2018 on whether the agency had completed a new life-cycle cost estimate for the Orion program. We also updated the actual launch date for the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) project and updated information on the launch date for the Ionospheric Connection Explorer (ICON) project.

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

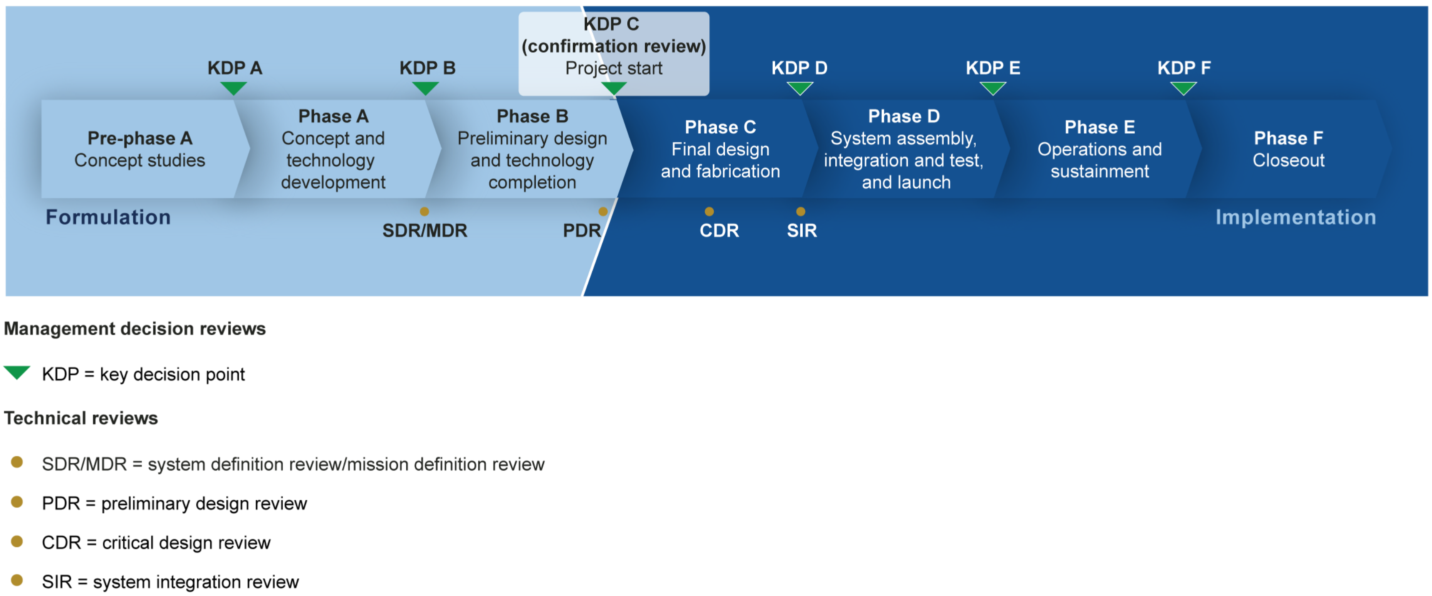
Background

NASA Acquisition Life Cycle for Space Flight Projects

The life cycle for NASA space flight projects consists of two phases—formulation, which takes a project from concept to preliminary design, and implementation, which includes building, launching, and operating the system, among other activities. NASA further divides formulation and implementation into phases, phase A through phase F. Major projects must get approval from senior NASA officials at key decision points before they can enter each new phase. Formulation culminates in a review at key decision point C, known as project confirmation, where cost and schedule baselines are established and documented in a decision memorandum. Figure 1 depicts NASA's life cycle for space flight projects.

[2] Eight projects were in an early stage of development, called formulation, when there are still unknowns about requirements, technology, and design. For those projects, we reported preliminary cost ranges and schedule estimates. The Commercial Crew Program has a tailored project life cycle and project management requirements. As a result, it was excluded from our cost and schedule performance analysis.

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



Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-18-576T

At the time of our review in May 2018, NASA had a portfolio of 26 major projects (see table 1). See appendix I for a brief description of each project.

Table 1: Major NASA Projects Reviewed in GAO's 2018 Assessment by Phase

Projects in formulation	Double Asteroid Redirection Test (DART)
	Europa Clipper
	Low Boom Flight Demonstrator (LBFD)
	Lucy
	Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)
	Psyche
	Restore-L
	Wide-Field Infrared Survey Telescope (WFIRST)
Projects in implementation	Commercial Crew Program (CCP)
	Exploration Ground Systems (EGS)
	Gravity Recovery and Climate Experiment Follow-On (GRACE-FO)
	Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2)
	Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight)
	Ionospheric Connection Explorer (ICON)
	James Webb Space Telescope (JWST)
	Landsat 9 (L9)
	Laser Communications Relay Demonstration (LCRD)
	Mars 2020
	NASA ISRO Synthetic Aperture Radar (NISAR)
	Orion Multi-Purpose Crew Vehicle (Orion)
	Parker Solar Probe (PSP) (formerly Solar Probe Plus)
	Radiation Budget Instrument (RBI)
	Space Launch System (SLS)
	Space Network Ground Segment Sustainment (SGSS)
	Surface Water and Ocean Topography (SWOT)
	Transiting Exoplanet Survey Satellite (TESS)

Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-18-576T

NASA Acquisition Management as a High-Risk Area

NASA acquisition management is an area that we monitor on our high-risk list.[3] Our high-risk series is a biennial report that keeps focused attention on government operations with greater vulnerabilities to fraud, waste, abuse, and mismanagement or that are in need of transformation

[3]GAO, *High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others*, GAO-17-317 (Washington, D.C.: Feb. 15, 2017). We first designated NASA contract management as a high-risk area in 1990. In 2009, we updated the title of the area to NASA acquisition management because of the scope of issues that needed to be resolved to address persistent cost growth and schedule delays.

to address economy, efficiency, or effectiveness challenges. In 1990, we first designated the area as high risk because there was little emphasis on end results, product performance, and cost control; the acquisition process itself was cumbersome and time-consuming; and NASA found itself procuring expensive hardware that did not work properly. For example, in April 1990, NASA deployed the $1.5 billion Hubble Space Telescope and soon after, the agency discovered that the primary mirror had been manufactured in the wrong shape, severely degrading some of the telescope's scientific capabilities.

Subsequently, we and other organizations, including the National Academy of Sciences and NASA's Office of the Inspector General, found that NASA's cost estimates were overly optimistic.[4] Our reviews also found that NASA continued to experience significant cost and schedule growth due, in part, to not having a disciplined cost estimating process.

- In 1992, we reviewed the cost and schedule performance of 29 NASA programs and found that 25 of those programs experienced cost growth that ranged from 14 to 426 percent above their initial estimates.[5] Further, the median estimate change for all programs was an increase of 77 percent. General reasons that NASA provided for the cost growth included insufficient definition studies, program and funding instability, overly optimistic assumptions by program officials, and unrealistic contractor estimates. The more specific reasons for the cost growth we found included program redesigns, technical complexities, budget constraints, and incomplete cost estimates.
- In 2004, we reviewed the cost and schedule performance of 27 NASA programs and found that 17 of the programs experienced cost growth.[6] Cost growth for 10 of the 17 programs was over 25 percent.

[4]GAO, *Space Programs: NASA's Independent Cost Estimating Capability Needs Improvement,* GAO/NSIAD-93-73 (Washington, D.C.: Nov. 5, 1992); *NASA Program Costs: Space Missions Require Substantially more Funding Than Initially Estimated*, GAO/NSIAD-93-97 (Washington, D.C.: Dec. 31, 1992); National Research Council of the National Academies, *Controlling Cost Growth of NASA Earth and Space Science Missions* (Washington, D.C.: National Academies Press, 2010); and NASA Office of Inspector General, *Inspector General Assessment of NASA's Most Serious Management and Performance Challenges,* (Washington, D.C.: Feb. 4, 2002) and *NASA's Independent Cost Estimating Capability*, IG-00-045 (Washington, D.C.: Sept. 20, 2000).

[5]GAO/NSIAD-93-97.

[6]GAO, *NASA: Lack of Disciplined Cost-Estimating Processes Hinders Effective Program Management*, GAO-04-642 (Washington, D.C.: May 28, 2004).

We found that considerable change in NASA's program cost estimates—both increases and decreases—indicated that NASA lacked a clear understanding of how much its programs cost and how long they will take to achieve their objectives. Further, we found that NASA's basic cost-estimating processes—an important tool for managing programs—lacked the discipline needed to ensure that program estimates are reasonable.

In more recent years we have found that NASA's leadership was focused on improving acquisition outcomes and had taken some steps to improve its management.

- In 2006, NASA established a management review process to enable NASA's senior management to more effectively monitor a project's performance, including cost, schedule, and cross-cutting technical and nontechnical issues.
- In 2009, NASA began requiring that NASA major programs and projects develop a joint cost and schedule confidence level (JCL) prior to project confirmation in order to ensure that cost and schedule estimates were realistic and projects thoroughly planned for anticipated risks. The JCL is a point-in-time estimate that, among other things, includes all cost and schedule elements, incorporates and quantifies known risks, assesses the impacts of cost and schedule to date, and addresses available annual resources. NASA policy generally requires that projects be baselined and budgeted at the 70 percent confidence level.
- In 2012, the agency established metrics to more consistently measure a project's design progress and, in 2014, we found that most major projects in the portfolio were tracking and reporting those metrics. In addition, experts with whom we met confirmed that NASA's metrics are valid measures to assess design maturity in space systems.
- Since 2015, we have observed a positive trend of higher numbers of projects maturing technologies prior to preliminary design review.[7] Demonstrating that technologies will work as intended in a relevant environment serves as a fundamental element of a sound business case, and projects falling short of this standard often experience subsequent technical problems. Our best practices work has shown

[7]A technology is considered mature when it reaches a technology readiness level 6, which is achieved after demonstrating a representative prototype of the technology in a relevant environment that simulates the harsh conditions of space.

that maturing technologies prior to preliminary design review can minimize risks for projects entering development, which lowers the risk of subsequent cost growth and schedule delays.

We believe that many of these steps NASA has taken contributed to the largely positive trend of cost and schedule performance for NASA's portfolio of major projects between 2013 and 2017. In our May 2017 assessment of major projects, we found that out of 16 projects in development, 5 experienced cost growth and 4 experienced schedule delays over their development cost and schedule baselines.[8] Both of these measures were at or near the lowest levels we have reported since we began our annual assessments in 2009.

However, we also found in our February 2017 high risk update that NASA needed to do more with respect to anticipating and mitigating risks—especially with regard to large programs, estimating and forecasting costs for its largest projects, and implementing management tools.[9] We highlighted several actions that would be critical to improving NASA's acquisition outcomes, including the following:

- Ensuring that NASA conducted adequate and ongoing assessments of risks for larger programs because the impacts of any potential miscalculations will be felt across NASA's portfolio.
- Ensuring that NASA understood long-term human exploration program costs. While the three major human exploration programs—Orion, SLS, and the Exploration Ground Systems (EGS)—have been baselined, none of the three programs has a baseline that covers activities beyond the second planned flight. Long-term estimates, which could be revised as potential mission paths are narrowed and selected, would provide decision makers with a more informed understanding of costs and schedules associated with potential agency development paths.
- Ensuring that program offices regularly and consistently updated their JCL across the portfolio. As a project reaches the later stages of development, especially integration and testing, its risk posture may change. An updated project JCL would provide both project and

[8]GAO, *NASA: Assessments of Major Projects*, GAO-17-303SP (Washington, D.C.: May 16, 2017).

[9]GAO-17-317.

agency management with data on relevant risks that can guide project decisions.

- Ensuring that NASA continued its efforts to build capacity in areas such as cost and schedule estimating and measuring contractor performance.

Further, in our 2016 and 2017 assessments of major projects, we found that while the cost and schedule performance of NASA's portfolio was improving, a number of large, complex projects were in or would soon be entering the integration and test phase—the phase in development that often reveals unforeseen challenges that can lead to cost and schedule growth.[10] In May 2017, projects in this phase included all three human spaceflight programs and the James Webb Space Telescope (JWST).[11] Subsequently, we found that these programs experienced delays during this phase of development. For example, in December 2017, NASA announced a 13- to 19-month delay for the first integrated mission of Orion, SLS, and EGS. This mission is referred to as Exploration Mission 1 (EM-1) and will not have crew. In addition, in December 2017, we found that the JWST project continued to make progress towards launch, but the program was encountering technical challenges that required both time and money to fix and may lead to additional delays.[12] Subsequently, the JWST project delayed its launch readiness date by at least 19 months from October 2018 to May 2020.

Portfolio Cost and Schedule Deteriorated but Extent of Cost Growth Is Unknown

The cost and schedule performance of NASA's portfolio of major projects deteriorated between May 2017 and May 2018, but the extent of cost growth is unknown. NASA lacks a current cost estimate for its Orion crew capsule—one of the largest programs in the portfolio—but expects the program will exceed its cost baseline when NASA updates the program's life-cycle cost estimate. Because the Orion program accounts for about 22 percent of all development costs, even a small percentage of cost growth for the Orion program could significantly affect portfolio cost performance. The known negative cost and schedule performance is

[10] GAO, *NASA: Assessments of Major Projects,* GAO-16-309SP (Washington, D.C.: Mar. 30, 2016); and GAO-17-303SP.

[11] GAO-17-303SP.

[12] GAO, *NASA: Preliminary Observations on the Management of Space Telescopes*, GAO-18-277T (Washington, D.C.: Dec. 6, 2017).

largely driven by the cost and schedule growth of four projects—SLS, EGS, Space Network Ground Segment Sustainment (SGSS) and Mars 2020—that experienced technical problems compounded by programmatic challenges. Together, these projects experienced $638 million in cost growth and 59 months in aggregate schedule delays. Two projects—JWST and ICESat-2—experienced schedule delays due to technical challenges identified during integration and test. Another 3 projects—NASA Indian Space Research Organisation Synthetic Aperture Radar (NISAR), ICON, and GRACE-FO—experienced cost growth or delays largely due to factors outside of the projects' control, such as launch vehicle delays.

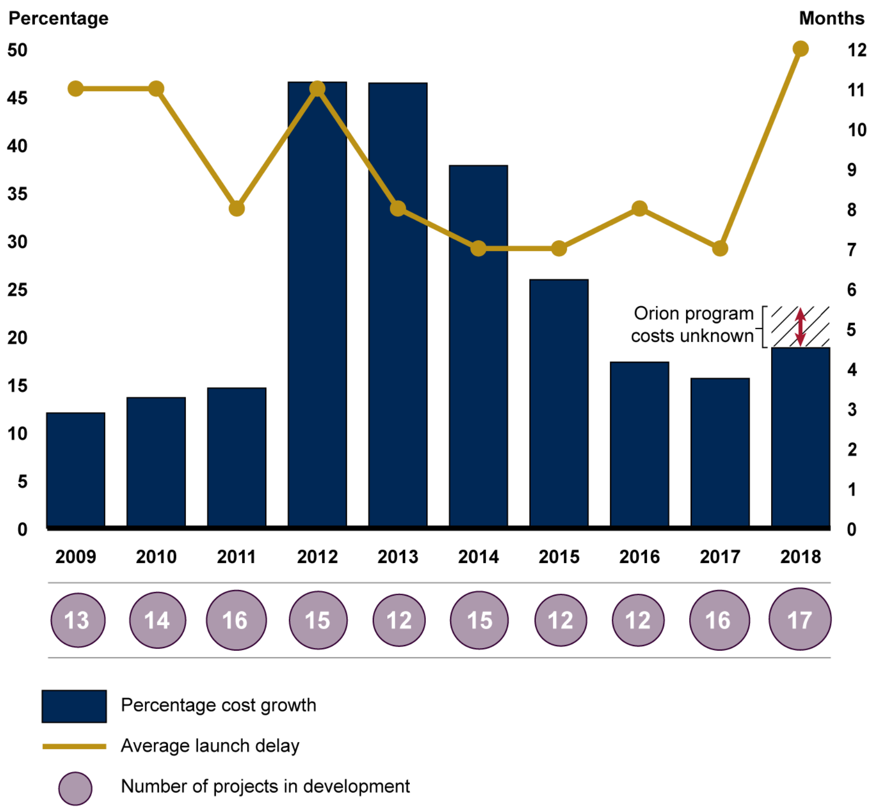
Portfolio Average Launch Delays Increased, but NASA Lacks a Current Orion Program Cost Estimate to Determine Extent of Cost Growth

The average launch delay increased from 7 months in our May 2017 report to 12 months in our May 2018 report—the highest schedule delay we have reported to date.[13] We were not able to determine the extent of portfolio cost growth this year because NASA does not have a current cost estimate for the Orion program—one of the largest programs in its portfolio—and officials expect the cost to increase. As of June 2017, the Orion program's development cost was about $6.6 billion; based on that estimate, it accounts for 22 percent of the portfolio's estimated $30.1 billion of development costs. As a result, a small percentage of cost growth for the Orion program could significantly affect cost performance. Even without including Orion cost growth, the overall development cost growth for the portfolio of 17 development projects increased to 18.8 percent, up from 15.6 percent in 2017 (see figure 2).[14]

[13] GAO-17-303SP.

[14] We have historically presented cost and schedule performance including and excluding the James Webb Space Telescope (JWST) because, prior to 2015, it had a development cost baseline significantly larger than other projects and the magnitude of its cost growth masked the performance of the remainder of the portfolio. Now that other projects in the portfolio, such as Orion and the Space Launch System, have large development cost baselines, we no longer present cost performance trends excluding JWST.

Figure 2: Development Cost Performance and Average Launch Delay for Major NASA Projects from 2009 to 2018



Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-18-576T

Note: The years given in the figure refer to the year we issued each of our annual assessments of NASA major projects reports. Cost and schedule performance is compared across each report period.

Senior-level NASA officials told us they expect that the Human Exploration and Operations Mission Directorate and the Orion program will complete an updated life-cycle cost estimate in June 2018. This would be approximately 10 months after the program raised to senior-level officials' attention that the program expects cost growth over its cost baseline during an August 2017 briefing concerning potential cost increases related to the launch delay for EM-1.[15] In early June 2018,

[15]The Orion program is baselined to the second combined mission of Orion, SLS, and EGS. This mission is known as Exploration Mission 2 (EM-2) and will have crew.

NASA officials said that they had not yet completed the updated life-cycle cost estimate.

In our May 2018 report, we found that 7 of 17 NASA major projects had stayed within cost and schedule estimates since our 2017 annual assessment of major projects, but 9 projects experienced cost growth or schedule delays and cost growth is expected for the Orion program. Table 2 provides data on the cost and schedule performance between our May 2017 and 2018 reports for the 17 major projects in development that have cost and schedule baselines.[16]

[16]GAO-17-303SP.

Table 2: Development Cost and Schedule Performance of Selected Major NASA Projects in Development as of May 2018 Assessment

Overall performance	Project	Confirmation date	Changes between May 2017 and May 2018		Cumulative performance	
		Year	Cost (millions)	Schedule (months)	Cost (millions)	Schedule (months)
Lower than expected cost	PSP	2014	$0.0	0	-$5.4	0
	GRACE-FO	2014	-$1.6	3	-$2.2	3
	TESS	2014	-$13.1	-2	-$39.9	-2
Within baseline	ICON	2014	$0.0	8	$0.0	8
	SWOT	2016	$0.0	0	$0.0	0
	LCRD	2017	$0.0	0	$0.0	0
	Landsat 9	2017	$0.0	0	$0.0	0
Higher than expected cost	Mars 2020[a]	2016	$12.9	0	$10.7	0
	NISAR	2016	$22.0	0	$22.0	0
Replan[c]	InSight	2014	$0.0	0	$131.7	26
	EGS (EM-1)	2014	$417.8	19	$421.4	19
	SLS (EM-1)	2014	$147.8	19	$147.8	19
Rebaseline[c]	JWST	2008	$0.0	19	$3,607.7	71
	ICESat-2	2012	$1.4	4	$206.3	17
	SGSS[b]	2013	$59.5	21	$421.6	48
Canceled	RBI	2016	$0.0	0	$0.0	0
Under revision	Orion (EM-2)[d]	2015	$0.0	0	-$151.7	0
Total:			**$646.7**	**91**	**$4,770.0**	**209**

Legend: PSP: Parker Solar Probe; GRACE-FO: Gravity Recovery and Climate Experiment Follow-On; TESS: Transiting Exoplanet Survey Satellite; ICON: Ionospheric Connection Explorer; SWOT: Surface Water and Ocean Topography; NISAR: NASA Indian Space Research Organisation – Synthetic Aperture Radar; LCRD: Laser Communications Relay Demonstration; InSight: Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport; EGS: Exploration Ground Systems; SLS: Space Launch System; EM-1: Exploration Mission 1; JWST: James Webb Space Telescope; ICESat-2: Ice, Cloud, and Land Elevation Satellite-2; SGSS: Space Network Ground Segment Sustainment; RBI: Radiation Budget Instrument; Orion: Orion Multi-Purpose Crew Vehicle; EM-2: Exploration Mission 2.

Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-18-576T

Note: The confirmation date is the year NASA established and documented a cost and schedule baseline for each project. Positive values indicate cost growth or launch delays. Negative values indicate cost decreases or earlier than planned launch dates.

[a]The Mars 2020 project used $2.2 million in funds originally budgeted for development for formulation activities. This partially offsets an increase of $12.9 million in development cost growth primarily due to increased costs associated with a technology demonstration instrument and entry, descent, and landing instrument.

[b]The SGSS project reported cost growth up through its first operational readiness review, which is currently planned for the end of fiscal year 2019. However, the project expects that there could be additional cost and schedule growth beyond what is reported here.

[c]A replan process is initiated if development costs increase by 15 percent or more. NASA replanned the SLS program even though development costs did not increase by 15 percent or more. A replan does not require a new project baseline to be established. A rebaseline is a process initiated if development costs increase by 30 percent or more. When development cost growth is likely to

exceed the development cost estimate by 15 percent or more, NASA must submit a report to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate. In addition, if a project or program milestone is likely to be delayed by 6 months or more, this report is also required.

[d]NASA officials said they are revising the Orion program's life-cycle cost estimate and expect to complete a new estimate in June 2018. The new cost is expected to exceed the program's development cost baseline. The current costs in the table reflect the estimate provided in June 2017. The cumulative cost change reflects the program shifting $151.7 million of funding previously budgeted for the development phase to the formulation phase.

The deteriorating cost and schedule performance of the portfolio in 2018 is the result of

- four projects—SLS, EGS, SGSS, and Mars 2020—addressing technical challenges that were compounded by risky programmatic decisions;
- two projects—JWST and ICESat-2—experiencing delays due to technical challenges identified during integration and test; and
- three projects—NISAR, ICON, and GRACE-FO—experiencing cost growth or delays largely due to factors outside of the projects' control.

We elaborate on these three scenarios below.

Technical challenges compounded by risky programmatic decisions. Together, SLS, EGS, SGSS, and Mars 2020 experienced $638 million in cost growth and 59 months in aggregate schedule delays due to technical problems that were compounded by programmatic challenges since our May 2017 report.[17] The SLS and EGS programs experienced cost growth and schedule delays associated with EM-1, their first combined mission along with the Orion program. We have found for several years that the human spaceflight programs—Orion, SLS, and EGS—are making progress maturing designs and building hardware, but also are experiencing some significant engineering and manufacturing challenges. For example, the SLS program ran into numerous challenges completing the welding of its core stage element in 2017. The program stopped welding on the core stage for months to identify and resolve low weld strength in the liquid oxygen and liquid hydrogen tanks due to low weld strength measurements found in the liquid oxygen tanks caused by a program and contractor decision to change the weld tool configuration during fabrication. The EGS program also experienced technical challenges, including with the design and installation of the ground

[17]GAO-17-303SP.

support equipment and the 10 umbilicals that connect SLS and Orion to the Mobile Launcher—which supports the assembly, testing, and servicing of SLS and provides the platform on which SLS and Orion will launch.

Finally, although the Orion program has not yet reported cost growth, it also experienced technical challenges. These challenges included software and hardware delays, and at least 14 months of delays with the European Service Module—which provides air, water, power, and propulsion to Orion during in-space flight—since the element's critical design review in June 2016. In April 2017, we found that, according to program officials, the delays with the service module were largely due to NASA, the European Space Agency, and the European Space Agency contractor underestimating the time and effort necessary to address design issues for the first production service module and the availability of parts from suppliers and subcontractors. NASA expects the Orion program to experience cost growth over its cost baseline to the second combined mission, Exploration Mission 2 (EM-2). However, the extent of the growth is unknown because, as noted above, NASA is currently revising the program's life-cycle cost estimate.

Technical challenges such as these are not unusual for large-scale programs, especially human exploration programs that are inherently complex and difficult. However, we have found that NASA has made programmatic decisions—including establishing low cost and schedule reserves, managing to aggressive schedules, and not following best practices for earned value management or creating reliable cost and schedule baselines—that have compounded the technical challenges (see table 3).[18] As a result, the three human spaceflight programs have been at risk of cost and schedule growth since NASA approved their baselines.

[18]GAO, *Space Launch System: Management Tools Should Better Track to Cost and Schedule Commitments to Adequately Monitor Increasing Risk,* GAO-15-596 (Washington, D.C.: July 16, 2015); *NASA Human Space Exploration: Opportunity Nears to Reassess Launch Vehicle and Ground Systems Cost and Schedule,* GAO-16-612 (Washington, D.C.: July 27, 2016); *Orion Multi-Purpose Crew Vehicle: Action Needed to Improve Visibility into Cost, Schedule, and Capacity to Resolve Technical Challenges,* GAO-16-620 (Washington, D.C.: July 27, 2016); and *NASA Human Space Exploration: Delay Likely for First Exploration Mission,* GAO-17-414 (Washington, D.C.: Apr. 27, 2017). Cost reserves are for costs that are expected to be incurred—for instance, to address project risks—but are not yet allocated to a specific part of the project. Schedule reserves are extra time in project schedules that can be allocated to specific activities, elements, and major subsystems to mitigate delays or address unforeseen risks.

Table 3: Examples of Risky Programmatic Decisions Made by National Aeronautics and Space Administration's (NASA) Human Spaceflight Programs

Programmatic decision	Example(s)	Negative effect	GAO report(s)
NASA baselined the Exploration Ground Systems (EGS), Orion Multi-Purpose Crew Vehicle (Orion), and Space Launch System (SLS) programs with low cost and schedule reserves.	In July 2016, we found that NASA baselined the SLS program with cost reserves of less than 2 percent, even though guidance for Marshall Space Flight Center—the NASA center with responsibility for the SLS program—established standard cost reserve for launch vehicle programs of 20 percent when the baseline is approved.	Operating with low cost and schedule reserves limits a program's ability to address risks and unforeseen technical challenges.	GAO-17-414 and GAO-16-612
NASA managed the EGS, Orion, and SLS programs to an internal schedule for completing development production that was aggressive and could exacerbate delays and lead to cost overruns.	In July 2016, we found that the EGS program planned to conduct the mobile launcher's verification and validation concurrent with ground support equipment systems and umbilicals installation to support the program's internal schedule goal. We found this to be a risky practice because of uncertainties regarding how systems not yet installed may affect the systems already installed.	Working towards a more aggressive internal goal is not a bad practice; however, increasing cost and schedule risk to the program in order to pursue such a goal is not beneficial to programs in the long term.	GAO-16-620 and GAO-16-612
The SLS program did not follow best practices for using earned value management, which integrates the project scope of work with cost, schedule, and performance elements for optimum project planning and control.	In July 2016, we found that the SLS program had not positioned itself well to provide accurate assessments of progress with the core stage because it operated for several years without a performance measurement baseline that is necessary to support full earned value management reporting. The use of earned value management is advocated by both GAO's best practices for cost estimating and NASA's own guidance.	Programs that do not use earned value data are limited in their ability to have accurate assessments of project progress, produce early warning signs of impending schedule delays and cost overruns, and provide unbiased estimates of anticipated costs at completion.	GAO-16-612
The Orion and SLS programs established baselines that were not fully reliable.[a]	In July 2016, we found that the Orion program did not generally follow best practices in preparing its cost and schedule estimates, which were key inputs into the program's joint cost and schedule confidence level processes and baseline. In July 2015, we found that cost and schedule estimates for the SLS program substantially met five of six characteristics that GAO considers best practices for preparing reliable estimates, but could not be deemed fully reliable because they only partially met the sixth characteristic—credibility.	Without sound cost and schedule estimates, decision makers do not have a clear understanding of the cost and schedule risk inherent in the program or important information needed to make programmatic decisions.	GAO-16-620 and GAO-15-596

Source: GAO analysis of prior GAO reports. | GAO-18-576T

[a]We did not assess EGS's cost and schedule estimates compared to best practices.

In December 2017, NASA announced the new internal launch readiness date for EM-1 is now December 2019, and has allocated 6 months of schedule reserve available to extend the date to June 2020 for possible manufacturing and production schedule risks. This represents a delay of

13-19 months for EM-1. It is too soon to know if NASA has addressed the programmatic challenges identified above. We will continue to follow up through future reviews.

Similarly, the SGSS project experienced new cost growth of $59.5 million and delayed its completion by 21 months. Project officials attributed the cost growth and delays to the contractor's incomplete understanding of its requirements, which led to poor contractor plans and late design changes. But project management has been a challenge as well.[19] The project has historically struggled to manage contractor performance and has faced both contractor and project staffing shortfalls, as we found in our prior reports starting in 2013.[20] For example, NASA managers noted concerns with contractor plans and staffing estimates in 2013 during project confirmation. In March 2015, we found that the project was being rebaselined due to the contractor's poor cost and schedule performance and in order to conform with limitations that NASA placed on the funding available to the contractor in fiscal years 2014 and 2015. The contractor was also operating with a limited number of staff at that time. In May 2017, we found that the project continued to experience contractor performance problems and had experienced cost growth and schedule delays over the 2015 rebaseline even as the project decreased its scope. In addition, the project experienced staff shortfalls in key areas, such as systems engineering and business management.

The Mars 2020 project experienced $12.9 million in development cost growth, but no schedule delays. The cost growth was primarily due to technical challenges on a technology demonstration instrument and higher than anticipated integration costs for an entry, descent, and landing instrument. Both instruments are funded by the Human Exploration and Operations and Space Technology Mission Directorates. NASA officials attributed the cost growth of the technology demonstration instrument—which is designed to convert carbon dioxide to oxygen—to

[19]In 2016, NASA announced it was reclassifying SGSS as a hybrid sustainment project for the Space Network. A hybrid sustainment effort is a sustainment effort that still includes development work. The SGSS project expects to experience additional cost growth and schedule delays, but the exact magnitude is unknown. The project was reevaluating its cost and schedules through its final acceptance review at the time of our review.

[20]GAO, *NASA: Assessments of Selected Large-Scale Projects*, GAO-13-276SP (Washington, D.C.: Apr. 17, 2013); *NASA: Assessments of Selected Large-Scale Projects*, GAO-14-338SP (Washington, D.C.: Apr. 15, 2014); *NASA: Assessments of Selected Large-Scale Projects*, GAO-15-320SP (Washington, D.C.: Mar. 24, 2015); GAO-16-309SP; and GAO-17-303SP.

the complexity of the technology development for the effort. At the project's preliminary design review in February 2016, a critical technology for the technology demonstration instrument did not meet the recommended level of maturity, which we have found can increase risk for systems entering product development. The project had matured the technology to this recommended level by its critical design review in February 2017. However, as a result of the focus on maturing this particular technology, other components of the instrument fell behind the planned schedule. Project costs for Mars 2020 also increased for an entry, descent, and landing instrument, due, in part, to cost increases for integration and to add additional staff to the instrument team to maintain schedule.

Finally, the Radiation Budget Instrument project would have likely exceeded its cost baseline if NASA had not decided to cancel the project in January 2018. According to NASA's cancellation memorandum, the project was canceled because of continued cost growth, technical issues, and poor contractor performance. In 2017, we found that the project was working to an aggressive schedule, and the prime contractor continued to experience cost overruns even after NASA added a deputy project manager and increased site visits and meetings with the contractor.[21] Subsequently, the project—which was developing an instrument to be hosted on a National Oceanic and Atmospheric Administration satellite—determined that it would not be able to meet its delivery date for integration with the satellite without requiring additional funding in excess of the project's cost baseline if other technical issues arose. In its cancellation memorandum, NASA stated continuing to fund the project from within the Earth Science Division budget would slow other important activities.

Technical challenges identified during integration and test. The JWST and ICESat-2 projects experienced technical challenges during integration and test that delayed their schedules. Both projects were previously rebaselined before entering system-level integration and testing, and the current schedule delays are beyond the new schedules that NASA set for the projects in 2011 for JWST and in 2014 for ICESat-2.

[21]GAO-17-303SP.

- The JWST project delayed its launch readiness date by at least 19 months from October 2018 to May 2020. NASA announced two delays for the project since our portfolio-wide review in May 2017.[22] First, as we found in February 2018, the project delayed its launch readiness date by up to 8 months primarily due to the integration of the various spacecraft elements taking longer than expected.[23] Specifically, execution of spacecraft integration and test tasks, due to complexity of work and cautious handling given the sensitivity of flight hardware, was slower than planned. In addition, before the delay, the project used all of its schedule reserves to its prior launch readiness date. This was the result of various contractor workmanship errors, particularly with respect to the spacecraft propulsion systems, as well as the resolution of various technical issues, including a test anomaly on the telescope and sunshield hardware challenges. Second, in March 2018, NASA announced that it had delayed the project's launch readiness date by an additional 11 months to approximately May 2020 and planned to establish an external independent review board to analyze the project's organizational and technical issues to inform a more specific launch time frame.

  The announcement also stated that after a new launch date is established, NASA would provide a new cost estimate that may exceed the $8 billion congressional cost cap that was established in 2011. NASA plans to finalize the project's cost and schedule estimate by the end of June 2018. Because the additional delays were announced while a draft of our May 2018 report was with NASA for comment, we plan to follow up on the reasons for the additional delays and the results of the analysis in a future review.

  In our prior assessments of JWST, we have made recommendations with regard to improving cost and schedule estimating, updating risk assessments, and strengthening management oversight. NASA has generally agreed and taken steps to implement a number of our recommendations. For example, in December 2015, we recommended that the JWST project require contractors to identify, explain, and document anomalies in contractor-delivered monthly

[22]GAO-17-303SP.

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

earned value management reports.[24] NASA concurred with this recommendation and, in February 2016, directed the contractors to implement the actions stated in the recommendation. However, NASA did not implement some recommendations, which if implemented, may have provided insight into the challenges it now faces. For example, in December 2012, we recommended the JWST project update its JCL.[25] Although NASA concurred with this recommendation, it did not take steps to implement it. An updated JCL may have portended the current schedule delays, which could have been proactively addressed by the project.

- The ICESat-2 project delayed its launch readiness date by 4 months from June to October 2018 due to technical issues with its only instrument, the Advanced Topographic Laser Altimeter System. A key part in the instrument's lasers failed during instrument environmental testing, which delayed the project's system integration review—the start of system-level integration and test. The manufacturer determined the primary cause of the anomaly was a flaw in the design of the mount that ensures a component of the optical module remains in a specific, precise position. The spare flight laser encountered the same problem during earlier testing, which indicated a systemic problem. The project redesigned and repaired the lasers and is proceeding through integration and test.

External factors. External factors—including responding to requests for additional data collection and delays due to launch-vehicle related issues—contributed to cost increases or schedule delays for the NISAR, ICON, and GRACE-FO projects.

- The NISAR project experienced cost growth as the result of an increase in the scope of data collection in response to additional data needs being identified by an interagency working group. The additional data include soil moisture and natural hazard data that would be of value for other federal agencies and the science community. NASA officials said the additional funding for development would be used to upgrade the ground stations so that they can receive the additional data at a higher downlink data rate and volume.

[24]GAO, James Webb Space Telescope: Project on Track but May Benefit from Improved Contractor Data to Better Understand Costs, GAO-16-112 (Washington, D.C.: Dec. 17, 2015).

[25]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).

- The ICON project missed its committed launch readiness date because of an accident involving its launch vehicle. In January 2017, two of the Pegasus launch vehicle's three stages were involved in a transport accident. The stages were subsequently returned to the launch vehicle contractor facility for inspection and testing, and no damage was found. The project had been on track to launch early. Subsequently, in September 2017, an anomaly found in testing of the launch vehicle bolt cutter assemblies resulted in additional delays. NASA had planned to launch ICON in mid-June 2018, but recently announced a delay after off-nominal data was observed from the rocket during transit to the launch site. NASA announced a new launch date would be determined at a later date.
- The GRACE-FO project delayed its launch readiness date from February to May 2018 due to issues with its planned launch vehicle and launch site. The launch vehicle is the responsibility of NASA's partner on the project—German Research Centre for Geosciences (GFZ). GRACE-FO had planned to launch at a Russian launch site. In February 2016, GFZ reported that it was notified by the Russian Federal Space Agency that the Dnepr launch vehicle was no longer available for GRACE-FO. GFZ, in June 2016, arranged to launch the two GRACE-FO spacecraft, along with commercial satellites, on a SpaceX Falcon 9. On May 22, 2018, GRACE-FO launched from Vandenberg Air Force Base in California.

In addition, the Commercial Crew Program also experienced delays, which are not included above because the program does not have a schedule baseline. Since the award of the current Commercial Crew contracts in September 2014, the program, Boeing, SpaceX, and multiple independent review bodies have all identified the contractors' delivery schedules as aggressive. In February 2017, we found that Boeing and SpaceX had determined that neither could meet their original 2017 dates for NASA to certify their systems for human spaceflight.[26] In January 2018, we found that both contractors had notified NASA that final certification dates have slipped again and are now in the first quarter of calendar year 2019.[27] The Commercial Crew Program's schedule

[26]GAO, *NASA Commercial Crew Program: Schedule Pressure Increases as Contractors Delay Key Events,* GAO-17-137 (Washington, D.C.: Feb. 16, 2017).

[27]GAO, *NASA Commercial Crew Program: Continued Delays Pose Risks for Uninterrupted Access to the International Space Station,* GAO-18-317T (Washington, D.C.: Jan. 17, 2018).

analysis indicates that certification may be further delayed to December 2019 for SpaceX and February 2020 for Boeing.

NASA Is Likely to Encounter Additional Cost Growth and Schedule Delays

The composition of the portfolio in the coming years is expected to include large and complex projects, putting NASA at risk of continued cost increases and schedule delays. Specifically, NASA plans to have complex projects enter the development portfolio in the next few years as it holds confirmation reviews and set cost and schedule baselines. This includes the Europa Clipper project and potentially the Wide-Field Infrared Survey Telescope (WFIRST) project. In February 2018, the President's 2019 Budget Request proposed canceling the WFIRST project due to the project's significant costs and higher priorities in the agency. However, the project may continue if funding is received. Together, preliminary estimates indicate that these two projects could cost as much as $7.8 billion. In addition, NASA expects to begin other large, complex projects like the Lunar Orbital Platform-Gateway—currently being discussed as a space station or outpost in lunar orbit—and a Europa Lander project in the coming years. A December 2017 space policy directive also instructed NASA to return astronauts to the moon for long-term exploration and to pursue human exploration of Mars and the broader solar system.

To its credit, NASA recently took steps to put a process in place to control the costs of two projects while in formulation, which may prove useful if properly executed.

- The Europa Clipper project implemented a process whereby cost growth threats would be offset by descoping instruments in whole or in part. For example, if an instrument exceeds its development cost by 20 percent, the project would propose a descope option to NASA that brings instrument cost below that threshold. NASA had not descoped any instruments as of our May 2018 report.
- The WFIRST project is responding to findings from an independent review that was conducted to ensure the mission's scope and required resources are well understood and executable. The review found that the mission scope is understood, but not aligned with the resources provided and concluded that the mission is not executable without adjustments and/or additional resources. For example, the study team found that NASA's current forecasted funding profile for the WFIRST project would require the project to slow down activities starting in fiscal year 2020, which would result in an increase in development cost and schedule. NASA agreed with the study team's

results and directed the project to reduce the cost and complexity of the design in order to maintain costs within the $3.2 billion preliminary cost target.

But even with these efforts, NASA's cost and schedule performance may be further tested in upcoming years as some expensive, complex projects linger in the portfolio longer than expected.

- As previously discussed, the Orion program expects cost growth and faces other schedule and technical risks as it moves through the integration and test phase for EM-1 into at least 2019 and then through 2023 for EM-2. As of August 2017, NASA officials expected that new hardware and addressing development challenges would be the factors contributing to increased cost for the program. For example, there was a cost impact when the program moved from a single-piece, or monolithic, heatshield design to one that employs blocks in order to improve its structural strength. Program officials said they are also assessing schedule delays for EM-2, and noted that the EM-2 launch date depends on the outcome of the EM-1 launch date.
- The SLS and EGS programs continue to face cost, schedule, and technical risks as they move through the integration and test phase into at least 2019. For example, SLS will have to complete a "green run" test which requires multiple first-time efforts. Specifically, the test is the culmination of the development effort and includes the core stage integration with its four main engines, fully fueling with cryogenic hydrogen and oxygen, and then firing all four engines for about 500 seconds. NASA currently has no schedule reserve to its target December 2019 launch readiness date for two key areas in the core stage schedule. First, there is no reserve between the end of core stage production and the delivery of the core stage to the test facility. Second, there is no reserve between the end of the testing and delivery to Kennedy Space Center for final integration and testing prior to launch.
- As previously discussed, the JWST project is at risk of exceeding its congressional cost cap, and faces schedule risks as it completes its remaining integration and test work. These activities have taken considerably longer than planned due to a variety of challenges, including reach and access limitations on the flight hardware. Additionally, the project faces significant work ahead. For example, the project must complete integration of spacecraft element hardware and conduct deployment and environmental tests of the integrated sunshield and spacecraft. Further, it must integrate the telescope

element with the spacecraft element to form the JWST observatory, and complete another set of challenging environmental tests on the full integrated observatory. At the same time, the project will need to mitigate dozens of remaining hardware and software risks to acceptable levels and address the project's many potential single point failures to the extent possible.

- The SGSS project expects to experience additional cost growth through the final acceptance review because the full scope of the effort has not been included in the cost. NASA only approved its new cost estimate through the initial operational readiness review, currently planned for September 2019. A project official said NASA headquarters asked the project to determine if there are ways to reduce the cost between the operational readiness review and the final acceptance review. NASA plans to conduct an independent review of the project in mid-2018 to inform a decision on whether to continue the project past the operational readiness review. If NASA decides to continue the project past this review, additional cost growth is expected for SGSS when NASA revisits project costs through future budget cycles.

In closing, NASA continues to make improvements to the acquisition management of its portfolio of major projects. However, the deterioration of the cost and schedule performance of NASA's portfolio this year and the likelihood of additional cost growth and schedule delays demonstrate the need for NASA to continue to take actions to further reduce acquisition risk as we and others have recommended. Continuing to improve cost and schedule estimating tools and practices—such as by providing projects with sufficient cost and schedule reserves to address risks and unforeseen technical challenges and ensuring that program offices regularly and consistently update their JCLs across the portfolio—could help to better position NASA for improved outcomes. We look forward to continuing to work with NASA and this subcommittee in addressing these issues.

Chairman Babin, Ranking Member Bera, and Members of the Subcommittee, this completes my prepared statement. I would be pleased to respond to any questions that you may have at this time.

GAO Contact and Staff Acknowledgments

If you or your staff have any questions about this testimony, please contact Cristina T. Chaplain, Director, Contracting and National Security Acquisitions 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 statement. GAO staff who made key contributions to this statement include Molly Traci, Assistant Director; Laura Greifner; Erin Kennedy; Miranda Riemer; Roxanna T. Sun; and Alyssa Weir.

Appendix I: Descriptions of National Aeronautics and Space Administration Major Projects Reviewed in GAO's 2018 Assessment

Table 4: Descriptions of the 26 National Aeronautics and Space Administration (NASA) Major Projects Reviewed in GAO's 2018 Assessment

Project name	Project description
Commercial Crew Program	The Commercial Crew Program facilitates and oversees the development of safe, reliable, and cost-effective crew transportation systems by commercial companies to carry NASA astronauts to and from the International Space Station. The program is a multi-phase effort that started in 2010. During the current phase, the program is working with two contractors—Boeing and SpaceX—that will design, develop, test, and operate the crew transportation systems. Once NASA determines the systems meet its standards for human spaceflight—a process called certification—the companies will fly up to six crewed missions to the space station.
Double Asteroid Redirection Test (DART)	The DART project plans to travel to the near-Earth asteroid Didymos, a binary system, and impact the smaller of the two bodies. NASA will assess the deflection result of the impact for potential future use on other potentially hazardous near-Earth objects. The project responds to near-Earth object guidance by the Office of Science and Technology Policy to better understand our impact mitigation posture, and to recommendations by the National Research Council Committee to conduct a test of a kinetic impactor. The DART mission is part of the Asteroid Impact and Deflection Assessment, which is an international collaboration with the European Space Agency.
Europa Clipper	The Europa Clipper mission aims to investigate whether the Jupiter moon could harbor conditions suitable for life. The project plans to launch a spacecraft in the 2020s, place it in orbit around Jupiter, and conduct a series of investigatory flybys of Europa. The mission's planned objectives include characterizing Europa's ice shell and any subsurface water, analyzing the composition and chemistry of its surface and ionosphere, understanding the formation of its surface features, and surveying sites for a potential landed mission.
Exploration Ground Systems (EGS)	The EGS program is modernizing and upgrading infrastructure at the Kennedy Space Center and developing software needed to integrate, process, and launch the Space Launch System (SLS) and Orion Multi-Purpose Crew Vehicle (Orion). The EGS program consists of several major construction and facilities projects including the Mobile Launcher, Crawler Transporter, Vehicle Assembly Building, and launch pad, all of which need to be complete before the first uncrewed exploration mission using the SLS and Orion vehicles.
Gravity Recovery and Climate Experiment Follow-On (GRACE-FO)	The GRACE-FO mission will continue and expand upon the 2002 GRACE mission, which ended science operations in October 2017. The system, which consists of two spacecraft working together to obtain scientific measurements, will provide high-resolution models of Earth's gravity field and insight into water movement on and beneath the Earth's surface for up to 5 years. These models will provide rates of ground water depletion and polar ice melt and enable improved planning for droughts and floods. GRACE-FO is a collaborative effort with the German Research Centre for Geosciences.
Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2)	The ICESat-2 mission is a follow-on mission to ICESat that will measure changes in polar ice-sheet mass and elevation. The measurements will provide researchers a better understanding of the mechanisms that drive polar ice changes and their effect on global sea level. ICESat-2's upgraded laser instrument will allow the satellite to make more frequent measurements and provide better elevation estimates over certain types of terrain than ICESat.
Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight)	InSight is a Mars lander with two primary objectives. It is intended to further understanding of the formation and evolution of terrestrial planets by determining Mars's size, its composition, and the physical state of the core; the thickness of the crust; and the composition and structure of the mantle, as well as the thermal state of the interior. It will also determine the present level of tectonic activity and the meteorite impact rate on Mars. InSight is based on the Phoenix lander design. Phoenix successfully landed on Mars in 2008.

Project name	Project description
Ionospheric Connection Explorer (ICON)	The ICON observatory will orbit Earth to explore its ionosphere—the boundary region between Earth and space where ionized plasma and neutral gas collide and react. Its four instruments will make direct measurements and use remote sensing to further researchers' understanding of Earth's upper atmosphere, the Earth-Sun connection, and the ways in which Earth weather drives space weather.
James Webb Space Telescope (JWST)	JWST is a large, infrared-optimized space telescope designed to help understand the origin and destiny of the universe, the creation and evolution of the first stars and galaxies, and the formation of stars and planetary systems. It will also help further the search for Earth-like planets. JWST will have a large primary mirror composed of 18 smaller mirrors and a sunshield the size of a tennis court. Both the mirror and sunshield are folded for launch and open once JWST is in space. JWST will reside in an orbit about 1 million miles from the Earth.
Landsat 9	Landsat 9 is the next satellite in the Landsat series Program, which provides a continuous space-based record of land surface observations to study, predict, and understand the consequences of land surface dynamics, such as deforestation. The program is a collaborative, joint mission between NASA and the U.S. Geological Survey. The Landsat data archive constitutes the longest continuous moderate-resolution record of the global land surface as viewed from space and is used by many fields, such as agriculture, mapping, forestry, and geology.
Laser Communications Relay Demonstration (LCRD)	LCRD is a technology demonstration mission with the goal of advancing optical communication technology for use in deep space and near-Earth systems. LCRD will demonstrate bidirectional laser communications between a satellite and ground stations, develop operational procedures, and transfer the technology to industry for future use on commercial and government satellites. NASA anticipates using the technology as a next generation Earth relay as well as to support near-Earth and deep space science, such as the International Space Station and human spaceflight missions. The project is a mission partner and will be a payload on a U.S. Air Force Space Test Program satellite.
Low Boom Flight Demonstrator (LBFD)	LBFD is a flight demonstration project planned to demonstrate that noise from supersonic flight—sonic boom—can be reduced to acceptable levels, allowing for eventual commercial use of overland supersonic flight paths. Plans include multiple flights beyond fiscal year 2022 to gather community responses to the flights and to create a database to support development of international noise rules for supersonic flight.
Lucy	Lucy will be the first mission to investigate the Trojans, which are a population of never-explored asteroids orbiting in tandem with Jupiter. The project aims to understand the formation and evolution of planetary systems by conducting flybys of these remnants of giant planet formation. The Lucy spacecraft will first encounter a main belt asteroid—located between the orbits of Mars and Jupiter—and then will travel to the outer solar system where the spacecraft will encounter six Trojans over an 11-year mission. The mission's planned measurements include asteroid surface color and composition, interior composition, and surface geology.
Mars 2020	Mars 2020 is part of the Mars Exploration Program, which seeks to further understand whether Mars was, is, or can be a habitable planet. Its rover and science instruments will explore Mars and conduct geological assessments, search for signs of ancient life, determine potential environmental habitability, and prepare soil and rock samples for potential future return to Earth. The rover will include a technology demonstration instrument designed to convert carbon dioxide into oxygen. Mars 2020 is based heavily on the Mars Science Laboratory, or Curiosity, which landed on Mars in 2012 and remains in operation.

Project name	Project description
NASA ISRO Synthetic Aperture Radar (NISAR)	NISAR is a joint project between NASA and Indian Space Research Organisation (ISRO) that will study the solid Earth, ice masses, and ecosystems. It aims to address questions related to global environmental change, Earth's carbon cycle, and natural hazards, such as earthquakes and volcanoes. The project will include the first dual frequency synthetic aperture radar instrument, which will use advanced radar imaging to construct large-scale data sets of the Earth's movements. NISAR represents the first major aerospace science partnership between NASA and ISRO.
Orion Multi-Purpose Crew Vehicle (Orion)	Orion is being developed to transport and support astronauts beyond low-Earth orbit, including traveling to Mars or an asteroid. The Orion program is continuing to advance development of the human safety features, designs, and systems started under the Constellation program, which was canceled in 2010. Orion is planned to launch atop NASA's Space Launch System. The current design of Orion consists of a crew module, service module, and launch abort system.
Parker Solar Probe (PSP)	PSP will be the first NASA mission to visit a star. Using the gravity of Venus, the spacecraft will orbit the Sun 24 times and gather information to increase knowledge about the solar wind, including its origin, acceleration, and how it is heated. PSP instruments will observe the generation and flow of solar winds from very close range and sample and take measurements of the Sun's outer atmosphere, where solar particles are energized. To achieve its mission, parts of the spacecraft must be able to withstand temperatures exceeding 2,500 degrees Fahrenheit and endure blasts of extreme radiation. The project was formerly named Solar Probe Plus, or SPP, and was renamed in May 2017.
Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)	PACE is a polar-orbiting mission that will use advanced global remote sensing instruments to improve scientists' understanding of ocean biology, biogeochemistry, ecology, aerosols, and cloud properties. PACE will extend climate-related observations begun under earlier NASA missions, which will enable researchers to study long-term trends on Earth's oceans and atmosphere, and ocean-atmosphere interactions. PACE will also enable assessments of air and coastal water quality, such as the locations of harmful algae blooms.
Psyche	Psyche will be the first mission to visit a metal asteroid and aims to understand a previously unexplored component of the early building blocks of planets: iron cores. The project plans to orbit the Psyche asteroid to determine if it is a planetary core, characterize its topography, assess the elemental composition, and determine the relative ages of its surface regions.
Radiation Budget Instrument (RBI)	RBI is a scanning radiometer that NASA planned to launch on the National Oceanic and Atmospheric Administration's (NOAA) Joint Polar Satellite System 2. RBI's planned mission was to support global climate monitoring by continuing measurements of the Earth's reflected sunlight and emitted thermal radiation made by NASA and NOAA satellites over the past 30 years. This data was intended to represent one of two key sets of measurements needed to determine whether the Earth is warming or cooling.
Restore-L	The Restore-L project will demonstrate the capability to refuel on-orbit satellites for eventual use by commercial entities. Specifically, Restore-L plans to autonomously rendezvous with, inspect, capture, refuel, adjust the orbit of, safely release, and depart from the U.S. Geological Survey's Landsat 7 satellite. Landsat 7 can extend operations if successfully refueled, but it is planned for retirement if the technology demonstration is unsuccessful.
Space Launch System (SLS)	SLS is intended to be NASA's first human-rated heavy-lift launch vehicle since the Saturn V was developed for the Apollo program. SLS is planned to launch NASA's Orion spacecraft and other systems on missions between the Earth and Moon and to enable deep space missions, including Mars. NASA is designing SLS to provide an initial lift capacity of 70 metric tons to low-Earth orbit, and be evolvable to 130 metric tons, enabling deep space missions. The 70-metric-ton capability will include a core stage, powered by four RS-25 engines, and two five-segment boosters. The 130-metric-ton capability will use a new upper stage and evolved boosters.

Project name	Project description
Space Network Ground Segment Sustainment (SGSS)	The SGSS project plans to develop and deliver a new ground system for one Space Network site. The Space Network provides essential communications and tracking services to NASA and non-NASA missions. Existing systems, based on 1980s technology, are increasingly obsolete and unsustainable. The new ground system will include updated systems, software, and equipment that will allow the Space Network to continue to provide critical communications services for the next several decades. The Space Network is managed by the Space Communication and Navigation program.
Surface Water and Ocean Topography (SWOT)	The SWOT mission will use its wide-swath radar altimetry technology to take repeated high-resolution measurements of the world's oceans and freshwater bodies to develop a global survey. This survey will make it possible to estimate water discharge into rivers more accurately, and help improve flood prediction. It will also provide global measurements of ocean surface topography and variations in ocean currents, which will help improve weather and climate predictions. SWOT is a joint project between NASA and the French Space Agency—the Centre National d'Etudes Spatiales.
Transiting Exoplanet Survey Satellite (TESS)	TESS will use four identical, wide field-of-view cameras to conduct the first extensive survey of the sky from space for transiting exoplanets—or planets in other solar systems. The mission's goal is to discover these exoplanets during transit, the time when the planet's orbit carries it in front of its star as viewed from Earth. The project plans to discover rocky and potentially habitable Earth-sized and super-Earth planets orbiting nearby bright stars for further evaluation through ground- and space-based observations by other missions, such as JWST.
Wide-Field Infrared Survey Telescope (WFIRST)	WFIRST is an observatory designed to perform wide-field imaging and survey of the near-infrared sky to answer questions about the structure and evolution of the universe, and expand our knowledge of planets beyond our solar system. The project will use a telescope that was originally built and qualified by another federal agency. The project plans to launch WFIRST in the mid-2020s to an orbit about 1 million miles from the Earth. The project is also planning a guest observer program, in which the project may provide observation time to academic and other institutions.

Source: GAO. | GAO-18-576T

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