United States Government Accountability Office

Report to Congressional Committees

April 2017

NASA HUMAN SPACE EXPLORATION

Delay Likely for First Exploration Mission

GAO-17-414

GAO Highlights

Highlights of GAO-17-414, a report to congressional committees

April 2017

NASA HUMAN SPACE EXPLORATION

Delay Likely for First Exploration Mission

Why GAO Did This Study

NASA is undertaking a trio of closely related programs to continue human space exploration beyond low-Earth orbit: the SLS vehicle; the Orion capsule, which will launch atop the SLS and carry astronauts; and EGS, the supporting ground systems. NASA's current exploration efforts are estimated to cost almost $24 billion—to include two Orion flights and one each for SLS and EGS—and constitute more than half of NASA's current portfolio development cost baseline. All three programs are necessary for EM-1 and are working toward a launch readiness date of November 2018. In a large body of work on this issue, including two separate July 2016 reports, GAO has found that these programs have a history of working to aggressive schedules.

The House Committee on Appropriations report accompanying H.R. 2578 included a provision for GAO to assess the acquisition progress of the Orion, SLS, and EGS, programs. This report assesses the extent to which these programs have risks that affect their progress toward meeting their commitments for EM-1. To do this work, GAO assessed documentation on schedule and program risks and interviewed program and NASA officials.

What GAO Recommends

NASA should confirm whether the current EM-1 date is still achievable no later than as part of its fiscal year 2018 budget submission, and propose a new, realistic EM-1 launch readiness date, if warranted, and report its findings to Congress. NASA concurred with both recommendations and agreed that EM-1 will be delayed.

View GAO-17-414. For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

With less than 2 years until the planned November 2018 launch date for its first exploration mission (EM-1), the National Aeronautics and Space Administration's (NASA) three human exploration programs—Orion Multi-Purpose Crew Vehicle (Orion), Space Launch System (SLS), and Exploration Ground Systems (EGS)—are making progress on their respective systems, but the EM-1 launch date is likely unachievable as technical challenges continue to cause schedule delays. All three programs face unique challenges in completing development, and each has little to no schedule reserve remaining between now and the EM-1 date, meaning they will have to complete all remaining work with little margin for error for unexpected challenges that may arise. The table below lists the remaining schedule reserve for each of the programs.

Schedule Reserve to Exploration Mission 1 for Orion Multi-Purpose Crew Vehicle, Space Launch System, and Exploration Ground Systems Programs

Program	Schedule reserve to Exploration Mission-1 (in days)
Orion Multi-Purpose Crew Vehicle	0
Space Launch System	80
Exploration Ground Systems	28

Source: GAO Analysis of NASA data | GAO-17-414

The programs all face challenges that may impact their remaining schedule reserve. For instance

- the Orion program's European Service Module is late and is currently driving the program schedule;
- the SLS program had to stop welding on the core stage—which functions as the SLS's fuel tank and structural backbone—for months after identifying low weld strengths. Program officials stated that welding resumed in April 2017 following the establishment of a corrective action plan;
- the EGS program is considering performing concurrent hardware installation and testing, which officials acknowledge would increase complexity; and
- each program must integrate its own hardware and software individually, after which EGS is responsible for integrating all three programs' components into one effort at Kennedy Space Center.

Low cost reserves further intensify the schedule pressure. Senior NASA officials said they are analyzing the launch schedule and expect that the EM-1 date will have to slip, but they have yet to make a decision on the feasibility of the current date or report on their findings. With budget discussions currently ongoing for fiscal year 2018, the last year prior to launch, Congress does not yet have insight into the feasibility of the EM-1 launch date, or the repercussions that any cost increase or delays could have in terms of cost and schedule impacts for NASA's entire portfolio. Unless NASA provides Congress with up-to-date information on whether the current EM-1 date is still achievable, as of the time the agency submits its 2018 budget request, both NASA and Congress will continue to be at risk of making decisions based on less than the entire picture and on likely unachievable schedules.

Contents

Letter		1
	Background	3
	Ongoing Delays Foreshadow a Likely Schedule Slip as NASA Reassesses the Launch Readiness Date	7
	Conclusions	14
	Recommendations for Executive Action	15
	Agency Comments and Our Evaluation	15
Appendix I	Objective, Scope, and Methodology	17
Appendix II	Comments from the National Aeronautics and Space Administration	18
Appendix III	GAO Contact and Staff Acknowledgments	20
Table		
	Table 1: Cost and Schedule Baselines for National Aeronautics and Space Administration Human Exploration Programs	6
Figures		
	Figure 1: Space Launch System and Orion Multi-Purpose Crew Vehicle Hardware	4
	Figure 2: Select Components of Exploration Ground Systems Program	5

Abbreviations

EGS	Exploration Ground Systems
EM-1	Exploration Mission 1
EM-2	Exploration Mission 2
ESA	European Space Agency
ESM	European service module
NASA	National Aeronautics and Space Administration
Orion	Orion Multi-Purpose Crew Vehicle
SLS	Space Launch System

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

April 27, 2017

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

The Honorable John Culberson
Chairman
The Honorable José Serrano
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
House of Representatives

The National Aeronautics and Space Administration (NASA) is developing the Orion Multi-Purpose Crew Vehicle (Orion) and its first exploration-class heavy-lift launch vehicle—the Space Launch System (SLS)—in over 40 years, along with the Exploration Ground Systems (EGS) program that provides the necessary ground support equipment. While NASA intends for the Orion, SLS, and EGS programs to provide an important capability for human exploration missions, the agency's more recent attempts to develop vehicles to transport humans beyond low-Earth orbit have ultimately been unsuccessful. Prior programs have been canceled after facing acquisition problems and funding-related issues. NASA's current exploration efforts are estimated to cost almost $24 billion—to include two Orion flights and one each for SLS and EGS—and constitute more than half of NASA's current portfolio development cost baseline. All three programs are necessary for the first integrated test flight, Exploration Mission 1 (EM-1), and are working toward a launch readiness date of November 2018.

GAO has designated NASA's management of acquisitions as a high-risk area for more than two decades. In February 2017, we found that the agency has maintained progress in reducing risk on major projects after previously struggling with poor cost estimation, weak oversight, and risk

underestimation.[1] However, we also found that while the Orion, SLS, and EGS programs are generally better positioned for success than past crewed vehicle efforts, management weaknesses—including overly ambitious schedules, unreliable cost estimating, limited reserves, and operating for extended periods of time without definitized contracts—have increased the likelihood that the programs will incur schedule delays and cost overruns, particularly when coupled with the technical risks that are inherent in any human spaceflight development.

As we have found in our prior work, the Orion, SLS, and EGS programs have encountered cost and schedule challenges.[2] The House Committee on Appropriations included a provision in its 2015 report for GAO to review the acquisition progress of NASA's human exploration programs, including Orion, SLS, and ground systems.[3] This report assesses the extent to which the Orion, SLS, and EGS programs have risks that affect progress toward meeting their schedule and cost commitments for EM-1.

To assess the programs' progress against their EM -1 cost and schedule commitments, we compared current program status data against the programs' cost and schedule baselines. To assess the risks for the Orion, SLS, and EGS programs, we obtained and reviewed quarterly reports and the programs' risk registers and met with relevant program and contractor officials regarding program risks and impacts in order to understand the programs' risks, the potential impacts, and program mitigation plans. To evaluate the programs' performance in preparing for EM-1, we reviewed program plans and schedules and compared that data and information to quarterly program status reviews and program update briefings to assess whether program components and software were progressing as expected. We also compared current program data against program

[1]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).

[2]GAO, *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: Opportunity Nears to Reassess Launch Vehicle and Ground Systems Cost and Schedule*, GAO-16-612 (Washington, D.C.: July 27, 2016).

[3]H.R. Rep. No. 114-130, at 60-61 (2015), accompanying H.R. 2578. The Ground Systems Development and Operations program includes both the 21st Century Space Launch Complex Initiative and the EGS appropriation. For the purposes of this report, we refer to EGS as a program because NASA approved cost and schedule baselines specific to the EGS effort and NASA's budget request refers to it as a program.

budget information to assess funding needs and cost growth. To assess the availability of the programs' cost and schedule reserves, we analyzed its budget documentation and interviewed program management from all three programs to discuss the programs' budget and reserve postures. For more information on our scope and methodology, see appendix I.

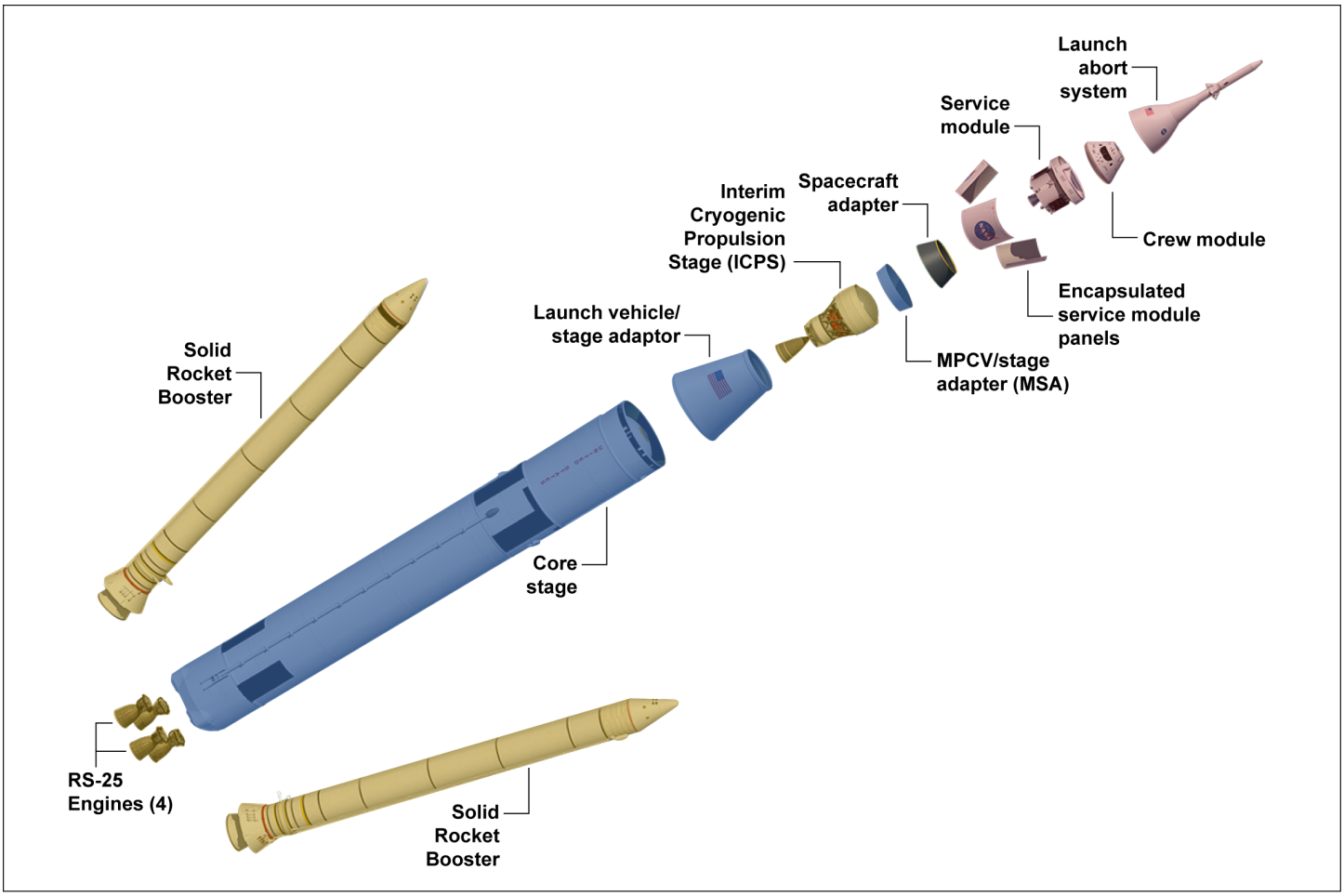
We conducted this performance audit from July 2016 to April 2017 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based 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

The NASA Authorization Act of 2010 directed NASA to develop a Space Launch System, to continue development of a crew vehicle, and prepare infrastructure at Kennedy Space Center to enable processing and launch of the launch system.[4] To fulfill this direction, NASA formally established the SLS program in 2011. Then, in 2012, the Orion project transitioned from its development under the Constellation program—a program that was intended to be the successor to the Space Shuttle but was canceled in 2010 due to factors that included cost and schedule growth—to a new development program aligned with SLS. To transition Orion from Constellation, NASA adapted the requirements from the former Orion plan with those of the newly created SLS and the associated ground systems programs. In addition, NASA and the European Space Agency (ESA) agreed that ESA would provide a portion of the service module for Orion. Figure 1 provides details about the heritage of each SLS hardware element and its source as well as identifies the major portions of the Orion crew vehicle.

[4]Pub. L. No. 111-267, §§ 302, 303, 305.

Figure 1: Space Launch System and Orion Multi-Purpose Crew Vehicle Hardware



Source: GAO analysis of National Aeronautics and Space Administration data (data and images). | GAO-17-414

The EGS program was established to renovate portions of the Kennedy Space Center to prepare for integrating hardware from the three programs as well as launching SLS and Orion. EGS is made up of nine major components, including: the Vehicle Assembly Building, Mobile Launcher, software, Launch Pad 39B, Crawler-Transporter, Launch Equipment Test Facility, Spacecraft Offline Processing, Launch Vehicle

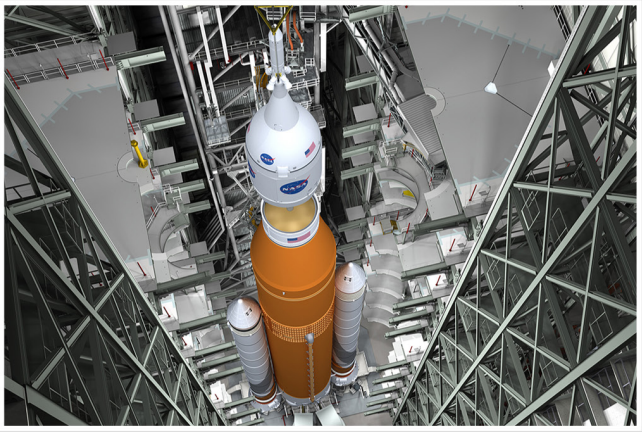
Offline Processing, and Landing and Recovery. See figure 2 for pictures of the Mobile Launcher, Vehicle Assembly Building, Launch Pad 39B, and Crawler-Transporter.

Figure 2: Select Components of Exploration Ground Systems Program

Mobile Launcher

Launch Pad 39B

Vehicle Assembly Building



Vehicle Assembly Building, inside High Bay 3

Crawler-Transporter

Source: National Aeronautics and Space Administration. | GAO-17-414

NASA established an agency baseline commitment—the cost and schedule baselines against which the program may be measured—for each program. NASA has committed to be ready to conduct one test flight, EM-1, no later than November 2018. During EM-1, the SLS vehicle is scheduled to launch an uncrewed Orion to a distant orbit some 70,000 kilometers beyond the moon. All three programs—SLS, Orion, and EGS—must be ready on or before this launch readiness date to support this integrated test flight. While the SLS and EGS program cost and schedule baselines are tied to the uncrewed EM-1 mission, the Orion program's cost and schedule baselines are tied to a second, crewed mission—EM-2. See table 1 for program baseline information.

Table 1: Cost and Schedule Baselines for National Aeronautics and Space Administration Human Exploration Programs

NASA human exploration programs	Agency baseline commitment		
	Exploration Mission (EM) 1 Launch Readiness Date	Exploration Mission (EM) 2 Launch Readiness Date	Cost (in billions of dollars)
Orion Multi-Purpose Crew Vehicle	—[a]	April 2023	11.3
Space Launch System	November 2018	—	9.7
Exploration Ground Systems	November 2018	—	2.8

Source: GAO presentation of NASA data | GAO-17-414

[a]The Orion program will participate in EM-1 and is working toward a November 2018 launch readiness date, but is baselined to EM-2.

All three programs are entering the integration and test phase of the development life cycle—which our prior work has shown to be when problems are commonly found and schedules tend to slip. In general, programs have schedule and cost reserves in order to address challenges that arise during development. Funded schedule reserve is extra time, with the money to pay for it, in the program's overall schedule in the event that there are delays or unforeseen problems. Cost reserves are additional funds that can be used to mitigate problems during the development of a program. For example, cost reserves can be used to buy additional materials to replace a component or, if a program needs to preserve schedule, cost reserves can be used to accelerate work by adding extra shifts to expedite manufacturing and save time.

Ongoing Delays Foreshadow a Likely Schedule Slip as NASA Reassesses the Launch Readiness Date

With less than two years until the committed November 2018 launch readiness date for EM-1, the three human exploration programs—Orion, SLS, and EGS—are making progress, but schedule pressure is escalating as technical challenges continue to cause schedule delays. All three programs face development challenges in completing work, and each has little to no schedule reserve remaining to the EM-1 date—meaning they will have to complete all remaining work with minimal delay during the most challenging stage of development. This includes completing design, production, and integration work at each program as well as integrating the hardware and software from the three programs in preparation for launch. Integration and testing is the phase where problems are most likely to be found, and the amount of potential problems is increased due to the two levels of integration—each inherently complex program must be integrated individually and then as an interdependent, combined enterprise. Because all three programs must be ready for launch to occur, a redesign of a single program's component, a test failure, or a significant hardware or software integration issue in any one area could delay the launch readiness date for all three programs.

The schedule pressure is intensified by the low levels of cost reserves held by all three programs to mitigate problems during development. In some cases, however, even if the programs held higher levels of cost reserves, using them to gain back schedule would be difficult because—at this late stage of development—work has become more sequential and there are fewer opportunities for workarounds, which the programs have relied on until now to preserve schedule. With little to no schedule or cost reserves remaining as the programs finalize production and enter integration and testing activities, the EM-1 launch readiness date is in a precarious position. While NASA officials told us they are assessing factors that could contribute to an EM-1 schedule slip, they have not committed to a timeline for completing that assessment or proposing an amended launch schedule, if needed. Therefore, it is unclear when Congress will be informed of NASA's findings and any impact those findings might have on NASA's fiscal year 2018 budget request.

Since we last reported on the human exploration programs in July 2016, the programs have made progress toward completing development, including the following:[5]

- **Orion:** After changing the heatshield design following a December 2014 test flight in which NASA determined that not all aspects of the original monolithic design would meet the more stringent requirements for EM-1 and EM-2 when the capsule will be exposed to greater temperature variance and longer durations, the Orion program and contractor reported that production of heatshield blocks is underway and production quality is very high.[6] Orion officials also stated that the risks associated with the ESM main engine—a heritage in-space maneuvering engine from the Space Shuttle program—have been largely addressed. The program was concerned with the state of internal components given their age; however, the engines have completed rounds of acceptance and vibration testing following replacement of valves and other components. In addition, the program and contractor stated that they have addressed all probable causes of crew module airbag anomalies from the December 2014 test flight. These bags are designed to inflate upon touchdown in the ocean to properly orient the crew module; however, some did not properly inflate or leaked due in part to the bags inflating before they were outside of the vehicle, which placed the bags under stress. While the root cause for the failures remains unknown, given the mitigation steps being taken, program officials now have high confidence in the system's performance going forward.
- **SLS:** Program officials stated that the solid rocket boosters have completed the second of two planned qualification tests and that the program has also implemented a design change to address an issue where the solid rocket propellant might loosen from the insulation on the inside of the booster casing, which may increase the risk of booster failure. The program office is performing analysis to ensure the mitigation meets expected safety margins. The program is producing test and flight unit core stage hardware and, according to program officials, has made progress manufacturing panels which will be bolted together to create the intertank section of the core stage. They also stated that early attempts to bend some of the thick

[5]GAO-16-620 and GAO-16-612.

[6]The heatshield will be capable of withstanding temperatures of up to 5,000 degrees Fahrenheit and will protect the Orion crew module during re-entry into Earth's atmosphere.

materials necessary for the core stage led to unrepairable cracks, but the contractor has updated its processes, which has allowed recently produced panels to pass inspections. The program has also begun integrated structural testing of its EM-1 in-space propulsion stage, Launch Vehicle Stage Adapter, and Orion Stage Adapter.

- **EGS:** Program officials stated that work for the Crawler Transporter and Launch Vehicle Offline Processing facility is complete. In addition, all 10 of the platforms that will allow access to the integrated SLS and Orion vehicles during final assembly in the Vehicle Assembly Building have been installed, according to EGS officials. Additionally, they have started verification and validation, the process by which the program assesses whether systems are capable of meeting their intended purpose and are being developed according to agency requirements, at the Multi-Payload Processing Facility—where spacecraft fueling will be performed. Program officials stated that 8 of the 20 pieces of launch equipment and accessories—for example, umbilical connections from the launch tower to the vehicle—have been built, finished testing, and are ready for installation onto the Mobile Launcher.

The magnitude of the schedule delays that the programs have experienced amid this progress, however, foreshadows a likely schedule slip for the November 2018 EM-1 launch readiness date. In addition, each program is facing risks that will likely consume what little schedule reserve exists, and low cost reserves limit mitigation options to achieve the planned launch readiness date. These ongoing challenges include the following:

Orion: The Orion program has no schedule reserve to EM-1 and the delivery of the European Service Module (ESM) and completion of flight software are the primary and secondary critical paths—or the path of longest duration through the sequence of activities that determines the earliest completion date—for both Orion and EM-1 as a whole. In December 2015, Orion officials stated that the program had zero schedule reserve to EM-1 and we reported in July 2016 that the program had already experienced several ESM development delays that impacted the ESM delivery, and that further delays could cause the EM-1 launch to slip.[7] As of the ESM's critical design review in summer 2016, ESA has delayed ESM delivery to the Orion program from January 2017 to April 2017, and senior NASA officials stated the delivery will likely slip to

[7]GAO-16-620.

August 2017 or later. Program officials stated that the delays are largely due to NASA, ESA, and the ESA contractor underestimating the time and effort necessary to address design issues for the first production ESM and the availability of parts from suppliers and subcontractors. For example, the contractor found welding failures in the ESM's propulsion tanks, and a number of parts deliveries have been late.

Orion program officials told us that following delivery from ESA, they will need the service module for 12 months for integration with the crew module and testing prior to providing the completed Orion spacecraft to the ground systems at Kennedy Space Center. This means if ESA's delivery date of the service module slips to August 2017, the Orion program will not be ready to deliver Orion to Kennedy Space Center until August 2018. NASA officials stated that they would not be able to maintain a launch readiness date of November 2018 if Kennedy Space Center receives the Orion spacecraft after July 2018. As a result, the November 2018 launch readiness date is likely unachievable unless NASA identifies further mitigation steps to accommodate delays.

In addition, the Orion program faces a number of other technical challenges including software delays and hardware design, but has limited cost reserves to address them until fiscal year 2018 when more cost reserves will be available. As we found in July 2016, the Orion program continues to employ most of its available budget to fund current work and holds most of its cost reserves in fiscal years 2019 and 2020.[8] Program officials told us that the Orion program is schedule-constrained at this point, meaning that even if additional funding were available, it could not alleviate all schedule pressure to EM-1.

SLS: The SLS program currently reports having the most program-level schedule reserve of the three programs—approximately 80 days—however, schedule pressure is mounting as the program completes production and integration and test events grow near. Development of the core stage—which functions as the SLS's fuel tank and structural backbone—is the program's critical path, meaning any delay in its development reduces schedule reserves for the whole program. A number of important events must successfully take place before the core stage, or the vehicle at large, are ready for EM-1. First, the contractor is scheduled to complete production of the core stage flight unit and deliver

[8]GAO-16-620.

it to Stennis Space Center for testing by September 2017. However, officials stated that they have exhausted schedule reserve for this delivery date to address "expected unknowns" with hardware processing due to this being the first time they have built the core stage. Further, according to officials, welding on the core stage was stopped for months due to low weld strength in the liquid oxygen and liquid hydrogen tanks caused by a program and contractor decision to change the weld tool configuration during fabrication. The altered configuration produced different welds that the program has had to confirm are within specification. While officials indicate that they now have a corrective action plan in place, and welding resumed in April 2017, they did not provide detail on the impact to program schedule reserve.

Once production of the core stage flight unit is complete, the program plans to deliver it to Stennis Space Center for testing. At Stennis Space Center, the core stage will be filled with cryogenic hydrogen and oxygen for the first time—a considerable process on its own, as officials stated they were finding and mitigating hydrogen leaks for the entire life of the Shuttle program—and will undergo a "green run" test. During the green run, the core stage flight model—integrated with four RS-25 engines—will be fired for about 500 seconds to test a flight-like engine-use profile. Following this, the program has 20 days of reserves—less any delivery delays and delays from issues that arise during testing—from the completion of the green run test until it must be shipped to Kennedy Space Center to begin integration with the boosters, upper stage, and Orion as well as all EGS equipment. Should further challenges arise during final production and testing, the program's 80 days of reserve will likely be reduced.

As we found in July 2016, 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—establishes standard cost reserves for launch vehicle programs of 20 percent when the baseline is approved.[9] NASA has not changed its cost reserve posture for this program since that time, meaning the program still has limited cost reserves to address risks and challenges.

[9]GAO-16-612 and Marshall Space Flight Center, Marshall Procedural Requirements, 7120.1, Chapter 17 (Aug. 26, 2014).

EGS: EGS program officials stated they used the majority of the 6 months of schedule reserve the program had when we reported in July 2016 to address, among other issues, complications at the Launch Equipment Test Facility and with the Mobile Launcher's ground support equipment installation.[10] The program now has 28 days of schedule reserve, which program officials stated is being held for integrated operations before EM-1, and zero days remaining for any further delays for EGS-specific projects. Without any schedule margin remaining for the EGS-specific projects, the program will be challenged to complete its remaining work that includes umbilical testing, ground support equipment and umbilical installation, and verification and validation testing. These efforts all carry schedule risks with expected delays that, if not mitigated, total 14 months. Program officials stated that they are actively trying to mitigate these schedule risks; however, they acknowledged that some mitigation tactics they are considering—such as performing some portion of these efforts concurrently—increase the complexity of these efforts. In addition, EGS officials indicated they are planning to consolidate some verification and validation testing to streamline the test flow, which they said would increase schedule risk but not technical risk. The program is also considering implementing additional work shifts to create additional schedule margin. The internal EGS delays and the cascading delays from Orion and SLS that EGS may have to absorb—as the program responsible for final integration of the three programs—contribute to NASA likely not achieving the November 2018 launch readiness date.

Similar to Orion and SLS, we previously found in July 2016 that the EGS program is operating with limited cost reserves to address future construction and software risks.[11] For example, we found that when NASA approved the program's baseline, the program had cost reserves of only 4 percent. While Kennedy Space Center—which is responsible for the EGS program—does not have cost reserve guidance in place, guidance from other NASA centers establishes higher levels of cost

[10]GAO-16-612.

[11]GAO-16-612.

reserves at this stage of development.[12] Further, according to EGS officials, the program used all of its fiscal year 2017 reserves in recent years, and has limited reserves in fiscal year 2018, hindering EGS's ability to address any remaining challenges.

GAO's work on acquisition best practices has shown that success in development efforts such as these programs depends on establishing an executable business case based on matching requirements and resources before committing to a new product development effort.[13] In our prior reviews of NASA's human exploration programs, we have found that all three programs have been using aggressive schedules and that SLS and EGS have low reserve levels compared to NASA standards.[14] We have also previously found that both SLS and Orion cost and schedule estimates—which inform their cost and schedule baselines—were unreliable when compared to best practices.[15]

In July 2016, we recommended that the NASA administrator direct the Human Exploration and Operations Mission Directorate to re-evaluate SLS and EGS cost reserves as it finalized its schedule and plans for EM-1 during a planned build-to-synchronization review—in summer 2016—in order to take advantage of all available time and resources and maximize the benefit of available cost reserves, and to verify that the November 2018 launch readiness date remained feasible.[16] This review was intended to demonstrate that the integrated launch vehicle, crew vehicle, and ground systems will perform as expected to meet EM-1 objectives. NASA concurred with our recommendation and as of January 2017, senior NASA officials told us that they have reordered integration

[12]Marshall Space Flight Center—the NASA center with responsibility for SLS—guidance establishes cost reserves at this stage of development of 20 percent, and Goddard Space Flight Center—the NASA center with responsibility for managing other complex NASA programs such as the James Webb Space Telescope—requires 25 percent cost reserves at this stage. Marshall Space Flight Center Procedural Requirements, 7120.1, Chapter 17 (Aug. 26, 2014) and Goddard Space Flight Center, Goddard Procedural Requirements 7120.7 (May 4, 2008).

[13]GAO, *Best Practices: Better Acquisition Outcomes Are Possible If DOD Can Apply Lessons from F/A-22 Program*, GAO-03-645T (Washington, D.C.: Apr. 11, 2003).

[14]GAO-16-620 and GAO-16-612.

[15]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) and GAO-16-620.

[16]GAO-16-612.

activities to try to meet the EM-1 launch schedule, but further analysis indicates that they will have to delay the launch readiness date. These officials stated that no decision has been made and NASA has not committed to a timeline in which to report its findings. Fiscal year 2018 is the last year before the November 2018 EM-1 launch readiness date. With fiscal year 2018 budget discussions ongoing, until it receives updated EM-1 schedule information, the Congress will be in the position of determining NASA's appropriations based on a launch readiness date that is likely not achievable.

Should NASA determine it is likely to exceed its cost estimate baseline by 15 percent or miss a milestone by 6 months or more, NASA is required to report those increases and delays—along with their impacts—to the Congress.[17] Given that these three human space exploration programs represent more than half of NASA's current portfolio development cost baseline, a cost increase or delay could have substantial repercussions for not only these programs but NASA's entire portfolio. A principle of federal internal controls is that managers should externally communicate the necessary quality information to achieve an entity's objective and address related risks.[18] If NASA's ongoing assessment of the November 2018 EM-1 launch readiness date reveals that a new, more realistic, date is warranted, prolonging any decisions regarding the extent of delays and cost overruns—no matter the magnitude—until after deliberations on NASA's fiscal year 2018 budget request would increase the risk that both NASA and the Congress continue making decisions potentially involving hundreds of millions of taxpayer dollars based on schedules that may no longer be feasible.

Conclusions

Human spaceflight and exploration programs are complex and require significant time and effort to design and develop hardware and software. While the Orion, SLS, and EGS programs are working toward a target EM-1 launch readiness date of November 2018, the threats to each program's schedule continue to mount, and the schedule reserve of each program is either very limited or nonexistent. In addition, as the target EM-1 launch readiness date nears—now less than two years away—the flexibility of the schedule to allow for replanning is likewise reduced. To

[17]51 U.S.C. § 30104(e).

[18]GAO, Standards for Internal Control in the Federal Government, GAO-14-704G (Washington, D.C.: Sept. 10, 2014).

this point, the programs have replanned program-level efforts and scheduled concurrent work despite the risks involved, and NASA is replanning integration efforts at the enterprise-level in an attempt to find additional schedule margin. However, beyond that, the programs have little to no cost reserves remaining to deal with challenges that may arise. By continuing to work toward this deadline, these programs are positioned to make potentially risky decisions in attempting to meet a schedule that is likely unachievable. Until NASA completes an analysis of factors that could contribute to an EM-1 schedule slip and reports on the feasibility of either its current or revised schedule, program managers will remain under pressure to achieve a goal that may be untenable, and the Congress will continue to base important budget decisions on an unclear picture of the time and money needed to support future human space exploration efforts.

Recommendations for Executive Action

In order to ensure that the Congress is able to make informed resource decisions regarding a viable EM-1 launch readiness date, we recommend that the NASA Administrator or Acting Administrator direct the Human Exploration and Operations Mission Directorate to take the following two actions:

- Confirm whether the EM-1 launch readiness date of November 2018 is achievable, as soon as practicable but no later than as part of its fiscal year 2018 budget submission process; and
- Propose a new, more realistic EM-1 date if warranted and report to Congress on the results of its EM-1 schedule analysis.

Agency Comments and Our Evaluation

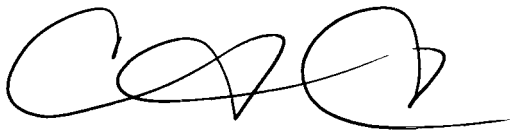
NASA provided written comments on a draft of this report. In the written comments, NASA concurred with both recommendations and stated that maintaining the November 2018 launch readiness date is no longer in the best interest of the programs. Further, NASA stated that it is reassessing the launch readiness schedule and anticipates proposing a new date by September 2017. These comments are reprinted in Appendix II. NASA also provided technical comments, which were incorporated as appropriate.

In its response, NASA stated that “many of the specific concerns referenced in the report are no longer concerns, and new ones have appeared and caution should be used in referencing the report on the specific technical issues, but the overall conclusions are valid.” We agree with NASA that the situation with these programs is dynamic and that

risks and challenges change over time. However, in commenting on the report, NASA did not provide us with evidence that they have overcome specific technical issues that we highlight. Further, in at least the instance of the European Service Module, the situation has deteriorated for the program since we sent the draft copy of the report to NASA for comment. At the time we sent the report for comment, the delivery date for the service module was April 2017, and officials anticipated it could slip to August 2017 or later. The delivery date is now September 2017 with a risk of an additional 2-month delay. We continue to believe that NASA is facing several technical issues across all three programs that will contribute to a delay for Exploration Mission-1.

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

If you or your staff have any questions about this report, please contact me at (202) 512-4841 or chaplainc@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix II.



Cristina T. Chaplain
Director, Acquisition and Sourcing Management

Appendix I: Objective, Scope, and Methodology

To assess the extent to which the National Aeronautics and Space Administration's (NASA) Orion Multi-Purpose Crew Vehicle (Orion), Space Launch System (SLS), and Exploration Ground Systems (EGS) programs have risks that affect their progress towards meeting their Exploration Mission 1 (EM-1) cost and schedule commitments, we compared current program status information against program cost and schedule baselines. To assess the risks for the Orion, SLS, and EGS programs and the extent to which those risks may impact cost and schedule commitments, we obtained and reviewed quarterly reports and the programs' risk registers, which list the top program risks and their potential cost and schedule impacts, including mitigation efforts to-date. We interviewed program and contractor officials on technical risks, potential impacts, and risk mitigation efforts underway and planned. To evaluate the program's performance in preparing for EM-1, we reviewed program plans and schedules and compared them to actual program performance data found in quarterly program status reviews and program update briefings to assess whether program components and software were progressing as expected. We also compared current program data against program budget information to assess funding needs and cost growth. To determine the programs' cost and schedule posture and to assess the availability of the programs' cost and schedule reserves approaching EM-1, we analyzed its budget documentation, interviewed program officials from all three programs with insight into the programs' budget and schedule and discussed how reserves were being used to mitigate known risks. Our work was performed at Johnson Space Center in Houston, Texas; Marshall Space Flight Center in Huntsville, Alabama; Kennedy Space Center in Titusville, Florida; Lockheed Martin Space Systems Company in Houston, Texas; and NASA headquarters in Washington, DC.

We conducted this performance audit from July 2016 to April 2017 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: Comments from the National Aeronautics and Space Administration

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

APR 12 2017

Reply to Attn of: Human Exploration and Operations Mission Directorate

Ms. Cristina T. Chaplain
Director
Acquisition 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, "NASA Human Space Exploration: Delay Likely for First Exploration Mission" (GAO-17-414), dated March 13, 2017.

Programs in this phase of development are extremely dynamic with critical path for development switching between elements. Issues that appear initially to have major schedule impacts can sometimes be mitigated with no impacts, and new problems appear that will drive schedule. We agree with the GAO that maintaining a November 2018 launch readiness date is not in the best interest of the program, and we are in the process of establishing a new target in 2019. Many of the specific concerns referenced in the report are no longer concerns, and new ones have appeared. Caution should be used in referencing the report on the specific technical issues, but the overall conclusions are valid.

In the draft report, GAO makes two recommendations intended to ensure that Congress is able to make informed resource decisions regarding a viable Exploration Mission (EM)-1 launch readiness date.

Specifically, GAO recommends the Administrator or Acting Administrator direct the Human Exploration and Operations Mission Directorate to:

Recommendation 1: Confirm whether the EM-1 launch readiness date of November 2018 is achievable, as soon as practicable but no later than as part of its fiscal year (FY) 2018 budget submission process.

Management's Response: NASA concurs with the recommendation. NASA is assessing the EM-1 schedule in light of a number of ongoing activities including the assessment of the potential for flying crew on EM-1, the impacts of damage caused by the tornado that impacted

Space Launch Systems core stage production at the Michoud Assembly Facility in Louisiana on February 7, and the ongoing FY 2018 President's budget formulation process.

Estimated Completion Date: September 30, 2017.

Recommendation 2: Propose a new, more realistic EM-1 date, if warranted, and report to Congress on the results of its EM-1 schedule analysis.

Management's Response: NASA concurs with the recommendation. This will be dependent on the results of the schedule analysis discussed in NASA's response to Recommendation 1.

Estimated Completion Date: September 30, 2017

Once again, thank you for the opportunity to comment on the subject draft report. If you have any questions or require additional information, please contact Michelle Bascoe at (202) 358-1574.

Sincerely,

William H. Gerstenmaier
Associate Administrator
for Human Exploration and Operations

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

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

Staff Acknowledgments

In addition to the contact named above, LaTonya Miller (Assistant Director), Molly Traci (Assistant Director), Juli Digate, Susan Ditto, Laura Greifner, Carrie Rogers, Ryan Stott, Roxanna T. Sun, and Marie Ahearn made key contributions to this report.