



June 2019

NASA HUMAN SPACE EXPLORATION

Persistent Delays and
Cost Growth
Reinforce Concerns
over Management of
Programs

GAO Highlights

Highlights of [GAO-19-377](#), a report to congressional committees

Why GAO Did This Study

NASA is undertaking a trio of closely related programs to continue human space exploration beyond low-Earth orbit. All three programs (SLS, Orion, and supporting ground systems) are working toward a launch readiness date of June 2020 for the first mission.

The House Committee on Appropriations included a provision in its 2017 report for GAO to continue to review NASA's human space exploration programs. This is the latest in a series of reports addressing the mandate. This report assesses (1) how NASA's human space exploration programs are performing relative to cost and schedule commitments, and (2) the extent to which NASA's use of contract award fees is achieving desired program outcomes. To do this work, GAO examined program cost and schedule reports and contractor data, and interviewed officials. This report does not assess the effect, if any, of the government shutdown that ended in January 2019.

What GAO Recommends

GAO is making four recommendations to NASA, including that the SLS program should calculate cost growth based on costs that are currently included in the first mission and the Orion program should update its cost estimate to reflect the schedule agreed to in its baseline. In addition, the SLS and Orion programs should reevaluate their strategy for incentivizing contractors. NASA concurred with three recommendations, and partially concurred with the recommendation related to the Orion program's cost estimate. GAO believes the recommendation remains valid, as discussed in the report.

View [GAO-19-377](#). For more information, contact Cristina T. Chaplain at (202) 512-4841 or chaplainc@gao.gov.

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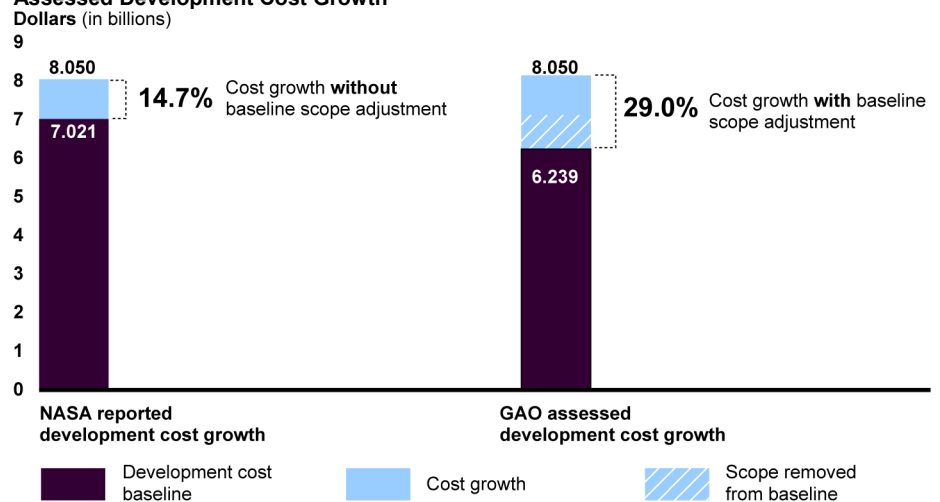
NASA HUMAN SPACE EXPLORATION

Persistent Delays and Cost Growth Reinforce Concerns over Management of Programs

What GAO Found

Due to continued production and testing challenges, the National Aeronautics and Space Administration's (NASA) three related human spaceflight programs have encountered additional launch delays and cost growth. In November 2018, within one year of announcing an up to 19-month delay for the three programs—the Space Launch System (SLS) vehicle, the Orion spacecraft, and supporting ground systems—NASA senior leaders acknowledged the revised date of June 2020 is unlikely. Any issues uncovered during planned integration and testing may push the launch date as late as June 2021. Moreover, while NASA acknowledges about \$1 billion in cost growth for the SLS program, it is understated. This is because NASA shifted some planned SLS scope to future missions but did not reduce the program's cost baseline accordingly. When GAO reduced the baseline to account for the reduced scope, the cost growth is about \$1.8 billion.

NASA's Reported Development Cost Growth for Space Launch System Compared to GAO's Assessed Development Cost Growth



Source: GAO analysis of National Aeronautics and Space Administration data. | [GAO-19-377](#)

In addition, NASA's updated cost estimate for the Orion program reflects 5.6 percent cost growth. The estimate is not complete, however, as it assumes a launch date that is 7 months earlier than Orion's baseline launch date. If the program does not meet the earlier launch date, costs will increase further. Updating baselines to reflect current mission scope and providing complete cost estimates would provide NASA management and Congress with a more transparent assessment of where NASA is having difficulty controlling costs.

NASA paid over \$200 million in award fees from 2014-2018 related to contractor performance on the SLS stages and Orion spacecraft contracts. But the programs continue to fall behind schedule and overrun costs. Ongoing contract renegotiations with Boeing for the SLS and Lockheed Martin for the Orion program provide NASA an opportunity to reevaluate its strategy to incentivize contractors to obtain better outcomes.

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Abbreviations

3D	three-dimensional
EGS	Exploration Ground Systems
EM-1	Exploration Mission 1
EM-2	Exploration Mission 2
ESD	Exploration Systems Development
ESM	European Service Module
FAR	Federal Acquisition Regulation
NASA	National Aeronautics and Space Administration
OIG	Office of Inspector General
OMB	Office of Management and Budget
Orion	Orion Multi-Purpose Crew Vehicle
SLS	Space Launch System
UCA	undefinitized contract action

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June 19, 2019

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

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

The National Aeronautics and Space Administration (NASA) is developing systems planned to transport humans beyond low-Earth orbit, including the Moon and eventually Mars. Deep space exploration requires the capability to transport crew and large masses of cargo beyond low-Earth orbit to distant destinations. The systems NASA is developing to achieve this include:

- the Space Launch System (SLS) program, which is developing a vehicle to launch a crew capsule and cargo beyond low-Earth orbit;
- the Orion Multi-Purpose Crew Vehicle (Orion) program, which is developing a crew capsule to transport humans beyond low-Earth orbit; and
- the Exploration Ground Systems (EGS) program, which is developing systems and infrastructure to support assembly, test, and launch of the SLS and Orion crew capsule, and recovery of the Orion crew capsule.

Each of these programs represents a large, complex technical and programmatic endeavor and is in the integration and test phase of development. Our prior work has shown this phase of the acquisition

process often reveals unforeseen challenges leading to cost growth and schedule delays.¹

GAO has designated NASA's management of acquisitions as a high-risk area for almost three decades. In our March 2019 high-risk report, we reported there was a lack of transparency in NASA's major project cost and schedules, especially for its human spaceflight programs.² We reported that the agency has not taken action on several recommendations related to understanding the long-term costs of its human exploration programs. For example, EGS and SLS do not have a cost and schedule baseline that covers activities beyond the first planned flight, and Orion does not have a baseline beyond the second planned flight. We have previously reported that without transparency into these estimates, NASA does not have the data to assess long-term affordability and Congress cannot make informed budgetary decisions.³

The House Committee on Appropriations included a provision in its 2017 report for GAO to continue to review NASA's human space exploration programs, specifically the SLS, EGS, and Orion programs.⁴ This report is the latest in a series of reports addressing the mandate. This report assesses (1) how NASA's human space exploration programs are performing, including any technical challenges, relative to their cost and schedule commitments, and (2) the extent to which NASA's use of contract award fees is achieving desired program outcomes.

To assess the performance of the human space exploration programs, including any technical challenges, relative to their cost and schedule commitments, we obtained and analyzed program cost and schedule

¹GAO, *Space Launch System: Resources Need to be Matched to Requirements to Decrease Risk and Support Long Term Affordability*, [GAO-14-631](#) (Washington, D.C.: Jul. 23, 2014); *Space Launch System: Management Tools Should Better Track to Cost and Schedule Commitments to Adequately Monitor Increasing Risk*, [GAO-15-596](#) (Washington, D.C.: Jul. 16, 2015); and *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).

²GAO, *High Risk Series: Substantial Efforts Needed to Achieve Greater Progress on High-Risk Areas*, [GAO-19-157SP](#) (Washington, D.C.: Mar. 6, 2019).

³GAO, *NASA Actions Needed to Improve Transparency and Assess Long-Term Affordability of Human Exploration Programs*, [GAO-14-385](#) (Washington, D.C.: May 8, 2014).

⁴H.R. Rep. No. 115-231, at 62 (2017).

estimates and compared them against baselines to determine cost and schedule growth. We also interviewed program officials to determine how the programs phase costs for future flights outside the current baseline. We also obtained and reviewed program risk registers and discussed the potential impacts of cost and schedule risks, including risk mitigation efforts to-date, with program officials. In addition, we assessed program schedules over time and compared performance against program plans to identify potential and realized schedule delays, including the impact of delays across the programs. We based our assessment on data collected prior to the federal government shutdown that occurred in December 2018 and January 2019. We determined the data we used were sufficiently reliable for the purposes of this engagement. This assessment does not reflect the effect, if any, of the shutdown on the programs' costs and schedules or NASA's March 2019 announcement that it is studying how to accelerate the SLS schedule.

To determine the extent to which NASA's use of contract award fees is achieving desired program outcomes, we analyzed award fee plans and fee determination records for the Orion crew spacecraft and SLS core stage—or stages—contracts. We selected these contracts because they represent the largest development efforts for each program. We analyzed contract documentation to determine the amount of award fee available on these contracts compared to other incentives, such as milestone incentives, and calculated fees paid to date. Moreover, we compared fee determination results to overall program outcomes since program confirmation. For more information on our scope and methodology, see appendix I.

We conducted this performance audit from March 2018 to June 2019 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

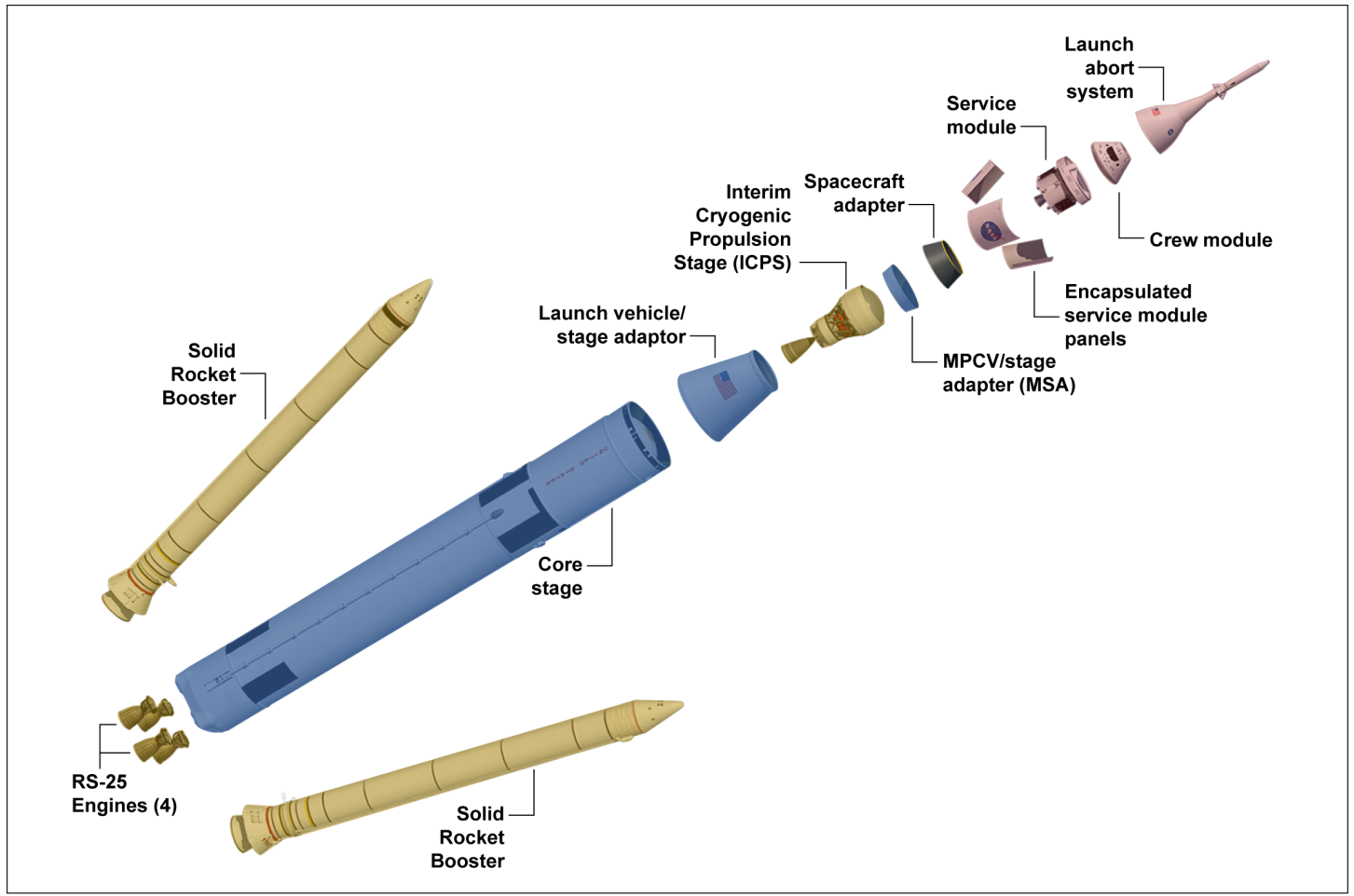
The NASA Authorization Act of 2010 directed NASA to develop a SLS, to continue development of a crew vehicle, and to prepare infrastructure at Kennedy Space Center to enable processing and launch of the launch

system.⁵ To fulfill this direction, NASA formally established the SLS launch vehicle program in 2011. Then, in 2012, NASA aligned the requirements for the Orion program with those of the newly created SLS vehicle and the associated ground systems programs.⁶ The Exploration Systems Development (ESD) organization reports to NASA's Associate Administrator for Human Exploration and Operations Mission Directorate and is responsible for managing and integrating the human space exploration programs. Figure 1 provides details about each SLS hardware element and its source as well as identifies the major portions of the Orion spacecraft.

⁵Pub. L. No. 111-267, §§ 302, 303, and 305.

⁶The Orion program began as part of NASA's Constellation program aimed at developing a human spaceflight system. The Constellation program was cancelled, however, in 2010 due to factors that included cost and schedule growth and funding gaps.

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



- Orion Multi-Purpose Crew Vehicle (MPCV)
- Existing system
- New development

Source: GAO analysis of National Aeronautics and Space Administration data (data and images). | GAO-19-377

NASA established the EGS program to modernize the Kennedy Space Center to prepare for integrating hardware, as well as processing and launching SLS and Orion, and recovery of the Orion crew capsule. The EGS program consists of a number of components and processing centers including the Vehicle Assembly Building, Mobile Launcher, and Crawler-Transporter.

The Mobile Launcher consists of (1) a two-story base that is the platform for the rocket and (2) a tower equipped with a number of connection lines, called umbilicals, and launch accessories that will provide SLS and Orion with power, communications, coolant, fuel, and stabilization prior to launch. During preparations for launch, the Crawler-Transporter will pick up and move the Mobile Launcher into the Vehicle Assembly Building. Inside the Vehicle Assembly Building, NASA will stack the SLS and Orion vehicle on the Mobile Launcher and complete integration for launch. Before launch, the Crawler-Transporter will carry the Mobile Launcher with SLS and Orion to the launch pad where engineers will lower the Mobile Launcher on to the pad and remove the Crawler-Transporter. During launch, each umbilical and launch accessory will release from its connection point, allowing the rocket and spacecraft to lift off from the launch pad. Figure 2 is a picture of the Mobile Launcher positioned on top of the Crawler-Transporter outside of the Vehicle Assembly Building.

Figure 2: Mobile Launcher on the Crawler-Transporter outside the Vehicle Assembly Building at Kennedy Space Center



Source: National Aeronautics and Space Administration. | GAO-19-377

During Exploration Mission 1 (EM-1), the SLS vehicle is 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 the EM-1 launch readiness date to support this integrated test flight. Exploration Mission 2 (EM-2) will be a 10- to 14-day crewed flight

with up to four astronauts that will orbit the moon and return to Earth to demonstrate the baseline Orion vehicle capability.

History of Program Cost and Schedule Changes

NASA establishes an agency baseline commitment—the cost and schedule baselines against which the program may be measured—for all projects that have a total life cycle cost of \$250 million or more. A rebaseline is a process initiated if the NASA Administrator determines the development cost growth is more than 30 percent of the estimate provided in the baseline of the report, or if other events make a rebaseline appropriate. A replan is a process generally driven by changes in program or project cost parameters, such as if development cost growth is 15 percent or more of the estimate in the baseline report or a major milestone is delayed by 6 months or more from the baseline date. A replan does not require a new project baseline to be established.

When the NASA Administrator determines that development cost growth is likely to exceed the development cost estimate by 15 percent or more, or a program milestone is likely to be delayed from the baseline's date by 6 months or more, NASA must submit a report to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate.⁷ Should a program exceed its development cost baseline by more than 30 percent, the program must be reauthorized by the Congress and rebaselined in order for the contractor to continue work beyond a specified time frame.⁸ NASA tied the SLS and EGS program cost and schedule baselines to the uncrewed EM-1 mission and the Orion program's cost and schedule baselines to EM-2.

Over the past 5 years, we have issued several reports assessing the progress of NASA's human space exploration programs relative to their agency baseline commitments.⁹ In April 2017, we found that given the

⁷51 U.S.C. § 30104.

⁸51 U.S.C. § 30104(e)(2).

⁹GAO, [GAO-14-631](#); [GAO-15-596](#); *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); *NASA Human Space Exploration: Delay Likely for First Exploration Mission*, [GAO-17-414](#) (Washington, D.C.: Apr. 27, 2017); *NASA Human Space Exploration: Integration Approach Presents Challenges to Oversight and Independence*, [GAO-18-28](#) (Washington, D.C.: Oct. 19, 2017).

combined effects of ongoing technical challenges in conjunction with limited cost and schedule reserves, it was unlikely that these programs would achieve the committed November 2018 launch readiness date.¹⁰ We recommended that NASA confirm whether this launch readiness date was achievable and, if warranted, propose a new, more realistic EM-1 date and report to Congress on the results of its schedule analysis. NASA agreed with both recommendations and stated that it was no longer in its best interest to pursue the November 2018 launch readiness date. Subsequently, NASA approved a new EM-1 schedule of December 2019, with 6 months of schedule reserve available to extend the date to June 2020, and revised costs (see table 1).

Table 1: Human Space Exploration Program Baselines and Current Plans (costs in billions)

	Agency Baseline Commitment		Replan (December 2017)		Development percentage cost growth	Delay (Months)
	Development Cost	Launch Date	Development Cost	Launch Date		
Space Launch System	\$7.021	November 2018 Exploration Mission-1 (EM-1)	\$7.169	December 2019–June 2020 EM-1	2.1%	13-19
Exploration Ground Systems	\$1.843	November 2018 EM -1	\$2.265	December 2019–June 2020 EM-1	22.9%	13-19
Orion Multi-Purpose Crew Vehicle	\$6.768	April 2023 Exploration Mission-2 (EM-2)	Not applicable because Orion’s performance is measured to EM-2.			

Source: GAO presentation of National Aeronautics and Space Administration data. | GAO-19-377

Because NASA delayed the EM-1 schedule by up to 19 months, the SLS and EGS programs—that are both baselined to EM-1—reported a replan to the Congress. The EGS program also reported its development costs increased by about 23 percent over the baseline. At the same time, NASA reported that the SLS program development costs would only increase by about 2 percent.

Contracts

Under the Federal Acquisition Regulation (FAR), a variety of contract types are available including those that incentivize a contractor in areas

¹⁰[GAO-17-414](#).

that may include performance, cost, or delivery. The type of contract used for any given acquisition inherently determines how risk is allocated between the government and the contractor. According to the FAR, since the contract type and the contract price are interrelated, the government must consider them together. The government can choose a contract type and negotiate price (or estimated cost and fee) that will result in reasonable contractor risk and provide the contractor with the greatest incentive for efficient and economical performance.¹¹ For example, under firm-fixed-price contracts, the contractor assumes full responsibility for performance costs. Under cost-reimbursement contracts, the government provides for the payment of allowable incurred costs, to the extent prescribed in the contract. The government uses cost-reimbursement contracts when, for example, there are uncertainties involved in contract performance.

Incentive contracts can be either fixed-price or cost-reimbursement type contracts. The contractor's responsibility for the performance costs and the profit or fee incentives in incentive contracts are tailored to the uncertainties involved in contract performance. Incentive contracts—including award fee and predetermined, formula-type incentive fee contracts—are designed to attain specific acquisition objectives by, in part, including appropriate incentive arrangements that (1) motivate contractor efforts that might not otherwise be emphasized, and (2) discourage contractor inefficiency and waste. Award fees generally emphasize multiple aspects of contractor performance in areas that the government assesses more subjectively. In contrast, predetermined formula-type incentives are generally associated with a cost incentive, but can also emphasize performance in areas that the government assesses more objectively.

The FAR indicates that award fee contracts are suitable when

- it is neither feasible nor effective to devise predetermined objective incentive targets,
- the likelihood of meeting acquisition objectives will be enhanced by using a contract that provides the government with the flexibility to

¹¹In federal contracting, the terms "profit" and "fee" refer to the amount of money paid to the contractor above and beyond either a fixed price or a contractor's reimbursable costs. The term "profit" is generally associated with fixed-price incentive contracts, and the profit is already included in the overall price of the contract, and the term "fee" is generally associated with cost-reimbursement contracts.

evaluate both actual performance and the conditions under which it was achieved, and

- the administrative effort and cost are justified.

Table 2 provides an overview of cost-plus-incentive-fee and cost-plus-award-fee contracts because these are the type used in the Orion and SLS programs.

Table 2: Overview of Cost-Plus-Incentive-Fee and Cost-Plus-Award-Fee Contract Types

Contract type	Characteristics	Generally appropriate for use when...
Cost-plus-incentive-fee	<ul style="list-style-type: none"> • Government pays contractor allowable incurred costs to extent prescribed in contract. • Fee is initially negotiated and later adjusted by a formula (known as a share ratio), based on the relationship of total allowable costs to total target costs. • Target cost, target fee, minimum and maximum fees, and fee adjustment formula are specified at contract inception. After performance, amount of fee paid is determined by the negotiated formula. 	<ul style="list-style-type: none"> • Requirements are not fully defined, technologies and design are not sufficiently mature, or integration risk is too great to use a fixed-price contract, such as when programs are in the technology development or engineering and manufacturing development phase. • A target cost and a fee adjustment formula can be negotiated that will likely motivate the contractor to effectively manage its work.
Cost-plus-award-fee	<ul style="list-style-type: none"> • Government pays contractor allowable incurred costs to extent prescribed in contract. • Base fee, which may be zero, is fixed at contract inception. • Award fee is determined by subjective evaluation of the contractor's performance. 	<ul style="list-style-type: none"> • Requirements are not fully defined, technologies and design are not sufficiently mature, or integration risk is too great to use a fixed-price contract, such as when programs are in the technology development or engineering and manufacturing development phase. • Government cannot establish predetermined objective incentive fee targets. • Likelihood of meeting acquisition objectives will be enhanced by the use of award fee. • Additional administrative effort required to monitor and evaluate performance is justified by the expected benefits.

Source: Federal Acquisition Regulation. | GAO-19-377

Multiple-incentive contracts contain more than one incentive. For example, these contracts may include both subjective award fee criteria and predetermined, formula-type incentives. Agencies can use incentive contracts to promote certain acquisition outcomes, such as keeping costs low, delivering a product on time, and achieving technical performance of the product.

NASA awarded incentive contracts to both Boeing and Lockheed Martin—a cost-plus-incentive-fee/award-fee contract to Boeing for the SLS stages effort and a cost-plus-award-fee contract to Lockheed Martin for the Orion crew spacecraft effort.¹² For the SLS stages incentive contract with Boeing, the contract includes both incentive and award fees, broken into these three components:

- Milestone-incentive fees. These fees are paid for successful completion of each program milestone event.
- Cost-incentive fees. These fees are initially negotiated and later adjusted by a formula and are paid based on the relationship of total allowable costs to total target costs.
- Award fees. These fees are determined through subjective evaluations relative to factors in the contract's award fee plan.

For the Orion crew spacecraft incentive contract with Lockheed Martin, the contract includes fee broken into three components. The government typically uses award fees when it is not feasible or effective to use predetermined objective criteria. Therefore, as noted above, award fees are typically determined against subjective criteria. However, this contract includes award fee with both subjective and objective criteria:

- Milestone award fees. These fees are paid for completing critical criteria and dates associated with each milestone.
- Performance incentive fee. These fees are paid for completing criteria and dates associated with each performance incentive.
- Period of performance award fee. These fees are determined through subjective evaluations relative to factors in the contract's award fee plan.

For purposes of discussion within this report, we group each of the fees for each contract into one of four categories—milestone fee, performance incentive fee, cost incentive fee, and award fee. When award fees are used that require a subjective assessment by the government, NASA generally defines award fee periods of at least 6 months for the duration of the contract and establishes performance evaluation boards to assess

¹²The original scope of NASA's contract with Boeing was to design, develop, and test the Ares I upper stage under the Constellation program. When the Constellation program was cancelled, NASA and Boeing modified the scope of the contract to eliminate the Constellation effort and to provide for development and production of all aspects of the SLS core stage.

the contractor's performance relative to the performance evaluation plan. For the contracts we reviewed, NASA evaluates contractor performance based on weighted evaluation factors to determine the award fee. Table 3 includes a description of the evaluation factors and the weighted percentages for each factor assigned to the SLS stages and Orion crew vehicle contracts.

Table 3: Award Fee Weighted Evaluation Factors by Contract for the SLS Stages and Orion Contracts

	Award fee evaluation factors and descriptions			
	Program Management: Evaluation of contractor performance in all areas of management.	Cost Management: Evaluation of contractor performance in all areas of cost management.	Technical Performance: Evaluation of the contractor in all areas of technical performance.	Small Business Goals: Assessment of performance against the subcontracting plan.
SLS / Boeing – Development and Manufacturing of Stages Contract	30 percent	25 percent	35 percent	10 percent
Orion / Lockheed Martin – Development and Manufacturing Contract	20 percent	25 percent	45 percent	10 percent

Source: GAO presentation of National Aeronautics and Space Administration data. | GAO-19-377

When developing a contractor's evaluation for a period of performance, the members of the performance evaluation boards for each contract use descriptive ratings in their evaluations. Performance monitors for different areas within the programs compile a list of the contractor's strengths and weaknesses relative to specific criteria and defined activities for each of the evaluation factors. The performance monitors then consider other factors, such as government-directed changes and obstacles that arose that may have affected the contractor's performance, and prepare performance reports. Members of the performance evaluation boards consider the performance monitor's reports and assign the scores and descriptive ratings for the specific evaluation period. Table 4 below outlines award fee adjectival ratings, award fee pool available to be earned, and descriptions of the award fee adjectival ratings from the Federal Acquisition Regulation.

Table 4: Award Fee Descriptive Ratings, Fee Pools, and Descriptions of Adjectival Ratings

Award fee descriptive rating	Award fee pool available to be earned	Description
Excellent	91%-100%	Contractor has exceeded almost all of the significant award-fee criteria and has met overall cost, schedule, and technical performance requirements of the contract in the aggregate as defined and measured against the criteria in the award-fee plan for the award-fee evaluation period.
Very good	76%-90%	Contractor has exceeded many of the significant award-fee criteria and has met overall cost, schedule, and technical performance requirements of the contract in the aggregate as defined and measured against the criteria in the award-fee plan for the award-fee evaluation period.
Good	51%-75%	Contractor has exceeded some of the significant award-fee criteria and has met overall cost, schedule, and technical performance requirements of the contract in the aggregate as defined and measured against the criteria in the award-fee plan for the award-fee evaluation period.
Satisfactory	No greater than 50%	Contractor has met overall cost, schedule, and technical performance requirements of the contract in the aggregate as defined and measured against the criteria in the award-fee plan for the award-fee evaluation period.
Unsatisfactory	0%	Contractor has failed to meet overall cost, schedule, and technical performance requirements of the contract in the aggregate as defined and measured against the criteria in the award-fee plan for the award-fee evaluation period.

Source: Federal Acquisition Regulation (FAR) § 16.401, Table 16-1. | GAO-19-377

Continued Underperformance Has Led to Additional Schedule Delays and Cost Growth

In November 2018—within 1 year of announcing a delay for the first mission—senior NASA officials acknowledged that the revised EM-1 launch date of December 2019 is unachievable and the June 2020 launch date (which takes into account schedule reserves) is unlikely. These officials estimate that there are 6 to 12 months of schedule risk associated with this later date, which means the first launch may occur as late as June 2021 if all risks are realized. This would be a 31-month delay from the schedule originally established in the programs’ baselines. Officials attribute the additional schedule delay to continued production challenges with the SLS core stage and the Orion crew and service modules. NASA officials also stated that the 6 to 12 months of risk to the launch date accounts for the possibilities that SLS and Orion testing and final cross-program integration and testing at Kennedy Space Center may result in further delays. These 6 to 12 months of schedule risk do not include the effects, if any, of the federal government shutdown that occurred in December 2018 and January 2019.

In addition, NASA’s reporting of cost data for the SLS and Orion programs is not fully transparent. NASA’s estimates for the SLS program

indicate 14.7 percent cost growth as of fourth quarter fiscal year 2018, but our analysis shows that number increases to 29.0 percent when accounting for costs that NASA shifted to future missions. Further, in summer 2018, NASA reported a 5.6 percent cost growth for the Orion program. However, this reported cost growth is associated with a program target launch date that is 7 months earlier than its agency baseline commitment launch date. If the Orion program executes to the launch date established in its agency baseline commitment, costs will increase further.

SLS: First Mission Will Incur Additional Delay as Challenges with Core Stage Production Continue, and Cost Growth Underreported

SLS Will Not Meet June 2020 Replan Schedule

The SLS program will not meet the June 2020 launch date for the first mission due, in part, to ongoing development issues with the core stage. For this mission, the SLS launch vehicle includes solid rocket boosters, an upper stage, and a core stage—which includes four main engines and the software necessary to command and control the vehicle. As of fall 2018, the program reported that the boosters, engines, and upper stage all had schedule reserves—time allocated to specific activities to address delays or unforeseen risks—to support a June 2020 launch. The core stage, however, did not have schedule reserves remaining as the program continues to work through development issues.

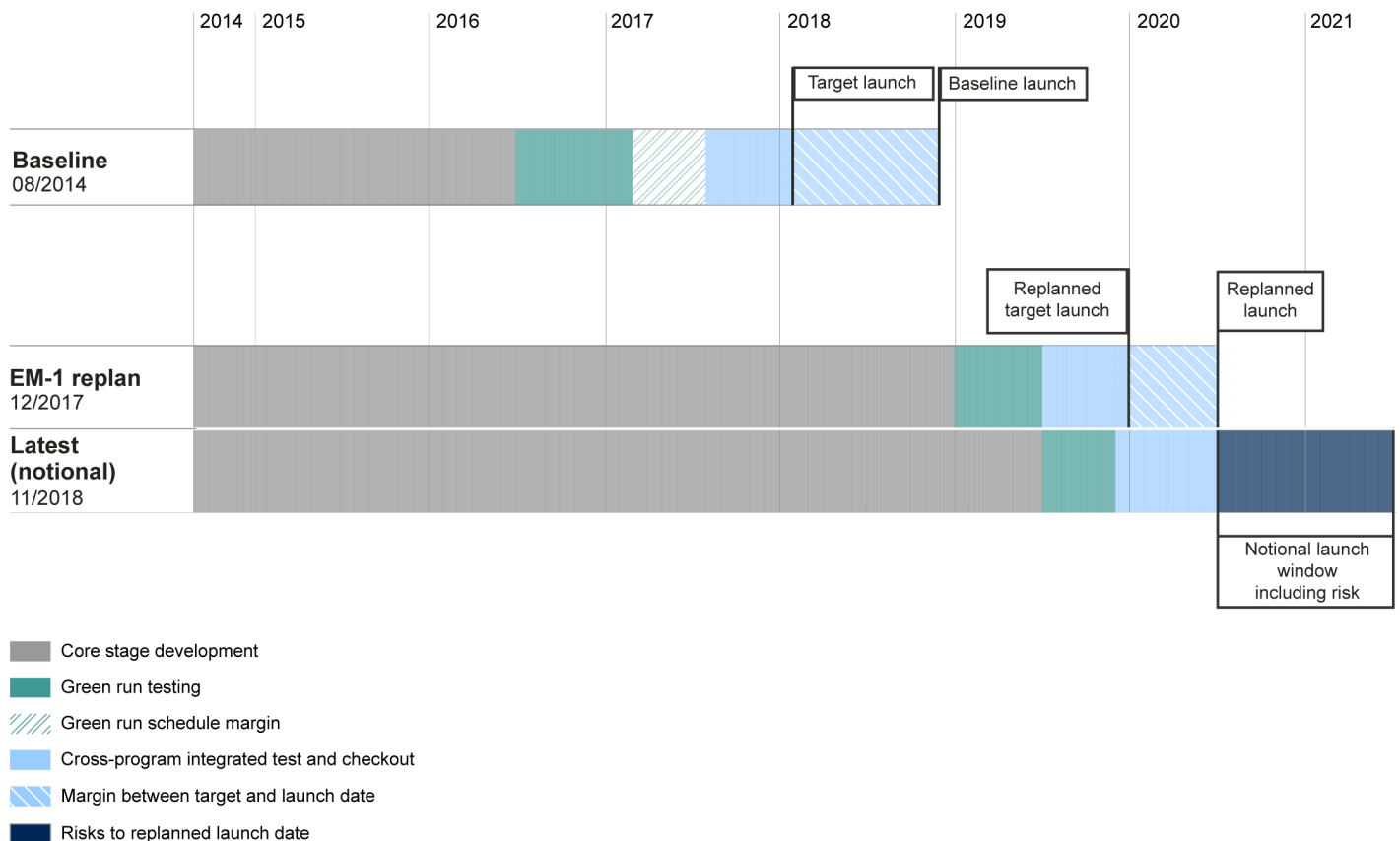
According to the SLS program schedule, core stage development culminates with “green run” testing. For this test, NASA will fuel the completed core stage with liquid hydrogen and liquid oxygen and fire the integrated four main engines for about 500 seconds. The green run test carries risks because it is the first time that several things are being done beyond just this initial fueling. For example, it is also the first time NASA will fire the four main engines together, test the integrated engine and core stage auxiliary power units in flight-like conditions, and use the SLS software in an integrated flight vehicle. In addition, NASA will conduct the test on the EM-1 flight vehicle hardware, which means the program would have to repair any damage from the test before flight.

The program has no schedule margin between the end of core stage production and the start of the green run test, and is tracking risks that may delay the test schedule. For example, as the NASA Office of Inspector General (OIG) found in its October 2018 report, the Stage Controller—the core stage’s command and control hardware and software needed to conduct the green run test—is 18 months behind schedule and may slip further.¹³ Any additional delays with the development of the core stage and stage controller will further delay the start of the green run test. In addition, the SLS program has no schedule margin between the green run test and delivery of the core stage to Kennedy Space Center for integration to address any issues that may arise during testing.

In November 2018, senior NASA officials stated that they have accounted for the potential of continued core stage development delays—along with risks to the Orion and EGS programs—and stated that there are an additional 6 to 12 months of risk to the EM-1 launch date. We found that a delay of this length would push the launch date for EM-1 out as far as June 2021 should all of the risks be realized. This would represent a 31-month delay from the original schedule baseline. Further, these 6 to 12 months of schedule risk do not include the effects, if any, of the federal government shutdown that occurred in December 2018 and January 2019. Figure 3 below compares schedules of key events for the core stage shortly after NASA established the program baseline in August 2014, the December 2017 replan, and the program’s schedule as of November 2018.

¹³NASA Office of Inspector General, *NASA’s Management of the Space Launch System Stages Contract*, IG-19-001 (Washington, D.C.: Oct. 10, 2018).

Figure 3: Space Launch System Program Development Schedule as of Program Baseline, Exploration Mission-1 (EM-1) Replan, and Latest as of November 2018



Source: GAO presentation of National Aeronautics and Space Administration (NASA) data and information. | GAO-19-377

Note: Target launch date reflects the launch date the program was working toward at the time. Baseline launch date reflects the launch date NASA committed to the Congress, which includes schedule reserves. Replanned launch date reflects the delayed launch date for the program, which includes schedule reserves.

Officials from the SLS program and Boeing, the contractor responsible for building the core stage, indicated that an issue driving core stage delays was underestimation of the complexity of manufacturing and assembling the core stage engine section—where the four RS-25 engines are mated to the core stage—and those activities have taken far longer than expected. For example, around the time of the December 2017 replan, the SLS program schedule indicated that it would take 4 months to complete the remaining work. By late 2018, the estimate for the same work had increased to 11 months. Part of that delay included time required to resolve residue and debris discovered in the fuel lines, which

was present because Boeing had not verified the processes that its vendors were using to clean the fuel lines. Further, installation of the fuel lines overlapped with other work in the engine section, making work in the limited space more difficult and complex than it otherwise would have been.

NASA officials indicated that there have been additional issues behind core stage delays, including the following:

- Boeing underestimated the staffing levels required to build the core stage in the time available. According to a NASA official, as core stage production began, Boeing was focused on minimizing the number of technicians, in part to keep costs low, and hired about 100 technicians. The official stated that Boeing now has about 250 technicians on staff in order to address ongoing delays, however, because a number of the additional staff came from non-spaceflight projects, some time was lost getting those staff up to speed on SLS. In addition, the official noted that technicians were spending time performing work away from the vehicle, such as collecting tools and parts for the work they were completing. According to the official, Boeing has since hired additional support staff to perform off-vehicle tasks such as pre-packaging tools in order to allow technicians to spend their time working on the vehicle.
- The build plans for the core stage were not adequately mature when the contractor began work on the hardware itself, which led to additional delays. For example, according to NASA officials, they expected the work instructions—detailed directions on how the vehicle should be built—to be largely complete by the program’s critical design review, which precedes the production decision. In this case, however, the build plans were not complete by the start of production. Officials stated that the lack of build plans slowed progress, as technicians can only perform work that they have instructions to carry out.
- In addition, the time to perform some work activities needed to build the designed vehicle was not included in the schedule. For example, more than 900 engine section brackets that were in the design were not on the schedule and, according to NASA officials, Boeing had to install the brackets later, adding complexity to the work schedule.

Boeing officials provided three additional perspectives regarding the delays.

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- Boeing officials explained that they did not anticipate any changes from NASA for the loads—impacts and stresses of mass, pressure, temperature, and vibration that the vehicle will experience—following the program’s critical design review, but instead NASA provided three significant updates to those loads. In some cases, the changes were significant enough that they invalidated legacy systems Boeing had planned to use, which required rework.¹⁴ However, SLS program officials stated that they continued to update loads data as the environments anticipated during launch became clearer.
 - Boeing officials also stated that they alerted NASA in September 2014 that a decision to decrease funding in fiscal year 2015 would require the contractor to delay the core stage delivery date. In October 2018, however, the NASA OIG reported that while Boeing anticipated receiving \$150 million less than planned in fiscal year 2015, the company received only \$53 million less; that a funding increase was received in fiscal year 2016; and that the value of Boeing’s contract increased by nearly \$1 billion in May 2016.¹⁵
 - Finally, Boeing officials stated that it has been challenging to execute NASA’s development approach that called for the first set of hardware built to be used for the initial launch. Boeing officials stated that they are more used to an approach in which they use the first hardware built to qualify the design and that hardware is never flown. The challenge with the current approach, according to Boeing officials, is that all the learning associated with a first build is occurring on the flight unit, which requires extra scrutiny and slows down the process. SLS program officials stated that this approach has been part of the development plan since the initial contract with Boeing was signed.

One area in which the program has benefited from the core stage delay is that development of SLS test and flight software, which has been a schedule concern for the program, now has additional time to complete development. Delays to date have been due to late hardware model deliveries and requirements changes according to program officials. The SLS program completed the qualification test—a verification that the software meets documented requirements—for the green run software in

¹⁴A 2001 NASA technical publication on launch vehicle design noted that the Space Shuttle went through five loads cycles and a number of mini-cycles to address specific issues; it also indicated that such iteration is not uncommon (NASA, *Launch Vehicle Design Process: Characterization, Technical Integration, and Lessons Learned*, NASA/TP-2001-210992, (Marshall Space Flight Center, Ala.: May 2001)).

¹⁵NASA OIG, IG-19-001.

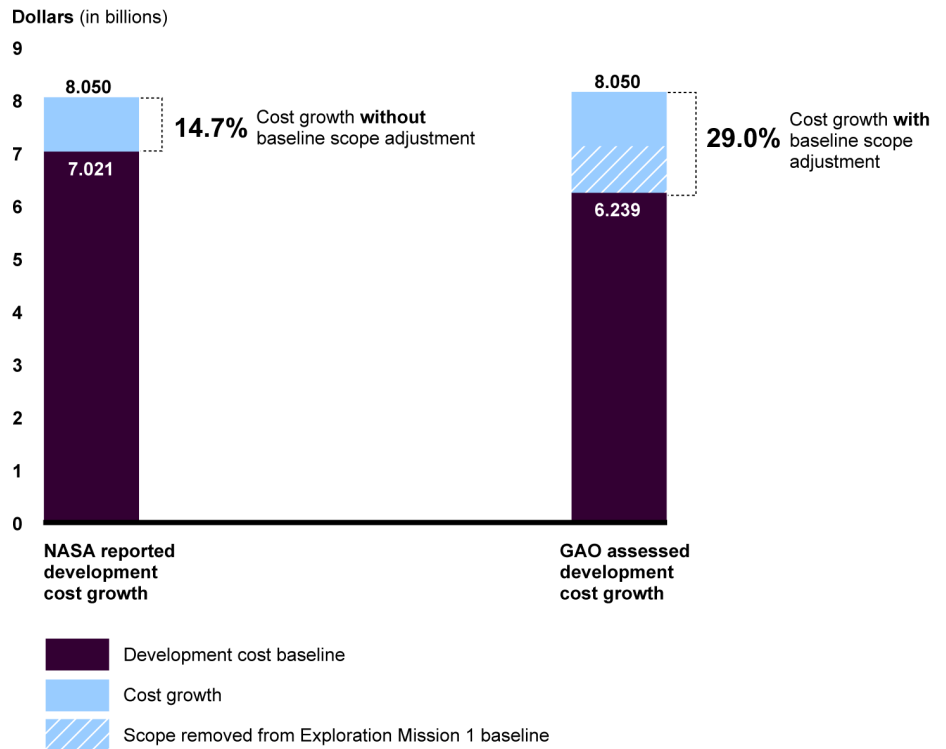
March 2018. Program officials stated that the verified test software release will be complete by April 2019, and the EM-1 flight software release will be complete by October 2019. The earlier they are able to complete the software before launch, the more time they will have to complete testing, fix any defects they find, and work with EGS to integrate with the ground software. Measuring to a June 2020 launch date, flight software development has about 6 months of additional time to address issues should they arise. However, the program has a number of test cycles remaining and the program continues to assess a risk regarding the potential impact that late requirements changes could have on software completion.

SLS Program Has Shifted Some Costs to Future Missions, Resulting in an Underreporting of Cost Growth for EM-1

The SLS program has been underreporting its development cost growth since the December 2017 replan because of a decision to shift some costs to future missions while not adjusting the baseline downward to reflect this shift. The SLS development cost baseline established in August 2014 for EM-1 includes cost estimates for the main vehicle elements—stages, liquid engines, boosters—and other areas. According to program officials, because of the December 2017 replan process, NASA decided that costs included as part of the SLS EM-1 baseline cost estimate would be more appropriately accounted for as costs for future flights. Thus, NASA decided not to include those costs, approximately \$782 million, as part of the revised SLS EM-1 cost estimate. However, NASA did not lower the \$7 billion SLS development cost baseline to account for this significant change in assumptions and shifting of costs to future flights, and NASA officials told us that they were not sure what the benefit to NASA would be in adjusting the baseline.

This decision presents challenges in accurately reporting SLS cost growth over time. NASA's decision not to adjust the cost baseline downward to reflect the reduced mission scope obscures cost growth for EM-1. NASA's cost estimate as of fourth quarter fiscal year 2018 for the SLS program indicated development cost growth had increased by \$1 billion, or 14.7 percent. However, our analysis shows that development cost growth actually increased by \$1.8 billion or 29.0 percent, when the development baseline is lowered to account for the reduced mission scope. Essentially, NASA is holding the baseline costs steady, while reducing the scope of work included in current cost estimates (see figure 4).

Figure 4: NASA's Reported Development Cost Growth for Space Launch System Compared to GAO's Assessed Development Cost Growth, as of September 2018



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-19-377

NASA's current approach for reporting cost growth misrepresents the cost performance of the program and thus undermines the usefulness of a baseline as an oversight tool. NASA's space flight program and project management requirements state that the agency baseline commitment for a program is the basis for the agency's commitment to the Office of Management and Budget (OMB) and the Congress based on program requirements, cost, schedule, technical content, and an agreed-to joint cost and schedule confidence level.¹⁶ Removing effort that amounts to more than a tenth of a program's development cost baseline is a change

¹⁶A joint cost and schedule confidence level produces a point-in-time estimate that includes, among other things, all cost and schedule elements, incorporates and quantifies known risks, assesses the effects of cost and schedule to date on the estimates, and addresses available annual resources.

in the commitment to OMB and the Congress and results in a baseline that does not reflect actual effort.

Further, the baseline is a key tool against which to measure the cost and schedule performance of a program. A program must be rebaselined and reauthorized by the Congress if the Administrator determines that development costs will increase by more than 30 percent.¹⁷ Accounting for shifted costs, our analysis indicates that NASA has reached 29.0 percent development cost growth for the SLS program.¹⁸

In addition, as we previously reported in May 2014, NASA does not have a cost and schedule baseline for SLS beyond the first flight.¹⁹ As a result, NASA cannot monitor or track costs shifted beyond EM-1 against a baseline. We recommended that NASA establish cost and schedule baselines that address the life cycle of each SLS increment, as well as for any evolved Orion or ground systems capability. NASA partially concurred with the recommendation, but has not taken any action to date.

By not adjusting the SLS baseline to account for the reduced scope, NASA will continue to report costs against an inflated baseline, hence underreporting the extent of cost growth. NASA's Associate Administrator and Chief Financial Officer stated that they understood our rationale for removing these costs from the EM-1 baseline and agreed that not doing so could result in underreporting of cost growth. Further, the Associate Administrator told us that the agency will be relooking at the SLS program's schedule, baseline, and calculation of cost growth.

¹⁷ 51 U.S.C. § 30104(f).

¹⁸ In addition, an October 2018 NASA Office of Inspector General (OIG) report found that NASA has had difficulty tracking actual costs for the EM-1 core stage because it does not require Boeing to report costs by mission. Specifically, the costs for development and production of the core stage elements for EM-1 and EM-2 as well as development on the new upper stage for future flights has been lumped together rather than broken out separately. As a result, the SLS program has had to estimate EM-1 core stage costs based on summary contractor cost data. NASA concurred with the NASA OIG's recommendation that the program and the contractor should separate the scope of the stages contract into separate contract line items to better assist with tracking costs. NASA OIG, IG-19-001.

¹⁹ [GAO-14-385](#).

Orion: Challenges Contribute to Additional Delay for First Mission and Program Cost Estimate Not Complete

Orion Is Not on Schedule to
Meet June 2020 Replan
Schedule for First Mission

The Orion program is not on schedule to meet the June 2020 launch date for the first mission due to delays with the European Service Module and ongoing component issues with the avionics systems for the crew module, including issues discovered during testing.

European Service Module (ESM). Through a barter agreement, the European Space Agency developed and produced the ESM, which provides propulsion, air, water, and power to the crew module while in space. The European Space Agency delivered the ESM to NASA in November 2018, following several delays with its development. According to program officials, the most recent set of delays prior to delivery were due to issues and failures during ESM propulsion system testing as well as the need to redesign power system components.

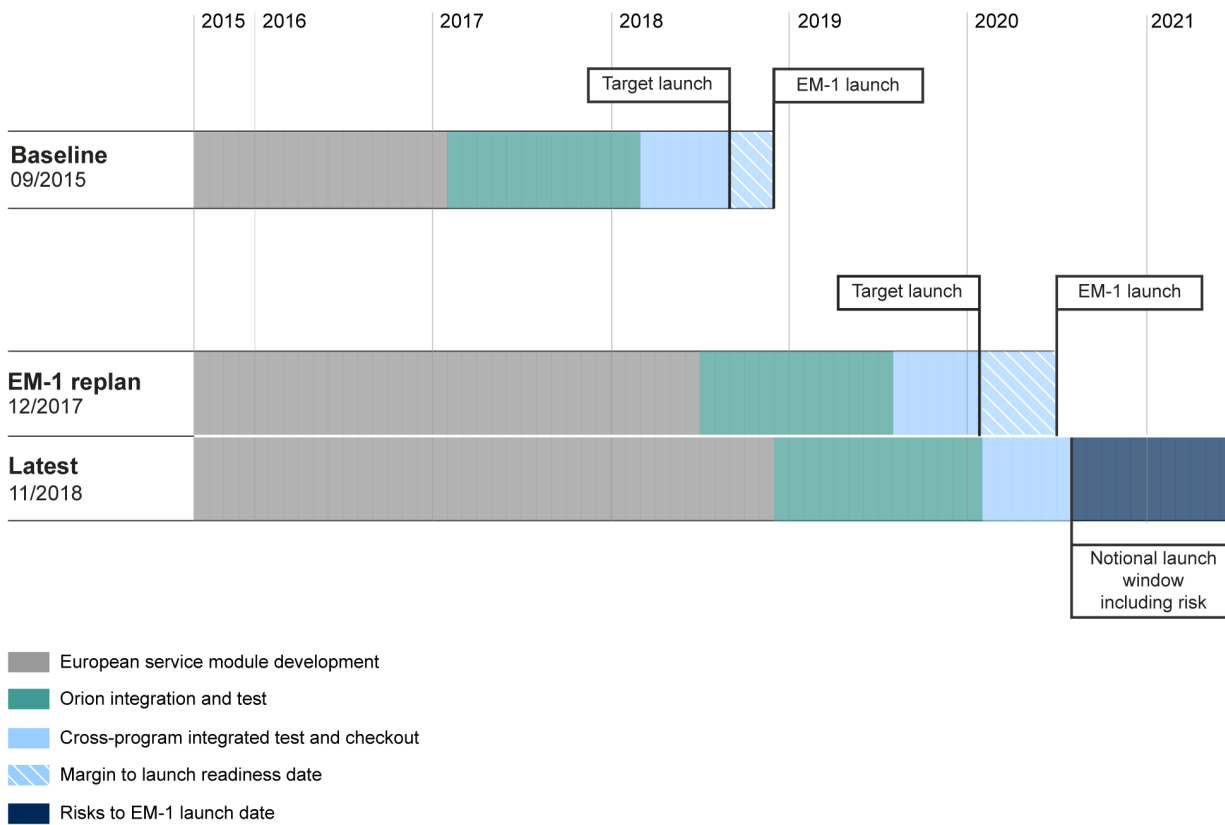
Orion and EGS officials explained that a total of 20 months is required from receipt of the ESM to prepare it for launch. This time frame includes 14 months for the Orion program to finalize testing of each module and complete program-level integration and testing and 6 months for the EGS program to complete integrated test and checkout with SLS and EGS.²⁰ As a result, the earliest the Orion program could be ready to support a first mission based on the service module schedule alone is July 2020, 20 months after NASA accepted delivery in November 2018. ESD officials told us that the 6 to 12 months of risk that could push EM-1 to June 2021 includes ESM-related delays. These 6 to 12 months of schedule risk do not include the effects, if any, of the federal government shutdown that occurred in December 2018 and January 2019.

Figure 5 compares schedules of key events for the Orion program, including delays with the ESM, from shortly after NASA established the

²⁰Integrated test and checkout is a series of events just prior to launch that includes integration of the vehicle, testing the integrated vehicle, and inspection of the vehicle. These procedures include, but are not limited to, stacking the booster segments, test fueling the vehicle, and communications systems tests.

program's baseline in September 2015, the December 2017 replan, and as of November 2018.

Figure 5: Orion Program Development Schedule as of Program Baseline, Exploration Mission-1 (EM-1) Replan, and Latest as of November 2018



Source: GAO presentation of National Aeronautics and Space Administration (NASA) data and information. | GAO-19-377

Note: Target launch date reflects the launch date the program was working toward at the time.

Crew Module. While the ESM remains the critical path—the path of longest duration through the sequence of activities that determines the earliest completion date—for the Orion program, the crew module is nearly the critical path due in part to component failures within the avionics systems during testing. Figure 6 is a picture of a crew module test article.

Figure 6: Orion Crew Module Test Article



Orion program performing crew module test article uprighting tests in Gulf of Mexico with U.S. Coast Guard, U.S. Air Force, and Texas A&M University at Galveston support.

Source: National Aeronautics and Space Administration/Bill Stafford. | GAO-19-377

In May 2018, we reported that the Orion program was addressing component issues in its avionics systems after they failed during vibration testing.²¹ For example, components throughout the crew and service module relied on computer cards used to regulate power. When those cards cracked during testing, the program needed to redesign the cards, retest them, and reinstall them for system tests. Since then, additional avionics failures have surfaced. In one instance, one of the vehicle's global positioning system receivers failed to power up. In another, a part failed on one of the inertial measurement units, which provide navigation information like vehicle rotation and acceleration. In March 2019, program officials told us that they have addressed these issues in the avionics systems and all flight hardware is installed.

²¹GAO, *NASA: Assessments of Major Projects*, [GAO-18-280SP](#) (Washington, D.C.: May 1, 2018).

Testing. The ability for Orion, SLS, and EGS to complete testing in the integrated test laboratory facility—where software and hardware or hardware simulators are tested together—remains an ongoing risk for both the first mission and then the timing of the second mission. The lab has limited time and test resources to complete the testing necessary for EM-1, and NASA officials indicated that at times it has more demand than it can support. In addition, some testing is taking longer than planned, delaying later tests. The risk associated with these delays is that the later the program discovers an issue, the less time there is to address the issue prior to launch.

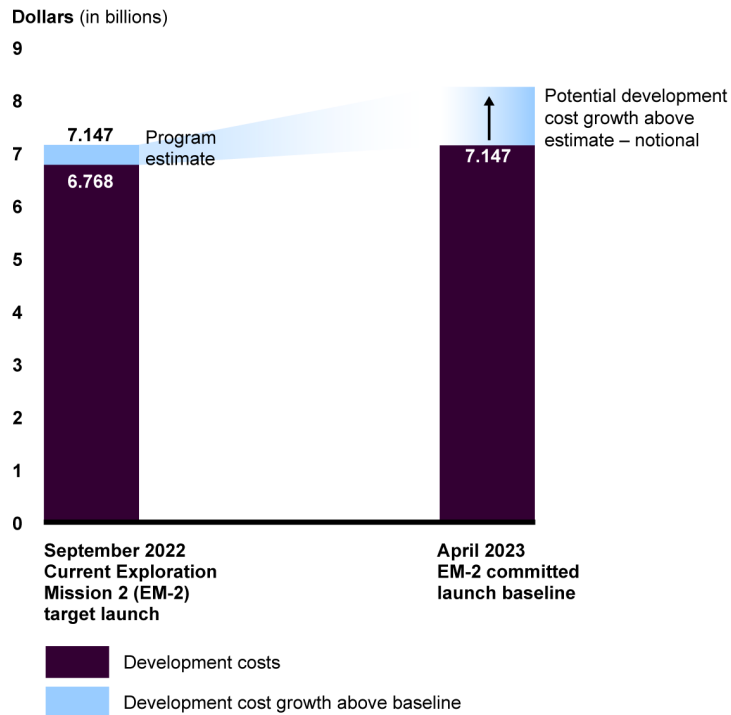
At the same time that the Orion program is completing EM-1 work in the integrated test lab, the program will also need to modify the lab's configuration in order to support EM-2 efforts because of hardware and software differences between missions. The schedule currently includes periods of time during EM-1 testing where EM-1 efforts will be shut down in order to work on lab modifications for EM-2. Although program officials indicated that test lab delays for EM-1 will not adversely affect lab efforts for EM-2, resources directed to EM-2 will mean less resources will be available during those times to support EM-1.

Cost Estimate Is Incomplete

The Orion program has reported development cost growth but is not measuring that growth using a complete cost estimate. In summer 2018, the Orion program reported development cost growth of \$379 million, or 5.6 percent above its \$6.768 billion development cost estimate. The program explained that the major drivers of this cost growth were the slip of the EM-1 launch date, which reflected delays in the delivery of the service module; Orion contractor underperformance; and NASA-directed scope increase.

However, during our review, Orion program officials stated that this cost estimate assumes an EM-2 launch date of September 2022, which is 7 months earlier than the program's agency baseline commitment date of April 2023 that forms the basis for commitments between NASA, the Congress, and OMB. As a result, NASA's current cost estimate for the Orion program is not complete because it does not account for costs that NASA would incur between September 2022 and April 2023. Subsequently, program officials told us that its cost projections fund one of those seven months. See figure 7.

Figure 7: Orion Development Cost and Schedule—Program Target and Baseline for Exploration Mission-2 (EM-2)



Source: GAO presentation of National Aeronautics and Space Administration data and information. | GAO-19-377

Note: The program’s current cost estimate includes one month of funded schedule margin to October 2022.

NASA officials originally told us that they do not have an Orion cost estimate through the EM-2 agency baseline commitment launch date of April 2023 because they plan to launch by September 2022, if not earlier. According to scheduling best practices, performance is measured against the program’s baseline even if a program is working to an earlier date.²²

By not estimating costs through its baseline launch date, the Orion program is limiting the NASA Associate Administrator’s insight into how the program is performing against the baseline. According to federal law, the Administrator must be immediately notified any time that a designated official has reasonable cause to believe that either the program’s

²²GAO, *Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-16-89G (Washington, D.C.: Dec. 22, 2015).

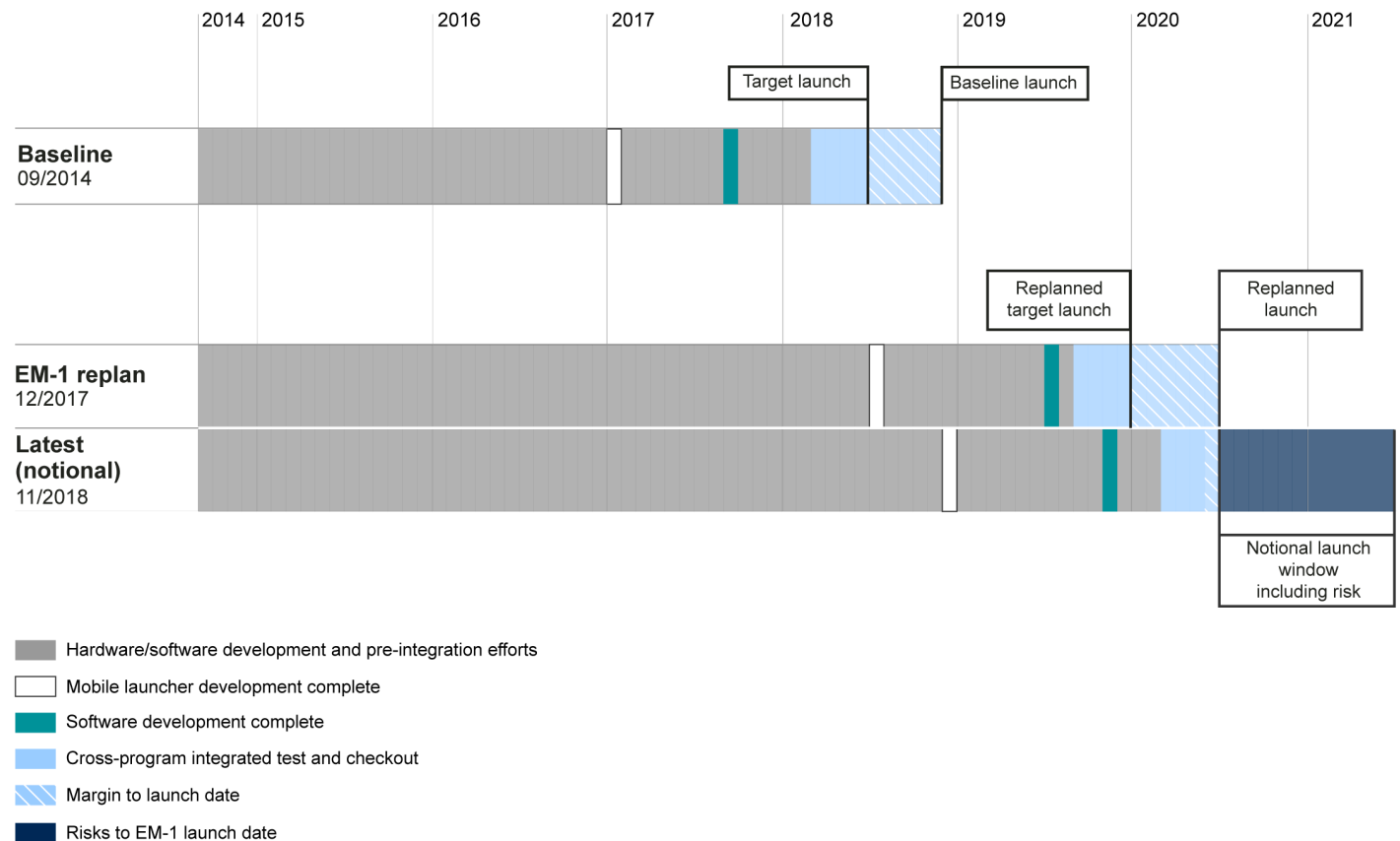
development cost is likely to exceed the estimate in the agency baseline commitment by 15 percent or more or a program milestone will slip 6 months or more beyond its schedule agency baseline commitment date.²³ If the Administrator confirms the cost growth or schedule delay exceeds the given threshold, the Administrator must submit a report to the Committee on Science and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate. Given that the program is already reporting cost growth to a date earlier than its baseline schedule, updating the cost estimate relative to the EM-2 baseline schedule would provide NASA management and Congress with more complete cost data and increased awareness of whether additional oversight is merited.

EGS: Delays and Development Challenges Have Eroded the Schedule, but Program Remains within Replanned Schedule and Costs

Since the December 2017 replan, the EGS program has had to address several technical challenges that consumed schedule reserves. Nevertheless, officials expect to have EGS facilities and software ready by June 2020, the planned launch date. The program has completed many of its projects, including the renovation of the Vehicle Assembly Building and the launch pad. Since the replan, however, the project has had to address technical challenges with the Mobile Launcher. Figure 8 below compares the EGS schedule—including timeframes for the Mobile Launcher and software completion—shortly after NASA established the program’s baseline in September 2014, the December 2017 replan, and as of November 2018. It also shows the potential launch window reflecting the 6-12 months of risk NASA is tracking that could push EM-1 to June 2021.

²³51 U.S.C. § 30104.

Figure 8: Exploration Ground Systems Program Development Schedule as of Program Baseline, Exploration Mission-1 (EM-1) Replan, and Latest as of November 2018



Source: GAO presentation of National Aeronautics and Space Administration (NASA) data. | GAO-19-377

Note: Target launch date reflects the launch date the program was working toward at the time. Baseline launch date reflects launch date committed to the Congress, which includes schedule reserves. Replanned launch date reflects the delayed launch date for the program, which includes schedule reserves.

Mobile Launcher. The Mobile Launcher schedule deteriorated since the December 2017 replan due to problems with finalizing construction work prior to moving it to the Vehicle Assembly Building. Moving the Mobile Launcher into the Vehicle Assembly Building was intended to allow the program to begin multi-element verification and validation, a process that checks that the various launch and processing systems at Kennedy Space Center meet requirements and specifications and can operate together to fulfill their intended purpose.

Challenges the program experienced with the Mobile Launcher included having to add structural supports after determining that the design was not adequate to carry the load of the SLS vehicle and fuel. In addition, program officials stated that construction work overall did not progress to the point desired to move the Mobile Launcher to the Vehicle Assembly Building. As a result, the program did not move the Mobile Launcher into the Vehicle Assembly Building until September 2018, 5 months later than in the schedule established after the December 2017 replan. Moving forward, the program has to complete the multi-element verification and validation process for the Mobile Launcher and Vehicle Assembly Building.

We have reported on a number of issues related to the EGS program's management of the Mobile Launcher, as well as the now-completed Vehicle Assembly Building project. For example, in 2016, we found that the program did not mature requirements and designs for the Mobile Launcher before beginning construction.²⁴ In addition, the EGS program completed all major structural changes to the Mobile Launcher prior to completing the design and installation of the ground support equipment and the nine umbilicals that connect the Mobile Launcher directly to the SLS and Orion. There have also been ground support equipment and umbilical design changes both during and after the Mobile Launcher's design phase because of vehicle requirement changes from SLS and Orion. Officials indicated this approach was problematic because the concurrency increased program risk. Further, according to officials, the decision to have separate contracts for design and construction exacerbated these challenges. Officials indicated that this contracting strategy meant that design changes required multiple levels of review and approval from NASA and each of the program's contractors, which in turn led to numerous contract modifications.

According to EGS officials, the program plans to incorporate lessons learned from developing the first Mobile Launcher into the acquisition approach for a second Mobile Launcher that NASA is building to allow for future configurations of the SLS vehicle. Specific lessons officials plan to carry forward to the second Mobile Launcher include:

²⁴[GAO-16-612](#).

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- implementing an integrated design process, including establishing a process to better handle requirement changes during design and construction;
 - developing and maintaining a three-dimensional (3D) model to facilitate integrated design; and
 - enabling builder involvement during the design process to avoid pitfalls during construction.

However, these lessons learned do not address metrics to assess design stability before starting construction. Our work on acquisition best practices show that good processes that mature designs early in development and ensure that the design meets requirements can position a program for future success and lead to more predictable cost and schedule outcomes.²⁵ Traditionally, we have used the number of releasable engineering drawings as a metric to assess design stability. Specifically, our work has found that achieving design stability at the product critical design review, usually held midway through product development, is a best practice. Completion of at least 90 percent of engineering drawings at this point provides tangible evidence that the product's design is stable.²⁶

We have also found that the U.S. Navy and the commercial shipbuilding industry use 3D product models as tools to document design stability.²⁷ We found that there are aspects of shipbuilding that are analogous to building a Mobile Launcher in that both involve designing and building a large metal structure and installing multiple complex integrated systems to support complex functions such as launching spacecraft, or in the case of the Navy, launching aircraft and/or missile systems. NASA officials agreed that developing a Mobile Launcher is analogous to shipbuilding. Best practices for commercial shipbuilding indicate that 3D product models documenting 100 percent of the system's basic and functional designs should be complete before construction begins.

²⁵GAO, *Best Practices: Using a Knowledge-based Approach to Improve Weapon Acquisition*, [GAO-04-386SP](#) (Washington, D.C.: Jan. 2004).

²⁶[GAO-04-386SP](#).

²⁷GAO, *Best Practices: High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding*, [GAO-09-322](#) (Washington, D.C.: May 13, 2009).

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- Basic design includes fixing the ship steel structure; routing all major distributive systems, including electricity, water, and other utilities; and ensuring the ship will meet the performance specifications.
 - Functional design includes providing further iteration of the basic design, providing information on the exact position of piping and other outfitting in each block, and completing a 3D product model.

The combined basic and functional designs in conjunction with the 3D product model provide the shipbuilder a clear understanding of the ship structure as well as how every system is set up and routed throughout the ship. This detailed knowledge allows commercial shipbuilders to design, build, and deliver complex ships such as floating production storage and offloading vessels, which are able to collect, process, and store oil from undersea oil fields, within schedule estimates.

The improved design processes the EGS program is pursuing in the development of the second Mobile Launcher, including the development of a 3D model to facilitate integrated design, have the potential to improve program outcomes. Further, achieving design stability before beginning construction would also improve this potential.

Software. The program's two software development efforts represent the EGS critical path, and program officials stated that recent changes have begun to address previous challenges with the software development. For example, officials explained that the program has implemented iterative integration testing and has identified lead engineers for each software development area. The iterative integration testing involves conducting tests on smaller segments of software throughout the development process instead of waiting to conduct testing when a software release is fully complete. According to officials, these efforts allow the program to identify and correct errors prior to completing a full software drop. These changes have also resulted in lower numbers of issues found in some software releases. Further, the 6-month delay to the SLS and Orion programs has provided additional flexibility to EGS's software development schedule.

Finally, with respect to EGS's performance against its cost baseline, EGS updated its cost estimate as part of the December 2017 replan. The EGS program continues to operate within costs established for the June 2020 launch date, \$3.2 billion, but any delays beyond June 2020 will result in additional cost growth.

Contractors Received Majority of Award Fees but NASA Experienced Poor Program Outcomes

NASA's award fee plans for the SLS stages and Orion crew spacecraft contracts provide for hundreds of millions of dollars to incentivize contractor performance, but the programs continue to fall behind schedule and incur cost overruns. Our past work shows that when incentive contracts are properly structured, the contractor has profit motive to keep costs low, deliver a product on time, and make decisions that help ensure the quality of the product. Our prior work also shows, however, that incentives are not always effective tools for achieving desired acquisition outcomes. We have found that, in some cases, there are significant disconnects between contractor performance for which the contractor was awarded the majority of award fees possible without achieving desired program results. Additionally, we have found that some agencies did not have methods to evaluate the effectiveness of award fees.²⁸

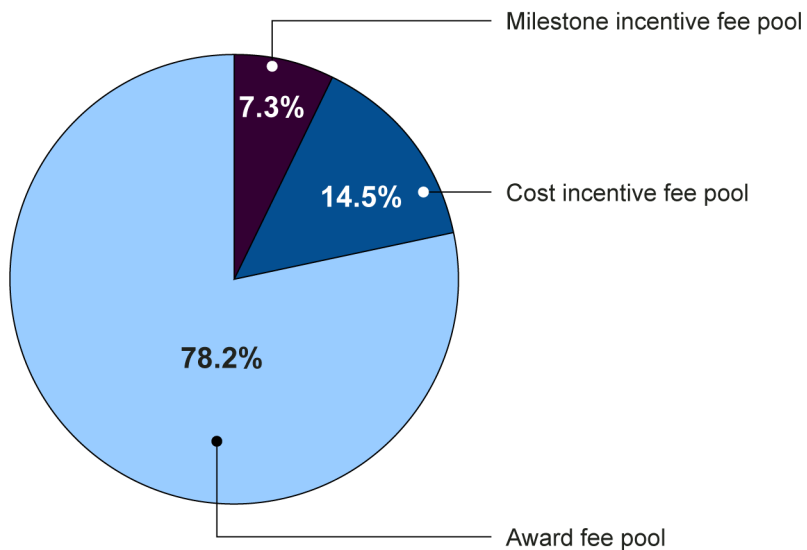
The incentive strategies for both the SLS stages and the Orion crew spacecraft contracts include multiple incentives—milestone fees, performance incentive fees, cost incentive fees, and award fees—aimed at incentivizing different aspects of contractor performance. These contracts' milestone fees, performance incentive fees, and cost incentive fees are generally determined against objective criteria, such as meeting a date and application of predetermined formulas. For example, NASA will pay a milestone fee to Boeing under the SLS contract when it meets a specific program milestone such as transferring the core stage to the government for the green run test. Under this contract, Boeing receives additional milestone fee when it beats a milestone date and reduced fee when it misses a milestone date. Likewise, pre-determined formula-type incentives—such as these contracts' performance incentive fees and cost incentive fees—are typically determined based on objective criteria, such as meeting technical metrics or predetermined cost targets.

Award fees on these types of contracts are generally determined at 6 to 12-month periodic evaluations of the contractor's performance against criteria outlined in the award fee plan. For example, according to officials, NASA may evaluate the contractor against technical performance and

²⁸GAO, *Defense Acquisitions: DOD Has Paid Billions in Award and Incentive Fees Regardless of Acquisition Outcomes*, [GAO-06-66](#) (Washington, D.C.: Dec. 19, 2005); *NASA Procurement: Use of Award Fees for Achieving Program Outcomes Should Be Improved*, [GAO-07-58](#) (Washington, D.C.: Jan. 17, 2007); and, *Federal Contracting: Guidance on Award Fees Has Led to Better Practices but Is Not Consistently Applied*, [GAO-09-630](#) (Washington, D.C.: May 29, 2009).

criteria, such as the ability to avoid and predict cost overruns, manage risk, or accomplish small business goals. Upon the completion of a formal review, performance evaluation board officials make recommendations to the fee determination official on the amount of fee to be paid. Figures 9 and 10 provide overviews of the total incentive fee available on the current contracts for the SLS stages contract and the Orion crew spacecraft contract, by type and percentage.

Figure 9: Types of Incentive Fee Available on the Space Launch System (SLS) Stages Contract by Percentage



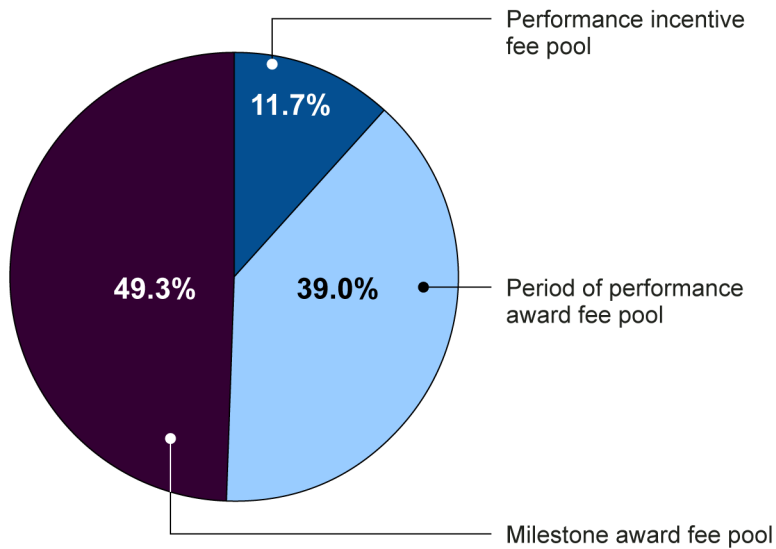
Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-19-377

Notes:

The amounts and types of fee available on the SLS Stages contract includes the full scope of this contract, not just the scope of the Exploration Mission-1 effort. The scope of work for the SLS contract includes development and production of a core stage for the first and second exploration missions as well as development and production of an Exploration Upper Stage. This is a more powerful upper stage intended to carry humans and cargo further away from Earth.

The SLS Boeing contract has a second award fee pool aimed at incentivizing integration of the core stage with other elements of the SLS program. We did not review this award fee pool because at the time of our review, NASA had agreed with a NASA Office of Inspector General (OIG) October 2018 recommendation to remove this fee structure. The NASA OIG found it lacked clear assessment criteria, was largely duplicative of the other award fee pool, and essentially rewarded Boeing for the same work. (NASA Office of the Inspector General, NASA’s Management of the Space Launch System Stages Contract, IG-19-001(Washington, D.C.: Oct. 10, 2018).

Figure 10: Types of Incentive Fee Available on the Orion Crew Spacecraft Contract by Percentage



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-19-377

Note: The amounts and types of fee available on the Orion crew spacecraft contract include the full scope of those contracts, not just the scope of the Exploration Mission-1 effort. The scope of work for the Orion contract includes two test flights, Exploration Flight Test-1 that occurred in December 2014 and Ascent Abort-2 that is scheduled for June 2019, two separate crew capsules, and two integrated crew modules to support the first two missions.

Under the terms of the current contracts, Boeing has earned about \$271 million in award fee and Lockheed Martin has earned about \$294 million in award fee. Since each program held its confirmation review, the point in time when a program established its cost and schedule baselines, NASA has paid the majority of available award fee to both contractors. Specifically, NASA has paid Boeing about 81 percent of available award fee—or about \$146 million—and Lockheed Martin about 93 percent—or about \$88 million—since their respective program confirmation reviews.²⁹

During the annual award fee periods, the descriptive ratings both contractors received ranged from good to excellent. In the subjective

²⁹The award fee payments for the Orion crew spacecraft contract are based on interim evaluations (and payments) until the program conducts the final evaluation at the end of the contractor period of performance. According to Orion program officials, the final evaluation will determine the amount of total award fee actually earned by the contractor and will supersede interim evaluations and payments made, but it is unusual for contractors to receive an amount less than the interim payments.

appraisals supporting these ratings, NASA identified both strengths that indicate areas of good contractor performance and weaknesses that indicate areas of poor contractor performance. Table 5 includes the results of award fee determinations since the respective program confirmations. The numerical score for each evaluation period represents the percentage of fee paid to the contractor from the available fee pool.

Table 5: Space Launch System (SLS) Stages and Orion Crew Module Award Fees since Program Confirmation

Program and contract	Evaluation period	Descriptive ratings and numerical score ^c	Fee paid
SLS (Stages) ^{ab}	July 2014-February 2015	Very good 79	\$41,368,040
	March 2015-October 2015	Very good 90	\$38,321,980
	November 2015-September 2016	Excellent 93	\$17,573,566
	October 2016-September 2017	Very good 86	\$31,092,875
	October 2017-September 2018	Good 58	\$17,824,215
Orion (Crew Spacecraft)	May 2015-April 2016	Excellent 95	\$29,039,629
	May 2016-April 2017	Excellent 92	\$29,160,429
	May 2017-April 2018	Excellent 91	\$29,407,377

Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-19-377

^aThe Space Launch System (SLS) Boeing contract has a second award fee pool aimed at incentivizing integration of the core stage with other elements of the SLS program. We did not review this award fee pool because at the time of our review, NASA had agreed with a NASA Office of Inspector General (OIG) October 2018 recommendation to remove this fee structure. The NASA OIG found it lacked clear assessment criteria, was largely duplicative of the other award fee pool, and essentially rewarded Boeing for the same work. (NASA Office of the Inspector General, NASA's Management of the Space Launch System Stages Contract, IG-19-001 (Washington, D.C.: Oct. 10, 2018).

^bThe SLS program plans to change its award fee evaluation periods from 12 months to 6 months moving forward.

^cThe numerical score for each evaluation period represents the percentage of fee awarded to the contractor from the available fee pool.

Examples of strengths and weaknesses NASA identified in the award fee letters include the following:

-
- For the Boeing award fee period ending February 2015, NASA identified several strengths, including effective and timely communication, but stated that its subcontractor management for the vertical assembly center was inadequate. In particular, the program discovered during this time that the as-built design of the vertical assembly center tool was not capable of serving its purpose, which is to build core stage hardware. The design issue resulted in several months of schedule delays. NASA also raised concerns about Boeing's ability to manage to the baseline schedule in a subsequent award period.
 - For the Lockheed Martin award fee period ending April 2017, NASA identified several strengths, including addressing top program development risks such as establishing a robust mitigation plan to address risks related to the heatshield block architecture. At the same time, NASA noted that Lockheed Martin was not able to maintain its schedule for the crew service module and that the contractor's schedule performance had decreased significantly over the previous year.

While both the SLS and Orion contractors have received the majority of available award fee in each award fee period, the programs have not always achieved overall desired outcomes. For example, in its December 2018 award fee letter to Boeing—representing the good assessment for the September 2017 through October 2018 period of performance—the fee determination official noted that the significant schedule delays on this contract have caused NASA to restructure the flight manifest for SLS. As previously discussed, within 1 year of announcing a delay for the first mission, senior NASA officials acknowledged that the SLS and Orion programs will not meet the new EM-1 schedule of December 2019, and the 6 months of schedule reserve available to extend the date to at least June 2020 has been consumed. In addition, the officials identified 6 to 12 months of risk to that date, which could increase the delay up to 31 months. These 6 to 12 months of schedule risk do not include the effects, if any, of the federal government shutdown that occurred in December 2018 and January 2019 due to a lapse in appropriations for fiscal year 2019.

Both the contractors and government bear responsibilities for these delays. We have previously 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—that have compounded technical challenges that are expected for inherently complex and difficult large-scale

acquisitions.³⁰ Further, we previously reported that NASA did not follow best practices for establishing cost and schedule baselines for these programs nor update cost and schedule analyses to reflect new risks.³¹ As a result, NASA overpromised what it could deliver from a cost and schedule perspective.

At the same time, both contractors have had challenges that contributed to past delays. For example, in 2015, Boeing was unable to manufacture an intertank panel—which resides between the liquid oxygen and liquid hydrogen tanks—without significant cracking. At the time, NASA estimated that resolving this issue could result in a 6-month slip to the production schedule. Further, as previously discussed, NASA discovered during installation that fuel lines used in the engine section were contaminated with residue and other debris. According to a program official, Boeing had not verified the processes that its vendors were using to clean the fuel lines, resulting in about 2 months' delay to resolve residue and debris issues. SLS officials indicated that the engine section has a very complex design with many parts in a relatively small, cramped area, so any time problems are found with parts that have already been installed, removing, repairing or replacing them often requires that other parts be removed. Furthermore, as some of the tubing sections had already been installed, resolving this issue, including inspecting, shipping, and cleaning the tubing, affected the overall program schedule.

In addition, NASA determined in 2017 that Lockheed Martin would not meet the delivery date for the crew module—even if the European Service Module were on schedule—when numerous problems including design issues, damage during testing, and manufacturing process changes resulted in major schedule impacts to the program. Lockheed Martin also had a number of issues with subcontractor-supplied avionics system components failing during testing that have required time to address. NASA has highlighted concerns over Lockheed Martin's ability to manage subcontractors in award fee evaluation periods from 2016 to 2018, and the resulting significant cost, schedule, and technical risk impacts to the program. In an attempt to resolve these issues and to improve subcontractor oversight moving forward, Lockheed Martin officials told us that they have placed staff in the subcontractor facilities.

³⁰[GAO-18-280SP](#).

³¹[GAO-15-596](#); [GAO-16-612](#); [GAO-16-620](#).

Because of these cost increases and delays, the agency plans to renegotiate the Boeing contract for SLS. NASA officials stated that Boeing expects its costs to exceed the cost-reimbursement contract's not-to-exceed estimated total cost, which will lead to contract renegotiation. Consequently, the contractor has been executing work under an undefinitized contract action since September 2018. Contract actions such as these authorize contractors to begin work before reaching a final agreement with the government on contract terms and conditions.³²

Orion program officials stated that NASA is modifying the cost and period of performance aspects of its contract with Lockheed Martin for Orion development and negotiating a new contract with Lockheed Martin for Orion operations and production. Officials told us the following:

- NASA is modifying the Orion development contract with Lockheed Martin because the contractor will exceed the cost reimbursement contract's not-to-exceed estimated total cost. Orion program officials indicated that poor performance on the part of the contractor resulted in the contractor exceeding the costs allowed under the contract without completing the full scope of work. Consequently, NASA is modifying the contract to allow increased costs. Orion officials indicated that since the cost growth is contractor caused, the contractor will not have the ability to earn any fees on this increased cost.
- NASA is also modifying the Orion development contract to extend the contract period of performance. The current contract's period of performance ends in December 2020, which is earlier than NASA's planned EM-2 launch date of June 2022. Orion program officials stated that this extension is largely driven by delays in receipt of the European Service Module.
- According to officials, NASA is negotiating the terms of the Orion production and operations contract with Lockheed Martin. This contract is expected to support future production of the Orion spacecraft from Exploration Mission-3 potentially through 2029. In addition to production, this effort will include sustaining engineering and flight operations support, with limited development to allow mission kits to be built to specifications as mission objective are

³²An undefinitized contract action (UCA) is a contract modification, or a delivery/task order in which the final price or estimated cost and fee have not been negotiated and mutually agreed to by NASA and the contractor. NASA FAR Supplement § 1843.7001.

defined. Orion program officials indicated that NASA plans to eventually transition the contract to a fixed-price type contract for production, but that the development of mission kits will remain under a cost-reimbursement type contract with some type of incentive fee.

In November 2018, senior leaders within the ESD organization told us that it was not clear whether NASA would renegotiate how incentive fees are distributed among milestone incentive fee, or cost incentive fee, and award fee as part of the upcoming Boeing contract renegotiations. NASA, however, has made these types of changes in the past. For instance, the Orion program redistributed fees in 2014 to include an incentive fee component when the contract transitioned from the Constellation program to the Orion program.

The Federal Acquisition Regulation and NASA contracting guidance indicate that award fee is appropriate when the work to be performed is such that it is neither feasible nor effective to devise predetermined objective incentive targets applicable to cost, schedule, and technical performance. However, now that the SLS and Orion programs are further into the acquisition life cycle, the programs are at the point in development wherein it may be possible to determine more objective targets for cost, schedule, and technical performance, especially for the first mission. Further, a principle of federal internal controls is that management should design control activities to achieve objectives and respond to risks.³³ This includes management conducting reviews to compare actual performance to planned or expected results, and taking corrective actions to achieve objectives. Without reevaluating its strategy for incentivizing contractors, NASA will miss an opportunity to consider whether changes to the incentive structure could better achieve expected results, such as motivating the contractor to meet upcoming milestone events within cost and schedule targets.

Conclusions

NASA's SLS, Orion, and EGS programs are a multi-billion dollar effort to transport humans beyond low-Earth orbit, but the agency has been unable to achieve agreed-to cost and schedule performance. NASA acknowledges that future delays to the June 2020 launch date are likely, but the agency's approach in estimating cost growth for the SLS and

³³GAO, *Standards for Internal Control in the Federal Government*, [GAO-14-704G](#), (Washington, D.C.: September 2014). An internal control is any process used by management to help an entity achieve its desired or stated objectives.

Orion programs is misleading. And it does not provide decision makers, including the Administrator, complete cost data with which to assess whether Congress needs to be notified of a cost increase, pursuant to law. By not using a similar set of assumptions regarding what costs are included in the SLS baseline and updated SLS cost estimates, NASA is underreporting the magnitude of the program's cost growth. Similarly, NASA is underreporting the Orion program's cost performance by measuring cost growth to an earlier-than-agreed-to schedule date. As a result, Congress and the public continue to accept further delays to the launch of the first mission without a clear understanding of the costs associated with those delays.

Further, NASA is now turning its attention to new projects to support future missions, including building a second Mobile Launcher. Ensuring design stability before construction start would better position NASA to improve its acquisition outcomes for this next Mobile Launcher.

Finally, contractor performance to date has not produced desirable program cost and schedule outcomes. Ongoing and planned contract negotiations present an opportunity to restructure the government's approach to incentives. Such steps may better position the agency to obtain better outcomes going forward.

Recommendations for Executive Action

We are making the following 4 recommendations to NASA:

We recommend the NASA Administrator ensure that the NASA Associate Administrator for Human Exploration and Operations direct the SLS program to calculate its development cost growth using a baseline that is appropriately adjusted for scope and costs NASA has determined are not associated with the first flight, and determine if the development cost growth has increased by 30 percent or more. (Recommendation 1)

We recommend the NASA Administrator ensure that the NASA Associate Administrator for Human Exploration and Operations direct the Orion program to update its cost estimate to reflect its committed EM-2 baseline date of April 2023. (Recommendation 2)

We recommend the NASA Administrator ensure that the NASA Associate Administrator for Human Exploration and Operations direct the EGS program to demonstrate design maturity by completing 3D product modeling of the basic and functional design of the second Mobile Launcher prior to construction start. (Recommendation 3)

We recommend the NASA Administrator ensure that the NASA Associate Administrator for Human Exploration and Operations direct the SLS and Orion programs to reevaluate their strategies for incentivizing contractors and determine whether they could more effectively incentivize contractors to achieve the outcomes intended as part of ongoing and planned contract negotiations. (Recommendation 4)

Agency Comments and Our Evaluation

NASA provided written comments on a draft of this report. These comments, and our assessment of them, are included in appendix II. NASA also provided technical comments, which were incorporated as appropriate.

In responding to a draft of this report, NASA concurred with three recommendations and partially concurred with a fourth recommendation, and identified actions that they plan to take.

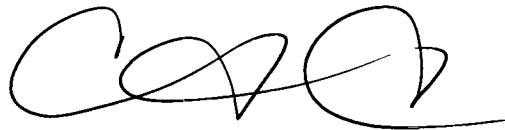
NASA partially concurred with our recommendation to direct the Orion program to update its cost estimate to reflect its committed EM-2 baseline date of April 2023. In its response, NASA stated providing the estimate to the forecasted launch date—September 2022—rather than to the committed baseline date of April 2023 is the most appropriate approach. Further, NASA stated that any additional slips to the program involve considerable uncertainty associated with “unknown-unknowns” which are, by their very definition, impossible to predict or forecast and that attempting to forecast these at this point is neither practical nor useful to help manage the program. If the schedule projections go beyond September 2022, NASA stated that the Orion program will follow standard Agency processes and update its cost estimate to reflect the updated schedule projections.

NASA established Orion’s EM-2 launch date of April 2023 as part of the agency’s program confirmation process in 2015. According to federal law, NASA is required to track and report progress relative to the cost and schedule baselines established at the program’s confirmation review. While programs often pursue goals trying to beat these dates and/or cost estimates, the primary purpose of a cost and schedule baseline is to provide a consistent basis for measuring program progress over time. By developing cost estimates only to the program’s goals and not relative to the established baseline, the Orion program is not providing the Agency or the Congress the means of measuring progress relative to the baseline. We agree that it is difficult to forecast the potential impacts of unexpected problems. NASA guidance, however, provides instructions to

programs on the percentage/relative level of cost reserves that should be maintained to deal with potential unknown-unknowns that are likely to come up late in development. We continue to believe that NASA should fully implement this recommendation.

We are sending copies of this report to the NASA Administrator and interested 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 major contributions to this report are listed in appendix III.



Cristina T. Chaplain
Director, Contracting and National Security Acquisitions

Appendix I: Objectives, Scope, and Methodology

To assess the performance of the human space exploration programs, including any technical challenges, relative to their cost and schedule commitments, we obtained and analyzed cost and schedule estimates for the Space Launch System (SLS), Orion Multi-Purpose Crew Vehicle (Orion), and Exploration Ground Systems (EGS) programs through November 2018. We then compared these estimates against program baselines to determine cost growth and schedule delays. We also interviewed SLS program officials and reviewed cost data to determine how the program phases costs for future flights outside the current baseline. We then analyzed the SLS program's current cost estimate to determine how the scope of the current estimate had changed relative to the scope of the SLS baseline cost estimate. Moreover, 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 then discussed risks with program officials. We also compared program schedules across three points in time—schedules from when NASA first established baselines for each program, schedules established for each program following the replan in December 2017, and schedules as of November 2018—to assess whether program components and software were progressing as expected.

Furthermore, for the EGS program, we reviewed program-level lessons learned regarding the acquisition of the Mobile Launcher against acquisition best practices to determine the extent to which the program plans to incorporate these best practices as part of its acquisition planning for the second Mobile Launcher.

To determine the extent to which NASA's use of contract award fees are achieving desired outcomes, we analyzed contract modifications, award fee plans, and fee determination records for the Orion crew spacecraft and SLS stages—or stages—contracts. We selected these contracts because they represent the largest development efforts for each program. We analyzed contract documentation to determine the amount of award fee available on these contracts compared to other incentives, such as milestone incentives, and calculated fees paid to date. Specifically, for award fee on both contracts, we reviewed fee determination records for evaluation periods after the SLS program's confirmation review in 2014 and the Orion program's confirmation review in 2015 to determine fees paid, numeric and descriptive ratings awarded for each period and contractor strengths and weaknesses identified by the program. Moreover, we reviewed award fee documentation to identify broader program challenges and compared fee determination results to overall program outcomes since program confirmation. For the Orion contract,

the scope of our incentive fee analysis included the full scope of incentive fees available for developing and manufacturing the Orion spacecraft from the beginning of the contract. For the SLS contract the scope of our incentive fee analysis included the incentive fees available for 1) contract line item number 9 of the contract which includes the full scope of stages work supporting SLS's EM-1 effort, and 2) contract line item number 12 indefinite-delivery, indefinite-quantity support task activities for contract line item number 9.

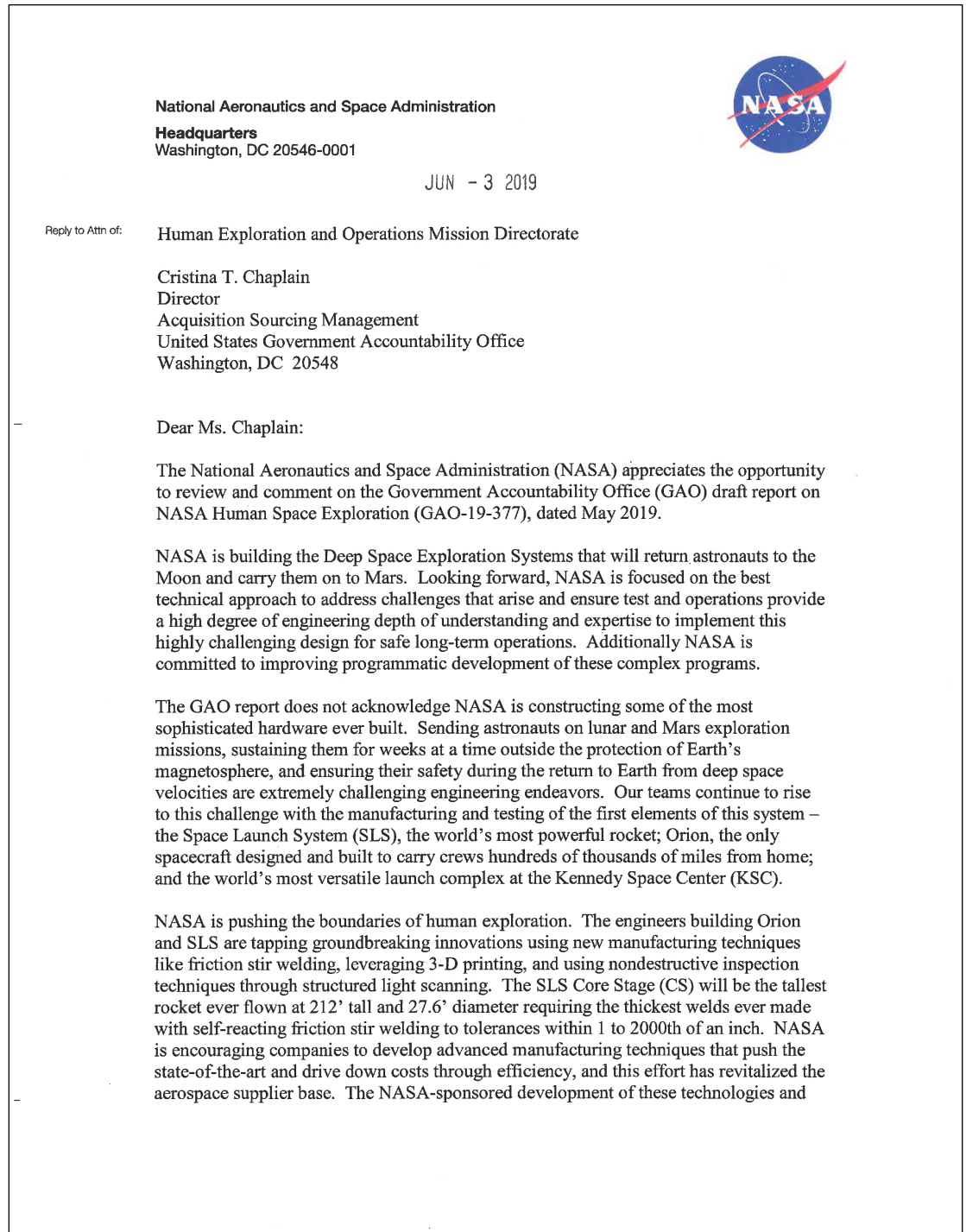
We performed our work at Johnson Space Center in Houston, Texas; the Boeing Company in Huntsville, Alabama; Marshall Space Flight Center in Huntsville, Alabama; Kennedy Space Center in Kennedy Space Center, Florida; Lockheed Martin Space Systems Company in Houston, Texas; and NASA headquarters in Washington, DC.

We based our assessment on data collected prior to the federal government shutdown that occurred in December 2018 and January 2019 due to a lapse in appropriations for fiscal year 2019. This assessment does not reflect the effect, if any, of the shutdown on the programs' costs and schedules or a March 2019 announcement that NASA is studying how to accelerate the SLS schedule. We assessed the reliability of program data we used to support this engagement using GAO reliability standards as appropriate, including reviewing related documentation, interviewing knowledgeable agency officials, and performing selected testing of data. We determined the data was sufficiently reliable for the purposes of this engagement.

We conducted this performance audit from March 2018 to June 2019 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

Note: GAO comments supplementing those in the report text appear at the end of this appendix.



See comment 1.

advanced manufacturing makes these new capabilities available to all future companies that want to use them. This approach helps the entire nation and not just one company.

Like all other development programs, the challenges we have experienced are significant, but not insurmountable. The issues encountered are commensurate with first-time production programs on a large scale and should not be unexpected. NASA is concerned focusing only on cost and schedule discounts the importance of proper technical resolution that is essential for long-term commitment to operating a deep space system. NASA is operating in a dynamic environment, building a multi-decadal program, with content that is subject to change as NASA's deep space exploration objectives evolve and program direction is adjusted. Technical and programmatic management must be balanced. NASA will continue to follow our standards, approaches, and test practices, built on and refined over almost 60 years of space flight experience. Best practices and the program management environment are changing. NASA is open to these changes and your suggestions for improvement.

Significant progress has been made towards the first test flights, Exploration Mission One (EM-1) and EM-2. The Orion crew module for EM-1 is nearly complete and will soon start the intricate process of mating and testing with the European-built service module. The pressure vessel for EM-2 has been completed and delivered to KSC where outfitting for our first human flight vehicle is underway. Progress is also being made in the production of the European Service Module-2. Orion will soon perform a full stress test of the capsule's launch abort system, built to very quickly get astronauts safely away from their launch vehicle if there is a problem during ascent.

All five SLS CS-1 components including the Engine Section (ES), Liquid Hydrogen (LH2) Tank, Intertank, Liquid Oxygen (LOX) Tank, and Forward Skirt are manufactured. Forward Join is complete with three of the five major components (1/3 of the final length of the stage) structurally joined. Work is already underway on the CS, boosters, and engines that will power EM-2.

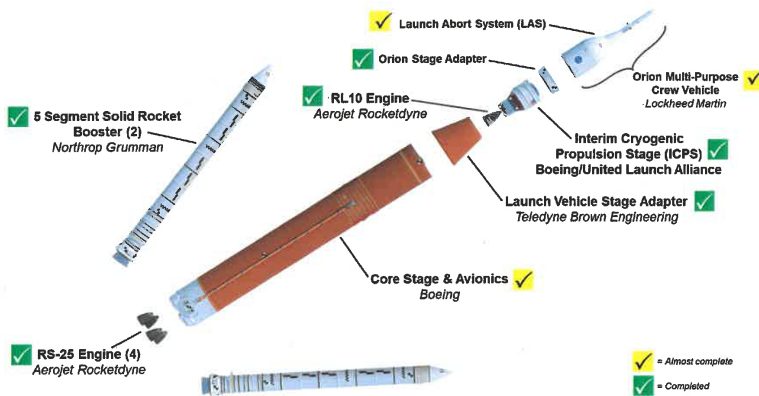
Substantial progress has been made in qualifying the SLS loads and environments. The integrated structural testing of the Integrated Spacecraft and Payload Element, which validated structural capabilities of the integrated Launch Vehicle Stage Adapter, Orion Stage Adapter (OSA), and Interim Cryogenic Propulsion Stage (ICPS) using Structural Test Articles (STA) was completed in May 2017. The CS ES completed structural qualification testing in May 2018 and the CS Intertank completed structural qualification testing in April 2019. The LH2 Tank STA was delivered in January 2019 and has been installed in the test stand; testing begins this summer. And, finally, the LOX Tank STA is scheduled to arrive at Marshall Space Flight Center in June.

Exploration Ground Systems (EGS) at KSC has successfully refurbished the Mobile Launcher (ML) in order to accommodate SLS, including reinforcement with 1,000 tons of new steel and the fabrication and installation of nine new umbilical arms. This 380-foot structure was successfully rolled to Launch Pad 39B and later to the Vehicle Assembly Building atop the modernized Crawler-Transporter 2 which performed

flawlessly on the 9-mile round trip journey. The ground systems team continues to receive and process flight hardware including the OSA and ICPS.

The SLS, Orion crew spacecraft, and EGS form the critical transportation backbone for NASA's Exploration campaign. While the majority of the work is on track (see Figure 1), as has been previously noted, NASA is seeing specific areas of targeted challenges consistent with a first-time design, development, test, and build of a human spacecraft system for deep space. NASA is learning from these challenges and taking steps to improve management and performance in the SLS, Orion, and EGS programs.

Figure 1. Progress towards EM-1



Challenges associated with the development of the first CS, which the report has significantly attributed to NASA and the contractor underestimating complexity of ES assembly and resources necessary to meet schedule, are largely associated with first-time-through complex processes. These challenges included Vertical Assembly Center Tool Misalignment and LOX tank welding. NASA also experienced technical challenges associated with booster propellant/liner/insulation. The government-contractor team learned from these experiences and is implementing improvements. For example, Boeing instituted Tiger Teams which addressed thermal protection system application improvements, testing reductions, sensor installation improvements and Execution Improvement Teams which addressed nonconformance improvements, job kit improvements, tooling improvements, and overall factory schedule improvements. In addition to Boeing changes, the SLS Program implemented an enhanced SLS presence at the Michoud Assembly Facility, which included continuous senior level floor presence to allow for immediate management decisions to further improve schedule performance.

The Orion program has also overcome first-time build challenges, including challenges associated with the vendors supplying hardware to Airbus, and technical issues seen in component-level testing. Orion provided additional technician support to accelerate wire

See comment 2.

harness building, installation, and testing, and is implementing an improved test and integration schedule. Those lessons learned are being folded back into future EM builds, and we are seeing benefits in schedule and costs.

The GAO report repeatedly projects the worst-case schedule outcome. While NASA appreciates GAO's need to be candid in its review, the Agency does take exception to the unnecessarily negative language used in the report title and section headings and the lack of acknowledgement of progress the Agency has made.

See comment 3.

The GAO report does not acknowledge that NASA is operating in a dynamic environment, building a multi-decadal program, with multiple spacecraft and launch vehicle configurations, and with content that is subject to change as NASA's deep space exploration objective evolves and program direction is adjusted.

See comment 4.

NASA disagrees with GAO's assertion the Agency has not been transparent in its reporting of costs. NASA accepts that the frequent recurrence of continuing resolutions along with changes in program direction and appropriated funding lead to uncertainty and inefficiency that can adversely impact our programs' and projects' planning and execution. However, NASA has done its best to maintain transparency. When manifest changes were made, Exploration Systems Development (ESD) was transparent in its plan to reallocate fixed costs and sought and obtained approval from the NASA Associate Administrator to not change the Agency Baseline Commitment (ABC). ESD continually provided updated costs for the SLS ABC content at quarterly reviews and annually as part of the Agency's budgeting process. ESD was transparent in discussions with Office of Management and Budget, Office of Inspector General (OIG), and GAO stakeholders on the reallocation approach during audits and in their quarterly and annual reporting. NASA Exploration Systems Development programs are routinely audited by both the GAO and NASA's OIG; more than 40 audits have been conducted that involved ESD programs since 2011. NASA updated its rigorous budget estimates for SLS, EGS, and Orion programs based on the latest schedule estimates and development status. ESD believes reassessing costs to future flights once the changes to the manifest and capability evolution of the Enterprise were understood was appropriate, and disagrees with GAO's method of calculating cost growth.

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

Specifically, GAO recommends the Associate Administrator ensure the NASA Associate Administrator for Human Exploration and Operations (HEOMD):

Recommendation 1: Direct the SLS program to calculate its development cost growth using a baseline that is appropriately adjusted for scope and costs NASA has determined are not associated with the first flight, and determine if the development cost growth has increased by 30 percent or more.

Management's Response: NASA concurs. NASA will reevaluate SLS development cost performance against an appropriately scoped baseline during the course of its Lunar 2024 planning activities, to include the current EM-1 schedule assessment. The Agency is currently conducting a major review and will re-baseline the program using a risk-based assessment of technical, cost, and schedule. As discussed above, when HEOMD developed the original Management Agreement and ABC for the ESD programs, the upgrade to Block 1B for SLS did not exist. When it became clear the Agency would pursue the upgraded variant of SLS and a more frequent launch cadence, HEOMD made adjustments to the EM-1 fixed cost basis to appropriately account towards non-EM-1 activities, consistent with current planning. The Agency followed its NPR 7120.5 guideline, which is newly applied to multi-mission/multi-flight capability programs with fixed base and variable costs.

We will also work with GAO and determine a more appropriate way to monitor progress in developing a multi-mission program that is planned for operation for decades. Arbitrarily focusing on a single mission and not looking at long-term operating costs and engineering safety concerns could have grave impacts to this national human spaceflight system.

Estimated Completion Date: September 30, 2019.

Recommendation 2: Direct the Orion program to update its cost estimate to reflect its committed EM-2 baseline date of April 2023.

Management's Response: NASA partially concurs. The program follows standard Agency cost estimation processes to maintain its cost estimate to the agreed-to launch date as set by ESD. Cost and schedule status is reported and managed rigorously by the program. While it is true Orion life cycle development costs have experienced a growth of 5.5 percent since NASA conducted a Key Decision Point review of the Orion program in 2015, the program is still well within the schedule commitment of April 2023. When EM-1 was delayed to no earlier than December 2019, the program accelerated the Ascent Abort (AA) -2 flight test mission seven months to April 2019 and successfully held the schedule for 16 months until the government furlough impacted processing and delayed the launch, now scheduled for July 2019. The EM-1 spacecraft is nearing completion at KSC and will soon be sent to Plum Brook Station to undergo Thermal Vacuum testing just prior to being turned over to EGS for final launch processing. The EM-2 spacecraft assembly is well underway and has successfully completed its primary structure proof pressure test. These milestones represent the completion of a significant amount of development work and retire numerous technical risks. The cost estimate provided includes all the scope required with schedule margin and projects launch in September 2022 and includes one month of schedule margin. Providing the estimate to the forecasted launch date rather than through the end of the ABC is the most appropriate approach. Any additional slips to the program involve considerable uncertainty associated with "unknown-unknowns" which are, by their very definition, impossible to predict or forecast. Attempting to forecast these at this point is neither practical nor useful to help manage the program. However, if the schedule projections go beyond

September 2022, the Orion program will follow standard Agency processes and update its cost estimate to reflect the updated schedule projections. The Orion program will continue its balanced approach to complete the development of the spacecraft to safely take humans past the moon and return them to Earth through rigorous management of the cost and schedule. The focus is on making sure that the European Service Module is delivered on time and that EM-2 launch can decouple from EM-1 launch in order to make a late fall EM-2 launch.

Estimated Completion Date: N/A

Recommendation 3: Direct the EGS program to demonstrate design maturity by completing 3D product modeling of the basic and functional design of the second Mobile Launcher prior to construction start.

Management's Response: NASA concurs. The EGS program plans to award the ML-2 contract in June 2019. Based on ML-1 Lessons Learned, the acquisition strategy for ML-2 is to award a design/build contract to a single prime contractor. This form of acquisition ensures constructability is incorporated into the design before fabrication/construction activities begin. Use of 3D modeling is a requirement in the ML-2 contract. It will be the source for all engineering activities including integrated design reviews that serve as programmatic gates to demonstrate design maturity/stability in the process. The integrated design process ensures designs meet an acceptable level of maturity before capital investments are made, while at the same time allowing the program the flexibility to make some low risk decisions to procure long-lead items before the design is fully complete.

Estimated Completion Date: July 31, 2019

Recommendation 4: Direct the SLS and Orion programs to reevaluate their strategies for incentivizing contractors and determine whether they could more effectively incentivize contractors to achieve the outcomes intended as part of ongoing and planned contract negotiations.

Management's Response: NASA concurs with the intent of this recommendation. As part of normal contract performance monitoring, contract restructures, contract baseline adjustments, or planned new contract actions, the SLS Program Element offices and MSFC Office of Procurement review the existing contract type and fee structure to evaluate the effectiveness in achieving maximum benefit for NASA, and coordinate with the Headquarters Associate Administrator for Procurement and Associate Administrator for HEOMD any changes, additions, or deletions in contract type or structure.

SLS has recently effected some significant changes based on findings from its performance evaluation process, including suspending incentive fee milestones and

modifying incentive fee structures. SLS will provide GAO with specific examples that demonstrate how the program has implemented the recommendation.

The Orion program regularly reevaluates the strategy for incentivizing contractors. In 2006, the Orion Multi-Purpose Crew Vehicle (MPCV) contract was awarded as a Cost plus Award Fee (CPAF) contract, and it established Award Fee features that have been utilized to effectively incentivize contractor performance. In 2014, the Orion Program also established a new incentive fee metric to further incentivize contractor performance under the MPCV contract. The Orion Program has implemented the use of multiple contracting approaches to optimize contractor performance under the MPCV contract during its period of performance. The multiple incentive features in the MPCV award fee plan provide a balance for the effective management of contractual requirements. Moving forward, the Orion Production and Operations Contract (OPOC) will be a 100% indefinite delivery/indefinite quantity contract with the ability to issue Cost-Plus-Incentive-Fee (CPIF) and Firm-Fixed Price (FFP) orders for Orion production and operations (P&O).

The CPIF mission orders on OPOC will include performance incentive and cost incentive features. These incentive features are applied at the mission order level to ensure contractors are incentivized to achieve affordable, timely, safe, and successful mission completion. An aggressive cost incentive will motivate reduced production costs and timely performance, while a performance incentive with milestone payments and potential for fee reduction will motivate safe and successful mission completion. The cost and performance incentives will be weighted relative to total incentive fee such that there will be no circumstance in which cost savings are rewarded above successful mission performance.

The use of FFP for later mission orders on OPOC further transitions risk from the Government to the Contractor, by holding the contractor fully accountable for cost, schedule, and technical performance. In order to ensure the contractor is effectively motivated to achieve mission success, FFP mission orders under OPOC will include specific critical, primary, and secondary mission objectives, similar to the performance incentive on CPIF mission orders. FFP will be paid through performance-based milestone payments, with the final milestone being tied to successful performance of the mission objectives.

The use of CPIF on early OPOC mission orders provides an effective method of transitioning risk from the Government to the Contractor, with the ultimate goal of FFP ordering for base vehicle P&O on later mission orders.


Estimated Completion Date: June 30, 2019 (SLS will provide examples to GAO).

NASA believes that it is essential to take the time to effectively resolve first-time build challenges now, which leads to near-term schedule and cost challenges, but yields

significant benefits for out-year flight element manufacturing. NASA's goal for returning humans to cislunar space remains on track.

Once again, thank you for the opportunity to comment on this draft report. If you have any questions or require additional information, please contact Lynne Loewy at (202) 358-0549.

Sincerely,



William H. Gerstenmaier
Associate Administrator
for Human Exploration and Operations

GAO Comments

1. This report acknowledges the complexity of NASA's deep space exploration systems. The introduction section of this report acknowledges that NASA is developing systems planned to transport humans beyond low-Earth orbit, including the Moon and eventually Mars, and that each of these programs represents a large, complex technical and programmatic endeavor. The introduction also notes that these programs are in the integration and test phase of development, which our prior work has shown often reveals unforeseen challenges leading to cost growth and schedule delays.
2. Senior NASA officials told us that the revised EM-1 launch date of December 2019 is unachievable and the June 2020 launch date (which takes into account schedule reserves) is unlikely. These officials then estimated that there are 6 to 12 months of schedule risk associated with the June 2020 date. It would be misleading for us to continue to report the June 2020 launch date when we were told there was substantive risk to that date. Without a new approved schedule, Figure 3, Figure 5, and Figure 8 all present a notional launch window including the acknowledged schedule risks. We then used the information NASA provided us to report that the first launch may occur as late as June 2021, if all risks are realized.

Further, this substantial delay to the first mission was acknowledged by senior officials less than one year after NASA announced up to a 19 month delay. We maintain that continued underperformance contributed to these additional schedule delays and associated cost increases. For example, for SLS, NASA discovered during installation that fuel lines used in the engine section were contaminated with residue and other debris. According to a program official, Boeing had not verified the processes that its vendors were using to clean the fuel lines, resulting in about 2 months' delay to resolve residue and debris issues. For the Orion program, NASA determined in 2017 that Lockheed Martin would not meet the delivery date for the crew module—even if the European Service Module were on schedule—when numerous problems including design issues, damage during testing, and manufacturing process changes resulted in major schedule impacts to the program.

As a result, we also maintain that these delays and cost growth reinforce concerns over the management of the programs. In addition to the underperformance, NASA's management decisions on how to report cost growth is not fully transparent and, in particular, obscures the difficulties the SLS program has faced controlling costs.

3. We agree that that these are long-term, "multi-decadal" programs and that content is subject to change. As a result, we maintain that arbitrarily focusing on a single mission and not looking at long-term costs may have negative impacts to this human spaceflight system. We previously reported in May 2014, that NASA does not have a cost and schedule baseline for SLS beyond the first flight.¹ As a result, NASA cannot monitor or track costs shifted beyond EM-1 against a baseline. We recommended that NASA establish cost and schedule baselines that address the life cycle of each SLS increment, as well as for any evolved Orion or ground systems capability. NASA partially concurred with the recommendation, but has not taken any action to date. Until action is taken to do so, as noted above, NASA's decision to shift some SLS costs to future missions while not adjusting the baseline downward not only underestimates cost growth for the first mission, but also results in there being no mechanism to track these costs that NASA shifted to future missions.
4. Through the course of this review, NASA was transparent in its discussions with us of how it calculated costs for each of the programs. The findings of this report are not meant to convey that NASA is withholding information, but rather, that decisions NASA has made about how to calculate costs do not provide sufficient transparency into cost growth or cost estimates. Further, we have previously reported that without transparency into costs for future flights, NASA does not have the data to assess long-term affordability and Congress cannot make informed budgetary decisions.²

¹GAO, *NASA Actions Needed to Improve Transparency and Assess Long-Term Affordability of Human Exploration Programs*, [GAO-14-385](#) (Washington, D.C.: May 8, 2014).

²[GAO-14-385](#).

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

In addition to the contact named above, Molly Traci, Assistant Director; Andrea Bivens; Sylvia Schatz; Ryan Stott; Tanya Waller; John Warren; Alyssa Weir; and Robin Wilson made significant contributions to this report.

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