United States Government Accountability Office

Report to Congressional Committees

July 2018

NASA COMMERCIAL CREW PROGRAM

Plan Needed to Ensure Uninterrupted Access to the International Space Station

GAO-18-476

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GAO Highlights

Highlights of GAO-18-476, a report to congressional committees

Why GAO Did This Study

In 2014, NASA awarded two firm-fixed-price contracts to Boeing and SpaceX, worth a combined total of up to $6.8 billion, to develop crew transportation systems and conduct initial missions to the ISS. In February 2017, GAO found that both contractors had made progress, but their schedules were under mounting pressure. The contractors were originally required to provide NASA all the evidence it needed to certify that their systems met its requirements by 2017.

A House report accompanying H.R. 5393 included a provision for GAO to review the progress of NASA's human exploration programs. This report examines the Commercial Crew Program, including (1) the extent to which the contractors have made progress towards certification and (2) how NASA's certification process addresses safety of the contractors' crew transportation systems. GAO analyzed contracts, schedules, and other documentation and spoke with officials from NASA, the Commercial Crew Program, Boeing, SpaceX, and two of NASA's independent review bodies that provide oversight.

What GAO Recommends

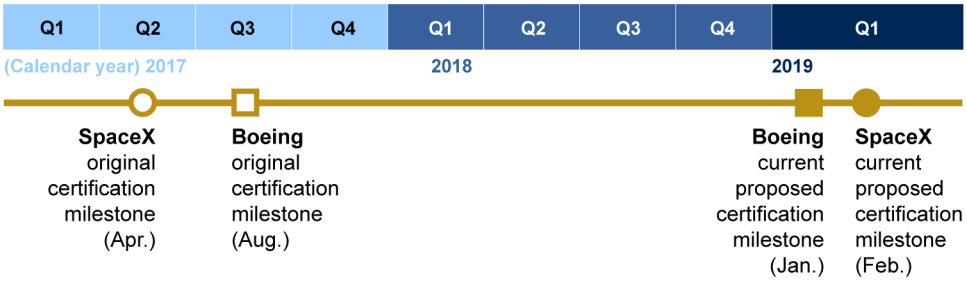
GAO is making five recommendations, including that NASA develop a contingency plan for ensuring a U.S. presence on the ISS and clarify how it will determine its risk tolerance for loss of crew. NASA concurred with three recommendations; partially concurred on the recommendation related to loss of crew; and non-concurred with a recommendation to report its schedule analysis to Congress. GAO believes these recommendations remain valid, as discussed in the report.

View GAO-18-476. For more information, contact Cristina T. Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

Both of the Commercial Crew Program's contractors, Boeing and Space Exploration Technologies Corporation (SpaceX), are making progress finalizing designs and building hardware for their crew transportation systems, but both contractors continue to delay their certification milestone (see figure). Certification is the process that the National Aeronautics and Space Administration (NASA) will use to ensure that each contractor's system meets its requirements for human spaceflight for the Commercial Crew Program.

Commercial Crew Program: SpaceX and Boeing's Certification Delays as of First Quarter Calendar Year 2018



Source: GAO analysis of National Aeronautics and Space Administration contracts and documents. | GAO-18-476

Further delays are likely as the Commercial Crew Program's schedule risk analysis shows that the certification milestone is likely to slip. The analysis identifies a range for each contractor, with an earliest and latest possible completion date, as well as an average. The average certification date was December 2019 for Boeing and January 2020 for SpaceX, according to the program's April 2018 analysis. Since the Space Shuttle was retired in 2011, the United States has been relying on Russia to carry astronauts to and from the International Space Station (ISS). Additional delays could result in a gap in U.S. access to the space station as NASA has contracted for seats on the Russian Soyuz spacecraft only through November 2019. NASA is considering potential options, but it does not have a contingency plan for ensuring uninterrupted U.S. access.

NASA's certification process addresses the safety of the contractors' crew transportation systems through several mechanisms, but there are factors that complicate the process. One of these factors is the loss of crew metric that was put in place to capture the probability of death or permanent disability to an astronaut. NASA has not identified a consistent approach for how to assess loss of crew. As a result, officials across NASA have multiple ways of assessing the metric that may yield different results. Consequently, the risk tolerance level that NASA is accepting with loss of crew varies based upon which entity is presenting the results of its assessment. Federal internal controls state that management should define risk tolerances so they are clear and measurable. Without a consistent approach for assessing the metric, the agency as a whole may not clearly capture or document its risk tolerance with respect to loss of crew.

Contents

Abbreviations

FAR	Federal Acquisition Regulation
ISS	International Space Station
NASA	National Aeronautics and Space Administration
ORDEM	Orbital Debris Engineering Model
SpaceX	Space Exploration Technologies Corporation

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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July 11, 2018

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

Following the retirement of the Space Shuttle in 2011, the United States was left with no domestic ability to provide crew access to the International Space Station (ISS). Since then, the National Aeronautics and Space Administration (NASA) has relied on obtaining seats on the Russian Soyuz spacecraft to maintain a U.S. presence on the station. NASA's Commercial Crew Program is facilitating the commercial development of a crew transportation system that can provide safe, reliable, and cost-effective transportation to and from the ISS and that would end this dependency. NASA's goal is to have one or more contractors that can provide crew transportation services to the ISS. NASA is planning for the ISS to be operational until at least 2024.

NASA's acquisition strategy for the Commercial Crew Program is similar to the one it used on the Commercial Cargo Program, but different from other spacecraft it has built for humans, from Mercury to Gemini and

Apollo to the Space Shuttle.[1] Each contractor is to design, develop, build, own, and operate its own spaceflight system and infrastructure. The contractors will have access to NASA's expertise and resources throughout the development process, but NASA engineers are not the ones making design decisions and NASA personnel will be less involved in processing, testing, launching, and operating the crew transportation system. In the end, NASA will buy a crew transportation service—a ride for its astronauts to and from the ISS—much like it does for ISS cargo.

In the most recent phase of the Commercial Crew Program, NASA awarded firm-fixed-price contracts in 2014 to Boeing and Space Exploration Technologies Corporation (SpaceX), valued at up to $4.2 billion and $2.6 billion, respectively, for the development of crew transportation systems that meet NASA requirements and for the initial service missions to the ISS. According to the contracts, the companies were originally supposed to complete certification—the process by which each contractor provides NASA the evidence it needs to certify that its systems meet performance and safety requirements—by 2017.

The House Report accompanying H.R. 5393, Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2017 includes a provision for GAO to review the acquisition progress of NASA's human exploration programs, including the Commercial Crew Program. For this review, we assessed (1) the extent to which the contractors have made progress towards meeting NASA's certification requirements and NASA's plans to ensure continued access to the ISS; and (2) how NASA's certification process addresses safety of the contractors' crew transportation systems. To assess the contractors' progress toward certification, we reviewed Commercial Crew Program and contract documents, including quarterly progress updates, monthly risk charts, and monthly schedule summaries. We also interviewed program and contract officials to identify steps being taken to mitigate risks and assess the extent of cost or schedule effects if the risk is realized. For each contractor, we compared the original contract schedule to the most current contract schedule and the contractors' internal development

[1]In November 2005, NASA established the Commercial Crew and Cargo program office at the Johnson Space Center to challenge the commercial space industry to establish capabilities and services that could support the ISS's crew and cargo transportation needs. For more information, see GAO, *NASA: Commercial Partners Are Making Progress, but Face Aggressive Schedules to Demonstrate Critical Space Station Cargo Transport Capabilities,* GAO-09-618 (Washington, D.C.: June 16, 2009).

schedules to determine upcoming events and expected delays. We also spoke with ISS program officials to determine how NASA plans to mitigate the effects of these delays on its access to the ISS.

To assess how NASA's certification process addresses safety of the contractors' crew transportation systems, we reviewed agency safety policies, program plans, and contract documents to establish when certification approval would be granted, what safety assessments were required of the program, and which safety factors would be considered in certification reviews. For each contractor, we compared agency requirements to contract requirements for a key safety metric known as "loss of crew," and interviewed program and agency officials to determine how loss of crew would be assessed and considered throughout the certification process. We reviewed program and agency documentation and interviewed program and agency officials to determine the role of the safety and mission assurance technical authority in the program. We also met with two organizations that provide NASA with independent assessments of the program, the program's standing review board and the Aerospace Safety Advisory Panel, to gain their perspectives on the contractor's progress and how NASA addresses safety in its certification process. Appendix I contains detailed information about our scope and methodology.

We conducted this performance audit from April 2017 to July 2018 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

NASA's Commercial Crew Program is a multi-phased effort that began in 2010. Across the phases, NASA has engaged several companies, using both agreements and contract vehicles to develop and demonstrate crew transportation capabilities. As the program has passed through these phases, NASA has generally narrowed down the number of participants. The early phases of the program were under Space Act agreements, which is what NASA calls the agreements entered into pursuant to its

other transaction authority.[2] These types of agreements are generally not subject to the Federal Acquisition Regulation (FAR) and allow the government and its contractors greater flexibility in many areas. Under these Space Act agreements, NASA relied on the commercial companies to propose specifics related to their crew transportation systems, including their design, the capabilities they would provide, and the level of private investment. In these phases, NASA provided technical support and determined whether the contractors met certain technical milestones. In most cases, NASA also provided funding.

For the final two phases of the program, NASA awarded FAR-based contracts. By using FAR-based contracts, NASA gained the ability to procure missions to the ISS, while continuing to provide technical expertise and funding to the contractors. NASA levied two sets of requirements on the contractors:

- the ISS program requirements, which must be met by all spacecraft visiting the ISS whether they carry cargo or crew; and
- the Commercial Crew Program requirements, which have a focus on system capabilities and safety rather than design.

The program also established a verification closure notice process, in which the contractors submit data to NASA to verify they have met all the requirements to be certified. This certification must occur before contractors are allowed to fly initial crewed missions to the ISS.

Current Program Contracts

In September 2014, NASA awarded firm-fixed-price contracts to Boeing and SpaceX, valued at up to $4.2 billion and $2.6 billion, respectively, for the Commercial Crew Transportation Capability phase. Under a firm-fixed-price contract, the contractor must perform a specified amount of work for the price negotiated by the contractor and government. This is in contrast to a cost-reimbursement contract, in which the government generally agrees to pay the contractor's allowable costs regardless of whether work is completed. During this phase, the contractors will complete development of crew transportation systems.

Boeing's spacecraft—CST-100 Starliner—is composed of a crew module and a service module.

[2]51 U.S.C. § 20113(e). This authority allows NASA to enter into agreements "other than" standard government contracts or other traditional mechanisms.

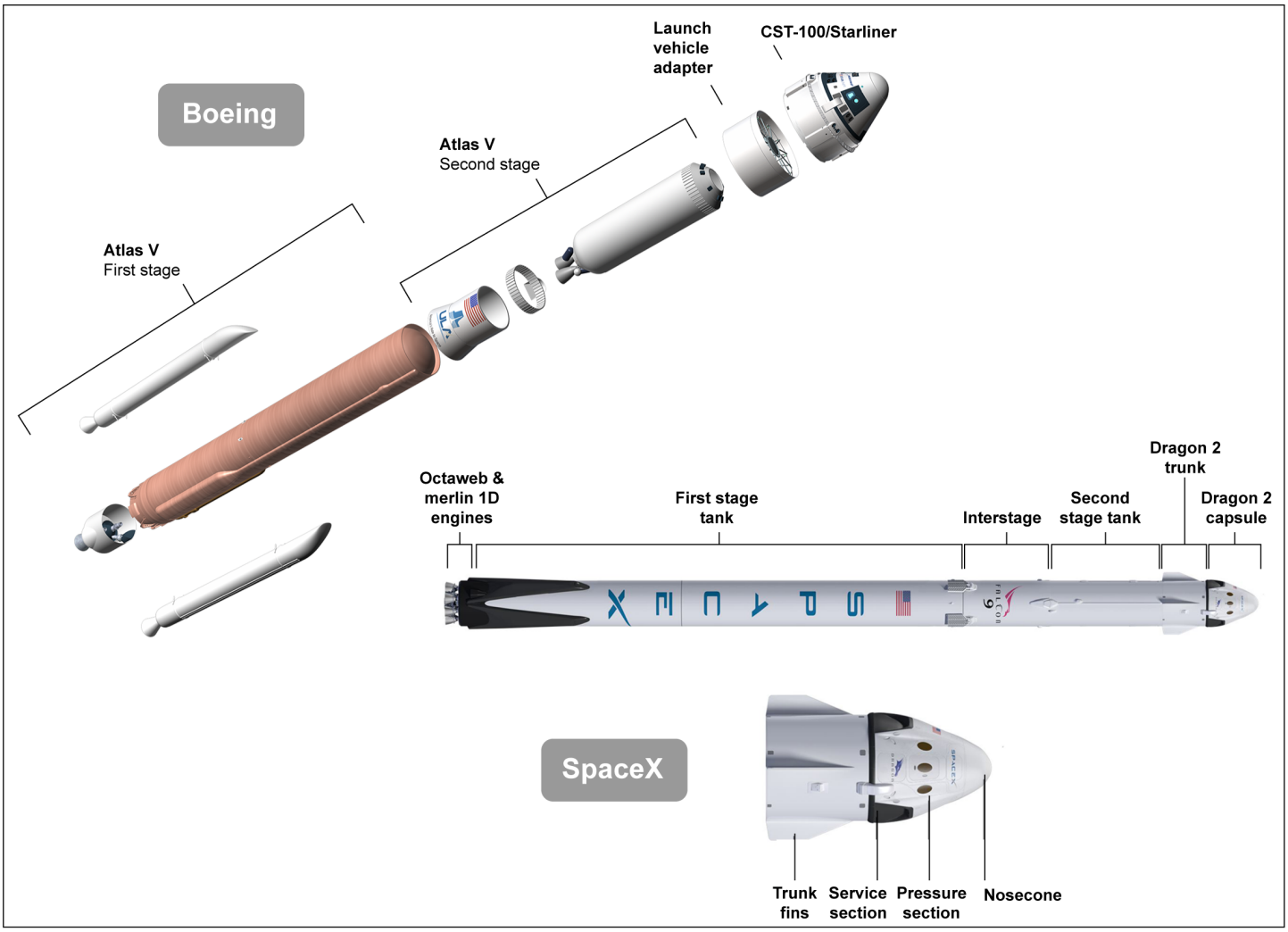
- The crew module will carry the crew and cargo. It also includes communication systems, docking mechanisms, and return systems for Earth landing.
- The service module provides propulsion on-orbit and in abort scenarios as well as radiators for thermal control.

SpaceX's spacecraft—Dragon 2—is composed of a capsule, which we refer to as the crew module, and a trunk, which we refer to as the support module.

- The crew module is composed of a pressure section and a service section. This module will carry the crew and cargo. It also includes avionics, docking mechanisms, and return systems for a water landing.
- The support module includes solar arrays for on-orbit power and guidance fins for escape abort scenarios.

Figure 1 shows the spacecraft and launch vehicles for Boeing and SpaceX's crew transportation systems.

Figure 1: Boeing and SpaceX Crew Transportation Systems



Source: Copyright © 2016 United Launch Alliance, LLC. (top image); @2016 SpaceX (bottom image). | GAO-18-476

The Commercial Crew Transportation Capability phase contracts include three types of services:

- **Contract Line Item 001** encompasses the firm-fixed-price design, development, test, and evaluation work needed to support NASA's certification of the contractor's spacecraft, launch vehicle, and ground support systems.

- **Contract Line Item 002** covers any service missions that NASA orders to transport astronauts to and from the ISS. Under this indefinite-delivery, indefinite-quantity line item, NASA has ordered six post-certification missions from each contractor.[3] Each service mission is its own firm-fixed-price task order. NASA must certify the contractors' systems before they can fly these missions.
- **Contract Line Item 003** is an indefinite-delivery, indefinite-quantity line item for any special studies, tests, and analyses that NASA may request. These tasks do not include any work necessary to accomplish the requirements under contract line item 001 and 002. As of April 2018, NASA had funded studies worth approximately $30 million to Boeing, including approximately $27 million for additional testing of the parachute system. NASA had funded studies worth approximately $44 million to SpaceX, including approximately $34 million for additional testing of the parachute system. For each contractor, the maximum value of this contract line item is $150 million.

NASA has made changes to the contracts that have increased their value. While the contracts are fixed-price, their values can increase if NASA adds work or otherwise changes requirements, among other means. As of April 2018, NASA requirement changes had increased the value of contract line item 001 for Boeing by approximately $191 million and for SpaceX by approximately $91 million.

Certification

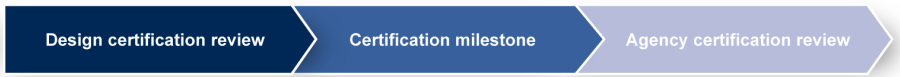
NASA divided the certification work under contract line item 001 into two acceptance events: the design certification review and the certification milestone. An acceptance event occurs when NASA approves a contractor's designs and acknowledges that the contractor's work is complete and meets the requirements of the contract.

The first acceptance event—the design certification review—verifies the contractor's crew transportation system's capability to safely approach, dock, mate, and depart from the ISS, among other requirements. After the contractor has successfully completed all of its flight tests, as well as various other activities, the second acceptance event—the certification milestone—determines whether the crew transportation system meets the

[3]An indefinite-delivery, indefinite-quantity contract may be used to acquire supplies or services during a specified period when the exact times and exact quantities of future requirements are not known at the time of contract award.

Commercial Crew Program's requirements. Following this contract milestone is an agency certification review, which authorizes the use of a contractor's system to transport NASA crew to and from the ISS. Figure 2 shows a notional path leading up to the agency certification review.

Figure 2: Notional Commercial Crew Program Path to Certification by NASA



Source: GAO analysis of National Aeronautics and Space Administration (NASA) documents. | GAO-18-476

The Commercial Crew Program's certification plan outlines how the program will incrementally review required deliverables leading up to, and supporting, the agency certification review. For each review, the plan describes the information that the contractor and the program will present. At the agency certification review, which is chaired by the Associate Administrator of the Human Exploration and Operations Mission Directorate, the agency will review the program's formal recommendation to certify the contractor's crew transportation system. Program officials said that their goal is to develop and review certification evidence incrementally in order to reduce the risk that issues will be identified during the agency certification review.

Prior GAO Work

In our February 2017 report,[4] we evaluated the progress made by the two contractors on the Commercial Crew Program and found the following:

- Both of the Commercial Crew Program's contractors had made progress developing their crew transportation systems, but both also had aggressive development schedules that were increasingly under pressure. We reported that both Boeing and SpaceX had determined that they would not be able to meet their original 2017 certification dates, and both expected certification to be delayed until 2018. We found that the schedule pressures were amplified by NASA's need to provide a viable crew transportation option because its contract with Russia's space agency was to provide crew transportation to the ISS for six astronauts through 2018 with rescue and return through late spring 2019. Purchasing additional seats from Russia involves a

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

contracting process that typically takes 3 years. Without a viable contingency option for ensuring uninterrupted access to the ISS in the event of further Commercial Crew delays, we concluded that NASA was at risk of not being able to maximize the return on its multibillion dollar investment in the space station.

- The Commercial Crew Program was using mechanisms laid out in its contracts to gain a high level of visibility into the contractors' crew transportation systems, but maintaining that level of visibility through certification could add schedule pressures. We noted that, for example, due to NASA's acquisition strategy for this program, its personnel were less involved in the testing, launching, and operation of the crew transportation system. While the program developed productive working relationships with both contractors, obtaining the level of visibility that the program required had also taken more time than the program or contractors had anticipated. Ultimately, we noted that the program had the responsibility for ensuring the safety of U.S. astronauts, and its contracts gave it deference to determine the level of visibility required to do so. We concluded that the program office could face difficult choices moving forward about how to maintain the level of visibility it feels it needs without adding to the program's schedule pressures.

In order to ensure that the United States had continued access to the ISS if the Commercial Crew Program's contractors experienced additional schedule delays, we recommended in our February 2017 report that the NASA Administrator develop a contingency plan for maintaining a presence on the ISS beyond 2018, including options to purchase additional Russian Soyuz seats, and report to Congress on the results.[5] NASA concurred with this recommendation, and in February 2017, NASA executed a contract modification that purchased two seats and included an option to purchase three additional crewmember seats from Boeing on the Russian Soyuz vehicle. These seats represent a contingency plan for U.S. access to the ISS through 2019. In April 2017, NASA informed the Congress of this action.

[5]GAO-17-137.

Contractors Have Made Progress, but NASA Has Not Finalized Plans to Ensure ISS Access Given Persistent Delays

Boeing and SpaceX continue to make progress developing their crew transportation systems, but both contractors have further delayed the certification milestone to early 2019. These changes have occurred as the contractors continue to work to aggressive schedules, and they have had to delay key events regularly. Further delays are likely as the Commercial Crew Program's schedule risk analysis shows that the certification milestone is likely to further slip. In addition, as of mid-June 2018, NASA officials told us that these dates may change soon but that both contractors have not yet provided official updates to their schedules to NASA. NASA has not fully shared information with Congress regarding the risks of future schedule delays for the contractors and, as a result, Congress lacks insight into when the contractors will be certified. Also, there may be a gap in access to the ISS if the Commercial Crew Program experiences additional delays. While NASA has begun to discuss potential options, it currently does not have a contingency plan for how to ensure an uninterrupted presence on the ISS beyond 2019.

Contractors Continue to Make Progress, but Risks Remain

Boeing and SpaceX have continued to make progress finalizing their designs and building hardware as they work toward their certification milestones. The contractors are manufacturing test articles to demonstrate system performance and flight spacecraft to support the uncrewed and crewed flight tests, which are expected to demonstrate the ability to meet contract requirements. As table 1 shows, these test articles and spacecraft vary in levels of completion. Some are built and undergoing testing while others are starting the manufacturing phase. Should any issues arise during integration and test or the flight tests, the contractors may have to complete rework on the spacecraft already under construction.

Table 1: Description of Boeing and SpaceX Hardware, Current Status, and Upcoming Events as of Second Quarter Calendar Year 2018

Spacecraft (Name and Type)	Purpose	Current Status	Upcoming Events
Boeing			
Flight spacecraft 1	Environmental testing Crewed flight test Second post-certification mission	Crew module: constructed, in final outfitting Service module: constructed, in final outfitting	Boeing plans to conduct environmental testing starting in the third quarter of 2018 to test the spacecraft in conditions that simulate the space environment.
Flight spacecraft 2	Uncrewed flight test First post-certification mission	Crew module: constructed, in initial outfitting Service module: in construction	Boeing plans to join the crew and service modules together in the third quarter of 2018.
Test article 1	Validate effectiveness of spacecraft design and abort system	Crew module: constructed and integrated Service module: constructed and integrated	This test article has undergone testing throughout 2017 and is expected to complete testing in mid-2018.
Test article 2	Support ground tests Pad abort test	Crew module: constructed and integrated Service module: in construction	This test article is completing testing before it will be reconfigured to support the pad abort test.
SpaceX			
Flight spacecraft 1	Uncrewed flight test	Crew module: constructed and integrated Support module: in construction	SpaceX plans to join the crew and support modules together in the second quarter of 2018.
Flight spacecraft 2	Crewed flight test	Crew module: in construction Support module: in construction	SpaceX plans to join the crew and support modules together in the third quarter of 2018.
Flight spacecraft 3	First post-certification mission	Crew module: in construction Support module: in construction	SpaceX plans to join the crew and support modules together in the first quarter of 2019.
Test article	Support spacecraft propulsion testing	Testing is underway to validate performance of the spacecraft engine propulsion system.	SpaceX plans to complete this testing by the third quarter of 2018.

Source: GAO analysis of National Aeronautics and Space Administration and contractor documents. | GAO-18-476.

While both contractors are making progress, the Commercial Crew Program is tracking risks that each contractor has to address through testing and other means as they work towards the certification milestone.

As we have previously reported, these types of risks are inherent in NASA's major acquisitions, which are highly complex, specialized, and often pushing the state of the art in space technology, but they could also delay the contractors' progress if issues arise during testing.[6]

The Commercial Crew Program's top programmatic risks identified for Boeing include challenges related to its abort system performance, parachutes, and launch vehicle.

- Abort System: Boeing is addressing a risk that its abort system, which it needs for human spaceflight certification, may not meet the program's requirement to have sufficient control of the vehicle through an abort. In some abort scenarios, Boeing has found that the spacecraft may tumble, which could pose a threat to the crew's safety. To validate the effectiveness of its abort system, Boeing has conducted extensive wind tunnel testing and plans to complete a pad abort test in July 2018.
- Parachute System: Boeing is also addressing a risk that during descent, a portion of the spacecraft's forward heat shield may re-contact the spacecraft after it is jettisoned and damage the parachute system.[7] Boeing's analysis indicates the risk exists only if one of two parachutes that pull the forward heat shield away from the spacecraft does not deploy as expected, and that potential re-contact is non-detrimental. However, NASA's independent analysis indicates that this may occur even if both parachutes deploy as expected. If the program determines this risk is unacceptable, Boeing would need to redesign the parachute system, which the program estimates could result in at least a 6-month delay.
- Launch Vehicle Data: One of the program's top programmatic and safety concerns is that it may not have enough information from Boeing's launch vehicle provider, United Launch Alliance, to assess whether the Atlas V launch vehicle prevents or controls cracking that could lead to catastrophic failures. NASA estimates that unfinished work in this area could take Boeing and the United Launch Alliance until the fourth quarter of 2018 to complete. Additionally, the first stage of the Atlas V is powered by the Russian built RD-180 engine, and, according to program and Boeing officials, access to its data is highly

[6]GAO-17-137.

[7]The forward heat shield protects the parachute system during re-entry to the Earth's atmosphere.

restricted by agreements between the U.S. and Russian governments. Since our last report, the Commercial Crew Program has lowered the risk that certification of the launch vehicle might not occur by negotiating steps to access necessary data, but work is still ongoing.[8]

The Commercial Crew Program's top programmatic risks identified for SpaceX are in part related to ongoing design and development efforts related to its launch vehicle design, the Falcon 9 Block 5.

- Composite Overwrap Pressure Vessel: This Block 5 design includes SpaceX's redesign of the composite overwrap pressure vessel, which is intended to contain a gas under high pressure. SpaceX officials stated the newly designed vessel aims to eliminate risks identified in the older design, which was involved in an anomaly that caused a mishap in September 2016. SpaceX plans to qualify the updated design for flight prior to the uncrewed flight test design certification review.
- Engine Turbine Cracking: The Block 5 design also includes design changes to address cracks in the turbine of its engine identified during development testing. NASA program officials told us that they had informed SpaceX that the cracks were an unacceptable risk for human spaceflight. SpaceX officials told us that they have made design changes to this Block 5 upgrade that did not result in any cracking during initial testing. However, this risk will not be closed until SpaceX successfully completes qualification testing in accordance with NASA's standards without any cracks. As of March 2018, SpaceX had not yet completed this testing.
- Propellant Loading Procedures: Both the program and a NASA advisory group have raised SpaceX's plan to fuel the launch vehicle after the astronauts are on board the spacecraft to be a potential safety risk. In the May 2018 meeting minutes, however, the Aerospace Safety Advisory Panel stated that with appropriate controls in place, this approach could be a viable option for the program to consider.[9] SpaceX's perspective is that this operation may be a lower risk to the crew because it reduces the crew exposure time while the launch vehicle is being loaded with propellant. To better understand

[8]GAO-17-137.

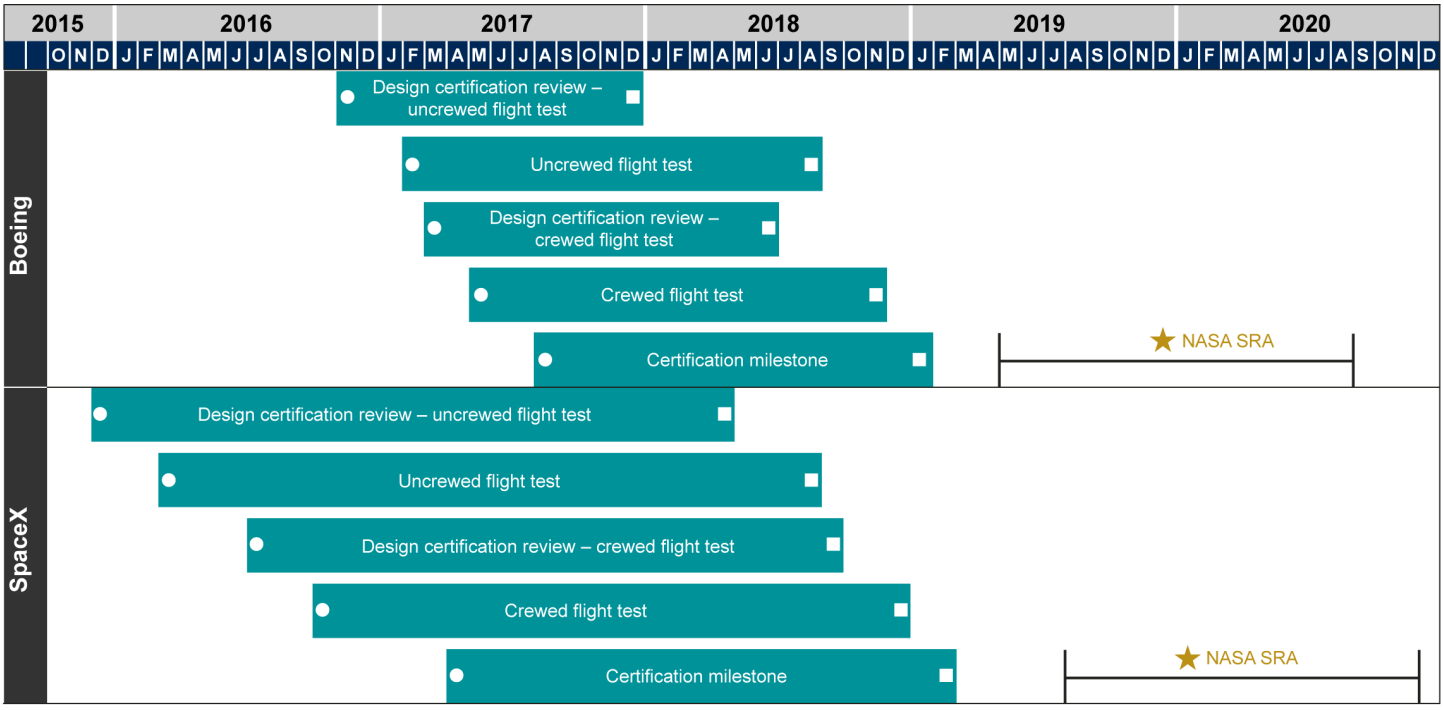
[9]The Aerospace Safety Advisory Panel is an independent review body that provides advice and makes recommendations to the NASA Administrator on matters related to safety.

the propellant loading procedures, the program and SpaceX agreed to demonstrate the loading process five times from the launch site in the final crew configuration prior to the crewed flight test. The five events include the uncrewed flight test and the in-flight abort test. Therefore, delays to those events would lead to delays to the agreed upon demonstrations, which could in turn delay the crewed flight test and certification milestone.

Program's Schedule Risk Analysis Indicates More Delays Likely to Certification Milestone

Both contractors have notified NASA that their certification milestones have slipped to January 2019 for Boeing and February 2019 for SpaceX, but the Commercial Crew Program's schedule risk analysis indicates more delays are likely. This analysis identifies a range for each contractor, with an earliest and latest possible completion date, as well as an average. In April 2018, the program's schedule risk analysis found there was zero percent chance that either contractor would achieve its current proposed certification milestone. The analysis's average certification date was December 2019 for Boeing and January 2020 for SpaceX. Figure 3 shows the original Boeing and SpaceX contract schedules and the current proposed schedule for five key events in each contract, as well as NASA's schedule risk analysis for the certification milestone.

Figure 3: Boeing and SpaceX's Proposed Commercial Crew Schedule Delays, as of First Quarter Calendar Year 2018, and the Commercial Crew Program's April 2018 Schedule Risk Analysis Range



Source: GAO analysis of National Aeronautics and Space Administration (NASA) and contractor documents. | GAO-18-476

Notes: The Commercial Crew Program's schedule risk analysis identifies a range, with an earliest and latest possible completion date, as well as an average.

The uncrewed and crewed flight tests are not contract milestones for Boeing. The dates for these events are from other Boeing or Commercial Crew documentation.

Each month, the program updates its schedule risk analysis based on the contractors' internal schedules as well as program officials' perspectives and insight into specific technical risks. The Commercial Crew Program manager told us that differences between the contractors' proposed schedules and the program's schedule risk analysis include:

- The contractors are aggressive and use their schedule dates to motivate their teams, while NASA adds additional schedule margin for testing.

- Both contractors assume an efficiency factor in getting to the crewed flight test that NASA does not factor into its analysis.

The program manager also told us that the program meets with each contractor monthly to discuss schedules and everyone agrees to the relationships between events in the schedule even if they disagree on the length of time required to complete events. The program manager added, however, that she relies on her prior experience to estimate schedule time frames as opposed to relying on the contractors' schedules, which are often optimistic.

Our analysis also shows that the contractors often delay their schedules. Both contractors have repeatedly stated that their schedules are aggressive and have set ambitious—rather than realistic—dates, only to frequently delay them. Since the current contracts were awarded in 2014, the Commercial Crew Program has held 13 quarterly reviews for each contractor. For the five key events identified above, Boeing has reported a delay at 7 of those quarterly reviews and SpaceX has reported a delay at 9 of them.[10]

In mid-June 2018, NASA officials told us that the dates for these key events may change soon. The information presented in Figure 3 above is based on first quarter calendar year 2018 data. NASA officials stated both contractors have not yet officially communicated new schedule dates to NASA as of the second quarter calendar year 2018. We found that both contractors have updated schedules that indicate delays are forthcoming for at least one key event, but NASA officials told us they lack confidence in those dates until they are officially communicated to NASA by the contractors. As a result, NASA is managing a multibillion dollar program without confidence in its schedule information as it approaches several big events, including uncrewed and crewed flight tests.

[10]At SpaceX's first quarter review in 2018, the contractor identified at least one key event was being reviewed—the design certification review for the uncrewed flight test—but this had not officially been delayed so we did not count that as a delay in our analysis.

NASA Has Neither Shared Complete Information on Delay Risk with Congress nor Developed a Contingency Plan

The risk of future delays in the contractors' schedules is critical information that NASA has not fully shared with Congress. Moreover, NASA has not yet developed a contingency plan to address the potential gaps that these delays could have on U.S. access to the ISS after 2019. Specifically, in the Explanatory Statement accompanying the fiscal year 2018 Consolidated and Further Continuing Appropriations Act, the House Appropriations Committee stated its expectation that NASA report quarterly to the Senate and House Committees on Appropriations on the status of the Commercial Crew Program contracts.[11] Previously, members of Congress had asked for this information in order to ensure that Congress had adequate insight into this program. While NASA includes both contractors' proposed schedules in its quarterly report to Congress, NASA does not include the results of its own schedule risk analysis. Given the frequency with which the contractors delay key events in their schedules, the program's schedule risk assessment provides valuable insight into potential delays that NASA currently is not providing to Congress.

In addition, as previously mentioned, NASA executed a contract modification that purchased two seats and included an option to purchase three additional crew member seats through Boeing for an undisclosed value and reported this action to Congress in April 2017.[12] Ultimately, the option was exercised, and NASA purchased a total of five seats on four different Soyuz flights. Boeing obtained these seats through a separate settlement with the Russian firm RSC Energia, which manufactures the Soyuz.

These seats were intended to serve as a contingency plan based on schedule information available at that time. However, subsequent delays, as well as the risk of future delays as discussed above, indicate that this contingency plan will likely no longer be sufficient. The earliest and latest possible completion dates for certification in NASA's April 2018 schedule risk analysis indicate it is possible that neither contractor would be ready before August 2020, leaving a potential gap in access of at least 9 months. We calculated the potential gap based on the contractor certification milestone dates, but there could be some additional time

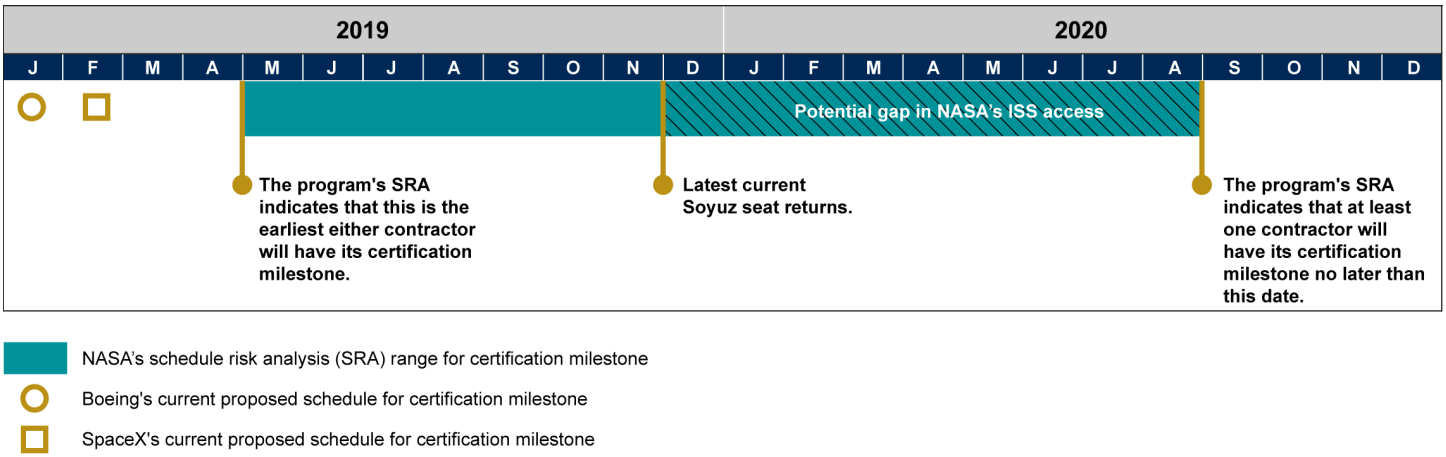
[11]H.R. Rep. No. 115-231.

[12]In 2015, NASA paid approximately $82 million per seat through its contract with the Russian Federal Space Agency (Roscosmos). See GAO-17-137.

required between that review and the first post-certification service mission to the ISS.

As seen in figure 4, if the contractors can maintain their current proposed schedules for their respective certification milestones, a gap in access to the ISS is not expected. However, there would be a gap in access to the ISS if neither contractor has its certification milestone before November 2019, which is when NASA expects the final Russian Soyuz seat for a U.S. astronaut to return.

Figure 4: Potential Gap in Access to the International Space Station (ISS) Based on the Commercial Crew Program's Schedule Risk Analysis Range as of April 2018



Source: GAO analysis of National Aeronautics and Space Administration (NASA) and contractor documents. | GAO-18-476

Senior NASA officials told us that sustaining a U.S. presence on the ISS is essential to maintain and operate integral systems, without which the ISS cannot function. Given the importance of maintaining a U.S. presence on the ISS, NASA officials have stated they are working on options to address the potential gap in access. However, officials told us that planning for contingencies is difficult given the extensive international negotiations required for some options. Obtaining additional Soyuz seats seems unlikely, as the process for manufacturing the spacecraft and contracting for those seats typically takes 3 years—meaning additional seats would not be available before 2021. As a result, according to NASA's Associate Administrator for Human Exploration and Operations, the options NASA is considering include:

- Refine the remaining Soyuz launch schedule to allow for a return in January 2020, as opposed to November 2019. This would provide 2

additional months of access to the ISS before the commercial crew flights need to start.

- Use the crewed flight tests as operational flights to transport U.S. astronauts to and from the ISS. In March 2018, NASA modified Boeing's contract to allow NASA to add a third crew member and extend the length of the flight test, if NASA chooses to do so. This would have limited usefulness, however, in filling a potential gap in access to the ISS if the schedule for Boeing's crewed flight test slips past the return date for the last Soyuz flight and SpaceX also continues to experience delays.

NASA's Associate Administrator for Human Exploration and Operations stated that he is "brainstorming" other options to ensure access to the ISS but does not have a formal plan. While options are not unlimited and decisions have to be made within the context of the current geopolitical environment, Congress stated in the NASA Authorization Act of 2005 that it is U.S. policy to possess the capability for human access to space on a continuous basis. In 2010, Congress further stated that one of the key objectives of the United States' human spaceflight policy is to sustain the capability for long-duration presence in low-Earth orbit through full utilization of the ISS. If NASA does not develop options for ensuring access to the ISS in the event of further Commercial Crew delays, it will not be able to ensure that the U.S. policy goal and objective for the ISS will be met.

Agency Certification Process Includes Mechanisms to Assess Safety, but Is Complicated by Assessment of Key Safety Metric and Oversight Structure

The Commercial Crew Program relies on several contractual mechanisms to assess safety throughout the certification process, and those mechanisms are in varying stages of completion. The program itself, its contractors, and two of NASA's independent review organizations have raised concerns about the program's ability to assess and evaluate all of the deliverables in a timely manner. In addition, one of the key safety requirements levied by the program is loss of crew, which captures the probability of death or disability to a crew member. NASA does not have a consistent approach for how to incorporate key inputs to assess this metric, which means the agency as a whole may not clearly capture or document its risk tolerance with respect to loss of crew. Further, the program's chief safety and mission assurance officer is dual hatted to serve simultaneously in a programmatic position as well as the program's safety technical authority. This approach creates an environment of competing interests because it relies on the same individual to manage technical and safety aspects on behalf of the program while also serving as the independent oversight of those same areas.

Program Has Several Contractual Mechanisms to Assess Safety

The contractors are required to provide several key deliverables to the Commercial Crew Program, which inform the agency certification review and help NASA determine the level of risk it is accepting with respect to safety of each spacecraft. As described below, these deliverables are in varying stages of completion and the program itself, its contractors, and two of NASA's independent review organizations have raised concerns about the program's ability to assess and evaluate all of the deliverables in a timely manner.

Certification Data Package. Among other things, the certification data package includes a list of seven system safety assessments. For example, the certification data package includes a fault tolerance assessment, which describes the system's ability to sustain a certain number of undesired events, such as software or operational anomalies. A human error analysis—one of the seven assessments in the data package—evaluates human errors to minimize their negative effects on the system.

- Boeing held its uncrewed flight test design certification review in December 2017 and submitted its certification data package for NASA approval. Boeing plans three more updates to this data package prior to the final certification milestone.
- SpaceX has begun to submit data and plans to submit its final certification data package as part of its crewed flight test design certification review, which is scheduled for September 2018.

According to the program's certification review plan, program officials will review and approve the contractors' certification data packages, which will be used to inform the agency certification review.

Phased Safety Review Process. A three-phased safety review process informs the program's quality assurance activities, and it is intended to ensure that the contractors have identified all safety-critical hazards and implemented associated controls prior to the first crewed flight test.

- In phase one, the contractors identified risks in their designs and developed reports on potential hazards, the controls they put in place to mitigate them, and explanations for how the controls will mitigate the hazards.
- In phase two, which is nearing completion, the program reviews and approves the contractors' hazard reports and develops strategies to verify and validate that the controls are effective. For example, if a

control requires that an item be waterproofed, verification and validation strategies could include inspections and tests to confirm that the item is waterproof. As of April 2018, the program had yet to complete this phase,[13] having approved 97 percent of Boeing's phase two reports and 72 percent of SpaceX's phase two reports.

- In phase three, the contractors will conduct the verification activities and submit the hazard reports to the program for approval. The program has begun phase three, including approving 19 percent of Boeing's phase three reports.

Program Requirements. While the program manager told us that all of the requirements contribute to the safety of the commercial systems, safety officials are required to approve a subset of these requirements. Examples of requirements approved by safety officials include the ability to leave the spacecraft in an emergency or to abort a launch. When a contractor is ready for NASA to verify that it has met a requirement, the contractor submits data for NASA to review through a verification closure notice. We define "safety-specific notices" as those requiring safety officials' approval. As shown in table 2, as of March 2018, the program had approved 2 percent of Boeing's safety-specific notices and 0 percent of SpaceX's safety-specific notices.

Table 2: Verification Closure Notice Progress for Commercial Crew Program Requirements, by Contractor as of March 2018

		Total	Number Approved	Percentage Approved
Boeing	Verification closure notices	**275**	30	11
	Safety-specific notices	**89**	2	2
SpaceX	Verification closure notices	**278**	7	3
	Safety-specific notices	**89**	0	0

Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-18-476.

Notes: The contractors have also started to submit notices for the International Space Station program requirements for the program to approve prior to the certification milestone.

Safety–specific notices are a subset of verification closure notices that require safety officials' approval.

Testing. The program also requires testing to verify and validate the crew transportation system. Agency officials emphasized the importance of testing to safety, stating that testing reduces uncertainty about a system's

[13]In February 2017, we found that the program had planned to complete phase two in early 2016, but was behind schedule. See GAO-17-137.

performance and can uncover unknown problems. As noted above, both contractors will be conducting an uncrewed and a crewed flight test prior to being certified. While a certain level of risk needs to be accepted to conduct human spaceflight, these flight tests help to mitigate this risk by validating the integrated performance of the hardware and software. Agency and program officials stated that the contractors' flight tests are critical evidence to support certification of a safe and reliable system.

As evidenced by the data above, the program still has a significant amount of work ahead with respect to approving certification packages and closing hazard reports and verification closure notices. We have previously found that the program's workload was an emerging schedule risk, and the contractors have continued to express concern about program officials' ability to process and approve certification paperwork in a timely manner.[14] Workload has also been a concern for two of NASA's independent review organizations. For example, the Aerospace Safety Advisory Panel noted in its January 2018 annual report that the sheer volume of work that remains for the program in terms of closing hazard reports and verification closure notices is significant. In addition, the program's safety and mission assurance office identified the upcoming bow wave of work in a shrinking time period as a top risk to achieving certification.

NASA Lacks a Consistent Approach to Assess Key Safety Metric

One mechanism the program put in place to assess the overall safety of each spacecraft—loss of crew—has been a focus of the Aerospace Safety Advisory Panel, Members of Congress, our prior work, and the program itself. Loss of crew captures the probability of death or permanent disability to one or more crew members. It has received a lot of attention, in part, because it has been a top risk for the program since 2015. Specifically, the program has been concerned that neither contractor would be able to meet the contract requirement of a 1 in 270 probability of incurring loss of crew. We identified two key concerns with how NASA is using the loss of crew metric: (1) inconsistent approaches to assess the loss of crew metric and (2) no identified plan to share lessons learned about using the loss of crew metric as a safety threshold.

A loss of crew value is generated through a probabilistic safety analysis, which models scenarios that could result in the loss of crew using various

[14]GAO-17-137 and GAO-18-317T.

inputs. According to the program's analysis, the probability of on-orbit debris damaging the vehicle has the greatest effect on a loss of crew value. This probability is informed by an orbital debris (debris) model, which was updated in 2014, after the loss of crew requirement was established. The updated debris model makes it harder to meet a loss of crew value, in part, because the modeling environment where the contractors' systems will operate has changed. For example, the updated model includes a larger span of orbit, greater range of debris sizes, and the addition of material density classifications, which were not included in the former model. Further, the probabilistic safety analysis may include operational mitigations, such as on-orbit inspections that would include using cameras on the ISS to visually survey the spacecraft for damage, which, according to officials, makes it easier to meet a loss of crew value.

NASA describes the probabilistic safety analysis as a powerful tool that should be used as part of the overall risk management process to ensure the risk associated with development and operation of a system is understood, evaluated, managed, and mitigated. However, we found differences in the approaches that officials plan to use to assess loss of crew as well as in the loss of crew value being measured that could limit the usefulness of this tool.

- **Agency Certification.** The agency certification review for each contractor will include an assessment of whether its crew transportation system meets a loss of crew threshold of 1 in 150 for missions to the ISS, which is based on a May 2011 safety memo from the Office of Safety and Mission Assurance. A loss of crew value with a higher denominator, such as 1 in 270, is harder to meet than with a lower denominator, such as 1 in 150. According to the Chief of the Office of Safety and Mission Assurance, he will assess the 1 in 150 threshold using a probabilistic safety analysis that includes the updated debris model and operational mitigations, such as the on-orbit inspections cited above.
- **Program Office.** According to program officials, they will assess whether either contractor meets a 1 in 270 loss of crew value based on a probabilistic safety analysis using the former debris model (not the updated model) and not including operational mitigations.
- **Contracting Officer.** According to the contracting officer, each contractor's loss of crew requirement is 1 in 270 without including operational mitigations. The contracting officer stated that SpaceX's contract requirement uses the updated debris model in the

probabilistic safety analysis, whereas Boeing's contract requirement uses the former debris model in the probabilistic safety analysis.

- **Program's Chief Safety and Mission Assurance Officer.** According to the program's chief safety and mission assurance officer, he will conduct a probabilistic safety analysis using the updated debris model and will not include operational mitigations to assess whether each contractor meets a 1 in 200 loss of crew value. This loss of crew value stems from a program update that occurred after the initial contracts were signed.

These different approaches are summarized in table 3 below.

Table 3: Loss of Crew Values and Probabilistic Safety Analysis Inputs NASA Plans to Include Vary across the Agency

		Probabilistic Safety Analysis Inputs	
	Loss of Crew Value	**Orbital Debris Model**	**Operational Mitigations**
Agency Certification	1 in 150	Updated	Included
Program Office	1 in 270	Former	Excluded
Contracting Officer	1 in 270	Updated – SpaceX Former – Boeing	Excluded
Program Chief Safety and Mission Assurance Officer	1 in 200	Updated	Excluded

Source line: GAO analysis of National Aeronautics and Space Administration data. | GAO-18-476.

Agency policy requires human spaceflight programs to set a safety threshold, which NASA did for the Commercial Crew Program when it identified the 1 in 150 loss of crew threshold in the May 2011 safety memo. Subsequently, the program set more rigorous loss of crew values in contract and program documents. NASA also updated the debris model, which we previously noted makes it more difficult to meet a loss of crew value. As a result, NASA does not have a consistent approach for how to incorporate key inputs to the probabilistic safety analysis, including changes to the debris model. Instead, the risk tolerance that NASA is accepting with loss of crew varies based upon which entity is presenting the results of its probabilistic safety analysis. For example, it is possible that the program's assessment will determine that neither contractor will meet the 1 in 270 contract requirement, but that the agency's assessment will determine that the contractors meet the 1 in 150 agency certification value because that analysis will include operational mitigations. Or the program's assessment could determine that Boeing meets the 1 in 270 contractual loss of crew requirement, but the agency's assessment may determine that Boeing does not meet the 1 in 150 agency certification value because that analysis will use the updated debris model.

Federal internal controls state that agency management should define objectives clearly to enable the identification of risks and define risk tolerances. Specifically, management should define risk tolerances in specific and measurable terms, so they are clearly stated and can be measured.[15] In this case, because there will be multiple analyses conducted using different inputs, NASA risks not clearly capturing or documenting, in a coherent manner, its overall risk tolerance with respect to loss of crew before a final decision must be made on whether to certify either crew transportation system.

Moreover, capturing the challenges and lessons learned from using the loss of crew metric is critical, particularly because agency officials told us that this is the first time this metric has been used as a safety threshold. Also, there are different viewpoints about the utility of the metric as a safety threshold across the agency. The program manager repeatedly told us that loss of crew is best used as a design tool. For example, program officials told us that both contractors incorporated additional orbital debris shielding into their designs to mitigate the orbital debris risk and improve their loss of crew values. In addition, the Aerospace Safety Advisory Panel reported in 2018 that loss of crew should not be viewed as an absolute measure of actual risk during operations.[16] However, the May 2011 agency safety memo states that a breach of the loss of crew threshold would initiate a termination review of the Commercial Crew Program, which is a more strict application of the loss of crew metric.

Both program and safety officials told us that, after the agency certification is complete and lessons learned are available to be compiled, sharing those lessons learned across NASA would be a good idea given the complexities associated with assessing the loss of crew metric. As of April 2018, however, agency officials said they did not have a plan for loss of crew knowledge-sharing. We have previously found that lessons learned provide a powerful method of sharing good ideas for improving work processes, facility or equipment design and operation, quality, safety, and cost-effectiveness.[17] Further, according to NASA's Knowledge

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

[16]Aerospace Safety Advisory Panel, *Annual Report for 2017* (Washington, D.C.: January 2018).

[17]GAO, *NASA: Better Mechanisms Needed for Sharing Lessons Learned*, GAO-02-195 (Washington, D.C.: Jan. 30, 2002).

Policy on Program and Projects, which is managed through the Office of the Chief Engineer, a principle of each center and mission directorate's knowledge strategy is that knowledge is the cornerstone of NASA's ability to achieve mission success.[18] The policy acknowledges that NASA faces continuous challenges in using what it knows effectively. These challenges include, but are not limited to, enabling the identification and flow of knowledge across organizational boundaries; preserving knowledge at risk of being lost; and providing means for individuals, teams, and the organization to learn from experiences. If NASA does not capture lessons learned from the Commercial Crew Program on using the loss of crew requirement to set a program's safety threshold and whether it met the agency's intended goal, future programs will not be able to benefit from the knowledge gained from this multibillion dollar investment.

The Commercial Crew Program's Organizational Structure Impairs Independence of Safety Technical Oversight Supporting the Certification Process

NASA's governance model prescribes a management structure that employs checks and balances among key organizations to ensure that decisions have the benefit of different points of view and are not made in isolation. As part of this structure, NASA established the technical authority process as a system of checks and balances to provide independent oversight of programs and projects in support of safety and mission success through the selection of specific individuals with delegated levels of authority. The technical authority process has been used in other parts of the government for acquisitions, including the Department of Defense and Department of Homeland Security.

The Commercial Crew Program is organizationally connected to three technical authorities within NASA: the Office of the Chief Engineer technical authority, the Office of Chief Health and Medical technical authority, and the Office of Safety and Mission Assurance (safety) technical authority. The safety technical authority is responsible for ensuring from an independent standpoint that the program's products and processes satisfy NASA's safety, reliability, and mission assurance policies. The NASA safety technical authority has delegated authority through the Kennedy Space Center Director to the Chief Safety and Mission Assurance Officer for the Commercial Crew Program.

[18]NASA Policy Directive 7120.6, Knowledge Policy on Programs and Projects, para. 5.d(4)(a) (Nov. 26, 2013).

We have previously reviewed how NASA has organized its technical authorities for its Exploration Systems Development organization—an organization that oversees the development of the Space Launch System, Orion crew capsule, and associated ground systems that have the goal of extending human presence beyond low-Earth orbit. In October 2017, we found that the Exploration Systems Development organization had established an organizational structure in which the technical authorities for engineering and safety and mission assurance were dual hatted simultaneously in programmatic positions.[19] We found that having the same individual simultaneously fill both a technical authority role and a program role created an environment of competing interests, where the technical authority's ability to impartially and objectively assess the programs while at the same time acting on behalf of the Exploration Systems Development organization in programmatic capacities may be subject to impairments.

We found that this was in contrast to a recommendation from the Columbia Accident Investigation Board report—the result of an in-depth assessment of the technical and organizational causes of the 2003 Space Shuttle Columbia accident—for NASA to establish a technical authority to serve independently of the Space Shuttle program, so that employees would not feel hampered to bring forward safety concerns or disagreements with programmatic decisions.[20] The board's findings that led to this recommendation included a broken safety culture in which it was difficult for minority and dissenting opinions to percolate up through the hierarchy; dual center and programmatic roles vested in one person that had confused lines of authority, responsibility, and accountability and made the oversight process susceptible to conflicts of interest; and oversight personnel in positions within the program, increasing the risk that these staffs' perspectives would be hindered by too much familiarity with the programs they were overseeing. In October 2017, we recommended that the division no longer dual hat two individuals who had both programmatic and technical authority responsibilities.[21] As of April 2018, NASA had taken steps to separate the engineering technical authority position from the programmatic position, and NASA's Chief of

[19]GAO, *NASA Human Space Exploration: Integration Approach Presents Challenges to Oversight and Independence*, GAO-18-28 (Washington, D.C.: Oct. 19, 2017).

[20]GAO-18-28.

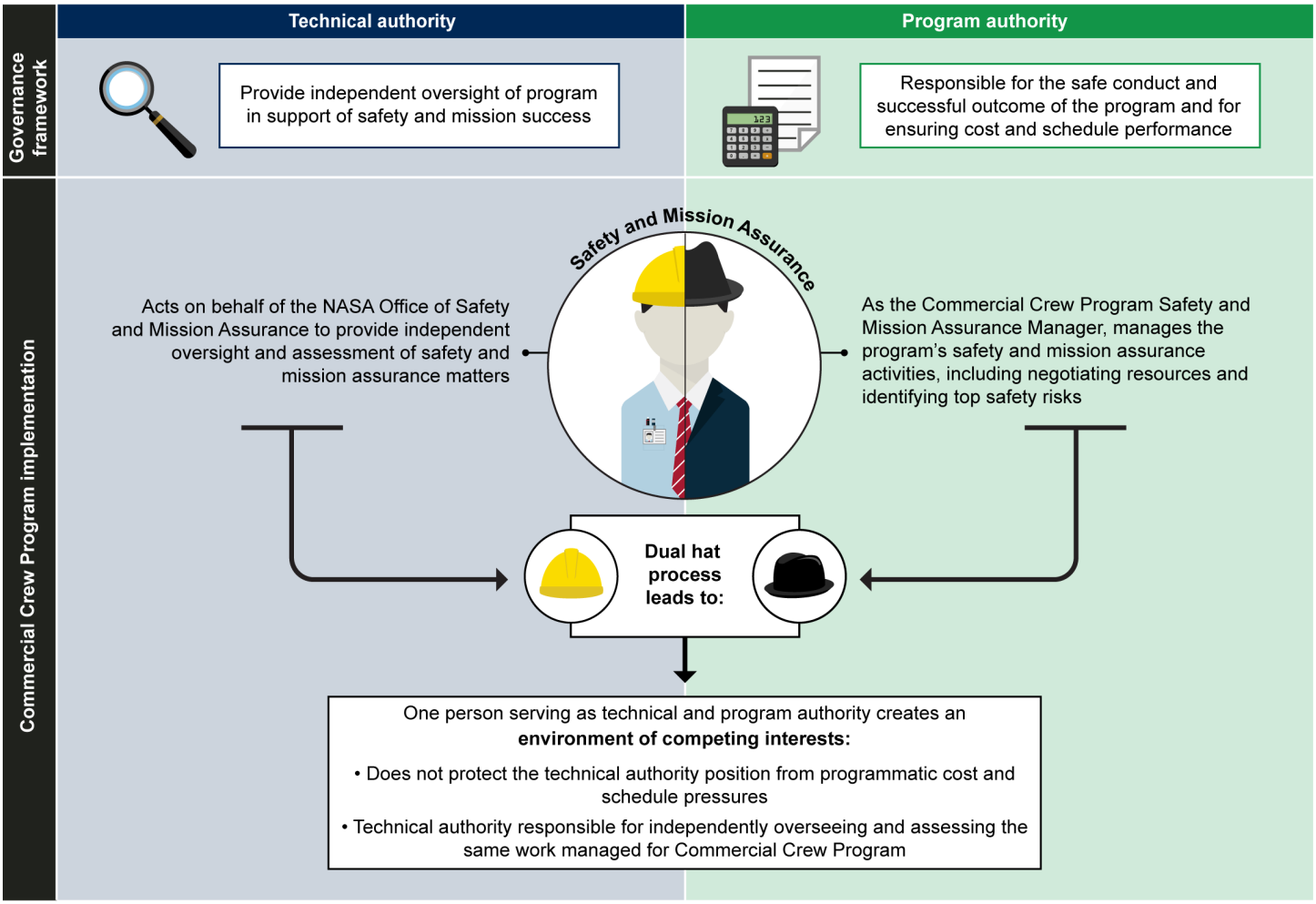
[21]GAO-18-28.

Safety and Mission Assurance said he planned to separate the safety position but had not yet completed that action.

The Commercial Crew Program employs a similar structure to the Exploration Systems Development organization in that the safety technical authority is dual hatted simultaneously in a programmatic position as the Commercial Crew Program's Safety and Mission Assurance Manager. According to the program's safety technical authority, in his programmatic role for the program, he helps set priorities for safety issues, including how staff will be utilized to meet those priorities. In the technical authority role, he provides independent oversight in support of safety and mission success. In his dual-hatted role, this official will be responsible for endorsing the program's certification recommendations in two different capacities: as the technical authority and as a program authority.

As a result, this structure relies on the same individual to completely separate two roles—one to manage the Commercial Crew Program's safety issues within programmatic cost and schedule constraints, and the other to assess the same issues in an independent oversight role. While the Commercial Crew Program may have an additional level of separation between the safety technical authority and the program's involvement in the design of commercial systems due to its shared assurance model with the commercial providers, the Commercial Crew Program still maintains a structure where one individual simultaneously serves in both technical authority and programmatic roles. Figure 5 describes some of the conflicting roles and responsibilities of this official in his two different positions.

Figure 5: Conflicting Roles and Responsibilities of Commercial Crew Program's Safety and Mission Assurance Technical Authority



Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-18-476

During our review, officials cited several factors in support of a dual-hatted approach:

- The safety technical authority retains independence because his technical authority reporting path and performance reviews are not under the purview of the Commercial Crew Program chain of command.
- Due to the Commercial Crew Program's shared assurance model with commercial providers, the program is operating in a quality assurance

role that provides an additional level of separation between the safety technical authority and the program's involvement in the design of commercial systems.

- For safety decisions involving cost and schedule where the individual who is dual hatted with both technical authority and programmatic responsibilities may feel conflicted, he stated that he would discuss these matters with his management to validate the logic behind his decision.
- There are cost and knowledge efficiencies gained from one individual serving in both programmatic and safety technical authority capacities.

NASA's Chief of Safety and Mission Assurance stated that he has great confidence in the individual currently serving in the dual hatted role for the Commercial Crew Program, but acknowledged there is inherent conflict even with the program's shared assurance model. In December 2017, he stated that, based on our previous work and current discussions, he intends to decouple the programmatic and technical authority responsibilities for the Commercial Crew Program but had not done so as of April 2018. Federal internal control standards state that an agency should design control activities to achieve objectives and respond to risks, which includes segregation of key duties and responsibilities to reduce the risk of error, misuse, or fraud.[22] By overlapping technical authority and programmatic responsibilities, NASA will continue to run the risk of creating an environment of competing interests for the Commercial Crew Program's safety technical authority.

Conclusions

NASA's Commercial Crew Program is a multibillion dollar effort to facilitate the commercial development of a crew transportation system that can end the United States' reliance on Russia to maintain an uninterrupted presence on the ISS. Boeing and SpaceX continue to make progress developing a capability to fly to the ISS, but both have continued to experience delays. Program analysis indicates risks of further delays in each contractor's current schedule, but NASA has not provided that information to Congress in its routine briefings. Without this information, Congress does not know the full extent of potential delays to inform decision making. Additional delays could also disrupt U.S. access to the ISS. While NASA is working on potential solutions, there is no

[22]GAO-14-704G.

contingency plan in place to address this potential gap. Without a viable contingency plan, NASA puts at risk achievement of the U.S. goal and objective for the ISS.

NASA must balance safety with acceptable risk for human spaceflight. As part of the certification process for each contractor's spacecraft, NASA has developed one key safety metric, loss of crew. However, the complicated nature of this metric is further muddled by the inconsistent approaches being used across NASA about what inputs to be considered. As a result, there is no clear articulation of what level of risk NASA will accept with respect to this program. In addition, NASA does not have plans to capture lessons learned from how the Commercial Crew Program has used this metric to assess safety and is missing an opportunity to capture this knowledge for future human spaceflight programs.

Finally, a space program's management and oversight approach is an integral part of ensuring that human spaceflight is as safe and successful as possible. Independence of the program management and oversight functions is key to achieving the balance between safety and success. The Commercial Crew Program's approach, however, burdens the safety technical authority with both programmatic and independent technical authority responsibilities. As a result, NASA has limited assurance that independence can be maintained as part of its institutional process to ensure safety and success.

Recommendations for Executive Action

We are making the following five recommendations to NASA:

The NASA Associate Administrator for Human Exploration and Operations should direct the Commercial Crew Program to include the results of its schedule risk analysis in its mandatory quarterly reports to Congress. (Recommendation 1)

The NASA Administrator should develop and maintain a contingency plan for ensuring a presence on the ISS until a Commercial Crew Program contractor is certified. (Recommendation 2)

The NASA Administrator should direct the Chief of Safety and Mission Assurance, the NASA Associate Administrator for Human Exploration and Operations, the Commercial Crew Program Manager, and the Commercial Crew Program Contracting Officer to collectively determine and document before the agency certification review how the agency will

determine its risk tolerance level with respect to loss of crew. (Recommendation 3)

After completing the agency certification review, NASA's Chief Engineer and Chief of Safety and Mission Assurance, with support from the NASA Associate Administrator for Human Exploration and Operations and the Commercial Crew Program Manager, should document lessons learned related to loss of crew as a safety threshold for future crewed spaceflight missions, given the complexity of the metric. (Recommendation 4)

The NASA Chief of Safety and Mission Assurance should restructure the technical authority within the Commercial Crew Program to ensure that the technical authority for the Office of Safety and Mission Assurance is no longer dual hatted with programmatic and independent technical authority responsibilities. (Recommendation 5)

Agency Comments and Our Evaluation

We provided a draft of this report to NASA for review and comment. NASA provided written comments that are reprinted in appendix II.

In its response, NASA concurred with three of our recommendations, did not concur with one, and partially concurred with another.

- NASA concurred with our recommendation to develop and maintain a contingency plan to ensure a U.S. presence on the ISS and expects to take action to close this recommendation by the end of December 2018.
- NASA concurred with our recommendation to document lessons learned related to the loss of crew requirement and expects to take action to close this recommendation by the end of May 2019.
- NASA concurred with our recommendation to restructure the safety technical authority so that it is no longer dual hatted with programmatic and independent technical authority responsibilities. NASA expects to take action to close this recommendation by the end of August 2018.

NASA did not concur with our recommendation that the Commercial Crew Program should include the results of its schedule risk analysis in its quarterly reports to Congress. NASA stated that it uses the contractors' schedules as a baseline to provide qualitative statements in the NASA summary that accompanies each contractor's quarterly reports to

Congress. NASA believes that this approach is appropriate and is in accordance with the explanatory statement accompanying the Consolidated and Further Continuing Appropriations Act, 2015. NASA also stated that it will be working to ensure that the contractors' schedules and the program's internal assessments sync up as the program gets closer to launch. As a result, NASA explained that there will not be a requirement for a detailed NASA assessment, because the contractors' schedule will either match NASA's analysis or NASA will discuss its position as it has done in previous reports to Congress.

We continue to believe the recommendation is valid because the program's schedule risk analysis would provide Congress with valuable insight into potential delays, which are likely. Both contractors have repeatedly stated that their schedules are aggressive and that the dates are ambitious. As a result, we found that the contractors frequently delay dates for key events. For example, Boeing has delayed its certification milestone by 17 months and SpaceX by 22 months since the original schedules were established. The program's recent schedule risk analysis indicates that more delays to certification are likely, but that information is not presented to Congress in NASA's quarterly reports. Without this information, Congress does not know the full extent of potential delays to inform decision making.

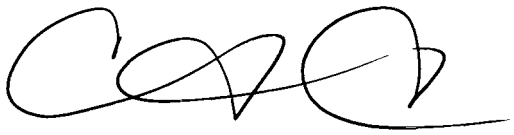
NASA partially concurred with our recommendation that the Chief of Safety and Mission Assurance, the NASA Associate Administrator for Human Exploration and Operations, the Commercial Crew Program Manager, and the Commercial Crew Program Contracting Officer should collectively determine and document how the agency will determine its risk tolerance level with respect to loss of crew before the agency certification review. In its response, NASA stated that it documented the agency's risk tolerance level with respect to loss of crew for the program in its May 2011 safety memo. Further, NASA stated that it documented the requirement to limit risks to the loss of crew in a certification requirements document. NASA stated that ultimately the Commercial Crew Program is accountable for ensuring that the contractors' systems meet the loss of crew value in this certification requirements document, which is a loss of crew value of 1 in 270. If a contractor's system cannot meet that loss of crew value, or any other requirement, the program will request a waiver as part of the human rating certification process to ensure transparency.

NASA acknowledged in its response that the existence of multiple documents defining residual risk requirements and an agency threshold

for loss of crew can be confusing. NASA's response, however, does not address our finding that it does not have a consistent approach for how to incorporate key inputs, including which debris model should be used or whether to include operational mitigations. NASA stated that it had taken action to address this recommendation; however, NASA did not outline any steps it took to resolve the concern that the risk tolerance for the loss of crew requirement depends on which entity is presenting the results of its analysis. We continue to believe that, before the agency certification review, the key parties must collectively determine how the agency will determine its risk tolerance with respect to loss of crew. We believe this approach will reduce confusion and increase transparency.

We are sending copies of this report to 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

The objectives of our review were to assess (1) the extent to which the contractors have made progress towards meeting the National Aeronautics and Space Administration's (NASA) certification requirements and NASA's plans to help ensure continued access to the International Space Station (ISS); and (2) how NASA's certification process addresses safety of the contractors' crew transportation systems.

To assess the contractors' progress towards certification, we obtained and reviewed program and contractor documents, including monthly and quarterly updates from April 2017 through May 2018. We interviewed program and contractor officials to discuss the contractors' recent progress, including upcoming events and any expected delays, and to understand technical risks, potential consequences, and planned mitigation activities. To identify total delays to date, we compared original contract schedules to Boeing and SpaceX's calendar year 2018 first quarter proposed schedules, which are the most recent. Based on our review of program and contractor documents, we defined the contractors' key events as: the uncrewed and crewed flight tests, the design certification reviews for each of those flights, and the certification milestone. We selected the two flight tests for each contractor as key events because they are intended to test key system capabilities, including the ability to launch, dock with the ISS, and return safely to Earth. We selected the design certification reviews because they verify the contractors' crew transportation systems' capability to safely approach, dock, mate, and depart from the ISS, among other requirements. We selected the certification milestone because it determines whether the crew transportation system meets the Commercial Crew Program's requirements.

To determine the extent to which contractors have delayed these key events over time, we analyzed the contractors' schedule data from the 13 quarterly progress reports to date, from first quarter 2015 through first quarter calendar year 2018. We also obtained the results of the program's April 2018 schedule risk analysis. We presented the schedule analysis range from the end of the month of the earliest possible completion date to the end of the month of the latest possible completion date. We reviewed the program's Congressional requirements to report on cost, schedule, and technical status. Finally, to assess the potential effects of any certification delays on NASA's access to ISS, we reviewed NASA's contracts with Boeing and the Russian Federal Space Agency for transportation on the Soyuz vehicle. We interviewed officials from the ISS program and NASA's Human Exploration and Operations Mission

Directorate to determine if the agency had developed contingency plans to mitigate the effects of any certification delays on its access to the ISS.

To assess how NASA's certification process addresses safety of the contractors' crew transportation systems, we reviewed agency safety policies, program plans, and contract documents to identify what safety assessments were required of the program, which safety factors would be considered in certification reviews, and when certification approval would be granted. We also interviewed program officials and the contractors about their safety policies and procedures as well as about the certification process. We identified the loss of crew requirements for the program and the contractors, and interviewed program and agency officials to determine how loss of crew would be assessed and considered throughout the certification process. To gain a broader understanding of the relative importance of loss of crew, we reviewed NASA safety policies, prior GAO reports, and annual reports from the Aerospace Safety Advisory Panel. To determine how the Orbital Debris Engineering Model (ORDEM) was updated and to assess differences between the former and updated models, we reviewed NASA documentation about the ORDEM 2000 and ORDEM 3.0 models and obtained information about the models from NASA's Orbital Debris Program Office.

To assess the program's progress in closing requirements, including those requirements specifically related to safety, we reviewed program data for each contractor on contract requirements and closure status. We limited this analysis to requirements included in the CCT-REQ-1130 *ISS Crew Transportation and Services Requirements Document* because these requirements are verified by the Commercial Crew Program, whereas requirements contained within SSP 50808 *ISS to Commercial Orbital Transportation Services Interface Requirements Document* are managed by the ISS Transportation and Integration Office. We classified requirements as "safety-specific" when the program's Office of Safety and Mission Assurance was listed as a verification closure notice signatory (i.e., approver). We then analyzed the program's data to determine how many verification closure notices had been approved for all requirements and for the subset of safety-specific requirements. We reviewed program and agency documentation, such as organizational charts, program plans, and safety policies as well as interviewed program and agency officials, to determine the role of the safety and mission assurance technical authority in the program. We also reviewed the 2003 Columbia Accident Investigation Board's Report's findings and recommendations related to culture and organizational management of human spaceflight

programs. We reviewed annual briefings and reports and met with representatives from two organizations that provide NASA with independent assessments of the program, the program's standing review board and the Aerospace Safety Advisory Panel, to gain their perspectives on the contractor's progress and how NASA addresses safety in its certification process. We also met with representatives from the National Transportation Safety Board and three experts with background on safety in human spaceflight in order to increase our contextual understanding of the role of safety in human spaceflight missions.

We conducted this performance audit from April 2017 to July 2018 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Comments from the National Aeronautics and Space Administration

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

JUN 20 2018

Reply to Attn of: Human Exploration and Operations Mission Directorate

Ms. Cristina T. Chaplain
Director
Contracting and National Security Acquisitions
United States Government Accountability Office
Washington, DC 20548

Dear Ms. Chaplain:

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Government Accountability Office (GAO) draft report entitled, "NASA Commercial Crew Program: Plan Needed to Ensure Uninterrupted Access to the International Space Station" (GAO-18-476) dated May 15, 2018.

In the draft report, GAO makes five recommendations intended to ensure continued access to the International Space Station (ISS). Specifically, GAO recommends the following:

Recommendation 1: The NASA Associate Administrator for Human Exploration and Operations should direct the Commercial Crew Program to include the results of its schedule risk analysis in its mandatory quarterly reports to Congress.

Management's Response: Non-Concur. NASA's process is to use the partners' schedules as the baseline and to provide a qualitative statement regarding milestone schedules in the NASA summary that accompanies each commercial partners' Congressional report. NASA believes this current reporting approach is appropriate and in accordance with the Explanatory Statement accompanying the FY 2015 Consolidated and Further Continuing Appropriations Act (P.L. 113-235). NASA is protecting for future schedule adjustments (see Management Response to recommendation #2). As we are now getting closer to launch, we expect and will be working to ensure that the partners' schedules and NASA's internal assessments are in agreement. There will not be a requirement for detailed NASA risk assessment. The partners schedule risk assessment will match NASA's analysis or NASA will discuss our position as we have in past reports.

Recommendation 2: The NASA Administrator should develop and maintain a contingency plan for ensuring a presence on the ISS until a Commercial Crew Program contractor is certified.

Management's Response: Concur. NASA is actively developing, assessing, and implementing options to protect for presence of crew on the ISS to support the United States On-orbit Segment (USOS). The ISS Program continues to work with the Commercial Crew Program (CCP) to monitor launch schedules and is developing options to provide schedule margin to the CCP by protecting USOS presence if current launch dates are delayed beyond the return of U.S. crews on Soyuz.

Estimated Completion Date: December 31, 2018.

Recommendation 3: The NASA Administrator should direct the Chief of Safety and Mission Assurance, the NASA Associate Administrator for Human Exploration and Operations, the Commercial Crew Program Manager, and the Commercial Crew Program Contracting Officer to collectively determine and document before the agency certification review how the agency will determine its risk tolerance level with respect to loss of crew.

Management's Response: Partially concur. NASA has documented the Agency's risk tolerance level with respect to loss of crew for CCP missions in the Decision Memorandum for the Administrator, "Agency's Safety Goals and Thresholds for the Crew Transportation Missions to the International Space Station (ISS)," dated May 17, 2011. In addition, NASA has documented the requirements, standards, and certification package contents that will be used to certify a commercial crew transportation system to carry NASA or NASA-sponsored crewmembers on LEO missions, including the requirement to limit risks to the loss of crew, in HEOMD CCTS Certification Requirements for NASA LEO Missions (HEOMD-CSD-10001, Rev. B).

NASA recognizes that the existence of multiple documents defining residual risk requirements and an agency risk threshold for loss of crew can be confusing. Ultimately, the Commercial Crew Program is accountable for ensuring that the commercial systems meet the operational and design certification technical requirements defined in HEOMD-CSD-10001, including limiting the risk to loss of crew to 1 in 270. The CCP will document the commercial system's ability to meet that and other HEOMD-CSD-10001 requirements through design and operational mitigations in its Human Rating Certification Package. If the commercial system cannot meet that requirement (or any other requirements), the program will request a waiver from NASA Headquarters as part of the Human Rating Certification process to ensure transparency and to continue emphasis of safety performance under its contracts.

Estimated Completion Date: Action Completed.

Recommendation 4: After completing the Agency certification review, NASA's Chief Engineer and Chief of Safety and Mission Assurance, with the support from the NASA Associate Administrator for Human Exploration and Operations and the Commercial Crew Program Manager, should document the lessons learned related to loss of crew as a safety threshold for future crewed spaceflight missions, given the complexity of the metric.

Management's Response: Concur. After the Certification Reviews, the Office of Safety and Mission Assurance, along with the Office of Chief Engineer, the Human Exploration and Operations Mission Directorate, and CCP, will document the lessons learned related to the loss of crew requirement and thresholds. These lessons learned will be applied as appropriate to the requirements for future crewed spaceflight missions.

Estimated Completion Date: May 31, 2019.

Recommendation 5: The NASA Chief of Safety and Mission Assurance should restructure the technical authority within the Commercial Crew Program to ensure that the technical authority for the Office of Safety and Mission Assurance is no longer dual-hatted with the programmatic and independent technical authority responsibilities.

Management's Response: Concur. The NASA Chief of Safety and Mission Assurance has reviewed the implementation of the Safety and Mission Assurance (SMA) technical authority for CCP. The SMA programmatic responsibilities and the independent technical authority responsibilities are separated into two unique and distinct positions in the organization. The CCP SMA Plan, CCT-PLN-3100, is in the process of being updated to reflect and clarify this separation of responsibilities.

Estimated Completion Date: August 31, 2018.

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

Sincerely,

William H. Gerstenmaier
Associate Administrator
for Human Explorations and Operations

Ralph R. Roe, Jr.
Chief Engineer

Terrence W. Wilcutt
Chief, Safety and Mission Assurance

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

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

Staff Acknowledgments

In addition to the contact named above, Molly Traci, Assistant Director; Kazue Chinen; Lorraine Ettaro; Lisa Fisher; Laura Greifner; Kurt Gurka; Miranda Riemer; Juli Steinhouse; Roxanna T. Sun; Hai Tran; Kristin Van Wychen; and Alyssa Weir made significant contributions to this report.