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NASA's Management of Crew Transportation to the International Space Station

November 14, 2019

Report No. IG-20-005

Office of Inspector General

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Results in Brief

NASA's Management of Crew Transportation to the International Space Station

November 14, 2019 IG-20-005 (A-19-007-00)

Why We Performed This Audit

For more than 20 years, the International Space Station (ISS) has operated as a laboratory, observatory, and factory in low Earth orbit. The ISS is comprised of two connecting segments: the Russian segment is operated by the Roscosmos State Corporation for Space Activities (Roscosmos) and the United States On-Orbit Segment (USOS) is operated by NASA and its international partners at the Canadian Space Agency, European Space Agency, and Japan Aerospace Exploration Agency. NASA spends between $3 and $4 billion annually to operate the ISS, including payments for transportation of crew and cargo. Since the end of the Space Shuttle Program in 2011, the Russian Soyuz vehicle has served as the sole means of transporting astronauts to and from the ISS.

In 2010, NASA initiated agreements with U.S. aerospace companies to develop commercial crew transportation capabilities with the goal of providing safe, reliable, and cost-effective transportation to and from the ISS. As of August 2019, the Commercial Crew Program (CCP) had obligated approximately $5.5 billion out of $8.5 billion awarded for this effort. However, after 5 years in the current phase of development, the program is several years behind its planned operational date. The two contractors hired by NASA under fixed-price contracts—The Boeing Company (Boeing) and Space Exploration Technologies Corporation (SpaceX)—are working toward their first crewed test flights, but both companies must address a variety of technical and safety issues before NASA certifies them to fly its astronauts. Boeing and SpaceX are each under contract to provide six operational missions for NASA—Boeing using its Starliner spacecraft and an Atlas V launch vehicle, and SpaceX with its Dragon 2 capsule and Falcon 9 rocket—and are expected to provide ISS access for at least 48 astronauts through 2024. However, until Boeing and SpaceX crewed flights begin, the Soyuz vehicle remains NASA's only flight option.

Given the expense and importance of NASA's commercial crew transportation program, our audit examined NASA's plans and progress for transporting astronauts to the ISS. Specifically, we assessed contractor schedule delays and related safety concerns, NASA's plans for continuity of transportation to the ISS, and NASA's pricing and timing strategies for missions using contractor vehicles. The audit's scope included both the CCP and ISS programs with a focus on Boeing, SpaceX, and Soyuz space flight systems. To complete this work, we evaluated flight schedules, contracts, and publicly available pricing information; reviewed technical and safety concerns and internal controls; and interviewed NASA, Boeing, and SpaceX personnel. We also reviewed relevant laws, regulations, policies, and prior audit reports.

What We Found

Boeing and SpaceX each face significant safety and technical challenges with parachutes, propulsion, and launch abort systems that need to be resolved prior to receiving NASA authorization to transport crew to the ISS. The complexity of these issues has already caused at least a 2-year delay in both contractors' development, testing, and qualification schedules and may further delay certification of the launch vehicles by an additional year. Consequently, given the amount, magnitude, and unknown nature of the technical challenges remaining with each contractor's certification activities, CCP will continue to be challenged to establish realistic launch dates. Furthermore, final vehicle certification for both contractors will likely be delayed at least until summer 2020 based on the number of ISS and CCP certification requirements that remain to be verified and validated. In order to optimize development timelines, NASA continues to accept deferrals or changes to components and capabilities originally planned to be demonstrated on each contractor's uncrewed test flights. Taken together, these factors may elevate the risk of a significant system failure or add further delays to the start of commercial crewed flights to the ISS.

While awaiting the start of commercial crew flights, NASA will likely experience a reduction in the number of USOS crew aboard the ISS from three to one beginning in spring 2020 given schedule delays in the development of Boeing and SpaceX space flight systems coupled with a reduction in the frequency of Soyuz flights. Options for addressing this potential crew reduction are limited but include purchasing additional Soyuz seats and extending the missions of USOS crewmembers. However, these options may not be viable given the 3-year lead time required to manufacture a Soyuz vehicle; expiration of a waiver that permitted NASA to make payments to the Russian government; and astronaut health constraints. A reduction in the number of crew aboard the USOS to a single astronaut would limit crew tasks primarily to operations and maintenance, leaving little time for scientific research and technology demonstrations needed to advance NASA's future human space exploration goals.

In our examination of the CCP contracts, we found that NASA agreed to pay an additional $287.2 million above Boeing's fixed prices to mitigate a perceived 18-month gap in ISS flights anticipated in 2019 for the company's third through sixth crewed missions and to ensure the company continued as a second commercial crew provider. For these four missions, NASA essentially paid Boeing higher prices to address a schedule slippage caused by Boeing's 13-month delay in completing the ISS Design Certification Review milestone and due to Boeing seeking higher prices than those specified in its fixed price contract. In our judgment, the additional compensation was unnecessary given that the risk of a gap between Boeing's second and third crewed missions was minimal when the Agency conducted its analysis in 2016. Furthermore, any presumed gap in commercial crew flights could have been addressed by the ISS Program's purchase of additional Soyuz seats. Nonetheless, we acknowledge the benefit of hindsight and appreciate the pressures faced by NASA managers at the time to keep the program on schedule to the extent possible. However, even with that understanding and using CCP's own schedule analysis, we found NASA could have saved $144 million by paying a premium only for missions three and four to cover the perceived gap while buying missions five and six later at the lower fixed prices. Additionally, NASA started the payment on the third mission 1 year earlier than needed and therefore did not use $43 million of the lead time flexibility purchased. Accordingly, we question $187 million of these price increases as unnecessary costs. Finally, given that NASA's objective was to address a potential crew transportation gap, we found that SpaceX was not provided an opportunity to propose a solution even though the company previously offered shorter production lead times than Boeing.

What We Recommended

In order to increase the efficiency and effectiveness of CCP, we made five recommendations to NASA's Acting Associate Administrator for Human Exploration and Operations Mission Directorate: (1) revise current schedules and establish realistic timetables for the remaining reviews and flights occurring before final certification and missions to the ISS; (2) correct identified safety-critical technical issues before the crewed test flights to ensure sufficient safety margins exist; (3) initiate internal processes and coordinate with congressional and other stakeholders to obtain an extension of the legal waiver to pay Russia for Soyuz seats; (4) complete a contingency plan for delayed CCP delivery by working with Roscosmos to determine the feasibility, efficiency, or necessity of (a) purchasing a Soyuz seat, (b) extending Soyuz docking times beyond 200 days, and (c) accelerating the launch of future Soyuz missions; and (5) continue to ensure the purchase of future commercial space services complies with government contracting regulations, including (a) adhering to fixed-pricing in contracts, (b) coordinating CCP and ISS Program acquisition plans, (c) utilizing existing contract language to apply equitable adjustments through negotiations for schedule changes, and (d) providing equal opportunities to both contractors to compete for additional capabilities or significant changes in contract scope and pricing tables. We provided a draft of this report to NASA management who concurred with all of our recommendations. We consider management's comments responsive and the recommendations will be closed upon completion and verification of the proposed corrective actions.

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Acronyms

ATP	Authorization to Proceed
CASIS	Center for the Advancement of Science in Space
CCDev1	Commercial Crew Development 1
CCDev2	Commercial Crew Development 2
CCiCap	Commercial Crew Integrated Capability
CCP	Commercial Crew Program
CCtCap	Commercial Crew Transportation Capability
COPV	Composite Overwrapped Pressure Vessel
CPC	Certification Products Contract
FAR	Federal Acquisition Regulation
HEOMD	Human Exploration and Operations Mission Directorate
INKSNA	Iran, North Korea, and Syria Nonproliferation Act
ISS	International Space Station
NPR	NASA Procedural Requirements
OIG	Office of Inspector General
SSP	Space Station Program
USOS	United States On-Orbit Segment
VCN	Verification Closure Notice

INTRODUCTION

Over the past two decades, 85 flights have transported 239 astronauts to the International Space Station (ISS or Station) on either a NASA Space Shuttle or a Roscosmos State Corporation for Space Activities (Roscosmos) Soyuz vehicle. However, since the end of the Space Shuttle Program in 2011, the Soyuz has served as the sole means of transporting astronauts to and from the ISS. As of July 2019, NASA had purchased 70 Soyuz seats worth $3.9 billion to ferry 70 U.S. and partner astronauts to and from the Station.

In planning for the post-Shuttle era, NASA moved from its traditional approach of working with private aerospace companies to build launch vehicles that the government would own and fully control (e.g., Apollo rockets and Space Shuttle vehicles) to a commercial approach in which NASA pays private companies a fixed price to develop crew transportation options and provide crew transportation flights to the ISS as a service, much like private companies currently provide cargo resupply services under fixed-priced contracts. In 2010, NASA initiated agreements with U.S. aerospace companies to develop commercial crew transportation technologies and subsystems with the goal of providing safe, reliable, and cost-effective transportation to and from the ISS. Since this capability was not expected to be operational until 2015, NASA planned to rely on its purchase of seats on Soyuz vehicles to sustain transportation of its astronauts to the ISS until commercial crew flights began.[1]

The goal of NASA's Commercial Crew Program is to foster an industry that meets the Agency's needs as well as to spur a commercial market for space flight in low Earth orbit. As of August 2019, NASA had obligated approximately $5.5 billion out of $8.5 billion awarded for this effort. However, the program is several years behind its planned operational date. After 5 years of development under a fixed-price contract, two contractors—The Boeing Company (Boeing) and Space Exploration Technologies Corporation (SpaceX)—are working toward their first crewed test flights prior to delivery of 12 operational missions for NASA that are expected to provide crew access to the ISS for at least 48 astronauts through 2024. However, both contractors have a variety of technical and safety issues to address before they are cleared to provide crew transportation to the ISS.

Given the expense and importance of NASA's commercial crew transportation program, our audit objective was to assess NASA's plans and progress for transporting astronauts to the ISS. Specifically, we assessed contractor schedule delays, safety concerns, NASA's plans for continuity of transportation to the ISS, and NASA's pricing and timing strategies. See Appendix A for details on the audit's scope and methodology.

[1] Due to the Commercial Crew Program receiving less appropriations than requested in fiscal years 2011 through 2013, the operational date was later adjusted to mid-2017.

Background

In 2004, President George W. Bush announced the Vision for Space Exploration that, among other initiatives, directed NASA to pursue access to the ISS and low Earth orbit for both crew and cargo by means of commercial partners. Congress subsequently enacted the NASA Authorization Act of 2005, directing the Agency to facilitate agreements with U.S. companies for research into and development of commercial crew and cargo space flight capabilities.[2] In response to the Act, NASA created the Commercial Crew and Cargo Program Office in 2005 and then later created a separate Commercial Crew Program (CCP) office in 2011. Managed within NASA's Human Exploration and Operations Mission Directorate (HEOMD), CCP's main offices are split between the Kennedy and Johnson Space Centers and employ approximately 360 full-time civil servant managers, engineers, and support personnel.

For more than 20 years, the ISS has served as a laboratory, observatory, and factory in low Earth orbit, allowing humans to learn about living and working in space. Spanning nearly a football field in length and weighing almost one million pounds, the ISS is comprised of two connecting segments: the Russian segment operated by Roscosmos, the Russian space agency, and the United States On-Orbit Segment (USOS) operated by NASA and its international partners—the Canadian Space Agency, European Space Agency, and Japan Aerospace Exploration Agency. NASA spends between \$3 and \$4 billion annually on the ISS, or about half of its annual human space flight budget, to include payments for transportation of crew and cargo.

To operate the Station and conduct research, NASA and its partners have generally maintained a rotating crew of three to four astronauts on the USOS side, while Roscosmos has generally maintained two to three cosmonauts in the Russian segment. USOS crewmembers routinely stay on the ISS for approximately 5 months to limit the negative impact extended stays in microgravity can have on their health. However, two crewmembers have remained on Station for a year to study the health effects of extended space exposures. Focusing on NASA's goals of returning to the Moon and eventually traveling to Mars, the ISS plays a key role in understanding and mitigating the risks to astronaut health and performance for long-duration space flight as well as testing technologies essential to such journeys.

Soyuz and ISS Flight Schedule

Roscosmos's Soyuz vehicle has been ferrying crew to the ISS since November 2000. Originally designed to carry cosmonauts to the Moon, the Soyuz is capable of carrying three crewmembers. Each Soyuz vehicle is certified to remain docked with the ISS for a maximum of 200 days.[3] Currently, since Roscosmos provides the sole option for transporting astronauts to the ISS, at least one Soyuz is always docked at the Station in case an emergency evacuation is needed, but typically two capsules are docked to allow up to six astronauts to remain on Station. Since 2006, NASA has purchased 70 seats worth approximately \$3.9 billion, including 5 seats purchased through Boeing for \$373.5 million.[4] Overall, NASA paid an average cost per seat of \$55.4 million for the 70 completed and planned missions from 2006 through

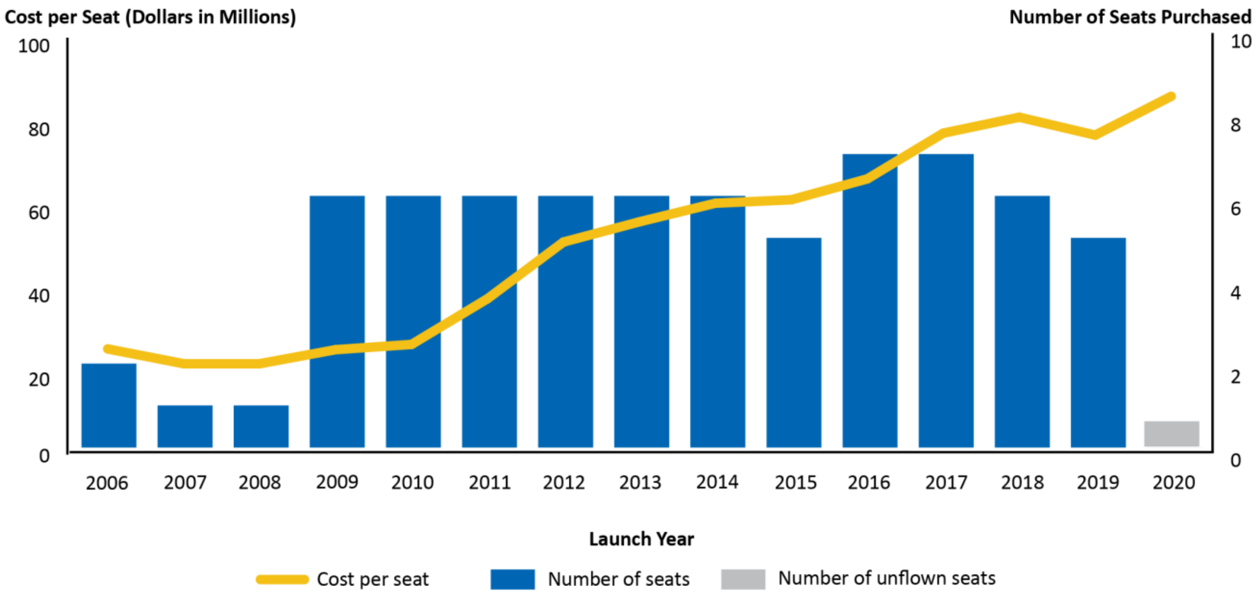
[2] NASA Authorization Act of 2005, Pub. L. No. 109-155, § 502, 119 Stat. 2895-2945 (2005).

[3] Soyuz vehicles are limited to 200-day missions due to constraints of the vehicle's propulsion system. NASA has accepted the extension of several Soyuz missions beyond 200 days, contingent on the undocking being performed in a specific attitude.

[4] In February 2017, NASA purchased from Boeing two Soyuz seats and then later three additional seats for \$373.5 million or \$74.7 million per seat. Boeing had the rights to sell the seats as a result of a settlement with RSC Energia—the Russian company that builds the Soyuz spacecraft for Roscosmos—due to a failed partnership to develop the capability to launch rockets from an off-shore platform in the ocean.

2020 with prices ranging from approximately $21.3 million to $86 million for each round trip. After 2017 when the CCP contractors were initially scheduled to begin crewed missions, NASA has used or contracted for 12 additional Soyuz seats at a cost of approximately $1 billion, or an average of $79.7 million per seat. Figure 1 details the average cost per seat per year NASA utilized or will utilize the seat.

Figure 1: Cost per Soyuz Seat By Launch Date



Source: NASA Office of Inspector General (OIG) analysis of Agency-provided contract information.

In anticipation of NASA's commercial crew launches and the reduced need for Soyuz transportation, beginning in January 2020 Roscosmos plans to reduce Soyuz flights from two overlapping flights to a single flight every 6 months, decreasing the capacity of crew aboard the ISS from six to three, assuming no U.S. commercial crew transportation vehicle is available as of April 2020. If commercial crew capabilities are available in 2020, the ISS could continuously host at least seven crewmembers with a Soyuz vehicle and a commercial crew vehicle both docked at the Station. However, if commercial flights do not begin operating by October 2020, ISS officials cautioned there are no Soyuz flights available to transport U.S. or partner crew to Station. That said, NASA and Roscosmos are continuing to examine whether a Soyuz can safely extend its time on Station beyond the current maximum of 200 days. Table 1 shows the planned flight schedule for both the Soyuz and commercial vehicles and the projected number of crewmembers on the Station based on NASA's in work schedule as of September 2019.

Table 1: Tentative ISS Crew Vehicle Flights and Crewmember Allocation

	2019					2020												2021											
	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Flight Schedule																													
Soyuz-1	58S		61S												63S												65S		
Soyuz-2	59S								62S												64S								
Boeing						Test Flight											Crew-2						Crew-3						
SpaceX											Crew-1																		
Crewmember Allocation																													
USOS	4	4	4	4	4	7	5	5	4	4	8[a]	5[a]	5[a]	5[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]
Roscosmos	2	2	2	2	2	2	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Total crew on ISS	**6**	**6**	**6**	**6**	**6**	**9**	**6**	**6**	**6**	**6**	**10**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**

Source: NASA OIG summary of ISS Flight Plan from September 24, 2019. Per management officials, this schedule is under Agency review and subject to change.

Note: Red cells indicate crewed scenarios that pose a risk to ISS operations because of reduced crew, yellow cells indicate nominal operations, and green cells indicate optimal conditions based on the current capacity of the ISS.

[a] NASA has not determined whether the fourth seat aboard the U.S. commercial vehicle flights will be made available to a USOS or Roscosmos crewmember.

Commercial Crew Contracts

After initially engaging eight companies to develop commercial crew technologies, subsystems, and integrated capabilities using Space Act Agreements, in 2014 NASA awarded firm-fixed-price Commercial Crew Transportation Capability (CCtCap) contracts to Boeing and SpaceX to complete their space flight development and conduct crewed missions to the ISS.[5] The CCtCap contracts set fixed prices for development activities and test flights, crewed missions to the ISS, and special studies. As of May 2019, Boeing and SpaceX's contracts were valued at $4.3 billion and $2.5 billion, respectively. Of those amounts, Boeing's costs for development and test flights were $2.2 billion, while SpaceX's were $1.2 billion. For crewed missions to the ISS, NASA awarded each contractor six round-trip missions. Assuming four astronauts per flight and using publicly available information, the estimated average cost per seat is approximately $90 million for Boeing and approximately $55 million for SpaceX, potentially providing cost savings over current Soyuz prices.[6] Additionally, each contract includes up to $150 million each for special studies requested by NASA, such as additional parachute testing on the contractors' capsules. As of May 2019, Boeing had been awarded $32 million and SpaceX $49 million for such special

[5] Space Act Agreements are a form of "Other Transaction Authority" provided to NASA in the National Aeronautics and Space Administration Act of 1958 that establish a set of legally enforceable commitments between NASA and a partner to accomplish a stated objective without imposing the extensive list of requirements routinely found in most government contracts. Since 2006, NASA has awarded $1.5 billion in Space Act Agreements to the following eight companies: Alliant Techsystems Inc.; Blue Origin, LLC; Boeing; Excalibur Almaz, Inc.; Paragon Space Development Corporation; Sierra Nevada Corporation; SpaceX; and United Launch Alliance.

[6] The average cost per seat was calculated by taking the total contract value and subtracting the development and test flight costs (previously disclosed in NASA's fiscal year 2020 budget request) and the special studies costs (disclosed in past Government Accountability Office reports) to determine the total mission cost for each contractor. This number was divided by the 24 seats currently assumed over the contactors' six confirmed missions. These figures were calculated using publicly available information and are averages, not exact costs.

studies. Even though the contracts are firm-fixed-price, changes in requirements, technical deficiencies, or schedule delays may result in equitable adjustments.[7] Appendix B describes the total funding for commercial crew activities between 2010 and 2024.

Crew mission pricing is set by a pricing table in each contract, which determines prices based on when and how many missions are ordered. In addition, the contracts specify the contractors' lead times—that is, the time needed to prepare a mission for launch—as 32 months for Boeing and 24 months for SpaceX. When the CCtCap contracts were awarded in 2014, mission pricing was initially based on the calendar year in which a flight was ordered. However, during discussions in 2016 about awarding task orders for the third through sixth missions, both contractors raised concerns about vague contract language because NASA could order missions without granting Authorization to Proceed (ATP), the formal process that initiates interim milestone payments. In response, NASA modified both contracts to set per-mission pricing based on the calendar year ATP was projected to be granted instead of when the missions were ordered.[8] This contract modification allowed NASA to order missions in December 2016 while using pricing based on granting ATP in later years.

NASA pays each contractor a fixed price using milestone payments for key events such as flight readiness reviews, launches, and successful missions. For each mission, NASA pays up to 75 percent of total mission costs prior to launch. To limit NASA's financial exposure, each CCtCap contract prohibits payments on subsequent missions until the contractor can demonstrate capabilities by completing a development milestone called the ISS Design Certification Review.[9] This limitation, for example, restricted Boeing and SpaceX from receiving payments for their third through sixth missions in 2016 until the ISS Design Certification Review milestone was completed.[10]

Commercial Crew Transportation Flight Systems

After completion of test flights and prior to flying regular missions to the ISS, the Boeing and SpaceX commercial launch vehicles must be certified by NASA. Boeing plans to utilize the U.S. Air Force's Launch Complex 41 at Cape Canaveral, Florida, to launch an Atlas V rocket to deliver its Crew Space Transportation-100 Starliner (Starliner) spacecraft into low Earth orbit where the spacecraft will

[7] Under an equitable adjustment, either party may be compensated for changes outside the agreed-upon requirements, price, or schedule. For the CCtCap contracts, Clause H.20 dictates the process for equitable adjustments due to schedule changes for crew missions.

[8] For example, under the prior contract language NASA could order up to four missions in a single year to obtain discounts without starting payments until the long-lead times for the mission were reached. Thus, without NASA adjusting the prior contract language, the pricing could be set in the year ordered even though the missions could be scheduled for several years in the future without the Agency being required to begin payments.

[9] Conducted prior to the first low Earth orbit crewed test flight, the flight test readiness process includes an ISS Design Certification Review of applicable elements from completed contractor certification milestones and a Flight Test Readiness Review. To complete the milestone and receive payment, each contractor must demonstrate that its crew transportation system and operations meet all applicable requirements; demonstrate schedule performance; and identify top safety, technical, cost, and schedule risks.

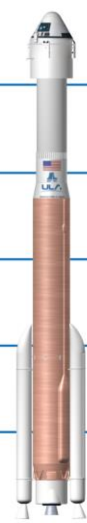
[10] The prohibition of payments prior to completion of the ISS Design Certification Review was waived for the third mission in 2018. A NASA official stated this limitation was put in place in response to a 2013 NASA OIG report examining cargo resupply services that criticized the Agency for making large payments before contractors had demonstrated their cargo delivery capabilities. NASA OIG, *Commercial Cargo: NASA's Management of Commercial Orbital Transportation Services and ISS Commercial Resupply Contracts* (IG-13-016, June 13, 2013).

rendezvous with the ISS.[11] While the Atlas V has a long history of mission success, it has not been used for human space flight. The Starliner capsule is a new and previously unflown spacecraft.

SpaceX will use NASA's former Space Shuttle Launch Pad 39A at Kennedy Space Center to launch an upgraded Falcon 9 rocket with a Dragon 2 spacecraft to deliver astronauts to the ISS. For crewed missions, NASA will need to include the upgraded Falcon 9 in its certification process, a rocket that has successfully launched SpaceX's Dragon 1 spacecraft on 17 cargo resupply missions to the ISS since 2010. During this period, SpaceX experienced one launch failure. The contractor's final two cargo resupply missions on the first contract will fly at the end of 2019 and the beginning of 2020. The crewed Dragon 2 is an updated design based on the Dragon 1. Starting with its 21st cargo mission to the ISS scheduled for mid-2020, SpaceX plans to use a similar Dragon 2 design for future ISS cargo deliveries. Figure 2 provides a summary of each contractor's crew system.

Figure 2: Commercial Crew Transportation Systems

	BOEING	SPACEX
SPACECRAFT	**Starliner** 4 crew	**Dragon 2** 4 crew
LAUNCH VEHICLE	**Atlas V** United Launch Alliance	**Falcon 9 (Block 5)** SpaceX
AVERAGE COST PER SEAT[a]	**$90 million**	**$55 million**
LAUNCH LOCATION	**Launch Complex 41** U.S. Air Force Cape Canaveral	**Launch Pad 39A** Kennedy Space Center
PROPOSED LAUNCH CADENCE	**1 mission per year** (up to 2 missions)	**1 mission per year** (up to 2 missions)



Source: NASA OIG analysis of Agency information.

[a] NASA OIG estimated the approximate average cost per seat assuming four astronauts per spacecraft and using publicly available information. The methodology used here is the same as footnote 6 of this report. The CCtCap contract also has a certification requirement for each spacecraft to be able carry 100 kilograms of cargo per mission to the Station.

Flight System Certification Process

CCP's goal is to ensure that all commercial space flight missions involving NASA astronauts are held to the same safety standards that were applied to government-developed systems in the past such as the Space Shuttle. To do so, CCP has developed a certification process under which Boeing and SpaceX must

[11] The Atlas V rocket was developed by United Launch Alliance, a joint venture between Boeing and Lockheed Martin Corporation.

meet a series of detailed NASA requirements.[12] Prior to each contractor's first low Earth orbit crewed test flight, the flight test readiness process requires a Design Certification Review and a Flight Test Readiness Review. The Design Certification Review formally documents the configuration baseline (hardware, software, and processes used in design, production, and operations) and the conditions under which a crew transportation vehicle is certified (performance, fabrication, and operational environments and constraints).[13] The Flight Test Readiness Review examines tests, demonstrations, analyses, and audits that establish a system's readiness for a safe and successful launch and for subsequent flight test operations.

In December 2011, NASA published a series of requirements, management standards, and certification standards to inform potential commercial crew contractors of the Agency's specific safety and human rating objectives.[14] These documents are based on the health and medical, engineering, safety, and mission assurance requirements NASA used for previous government-developed launch systems and describe the fundamental elements any new system must satisfy to receive Agency certification. The certification process involves all aspects of a crew transportation system, including design, demonstration, ground operations, integration, launch, abort, rendezvous, proximity operations, docking, orbital operations, reentry, and safe recovery. A final certification review is scheduled after the crewed test flight and before regular missions to the ISS begin. Both Boeing and SpaceX are required to use this guidance to ensure they are incorporating NASA's requirements into their spacecraft designs. Figure 3 shows the current certification schedule and the significant remaining events for each contractor. A detailed description of each event is found in Appendix C.

Both SpaceX and Boeing are in the final testing and integration phase of their space flight system development. Boeing is currently preparing for its uncrewed flight test of its Atlas V and Starliner configuration and conducted its test of the launch abort system in November 2019. SpaceX has already successfully completed its first uncrewed flight test of its Falcon 9 and Dragon 2 system and is retesting subsystems and working with NASA to verify that it meets the requirements for a crewed test flight. NASA's schedule indicates a crewed test flight before the end of 2019 or in early 2020. NASA officials stated that the final testing and launch schedules for the two vehicles are under revision and will not be approved until the new HEOMD leadership conducts his review of the schedules.

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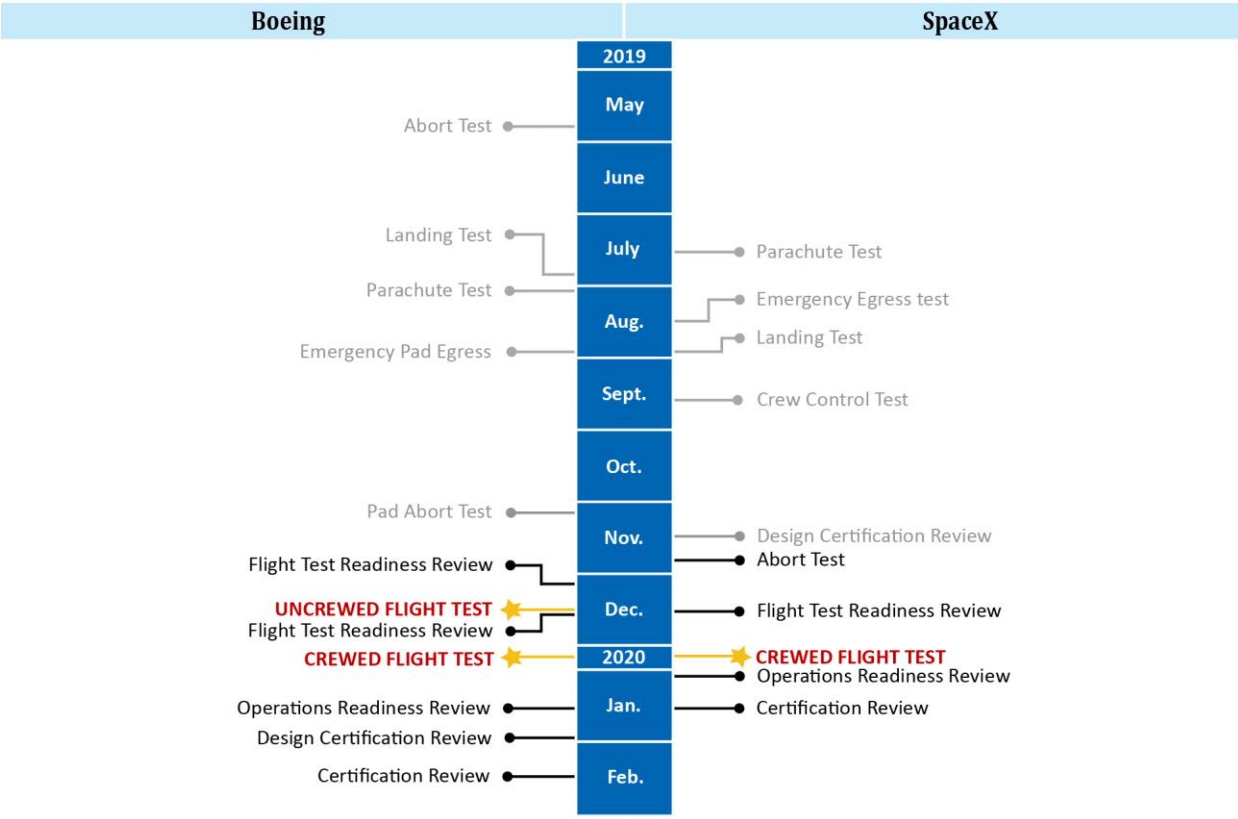
12 *Program Plan Commercial Crew Program* (CCT-PLN-1000 Rev. A, January 19, 2017). The CCtCap contracts are designed so each developmental milestone will build on the previous milestone, which creates an incremental acceptance of each vehicle's verification throughout the contracts.

13 *Crew Transportation Technical Management Processes* (CCT-PLN-1120 Rev. C, October 25, 2013).

14 These documents include the following: *ISS Crew Transportation and Services Requirements Document* (CCT-REQ-1130, Rev. F, September 6, 2017); *Crew Transportation Plan* (CCT-PLN-1100, Rev. A, January 19, 2017); *Crew Transportation Technical Management Processes* (CCT-PLN-1120, Rev. C-2, October 25, 2013); *Crew Transportation Technical Standards and Design Evaluation Criteria* (CCT-STD-1140, Rev. B, April 8, 2015); *Crew Transportation Operations Standards* (CCT-STD-1150, Rev. A-3, July 16, 2013); and *Crew Transportation System Design Reference Missions* (CCT-DRM-1110, Rev. Basic-3, December 8, 2011). All the documents have been revised since originally published in 2011. Space Station Program (SSP) 50808 contains the ISS's technical standards for operating in the vicinity of and docking with the Station. *International Space Station (ISS) to Commercial Orbital Transportation Services (COTS) Interface Requirements Document (IRD)* (SSP 50808, Rev. G, March 2018).

Figure 3: Working Timeline of Certification Events Between May 2019 and February 2020



Source: NASA OIG analysis of Agency information as of October 2019. Per management officials, this schedule is under Agency review and is subject to change.

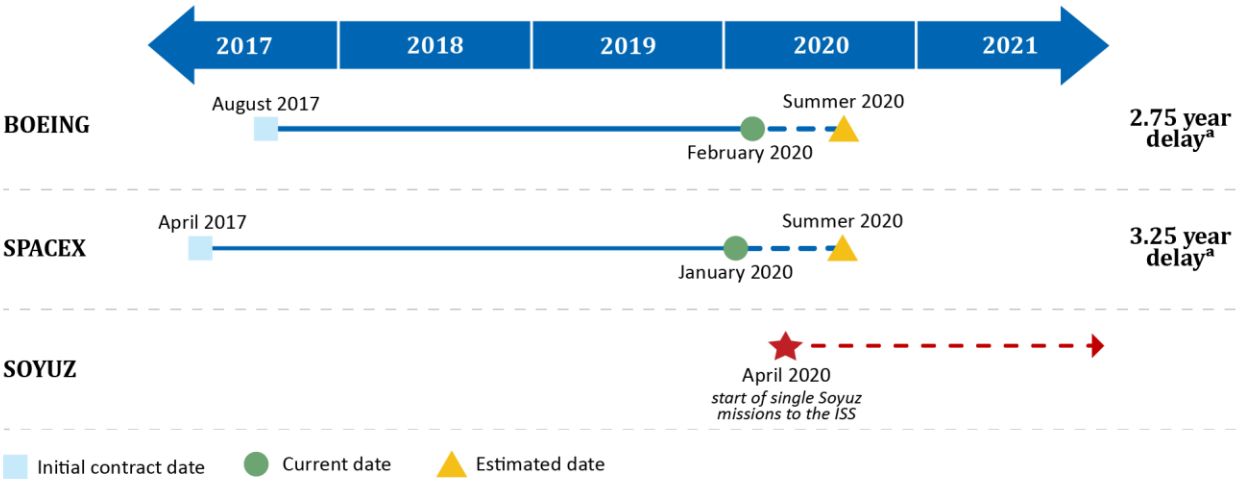
ONGOING TECHNICAL AND SAFETY CONCERNS MAKE IT DIFFICULT FOR NASA AND ITS CONTRACTORS TO ESTABLISH REALISTIC LAUNCH SCHEDULES

Boeing and SpaceX continue to experience delays in test flights and final certification as a result of design weaknesses discovered during testing, making it difficult for NASA to predict the amount of remaining work needed to ensure safe and reliable crew transportation. Certification schedules for both Boeing and SpaceX have already slipped more than 2 years due to technical and management challenges with additional schedule slippage anticipated. Furthermore, final vehicle certification for both contractors will likely be delayed at least until summer 2020 based on the number of ISS and CCP certification requirements that remain to be verified and validated. In order to optimize development timelines, NASA continues to accept deferrals or changes to components and capabilities originally planned to be demonstrated on each contractor's uncrewed test flights. Taken together, these factors may elevate the risk of a significant system failure or further delay the start of commercial flights to the ISS.

Technical Challenges Continue to Impact the Commercial Crew Program Schedule

Boeing and SpaceX each face significant technical challenges with parachutes, propulsion, and launch abort systems that need to be resolved prior to receiving NASA authorization to transport crew to and from the ISS. The complexity of these issues has already caused at least a 2-year delay in both contractors' development, testing, and qualification schedules and may further delay certification of the vehicles by an additional year. Consequently, given the amount, magnitude, and unknown nature of the technical challenges remaining with each contractor's certification activities, NASA will continue to be challenged to establish realistic launch dates for the start of commercial crew flights to the ISS. That said, CCP schedule assessments as of June 2019 suggest final certification for Boeing and SpaceX to fly crewed missions may not occur before summer 2020. By this time, the Soyuz launch schedule will have decreased from two missions every 6 months to a single flight—a scenario that will result in a single U.S. astronaut and two Roscosmos cosmonauts on the Station beginning in April 2020 barring any adjustments to current crew schedules. Figure 4 shows the expected delays in the final certification of Boeing and SpaceX's vehicles and the reduction in Soyuz flights beginning in April 2020.

Figure 4: Estimated Certification Delays for Boeing and SpaceX Based on CCP Schedule Analysis



Source: NASA OIG analysis of CCP documentation. Per management officials, this schedule is under Agency review and is subject to change.

[a] Years of delay is based on CCP's schedule risk assessment.

Outstanding Technical Risks Likely to Result in Additional Schedule Delays

Parachute Testing and Qualification

Parachutes are used to slow down a capsule upon re-entering the Earth's atmosphere to land it safely in the ocean or on the ground. Both Boeing and SpaceX are experiencing problems developing safe parachute systems. These challenges include NASA and the contractors coming to an agreement on how much extra strength is needed given the dynamic loads exerted on the parachutes as they are deployed at high speed. Testing over the past year has determined that both Boeing and SpaceX's re-entry systems contain parachute components that may have low safety margins. Moreover, as improvements and redesigns are made, adding strength to parachute components could also increase bulk—a consideration given the limited storage space allocated to the parachutes in each capsule. In addition, the type and amount of testing required before a crewed flight is considered safe to fly is still being determined by NASA.

Boeing, which chose a three-parachute system for its design, is certifying its parachutes through a process known as "qualification by similarity." This method uses a smaller number of system-level tests to certify that the parachute system meets requirements. As of August 2019, Boeing had successfully completed all of its qualification tests and three of six planned reliability tests.[15] Two additional reliability tests

[15] The contractors are responsible for the performance of verification activities that produce evidence for compliance with all applicable requirements. Certification refers to the contractors' successful implementation of the methods defined in the requirements to reduce risk to a residual level acceptable by NASA. Certification is obtained after test flights that include a crewed mission. Qualification encompasses the entire range of activity to verify the design conforms to requirements when subjected to environmental life-cycle conditions. Reliability refers to the probability that a system of hardware, software, and human elements will function as intended over a specified period of time under specified environmental conditions.

were added to help confirm the loads exerted on the parachute. However, these tests are expected to continue through the end of 2019 and may affect the timing of Boeing's crewed test launch.

In contrast, SpaceX chose a design that uses four parachutes. Originally, when first designing the Dragon 2 capsule, SpaceX had intended to use its propulsion systems for landing, with parachutes considered a backup system. As a result, the parachutes were developed using more lightweight and less robust materials. Given the effort required to qualify the propulsion system for safe operation, SpaceX decided to rely fully on its parachutes for landing, a system that would later require design modifications.

In August 2018, SpaceX experienced failures on two main parachute canopies during the return of its Dragon capsule from a cargo resupply mission to the ISS. This resulted in additional work to improve load balancing on the planned crewed parachute system. However, the parachute design for SpaceX cargo missions uses three instead of four parachutes and receives more turbulence from the cargo capsule compared to a crew capsule and therefore they are not suitable for direct comparison to one another. In April 2019, SpaceX experienced an anomaly during an air drop test intended to demonstrate that the Dragon 2 capsule could safely land with three instead of four parachutes. During the test, the three parachutes failed, resulting in the loss of the test sled. These design deficiencies have contributed to at least a 3-month delay in SpaceX's crewed test flight. As of July 2019, NASA officials were uncertain if the contractor's current parachute system will meet strength and performance requirements for the crewed test flight and are requiring additional testing. SpaceX received its updated parachute system in August 2019 from its subcontractor, and has since performed 15 tests of the new system. However, this parachute system also initially experienced two anomalies that resulted in corrective actions.

Propulsion and Launch Abort Systems

Propulsion systems transport the spacecraft to the desired orbit and execute flight path and vehicle attitude adjustments. These systems are inherently complex and require rigorous testing and evaluation to ensure crew safety and mission success. Likewise, launch abort systems used to maneuver the spacecraft away from the rocket in the event of an emergency on the launch pad or in flight must also be verified through robust testing and analysis. The risks stemming from the propulsion and launch abort systems include propellant leaks, exterior fires, or significant systems failures such as an explosion that could threaten crew safety. Technical issues with Boeing and SpaceX's propulsion and launch abort systems have added to delays in the schedule for crewed test flights, previously planned in December 2019 for both providers.

In June 2018, Boeing suffered an anomaly during a Starliner launch abort engine hot fire test due to malfunctioning valves that caused engine pressure fluctuations, fuel leaks, and a fire that subsequently damaged part of the test article. The purpose of this test was to demonstrate the vehicle's integrated propulsion system performance and system dynamics. Boeing successfully conducted follow-up tests to requalify the system in May 2019. As a result of the anomaly and required corrective actions to the propulsion system, the planned follow-on pad abort test was delayed a year until November 2019. During this test, a parachute deployment anomaly occurred resulting in deployment of only two of the three main parachutes. Boeing stated it identified a preliminary cause of the anomaly and is taking steps to address the issue. However, Boeing also emphasized that having two of three parachutes deploy successfully is acceptable for crew safety.

Additionally, Boeing's launch vehicle separation system has been identified by both NASA and the contractor as a high-risk item. Failure of this system is a major crew survivability concern during launch as it can impact the ability of the capsule to safely return to Earth for a water landing. Specifically, this system is a zero-fault tolerant design, which means that—contrary to CCP requirements—there is no back up should the system fail. In addition to preventing the loss of crew, NASA policy states that critical systems essential for crew safety shall not be designed with a single point of failure. Potentially catastrophic hazards that cannot be controlled may be granted a variance by NASA from the failure tolerance requirements.[16] In order to obtain such approval, Boeing must demonstrate that the risk of system failure can be controlled or mitigated, or alternatively be accepted as an elevated risk. Boeing requested and NASA has approved a variance after determining the contractor selected the best design for this application.

In April 2019, SpaceX's Dragon 2 exploded during a static fire test of its launch abort system. The spacecraft was the same uncrewed vehicle that flew to and returned safely from the ISS in March 2019. An anomaly occurred during the test just before ignition of the SuperDraco thrusters, resulting in the destruction of the spacecraft.[17] In July 2019, SpaceX's preliminary report traced the anomaly to components in the propulsion system that ignited due to fluid trapped in the lines during pressurization of the system, causing the explosion. SpaceX plans to implement a pressure relief safety device known as a rupture or burst disk to prevent trapped fluids during pressurization. While testing and analysis of this risk mitigation is almost complete, these actions may delay launch of SpaceX's crewed test flight previously scheduled for December 2019.[18]

SpaceX also experienced separate issues with the helium system used to pressurize the Falcon 9's fuel system during an ISS cargo mission in June 2015 and when conducting launch preparations for a commercial satellite in September 2016. These events resulted in the destruction of the vehicles and are both believed to be linked to the previous design of the rocket's Composite Overwrapped Pressure Vessel (COPV) and its supporting structure, both of which have been updated for use in SpaceX's crewed transportation system.[19] SpaceX determined the first failure involved hardware that broke in flight inside of the rocket's liquid oxygen tank and caused it to fail.[20] According to SpaceX, the second failure was likely the result of a COPV tank buckling due to new oxygen and helium loading procedures which caused the tank to fail and the second stage to explode on the launch pad during preparations for a static fire. SpaceX made design changes to its COPVs and NASA has accepted the changes. Additionally, according to NASA officials, the suspected design flaw of the COPV that contributed to the explosion has been eliminated from all COPVs that will be used on the crewed missions. SpaceX has also improved its workmanship processes and revised its fuel loading processes on the launch pad. SpaceX has since completed multiple successful launches with the updated COPVs and revised fuel loading process.

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[16] *ISS Crew Transportation and Services Requirements Document* (CCT-REQ-1130, September 6, 2017). CCT-REQ-1130 defines a hazard as a state or a set of conditions, internal or external to a system that has the potential to cause harm. Hazard analysis is the process of identifying hazards and their potential causal factors. A variance is a formal request for relief from a requirement.

[17] One of the static fire test objectives was to demonstrate the SuperDraco engines that will be used to maneuver the spacecraft away from the rocket in the event of an emergency abort on the pad or in flight.

[18] These dates are currently under review by NASA.

[19] Each stage of the Falcon 9 uses COPVs to store cold helium used to maintain tank pressure. Each COPV consists of an aluminum inner liner with a carbon overwrap.

[20] SpaceX found that a strut failed, which NASA's Independent Review Team also determined was a credible cause, but provided possible alternative scenarios to explain the initiating event that caused the liquid oxygen tank dome to crack.

Additional Issues that May Affect the Contractors' Certification Schedules

Additional factors such as NASA's safety review process, disagreements on technical issues, and unknown-unknown risks may delay the contractors' efforts to obtain certification to carry astronauts. The schedule impacts due to these factors are unknown, but the contractors have little schedule margin to meet launch dates in late 2019. Schedule margin—that is, extra time built into the schedule for contingencies—allows time to address both known risks as well as future situations impossible to predict, referred to as "unknown-unknowns." Factors that could delay the contractors' ability to obtain certifications from NASA are described below.

Volume of Work for the Safety Review Process

In addition to the technically complex testing and qualification work remaining for Boeing and SpaceX, NASA has a significant amount of work outstanding related to its safety review process that will likely delay crewed test flights into 2020. Tasks requiring resolution include completion of hazard analysis and reports and verification of closure notices. To ensure vehicle safety, CCP and ISS Program personnel review contractor-submitted hazard reports, which includes the rationale for how hazards have been mitigated. Safety risks, documented in the hazard reports, are ultimately approved by CCP and ISS program managers and indicate that the Agency understands and accepts the risks.

In addition to the analysis of safety hazards, as of August 2019 NASA had 597 Verification Closure Notices (VCN) requiring review and disposition for Boeing's first uncrewed test flight and 370 VCNs for SpaceX's crewed flight.[21] Reviews of these high volume verification activities that demonstrate compliance with Agency requirements are stressing an already limited staff. In fact, in June 2019, CCP reported to the Aerospace Safety Advisory Panel that unrealistic schedules are causing artificial deadlines, resulting in increased schedule pressure.[22]

As of July 2019, when its uncrewed launch was scheduled for October 2019, Boeing had 670 outstanding certification products that needed to be closed with acceptable flight rationale out of a total of 1,803.[23] As a point of comparison, 90 days prior to SpaceX's uncrewed test flight the Agency had completed 1,577 certification products and SpaceX had 574 still outstanding. If NASA determines that the evidence submitted for the hazard reports does not meet a particular verification standard, additional time likely will be required to resolve the issue. Moreover, CCP maintains a staff of only 360, an employee complement only slightly larger than the resources originally planned to support the certification of a single contractor. According to CCP program managers, CCP intended to achieve efficiencies with this smaller staff complement by staggering reviews of Boeing and SpaceX reports. However, with flight dates for both contractors now clustered so closely together, CCP staff faces substantial challenges to complete these efforts in time to meet launch schedules in December 2019. In light of these schedule pressures, NASA may face increased pressure to accept elevated risks before the initial crewed flights. However, during the course of our audit, senior NASA officials consistently asserted that regardless of any schedule pressure, they will not allow crewed flights to occur until it is safe to do so.

[21] VCNs are written explanations provided by the contractor to NASA that provide evidence—through analysis, inspection, test, or demonstration—that a NASA requirement has been satisfied.

[22] The Aerospace Safety Advisory Panel was established under Section 6 of the National Aeronautics and Space Administration Authorization Act of 1968. 51 U.S.C. § 31101. The Panel provides advice and makes recommendations to the NASA Administrator on matters related to safety.

[23] Flight rationale refers to the closure justification that satisfies acceptance of an exception to a requirement.

Disagreement on Technical Issues

Understanding and agreeing on technical requirements is critical to developing safe crewed transportation systems, particularly given that Boeing and SpaceX use vastly different hardware as well as development, managerial, and operational approaches. The NASA Authorization Act of 2010 requires NASA to provide independent assurance of flight safety and flight readiness prior to authorizing U.S. government personnel to participate as crew on board any commercially developed crew transportation system.[24] In response to this requirement, CCP created a system that validates the contractors' technical and performance requirements and standards; verifies compliance with those requirements and standards; and accepts residual technical risk due to hazards, waivers, and other noncompliances.[25]

Nonetheless, NASA officials have noted disagreements that persist between the Agency and the contractors on technical issues that could have significant impacts on flight schedules and the contractors' mission assurance. For example, NASA engineers and the contractors disagreed on the number of parachute drop tests the contractors needed to perform. After much discussion, both contractors eventually agreed to additional tests. Additional ongoing disagreements include loss of crew risk requirements; modeling and testing requirements; issues related to tank burst pressure, rupture, and leakage; and crew insertion prior to propellant loading operations.[26] Although these type of disagreements are to be expected when developing complex space flight systems that will carry crew, contractors are required to propose alternatives if they fail to meet the intent of a NASA requirement or request a variance. Requests for variances are required to include, at a minimum, a detailed rationale for the request, a risk assessment, and any planned risk mitigations and controls.[27] Ultimately, NASA must agree that the steps taken to mitigate or close the risks are acceptable. In addition, the path forward is in some cases—such as the parachutes—still being determined as the results of additional tests are examined.

Even if NASA approves a variance for a particular mission that does not mean the technical issue is fully mitigated for future crewed flights. For example, SpaceX's Dragon 2 COPVs did not pass qualification prior to the uncrewed SpaceX flight test in March 2019 due to a tank's failure to meet NASA's burst pressure requirements. Although disagreements existed between the NASA Engineering Safety Center and SpaceX, the Center ultimately concurred with CCP and SpaceX's flight rationale and risk assessment. NASA accepted the elevated risk for the March 2019 uncrewed SpaceX flight test, acknowledging that a COPV burst in the vicinity of or while attached to the ISS would result in loss of the Station. The Agency also noted the added risk to ISS was small when docked because the COPV pressures would be slightly lower than prior to launch. SpaceX subsequently mitigated the identified risks for crewed flights through process improvements and additional testing.

[24] National Aeronautics and Space Administration Authorization Act of 2010, Pub. L. No. 111-267 § 403(b)(5) (2010).

[25] *Commercial Crew Transportation System Certification Requirements for NASA Low Earth Orbit Missions* (HEOMD-CSD-10001, Rev. A, November 12, 2013).

[26] NASA's loss of crew risk requirement for its contractors is 1 in 270 for a 210-day ISS mission, which means the probability of losing the crew only occurs in 1 out of 270 flights.

[27] *Crew Transportation Technical Management Processes* (CCT-PLN-1120, Revision C-2, October 25, 2013).

Unknown-Unknowns

During the Space Shuttle era, NASA's analysis of Shuttle risk estimates indicated that loss of crew and loss of mission often significantly underestimated actual failure rates because many hazards cannot be properly identified and accurately assessed during the design phase. These risks are sometimes referred to as "unknown-unknowns." During development of their space flight systems, both Boeing and SpaceX have experienced a number of unexpected anomalies that have affected the CCP schedule. For example, Boeing experienced unexpected anomalies in its navigation system while SpaceX experienced anomalies in its deorbit procedures and COPVs. With flight tests and significant abort system testing activities remaining for both contractors, the number and significance of these and other unknown-unknowns may affect the launch schedule. Adding to this potential schedule pressure or slippage is the fact that Boeing and SpaceX have included little schedule margin to allow for such unexpected delays.

An example of unknown-unknowns surfaced following SpaceX's parachute drop tests in April 2019. Instrumentation developed by SpaceX and used during the tests identified a significant issue with parachute asymmetry that has repercussions for both Boeing and SpaceX's designs, as well as across the parachute industry. Asymmetrical parachute loading refers to uneven loads on a parachute system due to aerodynamics and the changing shape of the canopy that results in a greater risk of parachute failure when a portion of the system receives a load that exceeds its capability. This unknown-unknown has caused parachute experts to reexamine their assumptions about asymmetry and will require a substantial amount of testing and analysis to identify a safe resolution.

Financial Constraints

CCP uses firm-fixed-price contracts, providing both Boeing and SpaceX incentive to minimize changes that would require additional work in order to maximize profits. As firm-fixed-price contractors, Boeing and SpaceX bear the risk for any technical risks or schedule delays that occur absent NASA changing the mission scope, requirements, or schedule. For example, as the schedule has slipped nearly 3 years, milestone payments have also been delayed but the overall CCtCap contract costs have not increased more than 5 percent. In contrast, under a cost-plus contract structure where NASA pays for all contractor costs with additional fees, contract costs would increase with schedule delays as NASA covered the contractor's ongoing labor costs. While the government is not expected to compensate Boeing and SpaceX for the CCtCap delays, the contractors will not receive all of their milestone payments until their systems are certified and delivered. This may cause a hesitancy by contractors to commit resources for additional expensive testing without NASA agreeing to add more funds to the contract. For example, the additional parachute testing for both contractors illustrates where NASA added more funding to the CCtCap contracts for both Boeing and SpaceX because it required more testing. However, in a 2018 annual review CCP noted that in order to manage their costs effectively, both Boeing and SpaceX were operating with lean workforces and as such were reluctant to make design changes that typically come with heavy cost and schedule penalties for the contractors.

Deferring Capabilities May Elevate Risk or Delay Crewed Flights

As they work to meet flight test launch dates, we found Boeing and SpaceX are deferring some capabilities from their test flights that may elevate technical risks or lead to further delays in crewed missions to the ISS. When submitting proposals for CCtCap, both contractors demonstrated the importance of the "Test Like You Fly" technical standard and each added an uncrewed test flight to their development schedule, despite not being required to do so by NASA.[28] Such a flight test was envisioned to help validate flight systems before the crewed test flight, particularly in meeting requirements for operating in the vicinity of the ISS and during docking operations.

Contrary to its initial plans, Boeing will not fly a fully functional abort system on its uncrewed test flight and instead the first use of the system will be during the first crewed test flight. Moreover, Boeing originally planned to fly its uncrewed and crewed test flights in essentially the same configuration without deferring any requirements. Based upon this stabilized system configuration, NASA sought to fill a potential gap in crew access to the ISS by having astronauts on the Boeing crewed test flight remain at the ISS for 6 months rather than just a few days. To accomplish this, in March 2018, NASA paid Boeing $95 million to carry three astronauts on the test flight instead of two. Through August 2019, Boeing had completed 67 percent of its 597 VCNs for its first uncrewed test flight currently scheduled for launch in December 2019.[29]

SpaceX also deferred capabilities from its uncrewed flight test to its upcoming crewed flight test, a situation that means several critical new systems will be flown for the first time on the crewed flight. For example, SpaceX deferred life support system and propulsion upgrades to the crewed flight test, both of which are key to astronaut survival. The systems are now planned to be verified through ground testing before being flown with astronauts rather than the previously planned flight testing on the uncrewed mission. In addition, of the required 617 VCNs that must be closed before certification is complete, 377 were fully completed prior to the uncrewed test flight and a total of 370 are required for the crewed test flight. Through August 2019, NASA had accepted for closure 37 VCNs for this flight.

Although NASA and contractor managers insist that schedule pressure will not override the appropriate resolution of safety or technical issues, all parties are aware of the impending shortfall of transportation capabilities to the ISS if the U.S. contractors are unable to deliver astronauts to the ISS by February 2020. Thus, NASA must continue to guard against allowing schedule pressure to drive decisions that could adversely impact astronaut safety.

[28] NASA's technical standard for crewed transportation systems dictates that systems carrying humans are tested and flown in the same configuration and operational modes or as close to the crewed configuration as possible. The "Test Like You Fly" approach ensures that the system can accomplish the mission with the intended safety controls and robustness. According to NASA requirements, deviations from this standard should clearly describe how a contractor's validation plan will assure sufficient coverage of the expected flight environments and operational sequences that demonstrate critical functions, margins, and performance.

[29] The VCNs selected for closure prior to this flight total 597; however, for certification the number requiring closure totals 827.

COMMERCIAL TRANSPORTATION DELAYS MAY CAUSE A SIGNIFICANT REDUCTION IN CREW ACCESS AND ISS UTILIZATION IN 2020

NASA likely will experience a reduction in the number of USOS crew aboard the ISS from three to one beginning in spring 2020 given schedule delays in the development of Boeing and SpaceX space flight systems coupled with a reduction in the frequency of Soyuz flights. In the past, NASA has successfully ensured access to the ISS by purchasing unused Soyuz seats from Boeing and Roscosmos when four Soyuz vehicles flew per year. However, these alternatives may not be viable because only two Soyuz vehicles are planned for 2020. In addition, astronauts extending their on-Station assignments longer than the standard 6 months may face more significant space-flight-related health concerns. Any reduction in the number of crew aboard the USOS would limit astronaut tasks primarily to operations and maintenance, leaving little time for scientific research. Resulting reductions in Station research and technology demonstrations needed for NASA's future human space exploration goals could, in turn, delay development of life support systems envisioned to support the Lunar Gateway and testing of spacesuits intended for future Moon landings.

Without Commercial Transportation, U.S. and Partner Access to the ISS will Significantly Decrease

NASA's original plan was to end its reliance on purchasing Soyuz seats by bringing Boeing and SpaceX flights online with capsules able to transport four crewmembers to the Station. In anticipation of the start of these flights, NASA and Roscosmos agreed to reduce Soyuz flights from four to two per year beginning in January 2020. If commercial crew flights have not started by April 2020, the Station will be able to host only three crewmembers at a time—two cosmonauts and one USOS astronaut—instead of the planned crew contingent of seven.[30] Table 2 shows the projected number of crewmembers on the Station if NASA's commercial transportation capabilities are delayed beyond April 2020.

[30] In the event that the ISS crew size is reduced to three or fewer crewmembers for more than 21 days, the ISS Program is required to perform an integrated assessment to determine the ability of ISS systems and crew to continue ISS operations and identify measures to ensure ISS sustainability. NASA, *Generic Groundrules, Requirements, and Constraints Part 1: Strategic and Tactical Planning*, (SSP 50261-01 Rev. L § 8.1.1, September 2017).

Table 2: ISS Crew Contingent without Commercial Transportation Capabilities

	2019					2020											
	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
USOS Crew	4	4	4	4	4	4	2	2	1	1	1	1	1	1	0[a]	0[a]	0[a]
Roscosmos Crew	2	2	2	2	2	2	1	1	2	2	2	2	2	2	3	3	3
Total	**6**	**6**	**6**	**6**	**6**	**6**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**

Source: NASA OIG analysis of ISS Flight Plan from September 24, 2019. Per management officials, this schedule is under Agency review and is subject to change as of November 2019.

Note: Red cells indicate crewed scenarios that pose a risk to ISS operations, yellow cells indicate nominal operations, and green cells indicate optimal conditions based on the current capacity of the ISS.

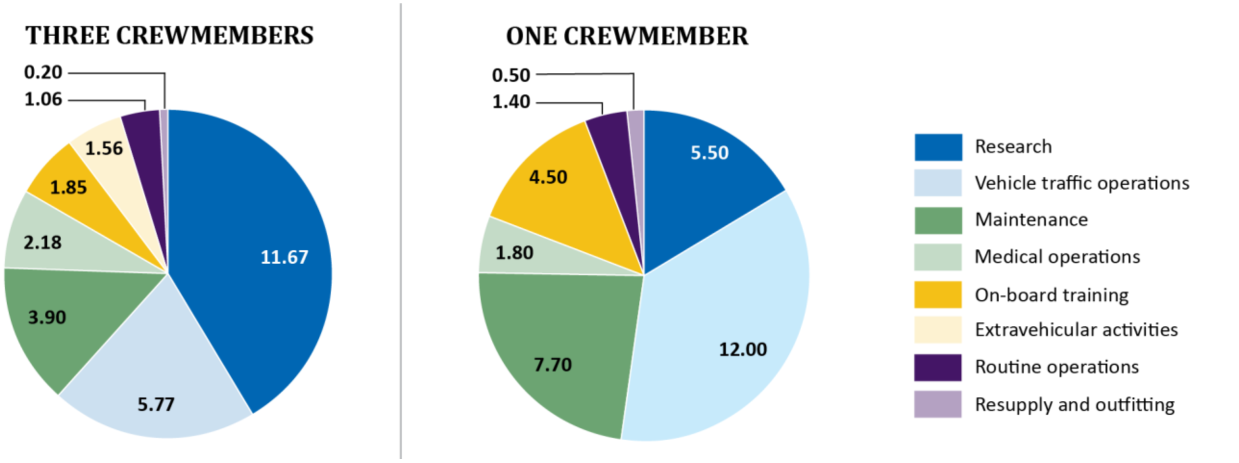
[a] Roscosmos currently plans to transport three crewmembers to the ISS aboard one Soyuz vehicle in October 2020, however, NASA has not purchased a seat aboard this vehicle and may face constraints in payments for the return flight, as discussed below.

Delays in Commercial Transportation Will Reduce ISS Scientific Research, Maintenance, and Commercialization Efforts

The ISS provides a long-duration, full-service laboratory and test bed for research and development that NASA is using to prepare for future missions beyond low Earth orbit.[31] With a USOS crew contingent of three, a typical work week allows each crewmember to perform roughly 12 hours of scientific research, 6 hours of vehicle traffic operations, and 4 hours of maintenance among a variety of other tasks and operations. However, if commercial crew transportation delays persist and the USOS segment is reduced to a single crewmember, that astronaut will be forced to focus primarily on vehicle and medical operations and ISS maintenance rather than scientific research (see Figure 5).

[31] *International Space Station (ISS) Program Plan* (Rev. A, October 2013).

Figure 5: Average Weekly Time Allocation per Crewmember Based on Three USOS Crewmembers versus One Crewmember



Source: NASA OIG analysis of Agency information.

If NASA is unable to secure additional transportation for USOS crew by April 2020, the single crewmember left onboard will only have time to perform an estimated 5.5 hours of research per week.[32] As of October 2019, the ISS is currently crewed with four USOS astronauts. As such, a reduction from 1,786 research hours to 143 hours over a 6-month period will significantly reduce the amount of research and number of experiments performed aboard the ISS.[33] Such a reduction may hinder NASA's ability to address astronaut health risks and develop capabilities needed for deep space exploration missions. Current research on board the ISS include studies on: (1) how long-duration stays on the ISS affect the brain's structure, arterial aging, and radiation exposure; (2) new life support systems, including methods of removing carbon dioxide from the air and water recovery; and (3) autonomous docking technologies for potential use on the Lunar Gateway. Additionally, a significant reduction in crew and research availability could delay planned testing of NASA's next-generation spacesuits. In 2017, we reported on a significant risk that a spacesuit prototype would not be produced in time for testing on the ISS before the Station's planned retirement in 2024.[34] NASA had planned to conduct testing on the advanced extravehicular mobility unit—a key part of the new spacesuit design—on the ISS in 2020, and significant deviations from that timetable may impact spacesuit availability for a planned lunar mission in 2024.

Reducing NASA's crew contingent will also likely reduce the time available for essential maintenance-related extravehicular activities while increasing the time crewmembers spend on intravehicular maintenance. Currently, NASA's maintenance schedule anticipates six extravehicular activities in 2020 to replace old batteries with new lithium-ion batteries. Because NASA does not allow extravehicular activities to be performed with only one astronaut, the Agency is training cosmonauts to

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[32] Of the 5.5 hours devoted to research, NASA will only be able to devote 2.75 hours to NASA-related research per week because the Agency is required to allocate 50 percent of its research to ISS National Laboratory-managed experiments. Pub. L. No. 111-267 § 504(d)(1), *National Aeronautics and Space Administration Authorization Act of 2010* (October 11, 2010).

[33] During increment 61, NASA was able to perform 68.5 hours of research per week due to hosting four crewmembers aboard the ISS.

[34] NASA OIG, *NASA's Management and Development of Spacesuits* (IG-17-018, April 26, 2017).

help perform any required repairs along with a USOS crewmember. However, such a scenario would elevate the Station's safety risk because only one other crewmember would remain inside the Station during such the extravehicular activity, reducing the redundancy to respond to internal or external emergencies during the extravehicular activity. In addition, NASA plans to conduct approximately 600 hours of intravehicular maintenance on the ISS in 2020. While NASA has accommodated other delays of preventative maintenance, some equipment may fail without timely refurbishment such as the cabin air heat exchanger and the Fluids Control and Pump Assembly.[35] With only one USOS crewmember aboard the ISS, NASA would need to devote 12 hours per week to intravehicular maintenance activities compared to the 4 hours per crewmember currently dedicated to these tasks with a crew complement of three astronauts.

Reductions in crew research time may also impact research aboard the ISS involving the ISS National Laboratory. Since August 2011, the Center for the Advancement of Science in Space, Inc. (CASIS) has managed non-NASA research activities on the U.S. portion of the ISS, known as the ISS National Laboratory. CASIS's ability to maximize research capabilities aboard the ISS depends significantly on NASA's ability to fully staff the ISS with four USOS crewmembers. Given CASIS's research and development portfolio, significant reductions in researcher access to crew time would negatively impact its plans. Furthermore, the ability to expand commercial interest in the ISS may be delayed if NASA is unable to complete its planned extravehicular activities in 2020. For example, the private company Nanoracks, LLC has begun construction of a commercial airlock set for launch in 2020 and signed commercial contracts for other entities to use the airlock.[36] Limited crew availability may result in delays in performing the extravehicular activities required to install the airlock, thereby affecting Nanoracks' plans.

Delays in commercial transportation may also impact NASA's efforts to commercialize the ISS. In 2019, NASA announced plans to stimulate commercial utilization of the ISS and low Earth orbit by, among other things, allowing commercial companies to fly private astronauts to the ISS as early as 2020.[37] However, NASA faces a number of constraints in implementing its commercialization goals. First, delays in the start of routine commercial crew flights to the ISS will impact the possibility and pace of private space flight participants. Second, until private space flight participants have access to the ISS, the reduction of available time to perform research aboard the ISS will constrain NASA astronauts' ability to dedicate time to commercial activities. Third, both Boeing and SpaceX's CCP contracts allow for the possibility of updating their spacecraft to carry additional crew beyond the four seats promised to NASA, but NASA would need to review updated certifications and approve those design changes before implementation. Any delays in CCP certification for NASA missions may impact the contractors' schedules for certifying vehicles and delivering private space flight participants to the ISS. According to the CCP contracts, NASA retains control of all the seats for each crewed mission. However, if NASA does not plan to utilize a seat, the contractor may fill it with a nongovernment space flight participant, subject to approval by the Agency and only if any additional costs are not borne by the government.

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[35] These items were identified as some of the internal units with the highest predicted annualized failure rates in 2019. An element of the Common Cabin Air Assembly, the heat exchanger controls temperature and humidity aboard the ISS, which is essential not only for maintaining livability aboard the ISS but also for protecting essential hardware and electronics. The Fluids Control and Pump Assembly pumps crew urine to the distillation assembly and removes both concentrated brine waste and water from the distillation assembly once the vacuum distillation process is completed.

[36] This airlock is an airtight room with two entrances that allow payloads to be transferred inside and outside the ISS.

[37] NASA, NASA Plan for Commercial LEO Development (June 7, 2019).

Options to Address Reduction in ISS Access are Limited

Without Boeing and SpaceX's commercial crew flights, NASA's options are limited for transporting astronauts to the ISS in spring 2020. Specifically, significant issues exist with securing additional Soyuz seats and extending the duration of astronaut missions on board the ISS to avoid a reduction in USOS crew. Due to slippage in the commercial crew schedule, in March 2018 NASA purchased two additional Soyuz seats for $86 million each, one for the September 2019 Soyuz flight and another on the upcoming April 2020 mission. This latter flight will ensure that at least one USOS astronaut is resident on the Station between April 2020 and October 2020. However, looking to Roscosmos to purchase additional Soyuz seats to increase the number of USOS crew on board the ISS during this period appears unlikely for two reasons. First, manufacturing a Soyuz vehicle requires a 3-year lead time. As such, the earliest Roscosmos could have one available is October 2022. And second, purchase of additional Soyuz seats would require a waiver from prohibitions in the Iran, North Korea, and Syria Nonproliferation Act (INKSNA) against making payments to the Russian government. NASA's current waiver expires on December 31, 2020, preventing payment for additional seats that launch or return after December 2020.[38]

In addition to a lack of additional Soyuz seats after mid-2020, the option of extending the duration of astronaut missions onboard the ISS may also prove problematic. Currently, two USOS crewmembers are scheduled to be on board the ISS from September 2019 until April 2020 (189 days). Astronauts typically stay aboard the ISS for 5 months, with the longest astronaut mission to date lasting 340 days.[39] Based on past NASA studies, astronauts face health and safety risks with a year-long stay aboard the ISS.[40] Consequently, any mission extension for one or both of the two USOS crewmembers aboard the Station in April 2020—the point at which NASA must determine who will remain aboard the Station—would likely surpass the year mark. For those two USOS crewmembers, a 6-month extension would increase the mission for one astronaut to 445 days and 378 days for the other. Moreover, such extensions would require the purchase of a return flight aboard a Soyuz vehicle, which would require an extension of the INKSNA waiver.

[38] The Iran Nonproliferation Act of 2000 discouraged U.S. dealings with states that would proliferate nuclear materials to Iran and required the President to report payments made to Russia in connection with the ISS. Pub. L. No. 106-178, 114 Stat. 38-45 (January 4, 2000). The Iran Nonproliferation Amendments Act of 2005 and the 2009 Consolidated Security, Disaster Assistance, and Continuing Appropriations Act amended the Iran Nonproliferation Act to allow for unreported payments to Russia until 2012 for ISS obligations. Pub. L. No. 109-112 § 3, 119 Stat. 2368 (November 22, 2005). Pub. L. No. 110-329 § 125, 112 Stat. 3577 (September 30, 2008). The North Korea Nonproliferation Act of 2006 amended this legislation to include North Korea and renamed the statute accordingly. P.L. 109-353, 120 Stat. 2015-2016 (October 13, 2006). The Space Exploration Sustainability Act amended INKSNA to extend NASA's exemption from reporting payments to Russia in connection with the ISS through 2020. Pub. L. No. 112-273 § 3, 126 Stat. 2454-2455 (January 14, 2013).

[39] In 2015, NASA initiated a mission in which an American astronaut and a Russian cosmonaut stayed on board the ISS for a year. The mission provided new insights into how the human body adjusts to weightlessness, isolation, radiation, and the stress of long-duration space flight.

[40] NASA tracks the highest risks to human health and performance in space exploration on its Human Research Program Integrated Research Plan, including the risks that arise due to long-duration space flight. NASA, *Human Research Program Integrated Research Plan* (HRP-47065 Rev. J, March 2019).

Furthermore, flight changes and extended flight durations impose personal hardships on the astronauts and their families. NASA's astronaut corps currently comprises 38 active astronauts, 9 of whom are already assigned to Soyuz missions, 10 are assigned to CCP flights, and 19 are in various stages of training. While officials state that the astronaut corps is flexible, major changes to the flight schedule can impact the crew individually and collectively as astronauts planning for one mission are reassigned to another. For example, one crewmember's mission was extended to a year-long stay only after she was already on board the Station, a situation that could occur again in 2020. Finally, testimonial evidence from astronauts conducting long-duration space missions and from studies of similar environments raise concerns that extended missions have the potential to result in depression and anxiety.[41]

[41] See NASA, *Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders: Evidence Report* (January 1, 2016) for NASA's review of studies related to the impact of long-duration space flight and isolation on crew performance.

NASA Overpaid Boeing to Prepare for Multiple Crewed Missions

For Boeing's third through sixth crewed missions, we found that NASA agreed to pay an additional $287.2 million above Boeing's fixed prices to mitigate a perceived 18-month gap in ISS flights anticipated in 2019 and to ensure the contractor continued as a second commercial crew provider, without offering similar opportunities to SpaceX.[42] For these four missions, NASA essentially paid Boeing higher prices in an attempt to address schedule slippage caused by Boeing's 13-month delay in completing the ISS Design Certification Review milestone and after the Agency and Boeing could not agree to use the contract's lower fixed price. In our judgment the additional compensation was unnecessary given the risk of a gap between Boeing's second and third crewed missions was minimal when the Agency's analysis occurred in 2016. Furthermore, any presumed gap in commercial crew flights would be addressed by NASA's purchase of additional Soyuz seats from Boeing. Nonetheless, we acknowledge the benefit of hindsight and appreciate the pressures faced by NASA managers at the time to keep the program on schedule to the extent possible. However, even with that understanding and using CCP's own schedule analysis, we found NASA could have saved $144 million by only ordering missions three and four while delaying orders for missions five and six. Additionally, NASA started the payment on the third mission one year earlier than needed and therefore did not use $43 million of the lead time flexibility purchased. Accordingly, we question $187 million of these price increases as unnecessary costs. Finally, given NASA's objective was to address a potential crew transportation gap, we found that SpaceX was not provided an opportunity to propose a solution even though the contractor previously offered shorter production lead times than Boeing.

NASA Paid Boeing More for Mission Flexibilities

In September 2016, Boeing initially proposed pricing for crewed missions three through six using the single 2016 mission price—a price that was substantially higher than the discounted price for ordering four missions in 2016 or the prices for single missions ordered in 2017 or later.[43] Boeing explained that each of the four missions should be treated like a separate order because NASA would not begin payments until the Authorization to Proceed (ATP) was granted (indicating the start of milestone payments), which could be several years later. However, the NASA Office of Procurement determined the use of the single 2016 mission price was not consistent with the terms of the contract and did not match the contract's fixed-price table, which established mission pricing based on when missions were ordered and the number of missions ordered.

[42] As discussed earlier in this report, a potential crew access gap may occur in 2020 due to further SpaceX and Boeing delays and a decrease in the number of Soyuz flights per year. The gap identified in 2016 related only to the time between Boeing's second and third missions and assumed Boeing was already certified and flying regular missions.

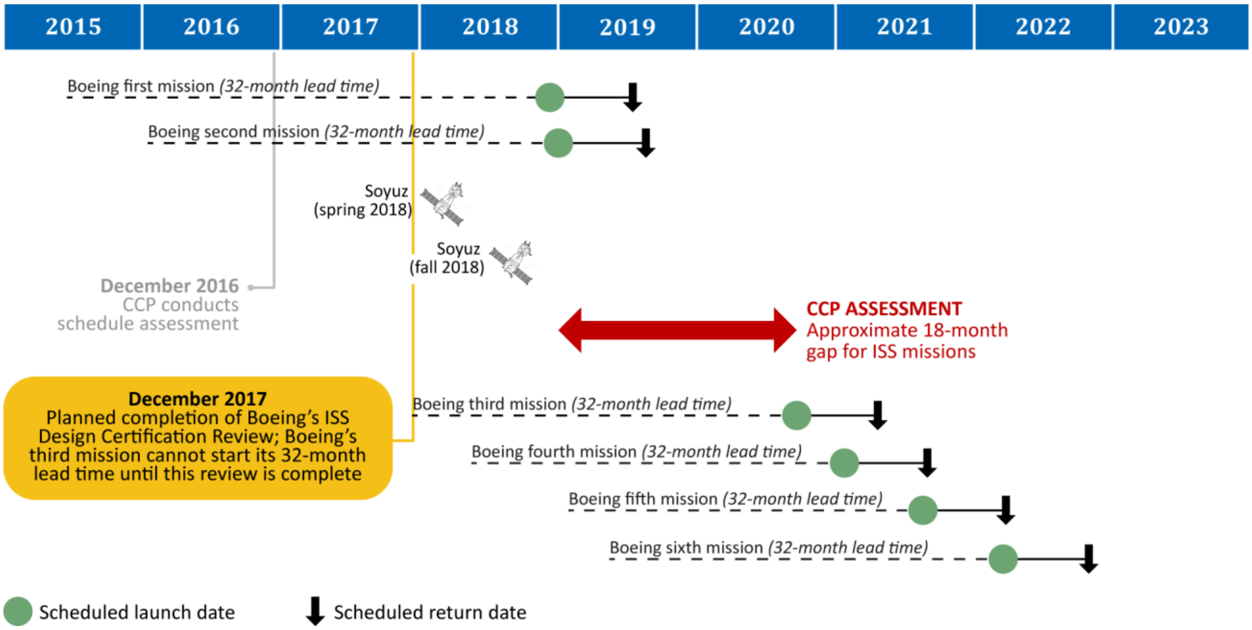
[43] For the CCtCap contracts, NASA does not publicly disclose specific contract pricing due to its proprietary nature. As such, while we discuss the impact of certain decisions on pricing, we do not disclose Boeing and SpaceX's fixed-price tables or crewed mission prices.

As a result of a series of meetings, NASA officials requested in December 2016 that Boeing use the existing fixed prices for missions granted ATP in 2017 and later. Further, as part of this request, NASA changed Boeing's mission requirements and requested the contractor propose prices for additional flexibilities to fill an anticipated crew access gap, including shortening its lead times for rocket and spacecraft production. After prolonged negotiations, Boeing proposed substantially reduced lead times for all four missions, the ability for NASA to have a varied launch cadence through 2024 based on Agency needs, and no penalties for some NASA-requested mission delays. Citing the desire for mission flexibilities primarily driven by the need to fill a crew access gap in case Boeing was the only transportation option available, NASA agreed to pay an additional $287.2 million above the fixed prices or an average increase of $71.8 million per mission for crewed missions three through six.

For the higher price than specified in the contract, NASA determined the added cost was reasonable for the additional flexibilities. The potential crew access gap identified was between Boeing's second crewed mission scheduled for January 2019 and Boeing's third mission in August 2020. This gap was due in part to development delays for certification, Boeing's 32-month production lead times, and contract prohibitions on starting payments for the third mission until completion of the ISS Design Certification Review milestone. At the time, Boeing's ISS Design Certification Review was delayed 13 months, which meant its third mission could not be granted ATP until at least December 2017, meaning the mission's earliest possible launch date would be August 2020. According to a CCP schedule assessment completed in December 2016—an assessment that assumed Boeing would be the only provider available for commercial crew transportation to the Station—these restrictions created a potential 18-month gap in ISS crew access starting with Boeing's second crewed mission in January 2019. At the time, NASA was concerned about maintaining continuous crew access to the ISS in light of SpaceX and Russian cargo vehicle failures in 2016.[44] Figure 6 shows the CCP Schedule Assessment used by program officials to calculate a possible 18-month crew access gap to the ISS assuming Boeing would be the only provider due to the possible unavailability of SpaceX and Roscosmos missions.

[44] During the task order negotiations, two launch failures directly impacted the CCP contractors. On September 1, 2016, a Falcon 9 similar to that planned for crew missions exploded on the launch pad during propellant loading for a static fire. This explosion also destroyed the rocket's commercial mission payload, an Israeli communications satellite called Amos-6. Three months later in December 2016, a Soyuz launch vehicle and Progress spacecraft similar to the type used for crewed missions failed several minutes into flight. SpaceX returned to flight with a commercial payload launch in January 2017 and resumed ISS cargo missions in February 2017. A Progress spacecraft returned to flight in February 2017, followed by a crewed Soyuz mission in April 2017.

Figure 6: CCP Schedule Assessment of ISS Flight Gap with Boeing as a Sole Provider

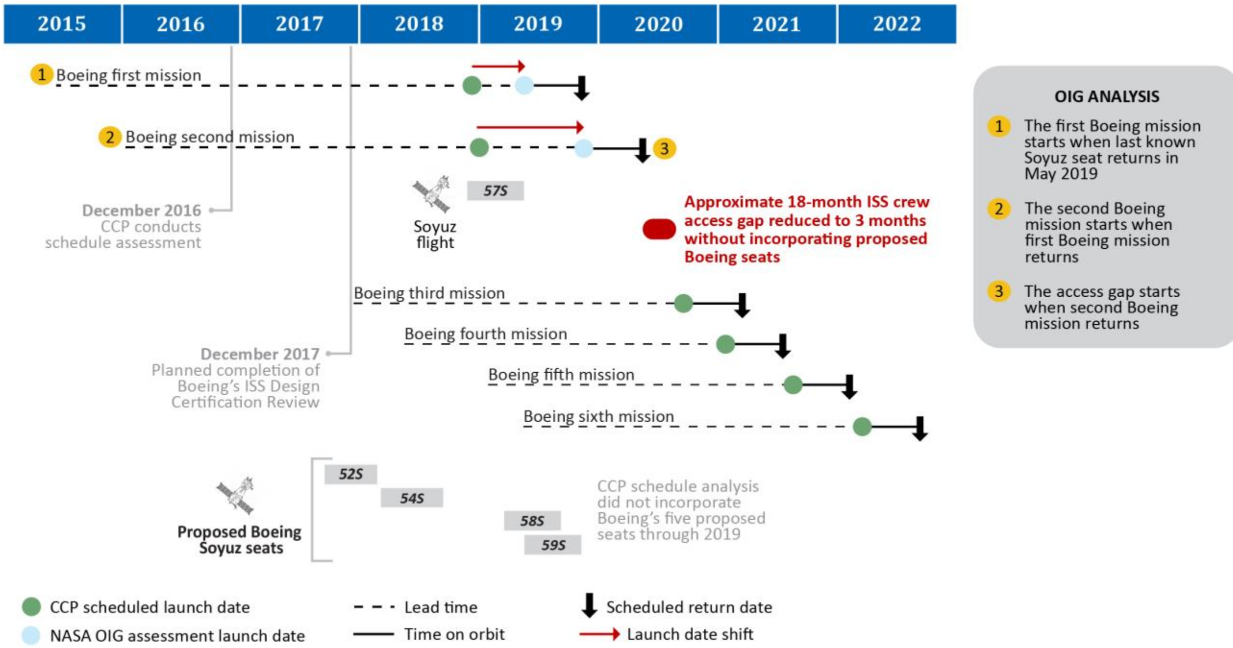


Source: NASA OIG presentation of CCP Schedule Assessment.

NASA's Assumptions for a Gap in Flights were Flawed

We found the risk of an 18-month ISS gap in flights was minimal in December 2016 when the analysis occurred. Additionally, the CCP's flight assumptions were flawed because they failed to take into consideration a normal flight cadence and the five Soyuz seats NASA planned to purchase from Boeing. In CCP's schedule assessment, the 18-month gap was marked from the planned launch of Boeing's second mission, even though the crewmembers typically stay on the Station 6 months before returning to Earth. CCP's analysis did not take into account the duration the astronauts would be on the ISS for the second mission, and adjusting for this reduces the perceived gap to 13 months. Further, Boeing's second mission was projected to launch in January 2019, only 1 month after the first mission was scheduled to launch in December 2018. This meant two Boeing missions would have flown at the same time, establishing an eight-person commercial crew on the ISS in addition to the Soyuz transported crews instead of spacing the missions out over 12 months to ensure two, four-person commercial crews. By delaying the second flight for 5 months to when the first mission returns to Earth, the potential gap could have been reduced to 8 months. Further, if NASA had delayed the launch of its first planned crewed mission until May 2019 when the USOS crewmembers returned on the final purchased Soyuz seats, the gap would be reduced to 3 months without impacting ISS operations. Figure 7 demonstrates how the projected ISS crew access gap could have been reduced through simple changes to the flight manifest.

Figure 7: Analysis of CCP Schedule and Flight Gap



Source: NASA OIG analysis of CCP Schedule Assessment.

NASA's crew access analysis also did not include the five Soyuz seats the Agency was planning to purchase from Boeing for flights in 2017 through 2019. However, HEOMD officials knew in November 2016—one month before the CCP crew access analysis was finalized—that Boeing would be submitting another proposal for Soyuz seats to fill the crew access gap after the last Soyuz mission returned in May 2019.[45] These seats, along with others already purchased from Roscosmos, provided uninterrupted crew access through November 2019 and provided the ISS Program redundancies without paying extra for shorter production lead times for four Boeing crewed missions. Five days after NASA committed to pay $287.2 million in price increases for four commercial crew missions, Boeing submitted an official proposal to sell NASA up to five Soyuz seats for $373.5 million for missions during the same time period. In total, Boeing received $660.7 million above the fixed prices set in the CCtCap pricing tables to pay for an accelerated production timetable for four crew missions and five Soyuz seats.

Boeing Was Already Required to Provide Up to Two Flights per Year

Both NASA and Boeing said the $287.2 million price increase for crew missions three though six was partially justified based on Boeing providing the capability to fly up to two missions per year through 2024. However, based on both the original contract and CCP requirements, we determined Boeing's proposal to fly up to two missions per year did not justify higher pricing because such a mission cadence was already a contract requirement. Under the terms of its original CCtCap contract, Boeing and SpaceX are required to be capable of two flights per year through 2024 and the contractors' pricing table

[45] CCP manages the purchase of commercial crew missions and the ISS Program manages the purchase of all Soyuz seats, including those sold by Boeing, to transport crew the ISS. However, HEOMD overseas procurement activities for both CCP and the ISS Program.

reflects the possibility of multiple missions in a year by providing discounts for missions ordered and launched in the same year. Nonetheless, CCP officials explained that the newly purchased flexibilities provided NASA the option to alter its launch cadence from 2019 through 2024 for any mission ordered prior to the start of each mission's now shortened lead time.[46] For example, NASA could shift two missions from 2019 to 2023 without any additional payments so long as the change occurred prior to the start of the lead times for the 2019 launch dates. While we agree the flexibility for a varied launch cadence without penalties has value, in our judgment, the shorter lead time alone would provide a similar capability through 2024.

NASA Failed to Exercise Multiple Alternatives to Achieve Mission Flexibility within Established Pricing Structure

NASA had contractual options to retain mission flexibility without agreeing to Boeing's price increases. These options included: (1) shifting the second Boeing mission 6 months later to coincide with the first crewed mission's end; (2) incorporating into its flight schedule the five Soyuz seats to be purchased from Boeing for 2018 and 2019; and (3) considering a small equitable adjustment to move up the third mission or waiving the third mission's restriction on granting ATP prior to ISS Design Certification Review—an action NASA later pursued. CCP's Office of Procurement conducted multiple analyses on alternative scenarios in an attempt to save money, but CCP and HEOMD officials determined it was in NASA's best interests to purchase all four missions at the higher prices to ensure increased launch flexibility and gain economies of scale with six missions for each contractor. Furthermore, CCP procurement officials said they did not have direct knowledge of the ISS Program's plans to purchase Soyuz seats from Boeing. As a result, they were not directed by CCP or HEOMD to incorporate the impact of purchasing those seats into its analysis justifying Boeing's requested price increases for speeding up its production schedule for four crewed flights.

According to several NASA officials, a significant consideration for paying Boeing such a premium was to ensure the contractor continued as a second crew transportation provider. CCP officials cited NASA's guidance to maintain two U.S. commercial crew providers to ensure redundancy in crew transportation as part of the rationale for approving the purchase of all four missions at higher prices. Additionally, senior CCP officials believed that due to financial considerations, Boeing could not continue as a commercial crew provider unless the contractor received the higher prices.

While the mission flexibilities NASA purchased from Boeing certainly added value with additional redundancies for crew transportation, we have concerns about NASA's decision to not follow the fixed-price table set at contract award. We found the premium NASA paid to Boeing was unnecessary based on the CCP's 2016 schedule assessment to fill a crew access gap and it remains to be seen whether NASA will utilize these flexibilities throughout the rest of the contract. Further, we acknowledge the benefit of hindsight when reviewing decisions made almost 3 years ago and, therefore, while we have concerns about CCP's schedule analysis, we used CCP's schedule assumptions made before the task order awards in 2016 when determining questioned costs as part of this audit.

[46] In NASA's original task order for the last four missions, Boeing was required to be capable of launching two missions in 2019 and two in 2020 subject to reconfirmation when ATP would be granted for each mission. This flexibility would allow NASA to move any of those missions to any other year through 2024 so long as it did not exceed two missions a year.

Ordering Four Missions at Once was an Excessive and Unnecessarily Costly Response to Perceived Access Gap

Even accepting CCP's analysis of a perceived ISS crew access gap from January 2019 to August 2020, in our judgment NASA could have saved $144 million by only paying a premium to Boeing to accelerate production of missions three and four while delaying orders for missions five and six. Under this approach, NASA would have agreed to a $71.8 million price increase for the first two missions in return for the shorter lead times to cover the potential 18-month gap in crew access. Assuming the ISS Design Certification Review would be completed in December 2017, NASA could have ordered the fifth and sixth missions without paying Boeing a premium for shorter production times. By purchasing just the third and fourth missions at these higher prices, NASA would have sufficiently mitigated the concerns raised by the SpaceX and Russia cargo failures by ensuring continuous access to the ISS through July 2020. Accordingly, we believe the $144 million NASA paid for accelerating the development lead times for Boeing's fifth and sixth missions was unreasonable, even when accepting CCP's analysis of a potential crew access gap. See Table 3 in Appendix D for a breakdown of these questioned costs.

Early Milestone Payments Negated Value of Shortened Lead Time

Despite paying an additional $71.8 million for a shorter lead time for Boeing's third mission to help address the perceived potential gap in crew access, NASA started milestone payments for this mission a year earlier than required by the contract because CCP needed more time to review Boeing's flight readiness documentation. In November 2018—for the third mission only—NASA removed the restriction of not granting ATP until the completion of the ISS Design Certification Review to ensure both the Agency and Boeing would have enough time to meet the initial target launch date. CCP then granted ATP and started milestone payments a year earlier than needed even though NASA paid a premium for a shorter production lead time. Less than a year later in August 2019, the third mission is now projected to launch in November 2022, four years after ATP was granted. Based on the $71.8 million price increase paid to Boeing for a shorter lead time, we determined NASA negated approximately $43 million of the value of this premium by granting ATP a year earlier than needed and not fully utilizing the mission flexibilities already purchased. See Table 3 in Appendix D for a breakdown of these questioned costs.

Excluding SpaceX Limited NASA's Options to Address Access Gap

In NASA's efforts to fill a perceived crew access gap, we found that SpaceX was not provided the same opportunity as Boeing to propose a solution. As a result, NASA paid Boeing an additional $287.2 million to accelerate its production schedule for four missions without reaching out to the Agency's second commercial crew contractor to maximize the Agency's options. Three months after proposals were due for the third through sixth crewed missions, NASA unilaterally changed its flight requirements for Boeing and the contractor submitted a revised proposal with shorter lead times and higher pricing than stipulated in the base contract. In contrast, SpaceX was not notified of this change in requirements and was not provided an opportunity to propose similar capabilities that could have resulted in less cost or broader mission flexibilities. CCP's December 2016 analysis showed that the potential gap for SpaceX crewed missions was up to 15 months due to lead times and restrictions on ATP payments. Further, NASA's revised requirement for Boeing's shorter lead times was sufficiently different from the original task order that it may have affected the contractual basis for allowing the missions to be ordered without competition.[47] CCP officials stated that the shorter lead times and other flexibilities came from a Boeing proposal and did not affect the competition requirements. Further, CCP officials said there was no value in approaching SpaceX since their 24-month lead times and existing flight rate were sufficient to meet their requirements based on the contract's fixed prices. However, we determined that it was actually NASA that sent a request to Boeing in December 2016 for revised mission prices based upon new mission flexibilities and requirements. Moreover, if Boeing and Soyuz flights were not available, SpaceX may have been able to address a gap in flights. In our judgment, contacting both providers would have been a prudent approach to maximize the Agency's options while also ensuring fairness.

[47] Prior to the task order award in December 2016, NASA issued a Justification for an Exception to Fair Opportunity letter on August 8, 2016, to award the final eight missions, four to each contractor, without competition. This eliminated the CCtCap requirement in Clause H.8 for both contracts for NASA to provide a fair opportunity to compete for task orders. Federal law and the Federal Acquisition Regulations (FAR) require competition of task orders absent exceptions. 10 U.S.C. § 2304c. FAR 16.505. However, in this case the Exception to Fair Opportunity was predicated on the CCtCap task orders using the agreed-upon pricing tables, terms, and requirements that were originally competed in the base contract for both contractors. Had this exception not applied, NASA would have been required to notify SpaceX of the change in requirements for shorter lead times and its negotiations with Boeing after submission of proposals.

CONCLUSION

Over 8 years have passed since U.S. astronauts last flew on a U.S. spacecraft. During that time, NASA and its commercial crew contractors—Boeing and SpaceX—have made significant progress toward developing commercial space flight systems to transport astronauts to and from the Station. However, after more than 2 years of delays both contractors will miss the current schedule to begin crewed test flights in late 2019. Addressing outstanding technical challenges, safety and performance testing, and verification of the contractors' requirements, hazards, and safety concerns likely will take significant time to complete. In our judgment, the level of work required makes the current schedule for both contractors leading up to final certification unrealistic and could pressure NASA to accept elevated risks for the early crewed flights. Additional schedule delays increase the risk that NASA and its contractors will not complete their space flight systems before Roscosmos reduces the number of Soyuz missions beginning in January 2020. If Boeing and SpaceX are unable to deliver crew to the ISS by April 2020, NASA will be forced to reduce the USOS crew contingent aboard the Station to a single astronaut. This would negatively impact important research activities on the Station as well as critical ISS maintenance, including installing new lithium-ion batteries.

In addition, we questioned NASA's payment of $144 million to Boeing for accelerating its production lead times for the contractor's fifth and sixth missions given the Agency's analysis did not consider a concurrent negotiation and forthcoming purchase of five additional Soyuz seats from Boeing. Further, we determined NASA negated approximately $43 million of the value of the third mission's price by granting ATP a year earlier than needed.

Recommendations, Management's Response, and Our Evaluation

In order to increase the efficiency and effectiveness of NASA's Commercial Crew Program, we made the following recommendations to NASA's Acting Associate Administrator for Human Exploration and Operations Mission Directorate:

1. Revise current schedules and establish realistic timetables for the remaining reviews and flights occurring before final certification and missions to the ISS.
2. Correct identified safety-critical technical issues before the crewed test flights, including parachute, propulsion, and launch abort systems, to ensure sufficient safety margins exist.
3. Initiate internal processes and coordinate with congressional and other stakeholders to obtain an extension of INKSNA exemptions.
4. Complete a contingency plan for delayed CCP delivery. In particular, work with Roscosmos to determine if the following or other actions are feasible, efficient, or necessary:
    a. Consider a contract modification to purchase a Soyuz seat before December 31, 2020, that includes prepayment in full before the fight occurs.
    b. Extend Soyuz docking times on the ISS beyond 200 days to extend the duration of current ISS crew stays.
    c. Accelerate the launch of future Soyuz missions to have up to six crew at a time instead of three to allow for uninterrupted Station operations until CCP contractors begin crewed missions.
5. Continue to ensure the purchase of future commercial space services complies with government contracting regulations, including taking such actions as:
    a. adhering to the established fixed-pricing in contracts for future orders,
    b. coordinating CCP and ISS Program acquisition plans to avoid purchases of unnecessary mission flexibilities,
    c. utilizing the existing contract language to apply equitable adjustments through negotiations for schedule changes instead of negotiating new mission pricing, and
    d. providing equal opportunities to both contractors to compete for additional capabilities or significant changes in the contract's scope and pricing tables.

We provided a draft of this report to NASA management who concurred with all of our recommendations. However, none of the proposed corrective actions have estimated closure dates. While we consider management's comments responsive, the recommendations will remain open until completion and verification of the proposed corrective actions within acceptable timeframes.

In addition to responding to the recommendations, the Agency provided comments on what it perceived as the report's three main findings: (1) schedule pressure/elevated risk, (2) ISS impacts of commercial crew program delays, and (3) premium payments made to Boeing for crewed missions.

In the report, we focused on the technical and safety concerns experienced by the commercial crew contractors that are delaying the timetable for initiating commercial crew flights to the ISS. During our review, NASA officials reported that certification of the contractors' commercial vehicles is driven by safety rather than schedule and noted that they intend to allow Boeing and SpaceX to carry NASA astronauts only when they deem it safe to do so. That said, we identified numerous capabilities initially planned for testing during the uncrewed test flights that were deferred to the crewed test flights and later in the name of schedule fidelity, deferrals that could adversely impact astronaut safety. As a result, the information presented in our report cautions CCP about the potential safety risks posed by schedule pressure.

With respect to the reduction in crew and ISS utilization, we presented a realistic assessment based on the schedule assessments conducted by CCP to date. We acknowledged NASA's past efforts to avoid a crew access gap by detailing the seats purchased from Russia between 2017 and 2019. Regardless of the number of Soyuz seats purchased in 2020, NASA will be able to host only one USOS crewmember aboard the ISS in April 2020 if Boeing or SpaceX are not able to transport crew by that time. Moreover, while NASA has been effective in the past in securing Soyuz seats for its astronauts, Roscosmos will be reducing their flight rate by half beginning in April 2020. This means that the best-case scenario will provide for one instead of the planned four astronauts aboard the USOS until commercial crew vehicles become operational, resulting in a marked reduction in research. While we are pleased to see that NASA is working on contingency plans, at the time of issuance of this report in November 2019, those plans were only in the initial stages of coordination.

Finally, NASA and Boeing did not follow the fixed prices set at contract award for Boeing's crewed missions 3 through 6. As noted in our report, NASA negotiated to pay a $287.2 million premium to Boeing for additional flexibilities primarily driven by the need to fill a perceived ISS flight gap. Our analysis found CCP's schedule assessment at the time was flawed with the assessment failing to provide adequate justification of the need to pay this premium. In developing this finding, we relied on CCP's own analysis at the time to determine the Agency did not need to purchase additional flexibilities for Boeing's fifth and sixth missions. While we agree that these flexibilities may have value in the future, we do not believe they were needed at the time of the award and it remains to be seen whether these flexibilities will be fully utilized throughout the remainder of the CCtCap contract.

Management's comments are reproduced in Appendix E. Technical comments provided by management have also been incorporated, as appropriate. In addition, in order to protect procurement sensitive and proprietary information, we conducted extensive reviews along with NASA to ensure this report could be released publicly.

Major contributors to this report include Ridge Bowman, Space Operations Director; Kevin Fagedes, Project Manager; Alyssa Megan Sieffert; Robert Proudfoot; Dimitra Tsamis; Shari Bergstein; Sarah McGrath; and Cedric Campbell.

If you have questions about this report or wish to comment on the quality or usefulness of this report, contact Laurence Hawkins, Audit Operations and Quality Assurance Director, at (202) 358-1543 or laurence.b.hawkins@nasa.gov.

Paul K. Martin
Inspector General

APPENDIX A: SCOPE AND METHODOLOGY

We performed this audit from February 2019 through November 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.

The overall objective of this audit was to examine NASA's plans and progress for transporting astronauts to the Station. The audit's scope included both the CCP and the ISS Program with a focus on Boeing, SpaceX, and Soyuz space flight systems. We also evaluated the CCP schedule, plans to assure access to the Station, and the pricing tables for the CCtCap contract. In addition, we reviewed technical risks and safety concerns related to CCP's development efforts. To complete this work, we reviewed internal controls as they related to the overall objective. We also interviewed personnel from HEOMD, CCP, the ISS Program, Kennedy Space Center, Johnson Space Center, Boeing, and SpaceX to determine CCP's progress towards assuring continued and safe crew access to the ISS.

We reviewed relevant laws, regulations, and policies to determine the established guidance and best practices. We obtained and reviewed prior reports related to NASA's ability to address the development and collaboration challenges of CCP. We reviewed NASA requirements and criteria for CCP. The documents we reviewed include the following:

- CCT-PLN-1000, Rev. A, *Crew Transportation Plan* (January 19, 2017)
- CCT-PLN-1010, Rev. A, *Mishap Preparedness and Contingency Plan* (November 17, 2015)
- CCT-PLN-1120, Rev. C-2, *Crew Transportation Technical Management Processes* (October 25, 2013)
- CCT-REQ-1130, Rev. F, *ISS Crew Transportation and Services Requirements Document* (September 6, 2017)
- CCT STD-1140, Rev. B, *Crew Transportation Technical Standards and Design Evaluation Criteria* (April 8, 2015)
- CCT-STD-1150, Rev. A-3, *Crew Transportation Operations Standards* (July 16, 2013)
- CCT-DRM-1110, Rev. Basic-3, *Crew Transportation System Design Reference Missions* (December 8, 2011)
- SSP 50808, Rev. G, *International Space Station Commercial Orbital Transportation Services Interface Requirements Document* (March 2018)
- SSP 50261-01, Rev. L, *ISS Program Generic Ground Rules, Requirements, and Constraints, Part I—Strategic and Tactical Planning* (September 2017)
- HEOMD-CSD-10001, Rev. A, *Commercial Crew Transportation System Certification Requirements for NASA Low Earth Orbit Missions* (November 18, 2013)
- NPR 8705.2C, *Human-Rating Requirements for Space Systems* (July 10, 2017)
- NNK14MA74C, *SpaceX Commercial Crew Transportation Capability Contract, with modifications* (September 16, 2014)

- NNK14MA75C, *Boeing Commercial Crew Transportation Capability Contract, with modifications* (September 16, 2014)

We obtained documents from CCP, the ISS Program, Boeing, and SpaceX in order to review the cost, schedule, and performance for the Soyuz seats and CCP vehicles. We reviewed CCP flight plans, quarterly briefings and status reports, and hazard and risk reports. In addition, we reviewed the CCP, Boeing, and SpaceX status reports for variances, requirements completion, and safety issues.

Use of Computer-Processed Data

We used computer-processed data to assess the costs of CCP and the Soyuz seats. For our audit objectives, we compared this data to information provided in the President's budget estimates, as well as to NASA's firm-fixed-price contracts with Boeing and SpaceX. We also obtained risk data from CCP that was maintained in NASA's risk management system. We assessed that the cost and risk data we received was sufficiently reliable, but we did not rely solely on the computer-processed data to support our findings, conclusions, or recommendations.

Review of Internal Controls

We evaluated the internal controls associated with the management of CCP. The control weaknesses we identified are discussed previously in this report. Our recommendations, if implemented, will correct the identified control weaknesses.

Prior Coverage

During the last 5 years, NASA OIG and the Government Accountability Office have issued 16 reports of significant relevance to the subject of this report. Unrestricted reports can be accessed at https://oig.nasa.gov/audits/auditReports.html and http://www.gao.gov, respectively.

NASA Office of Inspector General

NASA's Management and Utilization of the International Space Station (IG-18-021, July 30, 2018)

Audit of Commercial Resupply Services to the International Space Station (IG-18-016, April 26, 2017)

NASA's Commercial Crew Program: Update on Development and Certification Efforts (IG-16-028, September 1, 2016)

NASA's Response to SpaceX's June 2015 Launch Failure: Impacts on Commercial Resupply of the International Space Station (IG-16-025, June 28, 2016)

Extending the Operational Life of the International Space Station until 2014 (IG-14-031, September 18, 2014)

NASA's Use of Space Act Agreements (IG-14-020, June 5, 2014)

NASA's Management of the Commercial Crew Program (IG-14-001, November 13, 2013)

Government Accountability Office

NASA Commercial Crew Program: Schedule Uncertainty Persists for Start of Operational Missions to the International Space Station (GAO-19-504, June 2019)

NASA: Assessments of Major Projects (GAO-19-262SP, May 30, 2019)

NASA Commercial Crew Program: Plan Needed to Ensure Uninterrupted Access to the International Space Station (GAO-18-476, July 11, 2018)

NASA: Assessments of Major Projects (GAO-18-280SP, May 1, 2018)

NASA Commercial Crew Program: Continued Delays Pose Risks for Uninterrupted Access to the International Space Station (GAO-18-317T, January 17, 2018)

NASA: Assessments of Major Projects (GAO-17-303SP, May 16, 2017)

NASA Commercial Crew Program: Schedule Pressure Increases as Contractors Delay Key Events (GAO-17-137, February 2017)

NASA: Assessments of Major Projects (GAO-16-309SP, March 30, 2016)

NASA: Assessments of Selected Large-Scale Projects (GAO-14-338SP, April 15, 2014)

Appendix B: Summary of Commercial Crew Activities and Total Funding

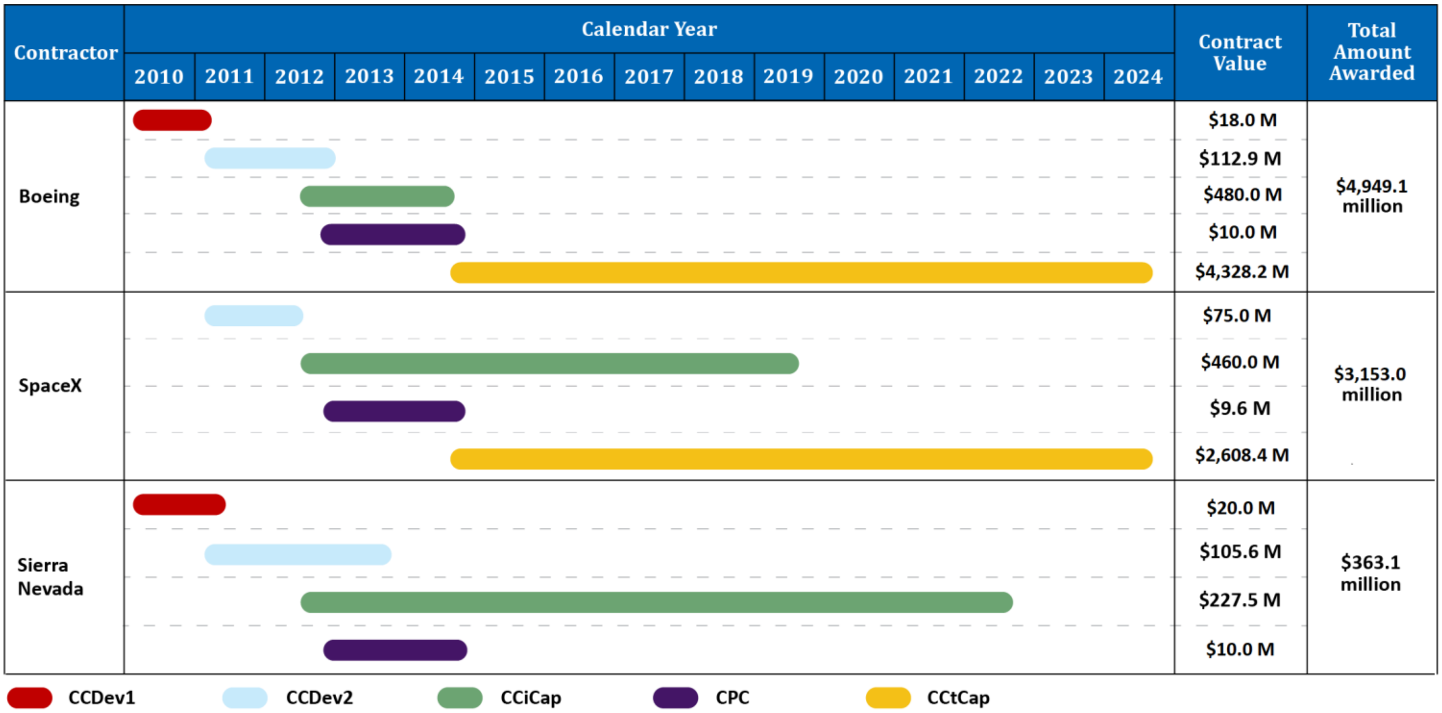
Since 2010, CCP has progressed through several phases of development, with NASA awarding funded and unfunded development activities for commercial crew transportation capabilities to eight companies for a total of $8.5 billion.[48]

- *Commercial Crew Development Round 1 (CCDev1).* NASA's efforts to facilitate the development of a commercial crew transportation capability began in February 2010 when the Agency awarded a total of $50 million in Space Act Agreements to five companies—Blue Origin, Boeing, Paragon Space Development Corporation, Sierra Nevada Corporation (Sierra Nevada), and United Launch Alliance—to fund research and design of key technologies and systems.
- *Commercial Crew Development Round 2 (CCDev2)*. Beginning in April 2011, NASA awarded additional Space Act Agreements worth $316 million to four companies—Blue Origin, Boeing, Sierra Nevada, and SpaceX—to continue development of their crewed space flight systems. NASA also entered into unfunded Space Act Agreements with three other companies—Alliant Techsystems, Excalibur Almaz Inc., and United Launch Alliance—to provide technical assistance on space transportation concepts.
- *Commercial Crew Integrated Capabilities (CCiCap)*. NASA then awarded in August 2012 a total of $1.168 billion in Space Act Agreements to Boeing, Sierra Nevada, and SpaceX to continue development and for each contractor to complete a Critical Design Review in preparation for upcoming ISS crew transportation contract awards.
- *Certification Products Contract (CPC)*. In CCP's first use of a FAR contract instead of a Space Act Agreement, the Agency awarded in December 2012 a total of $30 million to Boeing, Sierra Nevada, and SpaceX through CPCs to set the certification plans for each contractor.
- *Commercial Crew Transportation Capability (CCtCap)*. In September 2014, NASA awarded Boeing and SpaceX firm-fixed-price contracts worth $6.9 billion to complete development of their commercial crew transportation systems and carry astronauts to and from the ISS on a total of 12 missions through the ISS's planned retirement in 2024.

Figure 8 summarizes the commercial crew development funding history for Boeing, SpaceX, and Sierra Nevada through August 2019.

[48] These companies were Alliant Techsystems; Blue Origin; Boeing; Excalibur Almaz, Inc.; Paragon Space Development Corporation; Sierra Nevada; SpaceX; and United Launch Alliance.

Figure 8: Summary of CCP Activities and Total Funding



Source: NASA OIG analysis of Agency information through August 2019.

APPENDIX C: DESCRIPTION OF TESTS AND REVIEWS

Contractors are required to develop flight test programs to assess vehicle performance and margin. A test is a method of verification in which technical means, such as the use of special equipment, instrumentation, simulation techniques, and the application of established principles and procedures, are used for the evaluation of components, subsystems, and systems to determine compliance with requirements. CCP contractors conduct the following system tests:

- *Abort.* The forced early return of the crew when failures or the existence of uncontrolled catastrophic hazards prevent continuation of the mission profile and a return is required for crew survival.
- *Ascent abort.* An abort performed during ascent, where the crewed spacecraft is separated from the launch vehicle without the capability to achieve the desired orbit. The crew is safely returned to a landing site in a portion of the spacecraft normally used for entry and landing.
- *Emergency egress.* Capability for crew to exit the spacecraft and leave the hazardous situation or catastrophic event within the specified time.
- *Landing.* The final phase or region of flight consisting of transitioning from descent to approach, touchdown, and coming to rest.
- *Pad abort.* An abort performed where the crewed spacecraft is separated from the launch vehicle while the launch vehicle remains on the launch pad. As a result, the crewed spacecraft is safely transported to an area that is not susceptible to the dangers associated with the hazardous environment at the launch pad.
- *Software.* Computer instructions or data stored electronically. Systems software includes the operating systems and all the utilities that enable the computer to function. Applications software includes programs that do real work for users, such as word processors, spreadsheets, data management systems, and analysis tools. Software can be commercial off-the-shelf, contractor developed, government furnished, or combinations thereof.

NASA requires contractors to hold milestone reviews to formally evaluate the progress toward certification. Prior to their test flights, contractors have to complete the following reviews:

- *Design Certification Review.* Prior to the first low Earth orbit crewed test flight, the flight test readiness process will include a review of applicable elements from completed contractor certification milestones (for an interim contractor certification) and a Flight Test Readiness Review. The Design Certification Review formally documents the configuration baseline (hardware, software, and processes used in design, production, and operations) and the conditions under which a contractor is certified (performance, fabrication, and operational environments and constraints). This review also presents the current state of the verification and validation effort, including the overall status of all verification closures and any changes to the verification and validation plan since certification baseline review.

- *Flight Test Readiness Review.* For crewed flight tests, the Flight Test Readiness Review examines tests, demonstrations, analyses, and audits that determine a system's readiness for a safe and successful flight launch and for subsequent flight test operations. It also ensures that all flight and ground hardware, software, personnel, and procedures are operationally ready.
- *Operations Readiness Review.* Upon successful completion of the Flight Test Readiness Review, an Operations Readiness Review will be conducted. The Operations Readiness Review occurs once during a program's life-cycle (or at the introduction of new or significantly modified systems or facilities). The Operations Readiness Review evaluates all project and support (flight and ground) hardware, software, personnel, plans, processes, and procedures to ensure flight and associated ground systems are in compliance with program requirements and constraints during the sustaining phase.
- *Certification Review.* Upon successful completion of all flight tests, any additional Design Certification Reviews, and the Operations Readiness Review, the Certification Review determines that the crew transportation systems meet the mission needs for which it was developed.
- *Flight Readiness Review.* The Flight Readiness Review examines tests, demonstrations, analyses, and audits that determine a system's readiness for a safe and successful flight and launch and for subsequent flight operations. This review ensures all flight and ground hardware, software, personnel, and procedures are operationally ready.

Appendix D: Schedule of Questioned Costs and Dollar-Related Findings

Table 3 summarizes the questioned costs identified during our audit and discussed in this report. The first row of questioned costs is the result of NASA unnecessarily purchasing additional mission flexibilities for four Boeing crew missions when, at most, only two mission purchases with added flexibilities were needed. The second row of questioned costs is the result of NASA unnecessarily starting payments on the third mission earlier than contractually required despite paying a substantial premium for this increased mission flexibility.

Table 3: Questioned Costs and Associated Recommendations

Issue	Recommendation #	Questioned Costs
Unnecessary payments of the fifth and sixth Boeing crew mission, $71.8 million each, for unneeded mission flexibility.	5	$143,600,000
Unnecessarily starting payments on the third mission earlier than needed, negating the prorated value of reducing the long-lead time.	5	$43,080,000
	Total	**$186,680,000**

Source: NASA OIG analysis.

Note: Questioned costs are expenditures that are questioned by the OIG because of an alleged violation of law, regulation, or contractual requirement governing the expenditure of funds, costs that are not supported by adequate documentation at the time of our audit, or are unallowable, unnecessary, or unreasonable.

APPENDIX E: MANAGEMENT'S COMMENTS

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

NOV 0 8 2019

Reply to Attn of:

Human Exploration and Operations Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Human Exploration and Operations Mission Directorate (Acting)

SUBJECT: Agency Response to OIG Draft Report, "NASA's Management of Crew Transportation to the International Space Station" (A-19-007-00)

The National Aeronautics and Space Administration (NASA) appreciates the efforts that went into the review as well as the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled, "NASA's Management of Crew Transportation to the International Space Station" (A-19-007-00) dated October 8, 2019.

I want to address the three main themes of the OIG's report: schedule pressure/elevated risk, International Space Station (ISS) impacts of Commercial Crew Program (CCP) delays, and the pricing for Boeing's Post Certification Missions (PCMs).

Regarding the issue of schedule pressure/elevated risk, this issue has been repeatedly identified by many parties, including NASA, since the beginning of CCP. It is a well-known issue and NASA management has been careful to execute CCP in a way to avoid undue schedule pressure. While the OIG cited several unresolved technical issues (all of which are typical for a complex spaceflight development effort), NASA is pleased that the OIG did not identify any evidence of NASA or its contractors having been unduly influenced by schedule pressure.

In fact, the Aerospace Safety Advisory Panel (ASAP), the primary external group assessing CCP safety, confirmed that schedule pressure was not negatively influencing CCP decision-making after extensive review of CCP's technical and management status. From the ASAP 2017 Annual Report: "Despite the volume of remaining work, technical challenges, and end of the Soyuz transportation for U.S. crews, the ASAP sees no evidence that the CCP leadership is making decisions that prioritize schedule over crew safety."

Regarding the section in the report titled, "Commercial Transportation Delays May Cause a Significant Reduction in Utilization in 2020," the OIG has described a worst-case scenario that does not reflect NASA's consistent efforts during the life of the program to mitigate those risks. The scenario presented in the report assumes that CCP systems will be significantly delayed and that NASA will not take any future action to mitigate the impacts on the ISS of that delay. However, it should be noted that on five previous occasions, NASA has taken action to ensure continuous U.S. crew on the ISS when CCP schedule margins eroded. The ASAP, while presented with the same facts as the OIG, recognized this history and stated during its March 7, 2019 meeting: "ASAP is pleased to see that NASA has taken steps to ensure continued U.S. presence on the ISS, which mitigates any perceived schedule pressure on the CCP program."

This section also does not recognize the fact that NASA is currently in discussions with Roscosmos regarding options for ensuring continuous U.S. crew on ISS. NASA confirmed to the OIG that these discussions had begun during the OIG fact finding for this report. While these discussions have not concluded yet, NASA believes that the Agency will be able to support continuous U.S. crew on the ISS and that most if not all of the impacts cited in the OIG report will either be avoided altogether or will only be temporary.

Regarding the issue of Boeing PCM prices, it should be noted that the negotiations over the PCM pricing took place over a six-month period back in 2016 and the negotiations were complex and extensive. The final prices agreed to by NASA and Boeing were reviewed and approved by numerous NASA officials at the Kennedy Space Center and Headquarters, culminating in a 29-page price justification memorandum for the record.

NASA understands the OIG believes that NASA could have negotiated better prices for the PCMs. However, this is an opinion, three years after the fact and there is no evidence to support the conclusion that Boeing would have agreed to lower prices. Thus, NASA strongly disagrees with the OIG's characterization that NASA "overpaid" for the Boeing PCMs or that the final agreed-to prices were "unnecessary," "not justified," "unreasonable," or "higher" than some hypothetical lower amount. NASA believes the final PCM pricing represents appropriate value of the missions and also represents the value to NASA and the nation of having two independent U.S. human space transportation systems supporting ISS operations.

In the draft report, the OIG makes five recommendations addressed to the Acting Associate Administrator for Human Exploration and Operations Mission Directorate (HEOMD), intended to improve the efficiency and effectiveness of NASA's Commercial Crew Program (CCP). The OIG also identified questioned costs totaling $187 million relating to the acceleration of production lead times, as well as Authorization-to-Proceed with respect to the Boeing contract.

Specifically, the OIG recommends the following:

In order to increase the efficiency and effectiveness of NASA's Commercial Crew Program, the OIG makes the following recommendations to NASA's Acting Associate Administrator for HEOMD:

Recommendation 1: Revise current schedules and establish realistic timetables for the remaining reviews and flights occurring before final certification and missions to the International Space Station (ISS).

Management's Response: Concur. This process is already underway. On July 30, 2019, the NASA Administrator stated that "schedules matter" and put the CCP schedules under review.

Estimated Completion Date: The CCP schedules will be formally updated when the new leadership is in place for the Human Exploration and Operations Mission Directorate. If flight tests occur prior to new leadership being in place, NASA will update schedules accordingly.

Recommendation 2: Correct identified safety-critical technical issues before the crewed test flights, including parachute and propulsion systems including launch abort systems testing to ensure sufficient safety margins exist.

Management's Response: Concur. NASA would never fly crewed flights with known, unresolved safety-critical technical issues; and there has been no indication to suggest otherwise in NASA's management and execution of CCP.

Estimated Completion Date: All known safety-critical technical issues will be resolved prior to crewed flights.

Recommendation 3: Initiate internal processes and coordinate with congressional and other stakeholders to obtain an extension of Iran, North Korea, and Syria Nonproliferation Act (INKSNA) exemptions.

Management's Response: Concur. The extension of this exemption is essential for ongoing operations of the International Space Station. NASA included such an extension in its legislative proposal package for the 116th Congress, submitted on October 9, 2019.

Estimated Completion Date: Completed.

Recommendation 4: Complete a contingency plan for delayed CCP delivery. In particular, work with Roscosmos to determine if the following or other actions are feasible, efficient, or necessary:

a. Consider a contract modification to purchase a Soyuz seat before December 31, 2020, that includes prepayment in full before the fight occurs.

b. Extend Soyuz docking times on the ISS beyond 200 days to extend the duration of current ISS crew stays.

c. Accelerate the launch of future Soyuz missions to have up to six crew at a time instead of three to allow for uninterrupted Station operations until CCP contractors begin crewed missions.

Management's Response: Concur. NASA has sent a letter from the NASA Administrator to his counterpart at Roscosmos, dated October 24, 2019, requesting one seat on the fall 2020 Soyuz and one seat on the spring 2021 Soyuz.

a. NASA is assuming INKSNA relief and plans to use its standard payment schedule. Paying in full prior to December 2020 was determined to be not in the best interest of the U.S. Government.

b. Soyuz vehicles are certified to 200 days. Roscosmos has an ongoing effort to look at extending the certification duration. While not opposed, at this time, NASA is not pursuing a request to extend Soyuz mission past 200 days. If Roscosmos certification extension efforts result in more than 200 days, NASA would support those efforts.

c. Roscosmos is currently only funded for two Soyuz spacecrafts per year. Accelerating a Soyuz spacecraft to maintain six crew onboard ISS while honoring the 200-day requirement would result in a gap whereby no U.S. crew would be onboard ISS for a period of time. As such, NASA is not pursuing this option.

In addition to the actions listed above, NASA is providing Extra-Vehicular Activity and robotics training for a subset of cosmonauts to support U.S. Operating Segment operations. NASA is also looking at a possible extension of the duration of the Space X Demonstration 2 crewed test flight.

Estimated Completion Date: Completed.

Recommendation 5: Continue to ensure the purchase of future commercial space services complies with government contracting regulations, including taking such actions as:

a. adhering to the established fixed-pricing in contracts for future orders,

b. coordinating CCP and ISS Program acquisition plans to avoid purchases of unnecessary mission flexibilities,

c. utilizing the existing contract language to apply equitable adjustments through negotiations for schedule changes instead of negotiating new mission pricing, and

d. providing equal opportunities to both contractors to compete for additional capabilities or significant changes in the contract's scope and pricing tables.

Management's Response: Concur. NASA strongly believes that its purchases of commercial space services comply with government contracting regulations. Specifically, NASA uses established fixed pricing when negotiating orders; approves acquisition plans in accordance with federal and agency policy; negotiates contract modifications that reflect any applicable equitable adjustments; and provides equitable opportunities to both contractors. NASA will continue to do these things for future purchases.

Estimated Completion Date: Completed.

We appreciate the OIG's discussions regarding the SBU information in the report, however the review is continuing based on feedback received from the contractors. A determination to release the report publically cannot be made at this time. Additionally, although the OIG does not recommend recovery of questioned costs identified in the report, we do not agree that the dollar amounts cited were questionable, unnecessary, or unreasonable.

Once again, thank you for the opportunity to review and comment on the subject draft report. The feedback that NASA received from the OIG team was greatly appreciated. If you have any questions or require additional information regarding this response, please contact Michelle Bascoe on (202) 358-1574.

Kenneth D. Bowersox

Appendix F: Report Distribution

National Aeronautics and Space Administration

Administrator
Deputy Administrator
Associate Administrator
Chief of Staff
Acting Associate Administrator, Human Exploration and Operations Mission Directorate
Director, Commercial Space Flight Development Division
Director, International Space Station
Program Manager, Commercial Crew Program
Program Manager, International Space Station

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Senate Committee on Commerce, Science, and Transportation
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House Committee on Oversight and Reform
    Subcommittee on Government Operations

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    Subcommittee on Space and Aeronautics

(Assignment No. A-19-007-00)