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NASA's Commercial Crew Program: Update on Development and Certification Efforts

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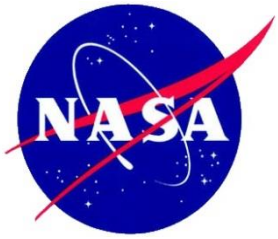

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RESULTS IN BRIEF

NASA's Commercial Crew Program: Update on Development and Certification Efforts

September 1, 2016 IG-16-028 (A-15-010-00)

WHY WE PERFORMED THIS AUDIT

Since the Space Shuttle Program ended in July 2011, the United States has lacked the domestic capability to transport crew to the International Space Station (ISS or Station), instead relying on the Russian Federal Space Agency (Roscosmos) to ferry astronauts at prices ranging from $21 million to $82 million per roundtrip. Prior to the end of the Shuttle Program, NASA began working with several U.S. companies to develop commercial crew transportation capabilities. The final phase of the Commercial Crew Program began in September 2014 when NASA selected The Boeing Company (Boeing) and Space Exploration Technologies Corporation (SpaceX) to complete development of crewed spaceflight systems and, assuming the systems meet the Agency's safety and performance requirements, receive certification to begin flying astronauts to the ISS on a regular basis.

In November 2013, we reported that although Boeing and SpaceX were making steady progress in the initial stages of development, the Commercial Crew Program faced several obstacles including an unstable funding stream, aligning cost estimates with Program schedule, providing timely requirement and certification guidance to the two companies, and increasing coordination with other Federal agencies that have a stake in manned spaceflight. We concluded that failure to address these challenges in a timely manner could significantly delay the availability of commercial crew transportation services and extend U.S. reliance on the Russians.

This report is a follow-up to our 2013 review. Our objective was to evaluate NASA's management of the Commercial Crew Program and determine if the Program is meeting cost and schedule goals. We also examined Program risks and the Agency's management of the certification process for Boeing and SpaceX. To complete this work, we reviewed internal controls and relevant laws, regulations, and policies. We also interviewed key personnel at NASA, Boeing, and SpaceX, among others.

WHAT WE FOUND

The Commercial Crew Program continues to face multiple challenges that will likely delay the first routine flight carrying NASA astronauts to the ISS until late 2018 – more than 3 years after NASA's original 2015 goal. While past funding shortfalls have contributed to the delay, technical challenges with the contractors' spacecraft designs are now driving the schedule slippages. For Boeing, these include issues relating to the effects of vibrations generated during launch and challenges regarding vehicle mass. For SpaceX, delays resulted from a change in capsule design to enable a water-based rather than ground-based landing and related concerns about the capsule taking on excessive water.

Moreover, both companies must satisfy NASA's safety review process to ensure they meet Agency human-rating requirements. As part of the certification process, Boeing and SpaceX conduct safety reviews and report to NASA on potential hazards and their plans for mitigating risks. We found significant delays in NASA's evaluation and approval of these hazard reports and related requests for variances from NASA requirements that increase the risk costly redesign work may be required late in development, which could further delay certification. Although NASA's goal is to complete its review within 8 weeks of receipt of a hazard report, the contractors told us reviews can take as long as 6 months. We also found NASA does not monitor the overall timeliness of its safety review process.

Given delays in the Commercial Crew Program, NASA has extended its contract with Roscosmos for astronaut transportation through 2018 at an additional cost of $490 million or $82 million a seat for six more seats. If the Program experiences additional delays, NASA may need to buy additional seats from Russia to ensure a continued U.S. presence on the ISS.

WHAT WE RECOMMENDED

To improve NASA's oversight of the Commercial Crew Program, we recommended the Associate Administrator for Human Exploration and Operations (1) implement procedures to monitor the timeliness of NASA's review process for hazard reports to help reduce risk to the Program's schedule and (2) coordinate with Boeing and SpaceX to document a path to timely resolution for variance requests and hazard reports that have exceeded the review period goals. In response to a draft of this report, NASA managers concurred with our first recommendation and described responsive corrective actions. Therefore, the recommendation is resolved and will be closed upon verification and completion of those actions.

NASA management partially concurred with our second recommendation, agreeing coordination with its commercial partners is necessary to ensure hazard reports and variance requests are addressed at the appropriate time and stating it will continue to have weekly discussions with the companies to develop a path for timely resolution. However, we believe NASA needs to take additional action to ensure timely review of hazard reports and avoid the possibility of costly redesign late in the development schedule. Therefore, this recommendation is unresolved pending further discussion with Agency officials.

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Acronyms

ASAP	Aerospace Safety Advisory Panel
CCtCap	Commercial Crew Transportation Capability
ER	Engineering Release
FY	Fiscal Year
ISS	International Space Station

INTRODUCTION

Since the Space Shuttle Program ended in July 2011, the United States has lacked the domestic capability to transport crew to and from the International Space Station (ISS or Station), and instead has relied on the Russian Federal Space Agency (Roscosmos). Between 2006 and 2018, NASA will pay Roscosmos approximately $3.4 billion to ferry 64 NASA and partner astronauts to and from the ISS in its Soyuz spacecraft at prices ranging from approximately $21.3 million to $81.9 million for each roundtrip.

Prior to the end of the Shuttle Program, NASA began working with several U.S. companies to develop the capability to provide safe, reliable, and cost effective crew transportation to and from the ISS and low Earth orbit.[1] The goal of the Commercial Crew Program is to foster an industry that would meet the Agency's needs as well as those of other Government and nongovernmental entities. As of May 2016, NASA had spent approximately $3.4 billion on this effort. The final phase of this effort began in September 2014 when NASA awarded the Space Exploration Technologies Corporation (SpaceX) and The Boeing Company (Boeing) firm-fixed-price contracts to complete development of their crew transportation systems and, assuming they meet the Agency's safety and performance requirements, receive certification to begin flying astronauts to the ISS on a regular basis.

In November 2013, we reported on the status of and challenges facing the Commercial Crew Program.[2] In that report, we noted the Program had received only 38 percent of its requested funding for fiscal years (FY) 2011 through 2013, and as a result, NASA had delayed the first crewed mission to the ISS from 2015 to at least 2017. We also found that although Boeing and SpaceX were making steady progress in the initial stages of development, the Program faced several obstacles, including an unstable funding stream, aligning cost estimates with Program schedule, providing timely requirement and certification guidance to Boeing and SpaceX, and coordinating with other Federal agencies that have a stake in manned spaceflight. We concluded that failure to address these challenges in a timely manner could significantly delay the availability of commercial crew transportation services and extend U.S. reliance on the Russians.

This report is a follow-up to our November 2013 report. Our overall objective was to assess NASA's progress in implementing the Commercial Crew Program. See Appendix A for details of the audit's scope and methodology.

[1] In 2004, President George W. Bush announced the Vision for Space Exploration which, 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. Thereafter, Congress enacted and the President signed the NASA Authorization Act of 2005, which directed the Agency to facilitate agreements with U.S. companies for the research and development of commercial spaceflight capabilities. In response to the Act, NASA created the Commercial Crew and Cargo Program Office in 2005. The Agency created a separate Commercial Crew Program Office in 2011.

[2] NASA Office of Inspector General, "NASA's Management of the Commercial Crew Program" (IG-14-001, November 13, 2013). We also examined the Program 2 years earlier: "NASA's Challenges Certifying and Acquiring Commercial Crew Transportation Services" (IG-11-022, June 30, 2011).

Background

Managed under NASA's Human Exploration and Operations Mission Directorate, the Commercial Crew Program has progressed through several phases of development:

- *Commercial Crew Development Round 1*. NASA's efforts to facilitate the development of a commercial crew transportation capability began in earnest in February 2010 when the Agency awarded $50 million in Space Act Agreements to five companies to help fund research and design of key technologies and systems.[3]
- *Commercial Crew Development Round 2*. Beginning in April 2011, NASA awarded Space Act Agreements worth nearly $270 million to four companies to continue development of their crewed spaceflight systems. Additional milestones were added to the agreements in September 2011, bringing their total aggregate value to $315.5 million. NASA also entered into unfunded Space Act Agreements with three other companies to provide technical assistance on space transportation concepts.[4]
- *Commercial Crew Integrated Capability*. In this phase, NASA awarded Space Act Agreements to Boeing ($480 million), SpaceX ($460 million), and Sierra Nevada ($227.5 million) to continue design and development of their transportation systems, including spacecraft, launch vehicles, and ground and mission systems. In addition to component testing and other design reviews, the goal was for Boeing and SpaceX to achieve a contractor-defined Critical Design Review by May 2014, and for Sierra Nevada to achieve a partial Critical Design Review by October 2013.[5]
- *Certification Products Contracts*. In December 2012, NASA awarded fixed-price contracts worth nearly $30 million to Boeing, SpaceX, and Sierra Nevada. The contracts covered development of certification plans, including identification of data needed to develop engineering standards, tests, and analyses of crew transportation designs. This was the first phase in which NASA awarded contracts rather than Space Act Agreements.
- *Commercial Crew Transportation Capability (CCtCap)*. In September 2014, NASA awarded fixed-price contracts worth a total of $6.8 billion to Boeing and SpaceX. These contracts include specific milestones the companies must meet to secure payment, such as completing design certification and operational readiness reviews, and are designed to culminate in certification by NASA that the companies' systems meet the Agency's safety and performance requirements and therefore are ready to transport astronauts. Before receiving final certification, each contractor will fly two test flights, the first without crew and the second with a reduced crew of

[3] Space Act Agreements – a form of "Other Transaction Authority" granted to NASA in the National Aeronautics and Space Administration Act of 1958 – 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. Space Act Agreements may be funded or unfunded. The five companies awarded funded Space Act Agreements for Commercial Crew Development Round 1 were Blue Origin, Boeing, Paragon Space Development Corporation, Sierra Nevada Corporation, and United Launch Alliance.

[4] The four companies awarded funded Space Act Agreements for Commercial Crew Development Round 2 were Blue Origin, Boeing, Sierra Nevada Corporation, and SpaceX. The three companies awarded unfunded Space Act Agreements for Commercial Crew Development Round 2 were Alliant Techsystems (ATK), Excalibur Almaz Inc., and United Launch Alliance.

[5] As defined by NASA, a Critical Design Review demonstrates a program or project design is sufficiently mature to proceed to full-scale fabrication, assembly, integration, and testing, and the technical effort is on track to complete the flight and ground system development and mission operations. A Critical Design Review is considered a key step in the process because it often reveals shortcomings a contractor must address before it finalizes its spacecraft design and begins the manufacturing process. For the Commercial Crew Program, Boeing, SpaceX, and Sierra Nevada defined their own requirements for passing Critical Design Review with review and concurrence by NASA.

two test pilots.[6] Once the contractors' systems are certified, each contractor will provide at least two, but as many as six, flights under the CCtCap contracts that are capable of transporting four to seven crew members to the ISS. As of May 31, 2016, NASA had paid Boeing $1.1 billion and SpaceX $498.7 million under the CCtCap contracts.[7]

Varied Approaches to System Design

While NASA imposed the same set of design requirements on both contractors, Boeing and SpaceX were allowed to establish additional milestones and specified target completion dates to meet both those requirements and the needs of their individual programs. As such, the contractors have different approaches to developing and launching their crewed missions.

Boeing's Launch Site at Cape Canaveral Air Force Station

Source: NASA.

Boeing plans to use a United Launch Alliance Atlas V launch vehicle to carry its CST-100 Starliner capsule to the ISS.[8] The Atlas V has a long history of successful uncrewed launches – 64 between August 2002 and July 2016, including an Orbital ATK cargo delivery to the ISS in March 2016.[9] Boeing plans to launch from the Cape Canaveral Air Force Station's Space Launch Complex 41. Boeing is assembling and processing the Starliner for launch at the Commercial Crew and Cargo Processing Facility at NASA's Kennedy Space Center. For 20 years, NASA used the facility to process the Space Shuttle between flights.

[6] The purpose of the uncrewed test flight is to validate launch vehicle and crew capsule integration, launch and flight operations, automated rendezvous and proximity operations, and docking with the ISS, as well as validate ISS interfaces. During the crewed flight, two test pilots will verify the sufficiency of flight operations, including docking with the ISS and returning to Earth.

[7] When all phases of the Commercial Crew Program are complete, Boeing will have received approximately $4.8 billion and SpaceX approximately $3.1 billion.

[8] United Launch Alliance is a joint venture between Boeing and Lockheed Martin.

[9] Although the Orbital ATK mission successfully reached the ISS, the Atlas's first stage shut down prematurely during launch. Following this incident, United Launch Alliance postponed Atlas V launches until it corrected the cause of the shutdown. Flights resumed on June 24, 2016.

SpaceX plans to launch its Crew Dragon capsule on the Falcon 9, a rocket of its own design and manufacture. Although a relative newcomer to the rocket industry, SpaceX also enjoys a successful launch rate – 28 launches between June 2010 and August 2016, including eight cargo resupply trips to the ISS, with only one failure.[10] SpaceX is modifying a former Space Shuttle launch pad at Kennedy Space Center to accommodate launches of its Falcon 9/Crew Dragon combination.

SpaceX Launch Site at the Kennedy Space Center

Source: SpaceX.

Although both Boeing and SpaceX are designing their capsules to carry up to seven crew members (or the equivalent combination of crew and cargo), they are using different landing approaches, with Boeing planning to land on a dry surface and SpaceX, at least initially, planning a water-based landing.[11] See Table 1 for a summary of the contractor profiles for Boeing and SpaceX.

Table 1: NASA Commercial Crew Contractor Profiles

	Boeing	SpaceX
		
Capsules	CST-100 Starliner	Crew Dragon
Launch vehicle	Atlas V	Falcon 9
Capability	7 crew or equivalent crew and cargo	7 crew or equivalent crew and cargo
Landing	Dry surface	Water
Total awarded under CCtCap	$4.2 billion	$2.6 billion

Source: NASA Office of Inspector General summary of Commercial Crew Program data.

[10] The failure occurred in June 2015 and involved a cargo resupply mission to the ISS that resulted in the loss of $118 million of NASA supplies. We examined NASA's response to the failure in a June 2016 report: "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).

[11] One of the ways in which SpaceX is attempting to reduce the cost of space travel is by reusing the first stage of its launch vehicle. Toward this goal, as of August 2016, SpaceX successfully landed the first stage of its Falcon 9 rocket on a drone ship on four separate occasions.

To help astronauts prepare for missions on these commercial vehicles, Boeing and SpaceX are developing training programs. See the following abstract for more information.

Astronaut Training for Commercial Crew

Boeing and SpaceX are each developing their own cockpit, controls, and training programs to prepare NASA crew members for missions on their respective commercial vehicles. In the summer of 2015, NASA selected four experienced astronauts to work with Boeing and SpaceX to provide input into "human-factor related engineering" and begin flight training on the vehicles.[a] All of these astronauts have military test pilot experience and have flown aboard Space Shuttle missions.

Boeing has created two trainers that nearly duplicate the Starliner's control panel, and plans to build additional simulators to cover all aspects of spaceflight, from boarding the spacecraft at the launch pad to safely climbing out at the end of the mission. Boeing plans to control its missions from the Johnson Space Center in Texas. SpaceX – which will control crewed missions from its factory in Hawthorne, California – has a fully mocked up Crew Dragon and a simulator at its facility.

[a] Human-factor related engineering refers to the design of machines, systems, work methods, and environments to address the safety, comfort, and productiveness of humans in a space vehicle.

Human Rating Requirements and Certification Process

"Human rating" is the process of ensuring a spacecraft or launch vehicle is capable of safely transporting humans to space. Generally, to receive a human rating from NASA a spacecraft must accommodate human needs, effectively utilize human capabilities, control hazards, manage safety risks, and, to the maximum extent possible, provide the capability to recover the crew safely from hazardous situations.

In December 2011, NASA published a series of detailed requirement, management, and certification standards to inform potential commercial crew contractors of the Agency's specific safety and human rating objectives.[12] These documents are based on the health and medical, engineering, and safety and mission assurance requirements NASA used for previous launch systems, such as the Space Shuttle, and describe the fundamental elements any new system must satisfy to receive Agency certification. According to NASA and its contractors, both Boeing and SpaceX have used this guidance to ensure they are incorporating NASA's requirements into their spacecraft designs.

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, recovery, and safe disposal or return. The process can be divided into three major steps:

[12] These documents include the following: "System Design Reference Missions" (CCT-DRM-1110, May 23, 2013), "Crew Transportation Plan" (CCT-PLN-1100, May 23, 2013), "Crew Transportation Technical Management Processes" (CCT-PLN-1120, October 25, 2013), "ISS Crew Transportation and Services Requirements Document" (CCT-REQ-1130, March 23, 2015), "Crew Transportation Technical Standards and Design Evaluation Criteria" (CCT-STD-1140, April 8, 2015), and "Crew Transportation Operations Standards" (CCT-STD-1150, July 16, 2013). All the documents have been revised since originally published in 2011.

1. The contractor develops and submits to NASA a certification plan for its crew transportation system asserting the system meets the Agency's safety, crew, and technical requirements and poses an acceptable level of risk to passengers.

2. The Commercial Crew and ISS programs evaluate and substantiate the contractor's certification plan and results.

3. NASA certifies the system once it has determined Agency requirements have been met.

Throughout the certification process, NASA personnel work closely with the contractor to clarify Agency requirements and obtain insight into the contractor's safety data and testing. The contractor provides NASA with access to relevant data – including their safety analyses – to ensure potential hazards and associated causes have been identified and sufficient controls implemented to mitigate risks. NASA also expects to perform additional analysis and independent testing in certain high-risk areas. For example, the Agency's Independent Verification and Validation Facility will review subcontractors' test plans and methodologies for software verification and validation activities to ensure testing is equivalent to NASA standards.[13] According to Commercial Crew Program personnel, final decisions regarding certification will be based both on contractor-submitted data and NASA's independent analysis of that data.

Although similar to the Space Shuttle development process in many respects, the certification process is fundamentally different in that the contractors rather than NASA develop and own the transportation systems and are responsible for executing the tasks necessary to secure certification from the Agency. According to NASA officials, this process seeks to minimize NASA's risk while maximizing contractor autonomy to innovate and achieve cost savings.

As part of the certification process and to provide insight into contractor efforts, several Commercial Crew Program officials are located at contractor facilities. Program officials also have remote and on-site access to contractor data, including

- plans, approaches, and activities for configuration management, risk management, safety and mission assurance, quality management, and systems effectiveness;
- contractor chaired review boards concerning design, technical, safety systems testing, hardware acceptance reviews, readiness reviews, and materials;
- design, testing, production, and operations schedules, work practices, documentation, and procedures;
- design, production, and operations requirements;
- flight simulations, dress rehearsals, crew training, simulation, and training for all mission phases (docking and undocking); and
- training and certification plan for crew and ground operators.

NASA prioritizes its review of contractor data by analyzing risks and reviewing contractor safety reports. For example, according to NASA material engineering personnel, the Agency used a sampling methodology that considers critical components to prioritize its review of contractor materials.

[13] Independent software verification and validation is used to review mission-critical software to improve its reliability and safety.

Risk Prioritization Process

Assessing risk – known as the risk prioritization process – is critical to any spaceflight development effort, and numerous factors are incorporated into the analysis of risk. Ensuring the timeliness and sufficiency of plans, designs, tests, analyses, and demonstrations can help ensure a program meets its targeted cost and schedule goals.

For the Commercial Crew Program, Boeing and SpaceX are contractually obligated to identify and track risks and their progress toward certification. In addition, they are required to provide NASA access to their risk systems and related data so that they can work with the Agency to address identified risks. This process was established to ensure NASA could perform a successful risk-based analysis that facilitates identification of high-risk areas in a timely manner. As part of this process, Boeing and SpaceX are required to notify the Commercial Crew Program of technical meetings, control boards, reviews, demonstrations, and tests to permit meaningful Government participation throughout the certification process. Significant risks identified by NASA, Boeing, or SpaceX are presented to the Human Exploration and Operations Mission Directorate Program Management Council during quarterly briefings for management awareness and decision making.

Further, as part of the risk prioritization process, Boeing and SpaceX conduct safety reviews and document hazards in hazard reports they submit for NASA's review. Depending on the severity of the hazard, these reports may be accompanied by a request for variance to modify or waive a NASA requirement.

Past Funding Shortfalls Have Delayed NASA's Commercial Crew Plans

As discussed in our previous report, for several years during its early development, the Commercial Crew Program received significantly less funding than requested.[14] As shown in Table 2, to date the cumulative difference between the President's budget requests for the Program and actual appropriations is approximately $1.1 billion. However, under the current CCtCap phase of the Program, Boeing and SpaceX are operating under firm-fixed price contracts, which provide a more stable cost estimate for the remaining work needed to certify the commercial crew vehicles. Further, in December 2015 – for the first time in 6 years – NASA received the full amount the President requested for the Program: $1.2 billion for FY 2016. Although not the only factor, the shortfall contributed to slippage in the Program's schedule. NASA officials said while full funding in FY 2016 will help reduce risks related to budget uncertainty, it will do little to address technical Program risks.

[14] NASA Office of Inspector General, "NASA's Management of the Commercial Crew Program," (IG-14-001, November 13, 2013).

Table 2: Commercial Crew Program Budget Requests by Fiscal Year (Dollars in Millions)

President's Budget Request	Fiscal Year												Total
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
FY 2009	$0	$0	$0	$0	$0								**$0**
FY 2010	$51	$0	$0	$0	$0	$0							**$51**
FY 2011	$51	$0	$500	$1,400	$1,400	$1,300	$1,200						**$5,851**
FY 2012	$51	$0	$321	$850	$850	$850	$850	$850					**$4,622**
FY 2013	$51	$0	$321	$397	$830	$830	$830	$830	$830				**$4,919**
FY 2014	$51	$0	$321	$397	$525	$821	$821	$821	$590	$371			**$4,718**
FY 2015	$51	$0	$321	$397	$525	$696	$848	$872	$792	$731	$172		**$5,405**
FY 2016	$51	$0	$321	$397	$525	$696	$805	$1,244	$1,185	$732	$173	$1	**$6,130**
FY 2017	$51	$0	$321	$397	$525	$696	$805	$1,244	$1,185	$732	$173	$36	**$6,165**
Final Congressional Appropriations	**$51**	**$0**	**$321**	**$397**	**$525**	**$696**	**$805**	**$1,244**	–	–	–	–	**$4,039**
Delta			($179)	($453)	($305)	($125)	($43)	$0	–	–	–	–	**($1,105)**

Source: NASA Office of Inspector General analysis of the President's budget data.

Note: The amount of funding received in prior years is in gray. Delta amounts are the differences between actual received amounts (final appropriations) versus the President's budget request, where applicable. Numbers in parenthesis are negative.

In its 2015 Annual Report, NASA's Aerospace Safety Advisory Panel (ASAP) commented on the impact of Program funding shortages, stating:

> The [Program] was underfunded during the critical early years of development. Specifically, the Program received only 57 percent of the requested funding in fiscal year (FY) 2011 through FY 2013. This underfunding in the critical early system design years resulted in a design at Critical Design Review that was not as mature as it might have been. This has also added to the program management and safety challenges. Going forward, there is high risk that the Program may not receive sufficient funding to execute the planned program. Careful attention and close cooperation among NASA, the White House, and the Congress is necessary to deliver safe and effective transportation to low Earth orbit.[15]

In addition, ASAP stated that even though both Boeing and SpaceX reported to be on track for crewed launches to the ISS in December 2017, significant challenges remained and there was a high likelihood of delays to the first test flights. ASAP also noted that hazard reporting was behind and showed a lack of design maturity at Critical Design Review, which meant the design process was going forward without the benefit of completed hazard analyses.

[15] ASAP, *Annual Report for 2015*, January 13, 2016.

MILESTONE SLIPPAGE HAS LED TO DELAYED LAUNCH DATES

The first certified flight carrying NASA astronauts to the ISS is unlikely to occur until late 2018 – more than 3 years after NASA's original 2015 goal. While past funding shortfalls have contributed to the delay, technical challenges are now driving schedule slippages. Until at least one of the commercial contractors are certified, NASA will continue to pay Russia more than $80 million a seat to transport astronauts to the Station on Russian vehicles.

Boeing and SpaceX Face Technical Challenges to Meeting Milestones

During early phases of the Commercial Crew Program, NASA's goal was to begin fully certified crewed missions to the ISS – routine commercial flights – by 2015. But following several years of funding shortfalls, the Agency established a new certification goal of 2017. However, since award of the CCtCap contracts in 2014, both Boeing and SpaceX have experienced numerous schedule revisions and slips, a common occurrence in the production of space systems.[16] In 2016, Boeing amended its schedule to reflect receipt of certification in January 2018 and the first certified flight in the spring of 2018. Conversely, SpaceX remains optimistic about its ability to meet the contract schedule and continues to work toward late 2017 for its first certified crewed mission. Notwithstanding the contractors' optimism, based on the information we gathered during our audit, we believe it unlikely that either Boeing or SpaceX will achieve certified, crewed flight to the ISS until late 2018.[17]

Boeing

Boeing's CCtCap contract initially included 23 milestones ranging from the establishment of an original requirements baseline to the final vehicle certification. Within the first 2 years of the contract, Boeing and NASA modified the contract to separate three of the milestones into multiple segments, replace one milestone, and add seven milestones related to NASA-imposed software upgrades, landing qualification tests, and hardware modifications.[18] These modifications increased the number of milestones to 34 and

[16] IG-14-001 and IG-12-021. Government Accountability Office, "NASA: Assessments of Selected Large-Scale Projects," (GAO-15-320SP, March 24, 2015).

[17] Boeing and SpaceX are required to complete one crewed test flight prior to receiving certification but this flight will not carry a full crew complement.

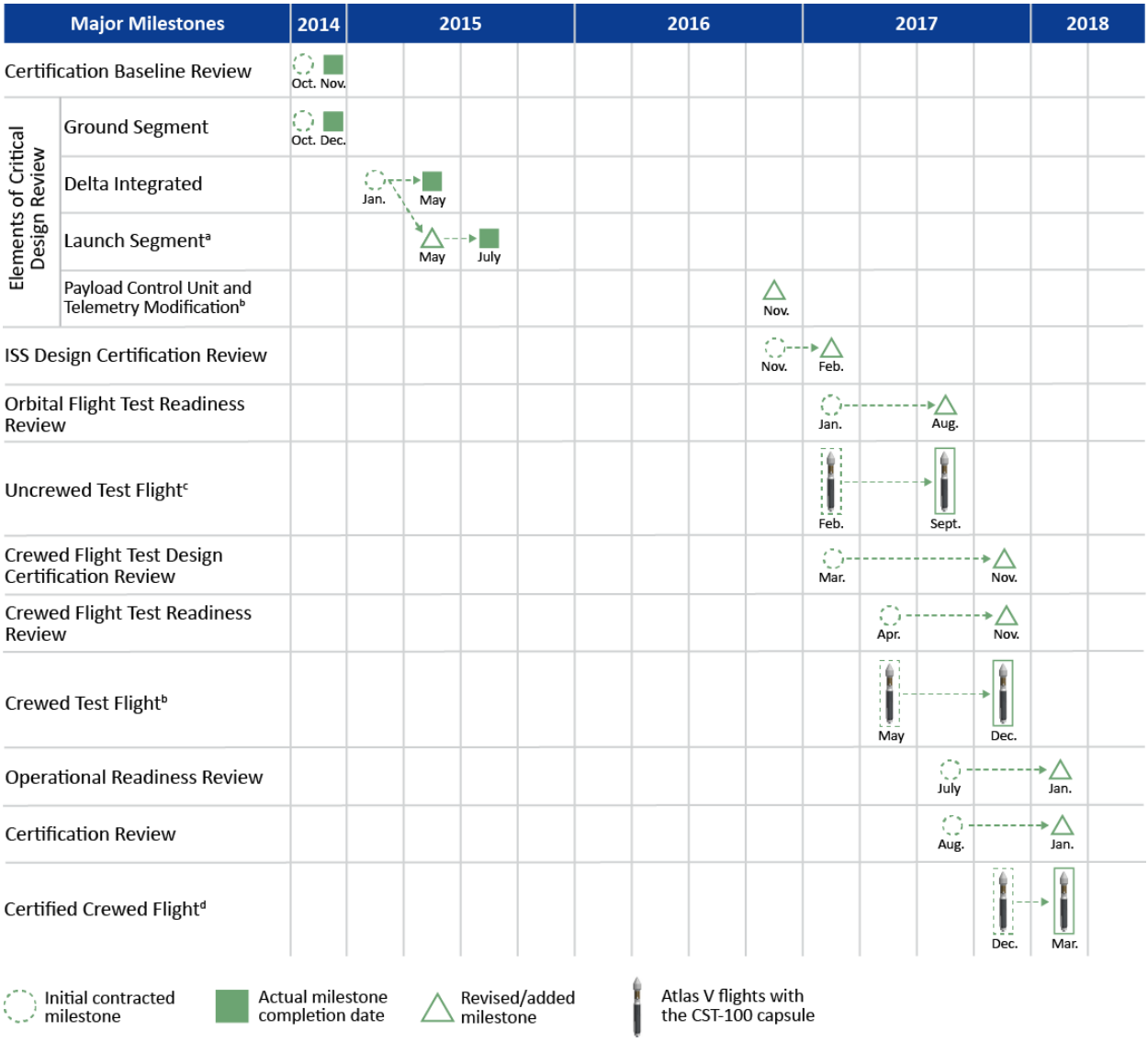
[18] Because the contractor receives payment only when it completes a milestone, dividing milestones into subcomponents enables the contractor to receive partial payments while development is ongoing.

the total contract value by approximately $46 million. As of June 2016, Boeing had completed 15 of the 34 milestones (44 percent) necessary to achieve certification and was scheduled to receive up to $1.067 billion (25 percent) of the total contract value in payment.

Of the 23 Boeing milestones, seven related to specific NASA program requirements: (1) Certification Baseline Review, (2) ISS Design Certification Review, (3) Orbital Flight Test Readiness Review, (4) Crewed Flight Test Design Review, (5) Crewed Flight Test Readiness Review, (6) Operations Readiness Review, and (7) Certification Review.[19] These milestones address development of the transportation system design, definition of the plan and schedule to obtain certification, and demonstration that the system meets all NASA requirements for uncrewed and first crewed flight tests leading up to final certification for operational flights to the ISS (for more information about these reviews, see Appendix B). As shown in Figure 1, the dates for NASA required milestones, as well as the Critical Design Review, were extended, which in turn pushed out the dates for Boeing's test flights and the first certified crewed flight.

[19] The number of milestones based on NASA requirements for Boeing differs from SpaceX because Boeing has two separate Design Certification Reviews and two Flight Test Readiness Reviews.

Figure 1: Major Boeing Milestones and Test Flight Delays (as of June 2016)



Source: NASA Office of Inspector General analysis of Commercial Crew Program milestone data.

[a] Boeing separated the Delta Integrated Critical Design Review into two parts, including the Launch Segment Critical Design Review.

[b] In April 2016, Boeing added three new milestones including a new delta Critical Design Review as a result of NASA imposed requirements related to hardware and software modifications.

[c] Boeing test flights are not contracted milestones and have historically fallen shortly after the flight test readiness reviews; therefore, these dates are Office of Inspector General estimates.

[d] The first certified crewed flight is the culmination of this contracted effort and thus tracked to measure the impact of program delays on this targeted launch. The contract includes at least two, but a maximum of six, certified flights.

As of July 2016, Boeing has completed four significant milestones:

- *Certification Baseline Review.* For this review, baseline requirements were confirmed to be in line with NASA guidance; the plan and schedule for completing design, development, test, and evaluation and certification for the system was defined; and top safety, technical, cost, and schedule risks were defined. Boeing completed this milestone in November 2014 after a 1- month delay.
- *Ground Segment Critical Design Review.* For this review, the ground segment design was determined sufficiently mature to support proceeding to full-scale fabrication, assembly, integration, and testing. Boeing completed this milestone in December 2014 after a 2-month delay.
- *Delta Integrated Critical Design Review and Launch Segment Critical Design Review.* For this review, the maturity of the design across the launch segment, spacecraft segment, and ground segment was determined appropriate to proceed to assembly, integration, and test activities. Boeing separated the review into two parts, with the Delta Integrated Critical Design Review completed in May 2015 after a 4-month delay and the Launch Segment Critical Design Review completed in July 2015 after a 2-month delay. Despite receiving formal approval to proceed from NASA, Boeing had numerous follow-up items to complete after these reviews, including increasing the level of technical expertise at reviews to maintain healthy checks and balances; assessing final launch parameters, including loads and temperatures; and determining the likelihood that Russian rocket engines may be unavailable and identifying other rocket engine options.
- *Structural Test Article Test Readiness Review Part 1.* This review was designed to ensure development of the primary structure of the capsule and launch vehicle adapter was progressing adequately. Boeing completed this milestone in December 2015 after an 8-month delay.

Boeing officials attributed the delays in achieving these milestones to (1) a 2-month delay (July 2014 to September 2014) in NASA awarding the contract; (2) the need to rearrange the order of some tasks to improve the efficiency of work flow; and (3) various technical challenges that arose after the contract was awarded. For example, Boeing has had to resolve issues relating to the effects of vibrations generated during launch, which can vary in a manner difficult to predict and can be strong enough to damage the vehicle and impact crew safety. These issues delayed the start of the Structural Test Article Test Readiness Review and Qualification Test Vehicle testing. In addition, Boeing experienced challenges with vehicle mass that affected its spacecraft design. Boeing officials told us that in retrospect its original schedule may have been too ambitious for some milestones. Given the technical challenges and contract modifications, Boeing has postponed a number of milestones planned for 2016 until 2017, including a pad abort test.

Looking forward, Boeing is scheduled to complete the final segment of Critical Design Review in November 2016. Following the Launch Segment Critical Design Review, in July 2015, NASA had provided Boeing with the approval to generally proceed with its design. However, in April 2016, one final milestone to the Critical Design Review Process was added as a result of new, NASA-imposed requirements related to hardware and software modifications. Boeing has also scheduled additional testing and certification milestones for the ISS Design Certification Review planned for February 2017 (originally scheduled for November 2016), during which the contractor will verify its capsule is capable of safely approaching, docking, mating, and departing from the Station. Thereafter, Boeing is scheduled

to conduct the Orbital Flight Test Readiness Review in August 2017 (originally scheduled for January 2017); the Crewed Flight Test Design Certification Review in November 2017 (originally scheduled for March 2017); and the Operational Readiness Review in January 2018 (originally scheduled for July 2017). Boeing's final crew transportation vehicle certification review is scheduled for January 2018, 5 months later than originally planned. However, that date is in doubt given that Boeing's crewed test flight is not projected to occur until the end of 2017. The contractor must complete the test flight and NASA must review the results of that flight before it grants certification.

Commercial Crew Program officials told us they agreed that Boeing's original schedule was aggressive as well as with the reasons it offered for the delays. In addition, they said that the qualification testing in late August 2016 may identify hardware concerns that will require redesign and therefore could lead to additional schedule delays. In particular, NASA is developing hardware that will enable the Boeing spacecraft to dock with the Station. But because of a tight testing and production schedule, NASA will have started producing this hardware prior to the qualification testing. As a result, any problems that come to light during the testing may require adjustments to hardware that is already in production. As such, further schedule slippages are anticipated, likely pushing the first certified crewed flight until late 2018.

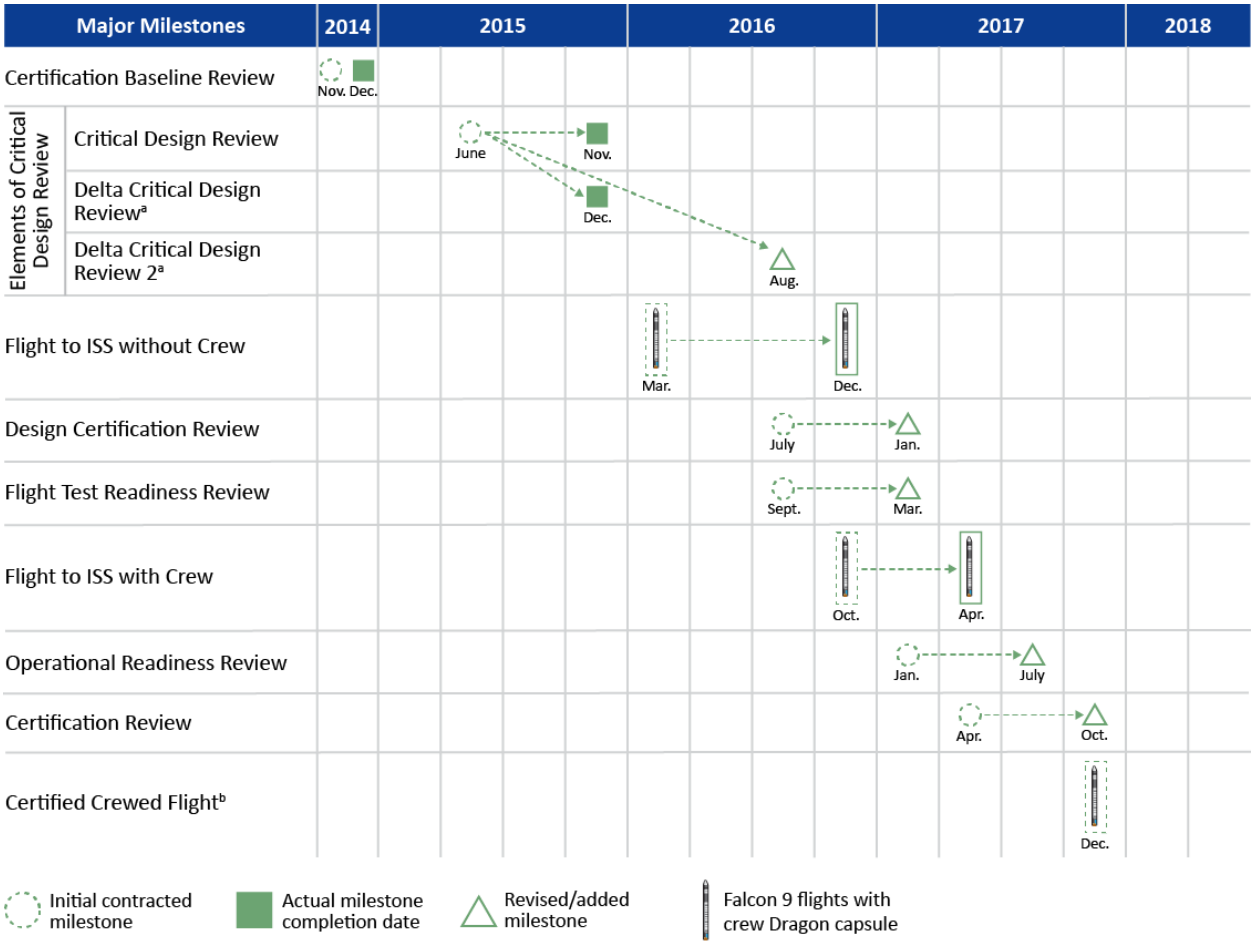
SpaceX

SpaceX's CCtCap contract initially included 18 milestones ranging from establishment of the original requirements baseline to final vehicle certification. During the first year of the contract, SpaceX and NASA agreed to separate SpaceX's Propulsion Module Testing and Critical Design Review into multiple segments, which increased the total milestones to 21.[20] As of June 2016, SpaceX had completed eight milestones (38 percent), five less than planned under the original schedule, and received $469 million (18 percent) of the total contract value.

Of the 18 SpaceX milestones, five related to specific NASA program requirements: (1) Certification Baseline Review, (2) Design Certification Review, (3) Flight Test Readiness Review, (4) Operations Readiness Review, and (5) Certification Review. As with Boeing, these reviews are intended to ensure SpaceX has developed its transportation system design, defined its plan and schedule, and demonstrated that the system meets NASA requirements for one uncrewed and one crewed flight test leading up to final certification for operational flights to the ISS (see Appendix C for detailed descriptions of these review). As shown in Figure 2, the dates for all of these milestones have also been extended, which has in turn delayed the two test flights. As of June 2016, SpaceX had not revised its schedule and was still planning its first certified crewed flight in December 2017. However, given the delays in achieving milestones necessary to receive certification, we believe it highly unlikely SpaceX will meet this goal.

[20] The total contract cost did not increase as a result of the increase in total number of milestones.

Figure 2: Major SpaceX Milestones and Test Flight Delays (as of June 2016)



Source: NASA Office of Inspector General analysis of Commercial Crew Program milestone data.

[a] Critical Design Review was separated into three parts: (1) Critical Design Review, (2) Delta Critical Design Review, and (3) Delta Critical Design Review 2.

[b] As of June 2016, SpaceX had not revised its anticipated first certified crew flight from December 2017. The first certified crewed flight is the ultimate culmination of this contracted effort and thus tracked to measure the impact of program delays on this targeted launch. The contract includes at least two, but a maximum of six, certified flights.

As of July 2016, SpaceX has completed four significant milestones:

- *Certification Baseline Review.* For this review, baseline requirements were confirmed to be in line with NASA guidance; the plan and schedule for completing design, development, test, and evaluation and certification for the system was defined; and top safety, technical, cost, and schedule risks were defined. SpaceX completed this milestone in December 2014 after a 1-month delay.
- *Initial Propulsion Module Testing.* This test of a flight-representative spacecraft propulsion system was conducted in October 2015 after a 6-month delay.
- *Critical Design Review, Delta Critical Design Review, and Delta Critical Design Review 2.* These reviews are intended to ensure the Falcon 9/Crew Dragon design satisfied all applicable requirements; assess the maturity of the system to determine whether it is appropriate to

proceed to fabrication, assembly, integration, and testing; and secure NASA approval of the contractor's product verification and validation plans. SpaceX completed the first part of the review, which focused on the design of its launch vehicle and uncrewed ground systems, in November 2015 after a 5-month delay. It completed the second part, which focused on the capsule and mission operations in December 2015 as scheduled. SpaceX is planning to undertake the third part of the review, which will focus on any remaining Dragon components, an updated seat design, and crewed ground systems, in August 2016. In total, SpaceX anticipates completing all three components 13 months later than originally planned.

- *Propulsive Descent Test Complete.* This test of the Pad Abort Test Vehicle to perform controlled propulsive burns in a dynamic environment was completed in December 2015 after a 3-month delay.

SpaceX also has not yet completed all milestones associated with Critical Design Review – a stage in the development process that often reveals shortcomings a contractor must address before it proceeds with full-scale fabrication, assembly, integration, and testing of its capsule. SpaceX officials attributed the delays to capsule design challenges, specifically switching from a design that used a ground-based landing to a water-based landing design in the first year after contract award. This resulted in significant challenges, including complications with vendor components and the effectiveness of the integrated landing system designed to ensure parachutes work and the capsule does not take on excessive water after landing in the ocean. In addition, SpaceX stated it had underestimated the number of interfaces to the weldment and radial bulkheads, which also resulted in design delays.[21] The Government Accountability Office recently reported that several of the SpaceX key subsystem vehicle designs are not yet mature, finding that SpaceX does not plan to complete seat designs until mid-2016.[22]

Once SpaceX completes the final phase of Critical Design Review, it must meet several additional milestones, including the uncrewed flight test currently scheduled for December 2016 (originally scheduled for March 2016); the Design Certification Review in January 2017 (originally scheduled for July 2016); a Flight Test Readiness Review in March 2017 (originally scheduled for September 2016); the crewed test flight in April 2017 (originally scheduled for October 2016); and the Operations Readiness Review in July 2017 (originally scheduled for January 2017). NASA hopes to conduct SpaceX's final certification review in October 2017 (originally scheduled for April 2017).

NASA Program officials anticipate SpaceX will encounter additional delays on the path to certification. For example, in January 2015, the tunnel that provides a passageway for astronauts and cargo between the Dragon and the ISS was reported to have cracked during the heat treatment phase of the manufacturing process. As a result, SpaceX delayed qualification testing by approximately one year to better align the tests as SpaceX moves toward certification. SpaceX has also experienced ongoing issues with stress fractures in turbopumps that must be resolved prior to flight.[23] Additionally, SpaceX has not yet completed parachute system level testing which may reveal issues that would require redesign that could further delay the test flights. Accordingly, we anticipate additional schedule slippage and do not expect certified flights by SpaceX earlier than late 2018.

[21] A weldment is formed by welding together an assembly of pieces. For the SpaceX vehicle, the radial bulkheads attach to the lower part of the weldment and separate the housing for thrusters, propellant tanks, parachutes, and other vital systems.

[22] Government Accountability Office, "NASA: Assessments of Major Projects" (GAO-16-309SP, March 30, 2016).

[23] A turbopump provides fuel to the main combustion chamber of an engine.

As stated earlier, SpaceX is scheduled to complete the final phase of its Critical Design Review in August 2016. As part of this review, SpaceX and NASA will assess lessons learned from the SpaceX's failed June 2015 cargo mission. According to the Associate Administrator for Human Exploration and Operations Mission Directorate, the accident provided an opportunity to gain a better understanding of weaknesses in SpaceX's rocket design, which in turn can be used to inform its crew design. Although SpaceX officials told us that the mishap has not delayed its crew development efforts because it had built sufficient margin into the schedule, they also noted the lack of margin remaining to accommodate any additional unexpected issues that may arise.

Falcon 9 Rocket Minutes Prior to Launch Failure

Source: NASA.

IMPROVEMENTS NEEDED TO ENSURE TIMELY REVIEWS OF CONTRACTOR DEVELOPMENT EFFORTS

NASA is responsible for managing the certification process for the Boeing and SpaceX commercial crew transportation systems to ensure they meet Agency human rating requirements. Timely insight into the contractors' activities is vital to ensure this process proceeds on schedule and within the agreed-upon budget. As part of the certification process and to provide insight into contractor efforts, Boeing and SpaceX conduct safety reviews and develop reports on potential hazards and the controls they have put in place to mitigate them (hazard reports) for NASA's review. We identified significant delays in NASA's evaluation and approval of these hazard reports and found the Agency does not monitor the overall timeliness of the process. These delays increase the risk that costly redesign work may be required late in development, which would further delay final certification and leave NASA reliant on Russia for crew transportation to the ISS.

Timeliness of NASA's Process for Assessing Contractor Safety Data

NASA has postponed resolution of a significant number of safety reviews until Boeing and SpaceX complete their designs and better define verification activities for identified hazards. This has placed additional schedule pressure on NASA's safety review cycle and has the potential to impact the timing of final certification. During the safety reviews, NASA officials analyze contractor data to evaluate the probability and effect of potential failures as well as contractor requests for exceptions (variances) to requirements. While NASA has a goal of completing reviews within 8 weeks of receipt of a hazard report, Boeing and SpaceX told us it can take as long as 6 months for the Agency to complete these reviews. Moreover, the Program does not monitor the overall timeliness of the reviews and officials acknowledged they are not meeting the 8-week goal.

Hazard Reporting and Variance Requests

Modeled after the ISS process, the contractor's hazard reports identify potential safety concerns and may result in the contractor requesting a variance to Agency requirements when its design does not meet NASA's requirements. The process begins with the contractor notifying NASA that a hazard report is ready for review.[24] Most reports are evaluated by the Commercial Crew Program Control Board, with issues relating to the ISS referred to the Space Station Program Control Board. In some cases both

[24] Boeing submitted its first hazard report in February 2015, and SpaceX in June 2015.

Boards may evaluate the issue.[25] Within approximately 5 weeks, Board comments are sent to the contractor and, when necessary, meetings are held with the contractor to discuss the issue. At the end of the 8-week period, the goal is for the report to either be updated and approved by the Board or returned to the contractor for further work. However, some hazard reports take longer to review because of their complexity. All hazard reports have to be approved before the contractor can receive certification.

In addition to reviewing hazard reports, the Boards also review requests for variances from NASA requirements. NASA classifies variances as exceptions, deviations, or waivers.[26] For example, the contractor could request a variance based on test results indicating that although a system component did not meet a specific Agency requirement, the probability or effect of a potential failure is not significant or has been mitigated. During these reviews, the Commercial Crew Program Control Board and/or Space Station Program Control Board assess the potential effect on other systems of granting the variance and determine whether the contractor has adequately mitigated the potential hazard to bring the risk of failure to an acceptable level. Any NASA reviewing organization not satisfied with a determination on a variance request can appeal to a higher authority, up to the NASA Administrator which can extend the review process.

Resolving Contractor Hazard Reports and Variance Requests

The Commercial Crew Program established an aggressive 8-week goal for completing reviews of hazard reports. As noted in our 2013 Commercial Crew Program audit report, similar assessments have taken as long as 9 months, and NASA officials told us that the review process for Agency projects like Ares I took even longer.[27] Commercial Crew Program officials acknowledge the reviews have taken longer than anticipated and identified the process as a significant risk to the Program's overall schedule. In addition, although NASA has dealt with the majority of variance requests in a timely manner, several variance requests have yet to be resolved and if denied, could lead to significant redesigns late in the development schedule.

Boeing submitted the first hazard report in February 2015, and, as of June 2016, Boeing and SpaceX have submitted a combined 172 reports. To date, NASA has reviewed 134 of these submissions and tentatively approved 105 (about 78 percent); however, almost all of the tentative approvals are contingent on receipt of additional verification testing results, and NASA has yet to decide on the remaining 29 reports pending completion of additional analysis and testing by Boeing and SpaceX.[28]

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[25] The Commercial Crew Program Control Board and Space Station Program Control Board are both comprised of personnel from the Commercial Crew and ISS programs, as well as from supporting organizations such as Mission Management and Integration, Spacecraft Systems, Launch Vehicle Systems, and Human Health and Performance.

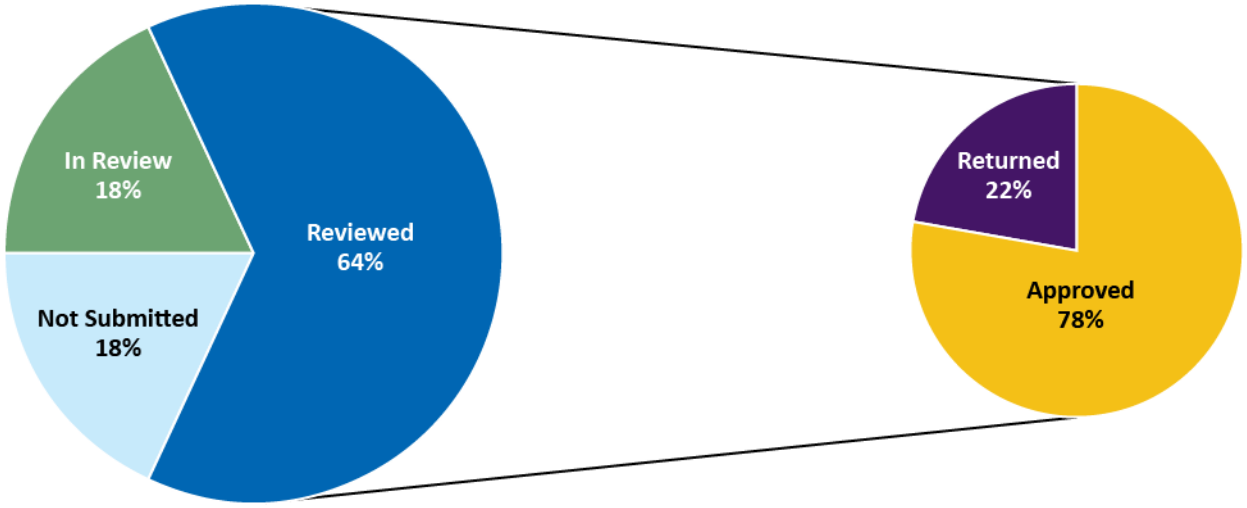
[26] IG-14-001. NASA defines deviations as requests made during the formulation, planning, or design stages of a program to address expected situations and provide temporary relief from a specific requirement in advance; exceptions as permanent relief from a specific requirement that may be requested at any time during the life cycle of a program; and waivers as temporary relief from a specific requirement after the baseline system has been approved.

[27] Ares I was the launch vehicle being developed as part of the Constellation Program before the Program was canceled in October 2011.

[28] As of June 2016, Boeing expects it will submit 119 hazard reports total, including 106 that have already been submitted. NASA has reviewed 93 of Boeing's submitted reports, approved 71, and rejected the other 22 pending changes. SpaceX expects to submit 90 hazard reports total, including 66 that have already been submitted. NASA has reviewed 41 of SpaceX's submitted reports, approved 34, and rejected 7 pending changes.

Because a significant number of reports are still in the review process, a backlog has developed. Moreover, Boeing and SpaceX are expected to submit additional reports before the development process is completed. If the contractors are required to make changes to their systems based on NASA's decisions on the reports, there could be more schedule delays. Figure 3 illustrates the overall status of the hazard reporting process as of June 2016.

Figure 3: Status of Hazard Report Process, as of June 2016



Source: NASA Office of Inspector General analysis of hazard report status data.

We also found the Commercial Crew Program is not monitoring the timeliness of its hazard report review process. Officials from the Commercial Crew Program Control Board and the Space Station Program Control Board told us their primary concern is safety, which requires a comprehensive review of each potential hazard. Although the Commercial Crew Program set the 8-week timetable to review hazard reports, they do not monitor compliance with this goal. We agree safety should be NASA's primary consideration; however, we believe timely review of hazard reports contributes to rather than detracts from safety concerns and monitoring progress of this process would provide management with greater visibility of contentious issues. Too many hazard reports left to the end of the process could result in reports getting less attention than they deserve or create pressure to approve variances to avoid design changes that could lead to cost increases or schedule delays.[29]

Boeing and SpaceX personnel expressed concern about the possibility that delayed review of hazard reports and variance requests could lead to redesigns late in the development schedule. For example, Boeing submitted a variance request in October 2014 related to the requirement for electricity usage while docked with the ISS. NASA wants more mature measurements based on the final design of the system before it grants the variance. If the variance is not approved, Boeing will have expended time testing a design NASA ultimately does not approve, potentially resulting in further schedule delays.

[29] This concern is similar to an issue identified in the NASA Office of Inspector General's 2013 Commercial Crew report where we found that NASA failed to monitor its timeliness in considering contractor's requests for variances. At our recommendation, NASA began monitoring the timeliness of this process and although NASA still experiences delays with a few specific variances, the overall timeliness of its reviews has significantly improved.

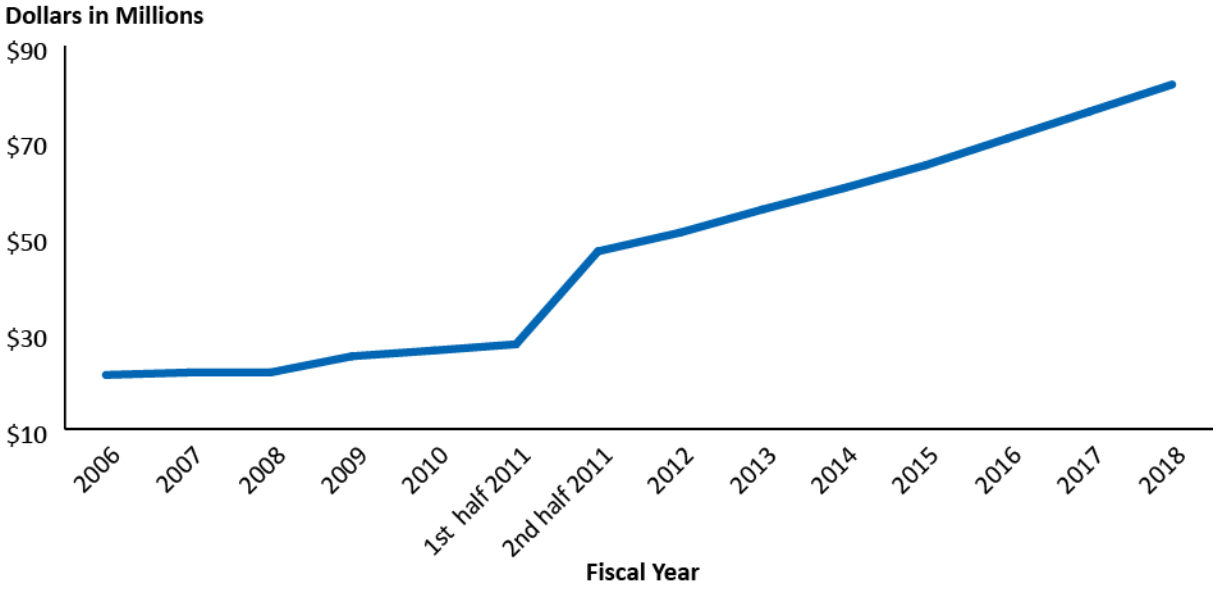
Delays in the Safety Review Process Place Additional Pressure on Schedule for Final Certification

In its January 2016 report, the ASAP expressed concerned that without adequate hazard reports, commercial crew design is proceeding without the benefit of an information source that might provide an opportunity to mitigate potentially serious hazards.[30] We share this concern and believe the mishap SpaceX experienced with its June 2015 cargo resupply mission to the ISS illustrates the criticality of these safety reviews. Specifically, the mishap showcased the importance of additional controls in the identification and mitigation of potential hazards on crewed flights. While the Commercial Cargo Program only required hazard reports for mission cargo and flight phases near the ISS, the reporting process for the Commercial Crew Program requires NASA engineers to take a closer look at potential hazards and to work in concert with Boeing and SpaceX to ensure timely and proper mitigation of any identified concerns. It is critical that NASA ensure safety-related concerns are sufficiently addressed. It is also important that such concerns are addressed in a timely manner, as delays in resolving hazard reports or processing variance requests could result in redesign efforts in 2017 or even 2018 and therefore severely impact the Commercial Crew Program's schedule. Ultimately, Boeing and SpaceX may be faced with delaying final design production or moving forward with a design to which NASA has not fully agreed.

Russian Crew Transportation Services Have Been Costly

Until a domestic commercial crew capacity is available, NASA will continue to rely on Russia to transport crew to the ISS. As shown in Figure 4, the roundtrip cost for a seat on the Soyuz has increased approximately 384 percent over the last decade from $21.3 million in 2006 to $81.9 million under the most recent contract modification signed in August 2015. Under the 2015 contract, NASA will pay approximately $491.2 million for six seats in 2018.

Figure 4: Soyuz Seat Cost by Fiscal Year



Source: NASA Office of Inspector General analysis of Soyuz seat costs.

[30] ASAP, Annual Report.

Table 3 shows the total number of Soyuz seats NASA has contracted for and the total cost of those seats by calendar year.

Table 3: Soyuz Seat Total Cost Per Launch Calendar Year

Launch (Calendar Year)	Number of Seats	Total Cost
2006	2	$50,200,000
2007	1	$21,800,000
2008	1	$21,800,000
2009	6	$150,997,000
2010	6	$158,550,000
2011	6	$224,426,636
2012	6	$306,000,000
2013	6	$335,070,000
2014	6	$361,875,600
2015	6	$364,868,040
2016	6	$424,045,824
2017	5	$381,641,240
2018[a]	7	$567,500,524
Total	**64**	**$3,368,774,864**

Source: NASA Office of Inspector General analysis of Soyuz cost data provided by NASA.

[a] The 2018 amount includes six seats purchased in the August 2015 contract modification as well as an additional seat purchased in an April 2014 contract modification.

Had the Agency met its original goal of securing commercial crew transportation by calendar year 2015, NASA could have avoided paying Russia close to $1 billion for Soyuz seats in 2017 and 2018, even factoring in the purchase of some seats in 2016 to cover the expected transition period.

CONCLUSION

The Commercial Crew Program continues to face multiple challenges to accomplishing its objectives, most prominently addressing the significant technical issues that have replaced funding shortfalls as the main contributor to schedule delays. Consequently, the start of regular crewed missions to the ISS by Boeing or SpaceX before late 2018 is unlikely.

Moreover, approval of the companies' hazard reports has been identified as a material risk to the Program's schedule. If the reports cannot be completed and reviewed in a timely manner, the companies may be required to perform redesign work late in the development schedule, resulting in additional delays and higher costs.

Given the delays in initiating a U.S. capacity to transport crew to the ISS, NASA has extended its contract with the Russian Space Agency for astronaut transportation through 2018 at an additional cost of $490 million. If the Commercial Crew Program experiences additional delays, NASA may need to buy additional seats from Russia to ensure a continued U.S. presence on the ISS.

RECOMMENDATIONS, MANAGEMENT'S RESPONSE, AND OUR EVALUATION

To improve NASA's oversight of the Commercial Crew Program, we recommended the Associate Administrator for Human Exploration and Operations

1. implement procedures to monitor the timeliness of NASA's review process for hazard reports to help reduce risk to the Program's schedule; and
2. coordinate with Boeing and SpaceX to document a path to timely resolution for variance requests and hazard reports that have exceeded the review period goals.

We provided a draft of this report to NASA management who concurred with our first recommendation and described corrective actions planned to address it. We found the planned actions responsive and will close the recommendation upon verification and completion of those actions.

NASA management partially concurred with our second recommendation, agreeing coordination with its commercial partners is necessary to ensure hazard reports and variance requests are addressed at the appropriate time and stating it will continue to have weekly discussions with the companies to develop a path for timely resolution. However, we continue to believe NASA needs to take actions to ensure timely review and avoid the possibility of costly redesign late in the development schedule. Therefore, this recommendation is unresolved pending further discussion with Agency officials.

Management's comments are reproduced in Appendix D. Their technical comments and sensitivity concerns provided by management have also been incorporated, as appropriate.

Major contributors to this report include, Laura Nicolosi, Mission Support Director; Karen VanSant, Project Manager; Troy Zigler; Susan Bachle; Rebecca Carpenter; and Michael Beims.

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 May 2015 through July 2016 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 evaluate NASA's management of the Commercial Crew Program and to determine if the Program is meeting its planned cost and schedule goals. We also examined Program risks and the management of certification requirements. To complete this work, we reviewed internal controls as they relate to the overall objective. We also interviewed key personnel within NASA's Human Exploration and Operations Mission Directorate, Commercial Crew Program officials at Kennedy Space Center and Johnson Space Center, and officials from Boeing, SpaceX, and the Federal Aviation Administration.

To determine NASA's management of the Commercial Crew Program, progress made, and challenges hindering the successful implementation of the Program, we reviewed relevant laws, regulations, and policies in order to determine compliance with required guidance and best practices. We obtained and reviewed prior reports and studies related to NASA's ability to address the development and collaboration challenges of the Program. We reviewed Federal and NASA policies, regulations, and instructions to determine the requirements and criteria for the Crew Program. The documents we reviewed included the following:

- Pub. L. No. 111-267, "National Aeronautics and Space Administration Authorization Act of 2010," October 11, 2010
- Pub. L. No. 111-314, "Enactment of Title 51 – National and Commercial Space Launch Programs," December 18, 2010
- Pub. L. No. 113-235, "Consolidated and Further Continuing Appropriations Act, 2015," December 16, 2014
- Pub. L. No. 114-90, "U.S. Commercial Space Launch Competitiveness Act," May 12, 2015
- NASA Policy Directive 1050.1I, "Authority to Enter into Space Act Agreements," December 23, 2008
- NASA Procedural Requirement 7150.5E, "NASA Space Flight Program and Projects Management Requirements," August 14, 2012
- NASA Procedural Requirement 87001.E, "NASA's Policy For Safety and Mission Success," October 28, 2008
- NASA Procedural Requirement 8705.2B, "Human-Rating Requirements for Space System," May 6, 2008
- Aerospace Safety Advisory Panel, *Annual Report for 2015*, January 13, 2016

We reviewed the hazard reporting process and analyzed the number of hazard reports submitted by Boeing and SpaceX. As part of our review, we analyzed the requirements for verifying activity or event traces provided by Boeing and SpaceX as part of their deliverable products. Our analysis was built on the number of verified activities or events linked to a given requirement and the number of requirements linked to a given verified activity or event. Boeing and SpaceX requirements for verifying activity or event planning appeared reasonable based on our trace analysis and where the contractors were at in the development process.

Use of Computer-Processed Data

We used computer-processed data to assess the costs of the Commercial Crew Program. We collected computer-processed cost data related to the Program in the form of milestone payment data from the beginning of the Program through June 2016. Program officials downloaded the data from NASA's financial management program and provided this data in Microsoft Excel. 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 the Commercial Crew Program that was maintained in NASA's risk management system and the contractors' risk systems. We assessed that the cost and data we received was sufficiently reliable, but we did not rely solely on the computer-processed data to support our findings, conclusions, or recommendations. Therefore, we believe the cost and risk information we obtained is sufficiently reliable for this report.

We also used computer-processed data to assess the contractors' processes for ensuring that NASA's human-rating requirements were being met. Specifically, we traced the contractors' identified testing procedures to NASA's certification requirements to ensure that all requirements were covered by one or more of the testing procedures. Additionally we checked the reasonableness of the tracing data. The data were downloaded as Excel spreadsheets from the Commercial Crew Program Office's website and those Excel spreadsheets were supplied by Boeing and SpaceX to the Program by extracting portions of each contractor's requirements and testing database into these spreadsheets. The tracing and reasonableness of the tracing appeared as expected for a program in the Critical Design Review timeframe, so we believe the tracing information is sufficiently reliable for this report.

Review of Internal Controls

We evaluated the internal controls associated with the management of the Commercial Crew Program. 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, the NASA Office of Inspector General (OIG) and the Government Accountability Office (GAO) have issued 19 reports of significant relevance to the subject of this report. Unrestricted reports can be accessed at http://oig.nasa.gov/audits/reports/FY16 and http://www.gao.gov, respectively.

NASA Office of Inspector General

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)

Commercial Cargo: NASA's Management of Commercial Orbital Transportation Services and ISS Commercial Resupply Contracts (IG-13-016, June 13, 2013)

NASA's Challenges to Meeting Cost, Schedule, and Performance Goals (IG-12-021, September 27, 2012)

NASA's Challenges Certifying and Acquiring Commercial Crew Transportation Services (IG-11-022, June 30, 2011)

Review of NASA's Acquisition of Commercial Launch Services (IG-11-012, February 17, 2011)

Government Accountability Office

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

NASA: Assessments of Selected Large-Scale Projects (GAO-15-320SP, March 24, 2015)

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

NASA: Assessments of Selected Large-Scale Projects (GAO-13-276SP, April 17, 2013)

Commercial Space Launches: FAA Should Update How It Assesses Federal Liability Risk (GAO-12-889, July 19, 2012)

Commercial Space Transportation: Industry Trends, Government Challenges, and International Competitiveness Issues (GAO-12-836T, June 20, 2012)

NASA: Significant Challenges Remain for Access, Use, and Sustainment of the International Space Station (GAO-12-587T, March 28, 2012)

NASA: Assessments of Selected Large-Scale Projects (GAO-12-207SP, March 1, 2012)

National Aeronautics and Space Administration: Acquisition Approach for Commercial Crew Transportation Includes Good Practices, but Faces Significant Challenges (GAO-12-282, December 15, 2011)

Key Controls NASA Employs to Guide Use and Management of Funded Space Act Agreements Are Generally Sufficient, but Some Could Be Strengthened and Clarified (GAO-12-230R, November 17, 2011)

NASA: Assessments of Selected Large-Scale Projects (GAO-11-239SP, March 3, 2011)

APPENDIX B: SUMMARY OF BOEING CONTRACT MILESTONES AND DATES

Milestone Number	Description	Original Contracted Estimated Completion Date	Added/Split Milestone Estimated Completion Date[a]	Revised, Actual ,or Upcoming Completion Dates[b]
1	**Certification Baseline Review:** A review to ensure baseline requirements identified are in line with NASA's guidance; identify the current Crew Transportation System design baseline; define the plan and schedule to complete design, development, test, evaluation, and certification for the Crew Transportation System design, production, and operations; and define top safety, technical, cost and schedule risks.	Sept.– Oct. 2014		Nov. 2014
2	**Ground Segment Critical Design Review:** A review to determine that maturity of the ground segment is appropriate to support proceeding with full-scale fabrication, assembly, integration, and test.	Oct. 2014		Dec. 2014
3	**Phase 2 Safety Review – Boeing Internal Review (Phase II Safety Review – Part B):** Review of the hazard reports/analyses, including cause identification, development of controls, and specific safety verification methods.	Dec. 2014		Jan. 2015
4	**Phase 2 Safety Review – Part B – NASA Safety Technical Review Board Readiness Review (Integrated Systems):** Split milestone from the Phase 2 Safety Review – Part B (Integrated Systems) milestone.		Feb. 2015	Mar. 2015
5	**Phase 2 Safety Review – Part B – NASA Safety Technical Review Board 80 % Completion (Integrated System):** Split milestone from the Phase 2 Safety Review – Part B (Integrated Systems) milestone.		June 2015	July 2015
6	**Delta Integrated Critical Design Review:** A review to determine that maturity of the design across launch segment, spacecraft segment, and ground segment is appropriate to proceed to assembly, integration, and test activities.	Jan. 2015		May 2015
7	**Launch Segment Critical Design Review:** Split milestone from the Integrated Critical Design Review.		May 2015	July 2015

Milestone Number	Description	Original Contracted Estimated Completion Date	Added/Split Milestone Estimated Completion Date[a]	Revised, Actual ,or Upcoming Completion Dates[b]
8	**Qualification Test Vehicle Production Readiness Review:** A review to verify that facilities, processes, and contingency plans are ready to begin spacecraft assembly operations.	Mar. 2015		Aug. 2015
9	**Checkout and Control System Activation/Validation Tests Complete:** Provide quick-look report briefing of Checkout and Control System activation and validation testing documenting test results and open work required for system to be ready to support Qualification Test Vehicle acceptance testing.	July 2015		Sept. 2015
10	**Qualification Test Vehicle Integrated Readiness Review:** A review to ensure test hardware, test plans, procedures, facilities, support equipment, and any required test support software are progressing in development to support planned test activities.	Aug. 2015		Dec. 2015
11	**Structural Test Article Test Readiness Review Part 1:** A review to ensure the test article is progressing in development.	Apr. 2015		Dec. 2015
12	**Structural Test Article Test Readiness Review Part 2:** Split milestone from Structural Test Article Test Readiness Review Part 1.		Feb. 2016	May 2016
13	**Flight Software Demonstration Nominal Launch, Docking, and De-Orbit:** A demonstration of the spacecraft flight software's ability to autonomously perform the mission for a nominal launch, rendezvous, docking, undocking, and de-orbit sequence.	Oct. 2015		Dec. 2015
14	**Orbital Flight Test Configuration, Performance, and Weight Status Report:** A review of preliminary report that includes launch vehicle configuration, Spacecraft configuration, integrated flight vehicle weight, performance estimate, and performance margins for the flight test mission.	Dec. 2015		Feb. 2016
15	**Mission Control Center Integrated Simulation System Acceptance Review:** An evaluation summary of Mission Control Center system validation test results, anomalies, and open work plans needed to achieve operational readiness to support training and integrated simulations.	Jan. 2016		Feb. 2016

Milestone Number	Description	Original Contracted Estimated Completion Date	Added/Split Milestone Estimated Completion Date[a]	Revised, Actual ,or Upcoming Completion Dates[b]
16 (Canceled)	**Qualification Test Vehicle Test Readiness Review:** A review to verify all requirements changes are complete, test article as-built configuration, test procedures are complete and approved, facilities and support equipment readiness to support test, all personnel have the required training, and review test based hazards to ensure controls are incorporated. (Canceled)	Apr. 2016 (Canceled)		Apr. 2016 (Canceled)
16	**Ground Verification Test and Environmental Qualification Test, Test Readiness Review:** Replaced the Qualification Test Vehicle Integrated Readiness Review, per Boeing's request. A review to ensure readiness to start Ground Verification Test and Environmental Qualification Test by verifying all requirements changes are complete, targeted test article as-built configurations will support objectives of tests, facilities and support equipment readiness to support test, all personnel supporting have the required training, and review of test based hazards to ensure proper controls are being incorporated.		Aug. 2016	
17	**Integrated Parachute System Drop Tests 1 and 2:** A complete integrated parachute drop test that will validate parachute system deployment sequence, timing and performance in preparation for the Pad Abort Test.	June 2016		June 2016
18	**Orbital Flight Test Flight Operations Review:** A review to evaluate and baseline flight operations products to ensure the safe and accurate implementation of mission requirements.	Aug. 2016		Feb. 2017
19	**Spacecraft Servicing Operational Readiness Review:** A review to demonstrate the readiness of ground support facilities and personnel to execute the planned objectives and requirements of flight and stage.	Nov. 2016		Nov. 2016
20	**ISS Design Certification Review (Delivery Milestone):** A review to demonstrate that the Crew Transportation System and operations meet all applicable requirements; demonstrate schedule performance; and define top safety, technical, cost, and schedule risks.	Nov. 2016		Feb. 2017

Milestone Number	Description	Original Contracted Estimated Completion Date	Added/Split Milestone Estimated Completion Date[a]	Revised, Actual ,or Upcoming Completion Dates[b]
21	**Service Module Hot Fire Launch Abort Test:** A complete launch abort engine firings to validate propulsion system performance in preparation for Pad Abort Test.	Sep. 2016		Jan. 2017
22	**ISS Software Interface Control Document – Boeing Internal Implementation Plan for Engineering Release (ER) 8.0/ER 9.0:** Milestone added due to NASA imposed software upgrades.		July 2016	
23	**Interim Review of Water/Land Landing Qualification:** Milestone added at NASA's request to conduct a review of the water/land landing qualification tests to ensure they are progressing and to incorporate any deviations of the plans that may be warranted.		Oct. 2016	
24	**ER 8.0 Release:** Milestone added due to NASA imposed software upgrades.		Nov. 2016	
25	**Pad Abort Test Complete:** A review of quick look report on completion of Pad Abort Test.	Dec. 2016		Oct. 2017
26	**Orbital Flight Test Readiness Review:** A review that demonstrates readiness to conduct an uncrewed Orbital Flight Test and defines a risk baseline for flight test activities.	Jan. 2017		Aug. 2017
27	**Crewed Flight Test Design Certification Review:** A review of the final system qualification performance and associated analyses to support Verification Closure Notices closures that were exceptions at the ISS Design Certification Review and review all open actions.	Mar. 2017		Nov. 2017
28	**Crewed Flight Test Readiness Review:** A review to demonstrate readiness to conduct a crewed flight test and define risk baseline for crewed flight test activities.	Apr. 2017		Nov. 2017
29	**Operational Readiness Review:** A review to demonstrate that the actual Crew Transportation System characteristics and procedures used in operations reflect the deployed state of the System. The review evaluates all project and support hardware, software, personnel, and procedures to ensure flight and associated ground system are in compliance with requirements.	July 2017		Jan. 2018
30	**ER 9.0 Release:** Milestone added due to NASA imposed software upgrades.		Apr. 2017	

Milestone Number	Description	Original Contracted Estimated Completion Date	Added/Split Milestone Estimated Completion Date[a]	Revised, Actual ,or Upcoming Completion Dates[b]
31	**Boeing Internal Payload Fault Isolation and Telemetry Implementation Plan:** A plan to ensure NASA imposed hardware and software changes related to the Payload Control Unit are ready to be executed by the teams.		May 2016	
32	**Payload Control Unit and Payload Telemetry Modification Delta Critical Design Review:** Perform a Delta Critical Design Review meeting focused on the design closure of all modified equipment and whether system performance is within certified limits. This review will encompass, at a minimum, the Payload Control Unit, harnesses, Ethernet cables, and software modifications.		Nov. 2016	
33	**Payload Control Unit Modification Install Readiness Review:** A review to ensure all aspects of the modification are ready for installation, assembly, integration, and test. The software, equipment, and production planning needed to modify the vehicle will be reviewed to ensure the modification can move ahead without the risk of rework.		Sept. 2017	
34	**Certification Review (Delivery Milestone):** A review in which the contractor provides evidence that the Crew Transportation System has met all NASA requirements and provides documentation of the crew safety and mission assurance risks.	Aug. 2017		Jan. 2018

Source: NASA Office of Inspector General analysis of Boeing completed and upcoming contract milestones.

[a] These milestones were added or split through modifications to the contract.
[b] Upcoming completion dates are as of June 2016 and reflect Boeing's most current expectation after the reevaluation of their Integrated Master Schedule.

APPENDIX C: SUMMARY OF SPACEX CONTRACT MILESTONES AND DATES

Milestone Number	Description	Original Estimated Completion Date	Added/Split Milestone Estimated Completion Date[a]	Revised, Actual, or Upcoming Completion Dates[b]
1	**Certification Baseline Review:** A review to ensure baseline requirements are identified in line with NASA guidance; identify the current Crew Transportation System design baseline; define the plan and schedule to complete design, development, test, and evaluation and certification for the Crew Transportation System design, production, and operations; and define top safety, technical, cost, and schedule risks.	Nov. 2014		Dec. 2014
2	**Avionics Test Bed Activation:** Flight-like avionics and flight-like harnessing are developed and built to perform system-level testing, demonstration, and validation of avionics hardware and software capabilities.	May 2015		July 2015
3	**Initial Propulsion Module Testing Complete:** Conduct testing of a flight-representative Crew Dragon spacecraft propulsion system.	Apr. 2015		Oct. 2015
4	**Validation Propulsion Module Testing Complete:** Split milestone from Initial Propulsion Module Testing Complete.		Aug. 2016	
5	**Critical Design Review:** A review to ensure that the detailed Dragon-Falcon 9 System design will satisfy all applicable requirements with adequate margins; is sufficiently mature to proceed with fabrication, assembly, integration, and test; and has completed the product verification and validation plans with NASA's approval.	June 2015		Nov. 2015
6	**Delta Critical Design Review:** Split milestone from Critical Design Review.		Dec. 2015	
7	**Delta Critical Design Review 2:** Split milestone from Critical Design Review.		Aug. 2016	
8	**Docking System Qualification Complete:** Qualify the docking system to the requirements and test with a fully functional qualification unit.	Aug. 2015		Dec. 2015

Milestone Number	Description	Original Estimated Completion Date	Added/Split Milestone Estimated Completion Date[a]	Revised, Actual, or Upcoming Completion Dates[b]
9	**Propulsive Land Landing Test Complete:** Conduct a propulsive landing test of Dragon under nominal hardware conditions. The vehicle will be dropped from an altitude sufficient to deploy parachutes and approach the landing burn under flight-like conditions. The intent of the test is to integrate the parachute, navigation, and propulsion systems into Dragon to demonstrate landing with command and control, as well as data acquisition. (Renamed Propulsive Descent Test Complete per SpaceX request)	Sept. 2015		Dec. 2015
10	**Launch Site Operational Readiness Review for Crew:** A review to demonstrate that the launch site meets requirements with acceptable level of risk for completing the flight to the ISS without crew milestone; evaluation of the effectiveness of the pad escape system.	Nov. 2015		Dec. 2015
11	**Flight Test Without Crew Certification Review:** A review to certify the design and safety of the flight to the ISS without crew; complete all requirements for the Dragon-Falcon 9 Crew Vehicle, ground segment, and mission operation elements in preparation for a mission to the ISS without crew.	Dec. 2015		Sep. 2016
12	**Environmental Control and Life Support System Integrated Test Complete:** Demonstrate that the Crew Dragon Environmental Control and Life Support System will support the metabolic loads of the crew and provide the conditions needed to sustain human life onboard the Dragon spacecraft during a nominal mission.	Feb. 2016		July 2016
13	**Flight to ISS Without Crew:** To conduct a flight test of the Dragon-Falcon 9 Crew Vehicle without crew; to provide early demonstration and risk reduction of the Dragon-Falcon 9, ground segment, and mission operations elements.	Mar. 2016		Dec. 2016
14	**Parachute Qualification Complete:** To conduct a series of tests on the parachute system in nominal and off-nominal configurations, enveloping conditions for abort and nominal entry scenarios.	Apr. 2016		Jan. 2017
15	**Spacesuit Qualification Testing Complete:** To conduct a series of tests on the space suit to qualify the design for flight.	May 2016		Sept. 2016

Milestone Number	Description	Original Estimated Completion Date	Added/Split Milestone Estimated Completion Date[a]	Revised, Actual, or Upcoming Completion Dates[b]
16	**Launch Site Operational Readiness Review for Crew:** A review to demonstrate the readiness of the launch complex crew ingress/egress system to show that the system meets all requirements with acceptable risk.	June 2016		June 2016
17	**Design Certification Review:** A review to demonstrate that the Crew Transportation System and operations meet all applicable requirements; demonstrate schedule performance; and define top safety, technical, cost, and schedule risks.	July 2016		Jan. 2017
18	**Flight Test Readiness Review:** A review to demonstrate readiness to conduct a crewed flight test and defines a risk baseline for crewed flight test activities.	Sept. 2016		Mar. 2017
19	**Flight to ISS With Crew:** Conduct a second test flight of the crew system, this time with crew, to provide an early demonstration and risk reduction of the system for operational missions.	Oct. 2016		Apr. 2017
20	**Operational Readiness Review:** A review to demonstrate that the Crew Transportation System characteristics and the procedures used in operations reflect the deployed state of the system; evaluation of all project and support hardware, software, personnel, and procedures to ensure flight and associated ground systems are in compliance with program requirements and constraints.	Jan. 2017		July 2017
21	**Certification Review:** A review in which the contractor provides evidence that the Crew Transportation System has met all NASA requirements and provides documentation of the crew safety and mission assurance risks.	Apr. 2017		Oct. 2017

Source: NASA Office of Inspector General analysis of SpaceX completed and upcoming contract milestones.

[a] These milestones were added or split through modifications to the contract.
[b] Upcoming completion dates reflect SpaceX's most current expectation as of June 2016.

APPENDIX D: MANAGEMENT'S COMMENTS

National Aeronautics and Space Administration

Office of the Administrator
Washington, DC 20546-0001

August 24, 2016

Human Exploration and Operations Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Human Exploration and Operations Mission Directorate

SUBJECT: Agency Response to OIG Draft Report, "NASA's Commercial Crew Program: Update on Development and Certification Efforts" (A-15-010-00)

NASA appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled, "NASA's Commercial Crew Program: Update on Development and Certification Efforts" (A-15-010-00), dated July 21, 2016.

In the draft report, the OIG makes two recommendations to the Associate Administrator for Human Exploration and Operations Mission Directorate (HEOMD), intended to improve NASA's oversight of the Commercial Crew Program.

Specifically, the OIG recommends that the Associate Administrator for HEOMD:

Recommendation 1: Implement procedures to monitor the timeliness of NASA's review process for hazard reports to help reduce risk to the Program's schedule.

Management's Response: Concur. The approval of hazard reports is a priority for NASA. The Commercial Crew Program (CCP) continues to monitor the timeliness of the review process, with an emphasis on managing the NASA review time, while monitoring the time required for contractor revision deliveries. NASA strives to provide timely feedback throughout the iterative process to ensure productive conversations at the Safety Technical Review Board (STRB) that either support an approval or provide clearly defined forward work for an eventual approval. Additionally, the hazards are reviewed and discussed at least bi-weekly during the CCP Certification Status Review, and the NASA Associate Administrator will review the hazards in response to an Agency level action at the Baseline Performance Review held monthly.

The Commercial Crew Program recognized its ability to monitor the review process could be improved. In May, CCP implemented a new tool to improve its tracking and reporting capabilities. CCP is currently assessing the tool and data to see if any improvements could enhance the process.

Monitoring the timeliness of the hazard review process is important, but more important is development of thorough and detailed hazard reports. The quality of the hazard reports will be critical to understanding the risks in the system and, ultimately, the safety of the crew. Certain hazard reports are more critical than others and the order in which the hazard reports are developed and approved is as important as the time needed for the review. Excessive focus on timeliness and schedule can result in reducing the overall safety of the system.

Estimated Completion Date: September 7, 2016

Recommendation 2: Coordinate with Boeing and SpaceX to document a path to timely resolution for variance requests and hazard reports that have exceeded the review period goals.

Management's Response: Partially concur. NASA agrees that coordination with the partners is necessary to ensure hazard reports and variance requests are being addressed at the appropriate time, and NASA has a process in place for timely resolution. CCP has weekly discussions with the partners to jointly develop a path for timely resolution, including focused discussions on items requiring management's attention. CCP will continue to work with the partners to ensure that detailed design information and sufficient data are available to support a thorough review prior to disposition at the board.

Some hazard reports will require extended evaluation periods before approval for a number of reasons, many outside of NASA's control; however, these are not the norm. For example, the Boeing Safety Technical Review Board (STRB) review process has a 90 percent success rate holding STRB discussions for the delivered hazard in ten weeks or less, demonstrating successful partnering.

As with the first recommendation, one must be careful to not focus solely on timeliness and review period goals. Variances and the logic and rationale behind the request are critical to understanding if the design will be safe. This evaluation can be complex and may require NASA to perform unique analysis or tests. Strictly adhering to a timeline can yield to either accepting an inappropriate variance or disapproving a variance that could result in a more efficient, safer, or less costly operation in the future. The process of accepting variances and hazard reports is critical to developing a safe design. Timeliness must not be over stressed in this process.

Estimated Completion Date: Complete

In addition, CCP regularly evaluates the schedules of the commercial crew companies. While there are risks associated with those schedules, as there are in all of NASA's human spaceflight development activities, CCP has a robust risk management process in place to

review, understand, and mitigate those risks. Also, it is important to note that both companies continue to add margin to their certification schedules for unseen problems whenever possible. The capability to deliver crews safely to and from low-Earth orbit destinations, such as the International Space Station, is fundamentally important to a robust United States space exploration program. NASA and the Nation look forward to the time when U.S. astronauts will once again travel to space from the United States on American-led systems.

We have reviewed the draft report for information that should not be publicly released. As a result of this review, we have identified information (provided separately) that we believe should not be publicly released.

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

William H. Gerstenmaier

APPENDIX E: REPORT DISTRIBUTION

National Aeronautics and Space Administration

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Deputy Administrator
Associate Administrator
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Deputy Chief of Staff
Associate Administrator, Human Exploration and Operations Mission Directorate
Director, Commercial Spaceflight Development
Director, Johnson Space Center
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Congressional Committees and Subcommittees, Chairman and Ranking Member

Senate Committee on Appropriations
    Subcommittee on Commerce, Justice, Science, and Related Agencies

Senate Committee on Commerce, Science, and Transportation
    Subcommittee on Space, Science, and Competitiveness

Senate Committee on Homeland Security and Governmental Affairs

House Committee on Appropriations
    Subcommittee on Commerce, Justice, Science, and Related Agencies

House Committee on Oversight and Government Reform
    Subcommittee on Government Operations

House Committee on Science, Space, and Technology
    Subcommittee on Oversight
    Subcommittee on Space

(Assignment No. A-15-010-00)