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NASA'S MANAGEMENT OF THE COMMERCIAL CREW PROGRAM

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Space Administration

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Acronyms

ASAP	Aerospace Safety Advisory Panel
CCDev1	Commercial Crew Development Round 1
CCDev2	Commercial Crew Development Round 2
CCiCap	Commercial Crew Integrated Capability
CCtCap	Commercial Crew Transportation Capability
CPC	Certification Products Contact
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulation
FY	Fiscal Year
GAO	Government Accountability Office
ISS	International Space Station
NPR	NASA Procedural Requirements
OIG	Office of Inspector General
OMB	Office of Management and Budget

OVERVIEW

NASA'S MANAGEMENT OF THE COMMERCIAL CREW PROGRAM

The Issue

Since the retirement of the Space Shuttle Program in July 2011, the United States has lacked a domestic capability to transport crew and – until recently – cargo to and from the International Space Station (ISS or Station). Consequently, NASA has been relying on the Russian Federal Space Agency (Roscosmos) for crew transportation. Between 2012 and 2017, NASA will pay Roscosmos $1.7 billion to ferry 30 NASA astronauts and international partners to and from the ISS at prices ranging from $47 million to more than $70 million each. After 2017, NASA hopes to obtain transportation to the ISS from American companies.

In anticipation of the Shuttle's retirement, Congress and the President directed NASA to foster the commercial spaceflight industry as a means of developing domestic cargo and crew transportation capabilities to the Station. In November 2005, NASA created the Commercial Crew and Cargo Program Office and in 2011, activated a separate Commercial Crew Program Office to reflect the increased funding and priority for commercial crew. As of August 31, 2013, NASA has spent $1.1 billion on its commercial crew development efforts. NASA is currently working with three companies – The Boeing Company (Boeing), Space Exploration Technologies Corporation (SpaceX), and Sierra Nevada Corporation (Sierra Nevada) – using a combination of funded Space Act Agreements and contracts based on the Federal Acquisition Regulation (FAR) to develop commercial crew transportation capabilities.[1]

In June 2013, the Office of Inspector General (OIG) issued a report examining NASA's efforts to foster a commercial market for cargo resupply missions to the ISS.[2] In the report, we discussed NASA's funding over the past 7 years of SpaceX and Orbital to further development of spaceflight capabilities and, on a separate track, the Agency's contracts with the companies for a combined 20 cargo resupply missions to the ISS. As a complement to that report, this review examines NASA's efforts to pursue commercial crew capabilities.

[1] Space Act Agreements are a form of "Other Transaction Authority" provided to NASA in the National Aeronautics and Space Administration Act of 1958 that establish a set of legally enforceable commitments between NASA and a partner to accomplish a stated objective without imposing the extensive list of requirements routinely found in most government contracts.

[2] NASA OIG, "Commercial Cargo: NASA's Management of Commercial Orbital Transportation Services and ISS Commercial Resupply Contracts" (IG-13-016, June 13, 2013). In March 2013, SpaceX successfully completed its second Station resupply mission, while Orbital Sciences Corporation (Orbital) is scheduled to undertake its first resupply mission in December 2013.

NASA's Commercial Crew Program is currently at a critical stage of development, as Boeing, SpaceX, and Sierra Nevada are expected to complete their spacecraft designs within the next year. While the partners are responsible for developing the vehicles, they rely heavily on NASA funding to meet current schedule requirements. At the same time, NASA maintains responsibility for ensuring that the partners' launch systems and spacecraft meet Agency safety and operational requirements. All three partners achieved what amounts to a Preliminary Design Review prior to NASA's award of the latest round of Space Act Agreements in 2012 and have set an optimistic schedule for achieving what each company defines as a Critical Design Review of their systems by mid-2014.[3]

After completion of the initial two rounds of development using Space Act Agreements, NASA originally planned a two-phased, FAR-based acquisition approach to develop commercial crew capabilities. Phase 1 was to consist of firm-fixed-price contracts to multiple companies for integrated design and early development followed by a second round of firm-fixed-price contracts for additional development, testing, evaluation, and certification of the contractors' crew transportation systems. Thereafter, NASA planned to enter into individual FAR-based contracts for each crewed mission with the hope of beginning flights to the ISS in 2016.

For fiscal year (FY) 2012, NASA received $397 million for its Commercial Crew Program; less than half its $850 million request. In light of this development, in August 2012, NASA revised its Commercial Crew Acquisition Strategy to rely on Space Act Agreements rather than FAR-based contracts for the integrated design phase of the program. The Agency also delayed the expected completion date of the commercial crew development phase from 2016 to 2017.

Using funded Space Act Agreements rather than FAR-based contracts to develop new transportation capabilities has several potential benefits. First, because the partners share development costs and the agreements involve fewer regulations and require less oversight by NASA, they may reduce the Agency's cost of acquiring these capabilities. Second, because NASA does not impose specific requirements on the companies as part of the agreements, the commercial partners are free to develop spacecraft designs that will support the needs of both NASA and other potential customers. Third, NASA officials said they believe the greater flexibility offered by Space Act Agreements promotes creativity and innovation.

[3] As defined by NASA, the Preliminary Design Review demonstrates that the overall preliminary design meets all requirements with acceptable risk and shows that the correct design options have been selected, interfaces have been identified, and verification methods have been described. The Critical Design Review determines if the integrated design is appropriately mature to continue to final design and fabrication. Both reviews are important to demonstrate that a system meets all requirements with acceptable risk and within cost and schedule constraints. For the Commercial Crew Program, the companies defined their own requirements for achieving both Preliminary and Critical Design Reviews, with review and concurrence by NASA. NASA funded Boeing and SpaceX to achieve Critical Design Review, but due to a limited budget has not funded Sierra Nevada's completion of that milestone.

However, NASA's use of Space Act Agreements also poses risks, most prominently limiting its ability to dictate specific design and safety requirements during the development process. In addition, oversight of partners in a Space Act Agreement relationship is more challenging. Taken together, these constraints make it harder to ensure that the companies will ultimately produce spaceflight systems that meet Agency requirements and that NASA can be confident will safely carry its astronauts to and from the ISS.

Given the significance of the Commercial Crew Program to NASA's human spaceflight efforts, we assessed: (1) the progress of each of the commercial partners toward developing a certified crew capability and (2) the major challenges that must be addressed to successfully implement the Program. Details of the audit's scope and methodology are in Appendix A.

Results

Although NASA's commercial partners are making steady progress in their initial development, the Commercial Crew Program faces several obstacles that may hinder NASA's ability to transport astronauts to the ISS in commercially supplied vehicles by 2017. These include an unstable funding stream, challenges in aligning cost estimates with the Program schedule, challenges in providing timely requirement and certification guidance, and coordination issues with other Federal agencies. Failure to address each of these challenges in a timely manner could significantly delay the availability of commercial crew transportation services and extend U.S. reliance on the Russians for crew transportation to the ISS.

NASA's Commercial Partners Meeting Early Development Milestones, but Face Significant Future Challenges. While their development approaches vary, all three commercial crew partners are successfully executing their spaceflight development efforts in accordance with their Space Act Agreements and FAR-based contracts. Each partner has completed its preliminary space system design and is in the process of finalizing that design and conducting component testing. In December 2012, NASA awarded all three partners a Phase 1 FAR-based certification contract pursuant to which the partners are working to ensure their space systems meet NASA requirements. However, Critical Design Review and other key milestones historically associated with cost and schedule delays remain to be completed.

NASA Must Overcome Major Hurdles to Provide Commercial Crew Transportation on Current Schedule. We identified four significant challenges to NASA's spaceflight development program for crewed flights to the ISS: unstable funding, alignment of cost estimates with the Program schedule, challenges in providing timely requirement and certification guidance, and spaceflight coordination issues with other Federal agencies.

Funding Instability Jeopardizes NASA's Plans to Begin Certified Crew Missions to the ISS by 2017. The Program received only 38 percent of its originally requested funding for FYs 2011 through 2013, bringing the current aggregate budget shortfall to $1.1 billion when comparing funding requested to funding received. As a result, NASA has delayed the first crewed mission to the ISS from FY 2015 to at least FY 2017. For FY 2013, Commercial Crew Program managers had already expected less than the requested $830 million and based their planning on a funding level of $525 million. The combination of a future flat-funding profile and lower-than-expected levels of funding over the past 3 years may delay the first crewed launch beyond 2017 and closer to 2020, the current expected end of the operational life of the ISS.[4]

Aligning Cost Estimates with Program Schedule May Enhance Management and Improve Transparency of Commercial Crew Program. Although NASA's Commercial Crew partners have completed their preliminary spacecraft designs, NASA managers have yet to develop a life cycle cost estimate for the Program. Life cycle costs are the anticipated annual costs of a program throughout its life, from preliminary design through the end of operations. According to Agency guidance, program managers should develop a life cycle cost estimate before Preliminary Design Review has been completed to help avoid future development delays caused by a lack of funding.[5] However, Program officials told us that this guidance does not apply to programs developed using Space Act Agreements and that developing such estimates for these type of programs is difficult due to a number of factors, including lack of historical cost data. Accordingly, rather than life cycle cost estimates, NASA developed independent government cost estimates projecting the overall cost to complete development and certification of the complete system based upon data supplied by the commercial partners, NASA insight into each company's program, and historical data from other NASA and Air Force rocket programs. Although these estimates provided some indication of the cost to develop a viable commercial crew transportation capability, they do not provide the same level of fidelity regarding overall costs as a life cycle cost estimate.

We acknowledge the difficulties in developing a comprehensive life cycle cost estimate for a program using a unique and still evolving acquisition approach for which there is limited comparable historical data. However, without a detailed cost estimate for each year of the program based upon a complete analysis of each subcomponent of the program over time, it is difficult for NASA to calculate how much funding is required each year given that costs over time can fluctuate significantly. Moreover, improved guidance requiring detailed cost estimates earlier in program development may help enhance the transparency of NASA's congressional budget submissions. To this point, members of Congress and the NASA Aerospace Safety Advisory Panel have stated that the lack of this type of information makes it difficult to know with any level of confidence the amount of government money required to develop a viable commercial

[4] NASA has studies underway to determine if the lifespan of the ISS can be extended until 2028, but no firm decisions have been made regarding any extension.

[5] NASA, "NASA Cost Estimating Handbook" (2008).

crew transportation capability.[6] In our judgment, because NASA now has some historical cost data from the Commercial Crew Program, it is better positioned to develop improved guidance for cost estimating when systems are developed using Space Act Agreements.

Timeliness of NASA's Process for Considering Alternative Human Rating Requirements Remains a Concern. NASA has been challenged to provide partners with timely requirement and certification guidance during the current period of development. While NASA used Space Act Agreements to encourage innovative designs by its partners during system development, it is using FAR-based firm-fixed-price contracts for the certification process. As such, the partners must rely on timely guidance and information from NASA, and delays could affect their ability to move forward with production. As a result, the certification contracts include a 90-day goal for NASA to respond to partner requests for requirement and certification guidance. However, the general Program Control Board process used by NASA to make programmatic decisions does not consistently result in 90-day resolution of these requests.

NASA's partners told us that they need resolution of requests for requirement and certification guidance within 30-90 days in order to avoid delays or additional costs. As of July 2013, over 65 percent of partner requests for alternate requirement standards and deviations have been pending more than 90 days without resolution. Although program officials said they expect to clear most of the requests in 120 days and that this timeline should meet the contractors' needs, we noted a significant number of requests pending more than 120 days. Cost increases and schedule overruns may result if NASA is unable to provide timely and accurate confirmation of requirements and certification guidance.

Coordination of Spaceflight Safety Issues with Other Federal Agencies is Ongoing. The transition from NASA-provided space transportation to low Earth orbit and the ISS to commercially supplied space transportation services, especially for human space travel, requires coordination between multiple government agencies. Although NASA and the Federal Aviation Administration (FAA) have taken positive steps to coordinate their efforts, complex range safety, legal, and insurance issues require additional coordination. NASA and the FAA signed a Memorandum of Understanding in June 2012 on how to collaborate on and coordinate their respective roles; however, the U.S. Air Force launch ranges are not yet part of what needs to be a coordinated effort and Program officials are attempting to establish a tri-party safety steering group composed of these three agencies. However, the steering group's authority and NASA's authority to influence other agencies' actions has not yet been clearly established. Failure to coordinate effectively with the FAA and the Air Force regarding these issues could adversely affect NASA's efforts to facilitate commercial human space travel.

[6] House Committee on Science, Space and Technology Hearing, "Recent Developments in NASA's Commercial Crew Acquisition Strategy" (September 14, 2012).

Management Action

In order to increase the accuracy and transparency of Agency budget submissions, we recommended that NASA revise its guidance, to the extent practical, to ensure that managers of space system development programs in which Space Act Agreements are used provide detailed cost estimates for each year of the program based upon a complete analysis of the program over time before preliminary designs are completed. We also recommended that the Associate Administrator for the Human Exploration and Operations Mission Directorate examine whether more comprehensive costs estimates should be developed by the Commercial Crew Program before the completion of the Critical Design Reviews by NASA's current commercial partners; routinely track adherence to the 90-day goal for responding to contractor requests for alternate requirement standards and variances and explore ways to facilitate the process; and, in conjunction with the FAA and the Air Force, formally establish a tri-agency Safety Steering Group for resolution of issues involving crew and public safety during commercial spaceflight operations.

NASA and the Associate Administrator concurred with our recommendations and agreed to take corrective actions. We consider these proposed corrective actions responsive; therefore, the recommendations are resolved and will be closed upon completion and verification of those actions.

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INTRODUCTION

Background

Since the termination of the Space Shuttle Program in July 2011, the United States has lacked a domestic capability to transport crew and – until recently – cargo to and from the International Space Station (ISS or Station). Consequently, NASA has been relying on the Russian Federal Space Agency (Roscosmos) for crew transportation, and the Europeans and the Japanese for cargo transportation. Between 2012 and 2017, NASA is committed to pay Roscosmos $1.7 billion to ferry its astronauts and international partners to and from the ISS, at prices ranging from $47 million to more than $70 million per seat. After 2017, NASA hopes to secure transportation to the ISS from an American company or companies.

In anticipation of the Shuttle's retirement, Federal law directed NASA to foster the commercial spaceflight industry as a means of developing domestic cargo and crew transportation capabilities to the Station. In November 2005, NASA created the Commercial Crew and Cargo Program Office to work toward this goal and in 2011, activated a separate Commercial Crew Program Office to reflect the increased funding and priority for commercial crew development.

The Office of Inspector General (OIG) issued a report in June 2013 examining NASA's efforts to foster a commercial cargo capability. In that audit, we discussed NASA's funding over the past 7 years of two companies – Space Exploration Technologies Corporation (SpaceX) and Orbital Sciences Corporation (Orbital) – to further development of spaceflight capabilities and, on a separate track, the Agency's contracts with the companies for a combined 20 cargo resupply missions to the ISS.[7] As a complement to that report, this review examines NASA's efforts to foster development of a commercial spaceflight industry capable of carrying NASA astronauts to the Station – known officially as the Commercial Crew Program.

Space Act Agreements. Under the National Aeronautics and Space Act of 1958, NASA has authority to enter into agreements with private companies and other non-Government entities that are not required to follow the general contract requirements of the Federal Acquisition Regulation (FAR). These Space Act Agreements establish a set of legally enforceable commitments between NASA and a partner to accomplish a stated objective

[7] NASA OIG, "Commercial Cargo: NASA's Management of Commercial Orbital Transportation Services and ISS Commercial Resupply Contracts" (IG-13-016, June 13, 2013). In March 2013, SpaceX successfully completed its second Station resupply mission, while Orbital is scheduled to undertake its first resupply mission in December 2013.

related to the Agency's mission that does not involve acquiring specific goods or services. As of September 2013, NASA reported having more than 2,500 Space Act Agreements with companies, educational institutions, state and Federal government organizations, and foreign governments and entities.

Space Act Agreements may be funded, reimbursable, or non-reimbursable (unfunded) agreements. NASA may enter into funded agreements only with domestic partners and only when it cannot achieve its objectives through other types of instruments, including traditional FAR-based contracts.[8] In non-reimbursable agreements, each party bears the cost of participation with no exchange of funds, while in reimbursable agreements a partner reimburses NASA for resources or services the Agency supplies, such as test facilities, supplies, or engineering expertise. Since 2006, NASA has awarded funded Space Act Agreements to 12 commercial partners with the goal of stimulating both the development of commercial capabilities NASA could use to transport its astronauts and cargo to the Station as well as a wider commercial market for spaceflight services.

Using funded Space Act Agreements rather than FAR-based contracts to develop new transportation capabilities has several potential benefits. First, because NASA's partners share development costs and the agreements involve fewer regulations and require less oversight by the Agency, they may reduce the cost to NASA of eventually acquiring services from these companies. Second, because NASA does not impose specific requirements on the companies as part of the agreements, they are free to develop spacecraft designs that will support the needs of both NASA and other potential customers. Third, NASA officials believe that the greater flexibility offered by Space Act Agreements promotes creativity and innovation.

However, NASA's use of Space Act Agreements also poses risks, most prominently limiting the Agency's ability to dictate specific requirements and its oversight of the companies during the development process. These limitations make it more difficult to ensure that the companies will ultimately produce spaceflight systems that meet Agency requirements and that NASA can be confident they will safely carry its astronauts to and from the ISS.

As part of the Space Act Agreements, NASA and the companies agreed to a series of developmental milestones that tie payments to satisfactory completion of such events as design reviews, sub-system testing, and safety and certification reviews. NASA negotiated milestone entry requirements and exit performance criteria with each partner based on their developmental approaches during the solicitation phase of the Agreements.[9] As opposed to a traditional FAR-based contract in which NASA dictates the detailed requirements a company must meet, these milestones and criteria were tailored by the individual companies and negotiated with NASA.

[8] NASA Policy Directive 1050.11, "Authority to Enter into Space Act Agreements" (December 23, 2008).

[9] Entry criteria are what a partner needs to perform or provide before reaching the milestone. Exit criteria are what must be performed in order to achieve successful completion of the milestone.

Although NASA has successfully used Space Act Agreements to develop commercial vehicles capable of carrying cargo to the ISS, using this approach to develop major spaceflight systems is still somewhat novel and one that NASA has been refining over time. To ensure a more thorough evaluation process – and based on lessons learned during the commercial cargo program – the Agency has added more specific criteria for determining when it will consider particular milestones satisfactorily completed. For example, the entry criteria for Commercial Crew's Critical Design Review include partners providing NASA over 40 specific technical products at least 30 days before the event takes place. In contrast, the entry criteria for Critical Design Review for NASA's commercial cargo program called for up to 16 sets of documents due only 7 to 14 days before the review.

Commercial Crew Program. 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 commercial partners to help fund research and design of key technologies and systems. Known as Commercial Crew Development Round 1 (CCDev1), NASA awarded funded agreements to Sierra Nevada Corporation (Sierra Nevada) ($20 million), The Boeing Company (Boeing) ($18 million), United Launch Alliance ($6.7 million), Blue Origin, LLC ($3.7 million), and Paragon Space Development Corporation (Paragon) ($1.44 million) for varying component designs for capsules and launch abort and life support systems. In April 2011, NASA awarded $270 million in Commercial Crew Development Round 2 (CCDev2) Space Act Agreements to Boeing, Sierra Nevada, SpaceX, and Blue Origin for further development ending in Preliminary Design Reviews. Additional milestones were added in September 2011, bringing the total aggregate value of CCDev2 to $315.5 million.[10] Subsequently, NASA entered into additional unfunded agreements with Alliance Techsystems, Inc., Excalibur Almaz, and United Launch Alliance to provide technical assistance on space transportation concepts that included the human rating of various launch systems. (See Appendix B for more information concerning these Commercial Crew Space Act Agreements.)

In December 2011, NASA published the Commercial Crew Transportation 1100 series, which now includes 281 technical and safety requirements commercial spaceflight vehicles will need to meet to receive NASA certification. This documentation also describes the methodology NASA uses to oversee partner activities, namely embedding "Partner Integration Teams" at each company composed of NASA employees who work with company personnel to gain insight and provide technical assistance. According to Program officials, these teams are helping NASA determine whether the partners have met their Space Act Agreement milestones and will be critical when the companies seek certification from the Agency for their vehicles.

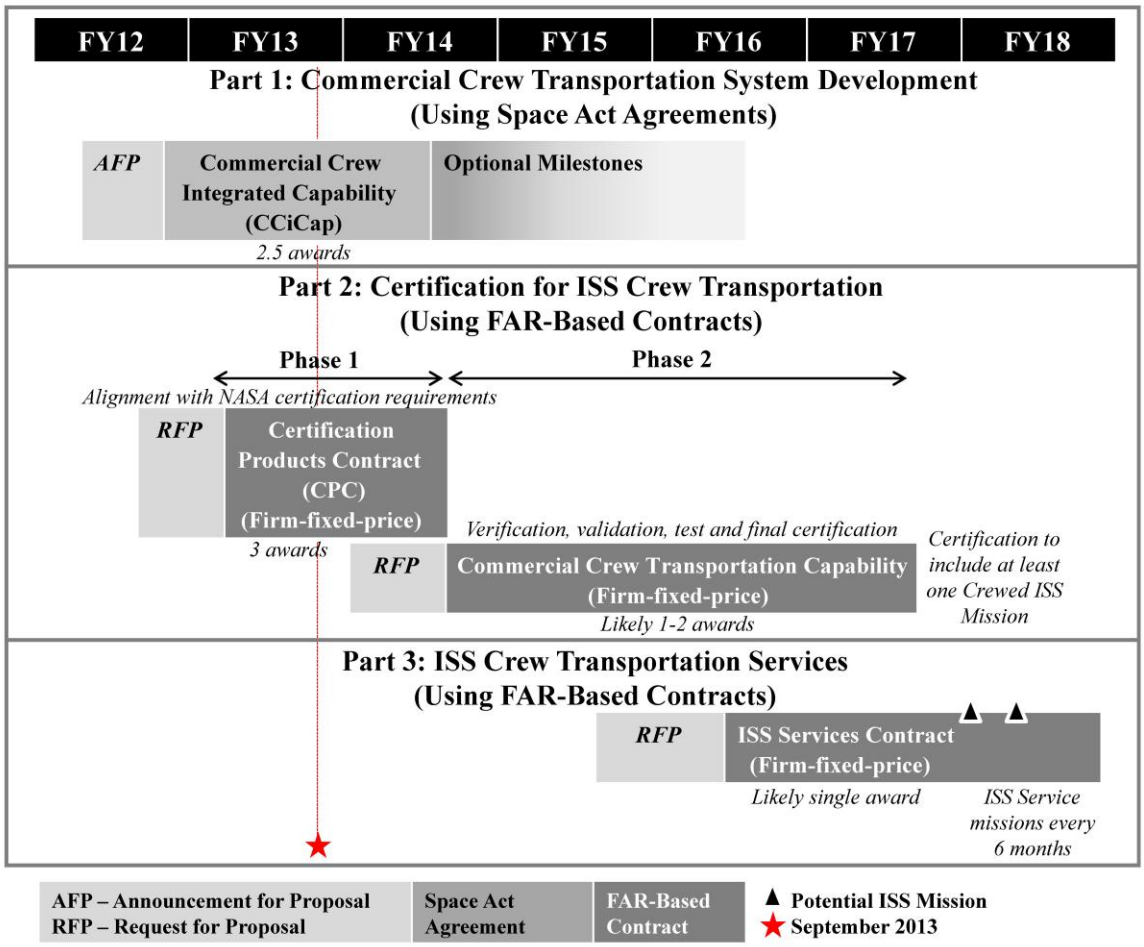
[10] Blue Origin completed the funded CCDev2 milestones and received final payment, but NASA and Blue Origin agreed to continue work until mid-2014 in an unfunded status.

Acquisition Strategy. After completion of the initial two rounds of development using Space Act Agreements, NASA planned a two-phased, FAR-based acquisition to further the development of its partners' commercial crew capabilities. Phase 1 was to consist of firm-fixed-price contracts to multiple companies for integrated design and early development followed by a second round of firm-fixed-price contracts for additional development, testing, evaluation, and certification of the contractors' crew transportation systems. Thereafter, NASA planned to enter into a FAR-based contract for crewed missions to the ISS, which it hoped to begin by 2016.

For fiscal year (FY) 2012, NASA requested $850 million for its Commercial Crew Program but received only $397 million. Consequently, NASA revised its Commercial Crew Acquisition Strategy to continue supporting partners' commercial development using Space Act Agreements rather than using FAR-based contracts to procure development work specifically tailored to NASA's requirements. The Agency also delayed the expected first commercial crew flight from the end of 2016 to mid-2017.

Figure 1 depicts NASA's revised acquisition strategy: Space Act Agreements for development (Part 1), FAR-based certification contracts to achieve a crewed demonstration and certification (Part 2), and a FAR-based services contract for delivery of NASA astronauts to the ISS (Part 3). As of August 2013, the same three companies working on development via Space Act Agreements – Boeing, SpaceX, and Sierra Nevada – are simultaneously preparing certification documents for review pursuant to the certification contract. (See Appendix C for a comparison of the original and revised acquisition strategies.)

Figure 1: Commercial Crew Acquisition Strategy



Source: NASA OIG presentation of Program information.

In Part 1 of its strategy, known as Commercial Crew Integrated Capability (CCiCap), NASA partnered with the companies using Space Act Agreements to mature the design and development of transportation systems that include spacecraft, launch vehicles, and ground and mission systems. Boeing was awarded $480 million, SpaceX $460 million, and Sierra Nevada $227.5 million. In addition to component testing and other design reviews, the goal is for Boeing and SpaceX is to achieve a company-defined Critical Design Review by May 2014 and Sierra Nevada a partial Critical Design Review by October 2013.[11]

In December 2012, NASA initiated Part 2 of its acquisition strategy by commencing work on the Certification Products Contract (CPC), the first of two phases of

[11] As defined by NASA, a Critical Design Review demonstrates that the maturity of the program's design is appropriate to support proceeding to full-scale fabrication, assembly, integration, and testing and that the technical effort is on track to complete the flight and ground system development and mission operations. For the Commercial Crew Program, the companies defined their own requirements for achieving Critical Design Review, with review and concurrence by NASA.

certification. These FAR-based contracts seek to ensure the partners' systems will meet NASA's safety and operational requirements. In Phase 1, NASA awarded firm-fixed-price contracts worth approximately $10 million each to Boeing, SpaceX, and Sierra Nevada for delivery and acceptance of certification plans for their crew transportation system. In Phase 2 of certification, known as the Commercial Crew Transportation Capability (CCtCap) and scheduled for award in July 2014, NASA plans to enter into at least one but ideally two firm-fixed-price contracts for the verification, validation, test, and final certification of a crew transportation system or systems. NASA plans to implement Part 3 of the acquisition strategy shown in Figure 1 by issuing a firm-fixed-price ISS transportation services contract to at least one partner in 2017.[12]

Competition in the Commercial Crew Program. NASA's current acquisition strategy attempts to control costs by encouraging competition and using a mix of Space Act Agreements and firm-fixed-price contracts.[13] NASA officials said that entering into Space Act Agreements with multiple partners encourages high performance because the companies can position themselves to compete for the certification and transportation services contract. Officials also said that engaging multiple partners maintains a needed redundancy if one provider cannot perform to the Agency's satisfaction.

While NASA officials said they would prefer to continue to work with at least two companies until the transportation services contract, a lack of funding will likely require them to "down select" to a single partner during Phase 2 of Certification, which is currently scheduled to begin in mid-2014. Moving forward with a single company increases the risk that NASA could be left without a viable commercial option to transport crew to the ISS should issues arise that either significantly delay or render inoperable the selected company's systems. While down selecting to one company is likely to save NASA money in the short term, experience from other major spaceflight programs illustrates that a lack of competition ultimately can drive up costs.[14]

[12] On July 19, 2013, NASA released a draft Request for Proposal for the Phase 2 Certification under which it is proposing to use a FAR-based, firm-fixed-price contract for the final stages of development and certification. This includes a crewed system demonstration mission to the ISS and the potential to execute up to six crewed service missions. This phase is now called CCtCap.

[13] Although firm-fixed-price contracts are referenced in the Agency's acquisition strategy, Program managers said a final decision on the type of contract the Agency will use has not been made.

[14] For example, cost per flight in the U.S. Air Force's Evolved Expendable Launch Vehicle Program increased from $72 million in 1998 to $460 million in 2012. The Air Force originally awarded contracts to Boeing and Lockheed Martin, but in 2006, the companies created a joint venture known as the United Launch Alliance. In 2011, the Government Accountability Office (GAO) reported that a lack of competition coupled with a significant decrease in demand caused the increase in per-flight costs. In December 2012, the Air Force awarded SpaceX two Evolved Expendable Launch Vehicle-class missions and in June 2013 signed a cooperative agreement with the company to begin certifying an upgraded version of the Falcon 9 for the two missions – the first scheduled to take place in 2014 at a cost of $97 million and the second in 2015 at a cost of $165 million – less than half the cost of current United Launch Alliance missions.

Objectives

Given the importance of the Commercial Crew Program to NASA's human spaceflight efforts, we assessed: (1) Boeing, Space X, and Sierra Nevada's progress toward developing a certified crew transportation capability and (2) the challenges remaining to successful implementation of the Program.

This audit focused on the funded partners in the CCiCap phase of the Commercial Crew Program. See Appendix A for details of the audit's scope and methodology, our review of internal controls, and a list of prior coverage. Prior coverage by NASA OIG includes a June 2011 audit report entitled, "NASA's Challenges Certifying and Acquiring Commercial Crew Transportation Services" (IG-11-022, June 30, 2011). Cost and schedule information in this report is current as of August 31, 2013.

NASA'S COMMERCIAL PARTNERS MEETING EARLY DEVELOPMENT MILESTONES BUT FACE SIGNIFICANT FUTURE CHALLENGES

While their development approaches vary, Boeing, SpaceX, and Sierra Nevada are achieving the development milestones specified in their Space Act Agreements with NASA. To date, each partner has completed its initial design and is in the process of finalizing that design and conducting component testing. In December 2012, NASA awarded the three companies Phase 1 FAR-based certification contracts designed to ensure that their spaceflight systems will meet NASA's safety and performance requirements. However, the Critical Design Review and other key developmental milestones historically associated with cost increases and schedule delays lie ahead.

Partners Have Varied Approaches to System Design

Under their Space Act Agreements, each company is required to complete its spacecraft design and a significant amount of component testing by mid-2014.[15] Each company's milestones focus on areas that highlight its individual approach to designing and developing spacecraft. For example, SpaceX's milestones include a Pad Abort Test scheduled for December 2013 and an evaluation of the structural integrity of the Dragon capsule scheduled for January 2014, both of which highlight the company's focus on fabricating components themselves and testing them on a routine basis. Boeing, on the other hand, has extensive experience designing, developing, and building space systems using a traditional acquisition approach for its work on the ISS and the Space Shuttle. Thus, Boeing's milestones focus on component-level design reviews, such as a structural Critical Design Review in October 2013 and a service module propulsion system Critical Design Review in November 2013.

As shown in Table 1, each company has a different approach to spacecraft development. For example, Boeing and Sierra Nevada plan to use the Atlas V launch vehicle to transport their spacecraft to the ISS, while SpaceX will launch the Dragon capsule with its own Falcon 9 rocket. The United Launch Alliance – which is partially owned by Boeing – builds the Atlas V, allowing Boeing to directly influence the upgrades required to certify the launch system for human transportation. In addition, Boeing and SpaceX utilize a similar capsule design that deploys a parachute for landing on a dry surface while Sierra Nevada plans to land its Dream Chaser on a conventional airport runway.

[15] Specifically, the Space Act Agreements provide that "the goals of the CCiCap investments are to enable significant progress on maturing the design and development of an integrated commercial transportation system while ensuring crew and passenger safety."

Table 1: NASA Commercial Partner Profiles

	Boeing	SpaceX	Sierra Nevada
Capsule	CST-100	Dragon	Dream Chaser
Launch Vehicle	Atlas V	Falcon 9	Atlas V
Capability	7 crew or equivalent crew and cargo	7 astronauts	Up to 7 astronauts and cargo
Landing	Dry surface	Dry surface/Ocean	Runway
Total NASA Investment as of August 31, 2013	$415.8 million	$327.8 million	$229.1 million
Total Awarded [a]	$620.9 million	$544.6 million	$363.1 million

[a] Total Awarded includes sum of all funds made available by NASA to these three companies for CCDev1, CCDev2, CCiCap, and CPC.

Source: OIG summary of Commercial Crew Program data.

Partners are Meeting Early Development Milestones

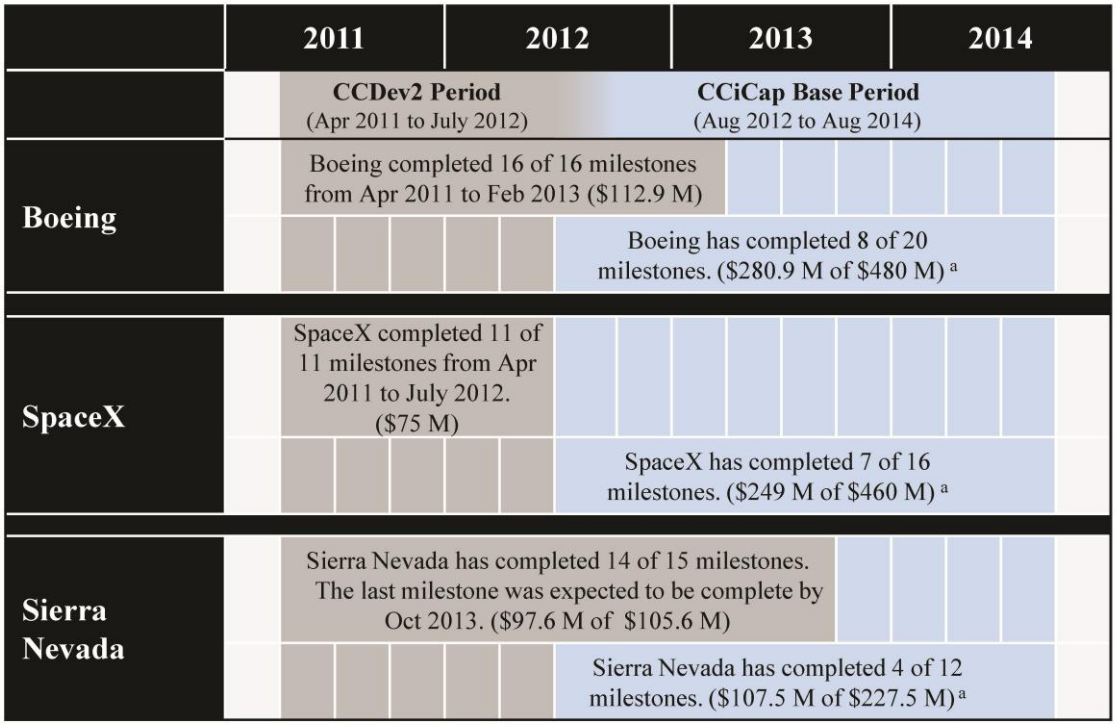
To date, Boeing, SpaceX, and Sierra Nevada have been meeting the milestones specified in their Space Act Agreements. These include completion of preliminary designs and conducting extensive component-level testing on various aspects of the vehicles. However, the design of the companies' systems have yet to be fully matured or achieve what amounts to a Critical Design Review. This review and the process used to prepare for it often reveal shortcomings that must be addressed prior to finalizing spacecraft design and initiating the manufacturing process.

Past studies have shown that unexpected costs and schedule delays are common during production of space systems.[16] As yet, none of the companies have begun producing an actual spacecraft for a flight to the ISS, only test articles and prototypes.

[16] GAO, "NASA: Assessments Selected Large Scale Projects" (GAO-12-207SP, March 2012).

Table 2 shows each partner's progress and performance as of August 2013. All three have completed a design review similar to the process NASA would use if it were developing the space systems in-house.[17] To date, SpaceX and Boeing have completed all milestones associated with CCDev2 and progressed beyond a Preliminary Design Review level of maturity. Sierra Nevada has one CCDev2 milestone remaining – a test flight of its engineering test article. While SpaceX completed all CCDev2 milestones on schedule, Boeing experienced minor delays with software development and Sierra Nevada experienced significant delays with drop tests.

Table 2: Status of Commercial Crew Program Partners



[a] Milestone completion as of August 31, 2013. Dollars are in millions.

Source: OIG summary of Commercial Crew Program data.

In addition, as of August 2013, all three partners were meeting their CCiCap milestones and have concurrently begun work on their CPCs. CPC Phase 1 work, which includes submitting reports and plans to NASA to ensure compliance with Agency requirements and certification guidance, began in January 2013.[18] By May 2014, each partner is

[17] A Preliminary Design Review demonstrates that the preliminary design meets all requirements with acceptable risk and shows that the correct design options have been selected, interfaces have been identified, and verification methods have been described.

[18] The CPC requires submission of four products: (1) alternate standards and variances (if applicable), (2) hazard reports, (3) verification and validation plans, and (4) certification plans. Each product was submitted to NASA in May 2013 for initial review, with final submissions due in February 2014.

scheduled to complete CPC Phase 1, while Boeing and SpaceX should complete a Critical Design Review. Sierra Nevada – which received about half the amount of money NASA provided the other two partners – is aiming to achieve the first of multiple incremental Critical Design Reviews by October 2013.

Boeing. As of August 2013, Boeing has completed 8 of their 20 CCiCap milestones and is scheduled to receive up to $480 million. In addition, NASA has the option to execute additional milestones designed to further mature Boeing's spacecraft design and enable a full system demonstration.

- Milestone 1 (August 2012) – completed an integrated system review.[19]
- Milestone 2 (October 2012) – completed a production design review to determine if subsystems are sufficiently mature to enter production and production plans are correct.
- Milestone 3 (November 2012) – completed a phase 1 safety review of requirements, vehicle architecture and design, and associated safety products.
- Milestone 4 (January 2013) – completed a software integrated engineering release demonstrating the capabilities of guidance and navigation and control software.
- Milestone 5 (January 2013) – completed a landing, recovery, and ground communications design review.
- Milestone 6 (February 2013) – completed a design review of the launch vehicle adapter by which the CST-100 capsule will be attached to the Atlas V launch vehicle.
- Milestone 7 (April 2013) – completed an integrated wind tunnel test to analyze the aerodynamic attributes of the launch vehicle and capsule during ascent.
- Milestone 8 (May 2013) – completed a dual engine centaur liquid oxygen duct development test to assess interface and water flow for liquid oxygen ducts.

Moving forward, Boeing has scheduled other reviews and testing expected to culminate in a Critical Design Review in April 2014. During CCDev2, Boeing experienced delays in software development and completed its final CCDev2 milestone in February 2013, 7 months behind schedule. According to NASA officials, Boeing must continue to address software issues or risk delaying its plans for a 2016 demonstration flight to the ISS.

[19] An integrated system review confirms that segments, components, and subsystems are available and ready to be integrated into the overall spaceflight system. In addition, such a review examines integration facilities, support personnel, and integration plans and procedures.

SpaceX.[20] As of August 2013, SpaceX has completed 7 of its 16 CCiCap milestones and is scheduled to receive $460 million. In addition, NASA may execute optional milestones designed to progress the company's system to a full demonstration by December 2015.

- Milestone 1 (August 2012) – held a kick-off meeting to present NASA with the company's plans for completing CCiCap milestones.
- Milestone 2 (August 2012) – submitted an analysis of its finances for its crew program to demonstrate the company's ability to successfully complete CCiCap goals.
- Milestone 3 (October 2012) – completed an integrated systems requirements review, including a review of its plans for system design, production, and operations and how they will meet NASA's requirements.
- Milestone 4 (December 2012) – completed a ground systems and ascent Preliminary Design Review to demonstrate that its system meets all related requirements with acceptable risk and within schedule constraints.
- Milestone 5 (March 2013) – completed a pad abort test review to demonstrate the maturity of the pad abort test article design and test concept of operations.
- Milestone 6 (May 2013) – completed a human certification plan review to define in detail the company's approach to certifying the design of the spacecraft, launch vehicle, and ground and mission operations systems.
- Milestone 7 (July 2013) – completed the on-orbit and entry Preliminary Design Review to demonstrate that its system can orbit, rendezvous, and dock with the ISS.

Moving forward, SpaceX has scheduled additional testing and certification milestones, including an on-orbit and entry Preliminary Design Review and an in-flight abort test review as they work toward a Critical Design Review in March 2014.

Sierra Nevada. As of August 2013, Sierra Nevada has completed 4 of their 12 CCiCap milestones and is scheduled to receive up to $227.5 million. The company has laid out a plan that includes advanced development milestones culminating in a full systems demonstration to the ISS before the end of 2017. Unlike the other partners, NASA has only funded Sierra Nevada for the first of multiple incremental Critical Design Reviews. However, NASA may choose to fund additional incremental Critical Design Reviews and other optional milestones.

[20] SpaceX entered the commercial crew arena with a flight-tested rocket system. The company's Falcon 9 rocket and Dragon Capsule have flown four times to low Earth orbit and berthed to the ISS three times on cargo missions. Although not yet human rated, SpaceX designed the Dragon for astronaut transportation.

- Milestone 1 (August 2012) – completed a review of its plan for implementing CCiCap.
- Milestone 2 (October 2012) – completed an integration system baseline review demonstrating maturity of its integration plan and operations design.
- Milestone 3 (January 2013) – completed an integration system safety analysis review demonstrating the safety of the Dream Chaser Space System.
- Milestone 5 (June 2013) – completed an investment milestone reflecting its financial commitment and ability to co-fund its system.[21]

Moving forward, Sierra Nevada has scheduled additional reviews and tests, including wind tunnel testing scheduled to be completed in February 2014. Sierra Nevada faced challenges during CCDev2 with respect to performing a successful drop test and has yet to complete this milestone, which was scheduled for October 2013. To maintain its schedule during CCiCap, Sierra Nevada must work to address these delays and complete the remaining milestones, which consist of extensive testing of crew and life support systems and additional aerodynamic tests.

[21] Sierra Nevada is scheduled to complete Milestone 4 in late 2013, which will consist of one to five engineering test article free flight(s) to analyze aerodynamic data during the approach and landing phase of the Dream Chaser.

NASA MUST OVERCOME MAJOR HURDLES TO PROVIDE COMMERCIAL CREW TRANSPORTATION ON CURRENT SCHEDULE

Although NASA's three commercial crew partners have been achieving their early development milestones, the Commercial Crew Program faces significant internal and external challenges to meeting NASA's goal of securing crew transportation to the ISS by 2017. First, for the past several years the Program has received significantly less funding than NASA requested. As a result, NASA has delayed the target date for the first crewed flight to the ISS to FY 2017, only 3 years before the currently scheduled end of ISS operations.[22] Further, experience has shown that reduced funding profiles are not consistent with best practices for space system development and continuation of this funding pattern could result in additional cost increases, schedule delays, and a lack of competition later in the Program's development. Second, NASA has yet to project the total amount of funding required by year, which makes it difficult for the Agency to manage its wider portfolio of spaceflight programs and at the same time reduces the transparency of the Program's budget submissions. Third, the process for providing timely guidance to partners for satisfying NASA's human rating and certification requirements could be improved. If NASA is unable to confirm design requirements and provide certification guidance in a timely manner, the companies could face costly and time-consuming redesign work late in system development. Finally, coordination of important safety issues with the Federal Aviation Administration (FAA) and the Air Force is ongoing, but not yet resolved. Failure to address these challenges could significantly delay the availability of commercial crew transportation services and extend U.S. reliance on the Russians for crew transportation to the ISS.

Funding Instability Jeopardizes NASA's Plans to Begin Certified Crew Missions to the ISS by 2017

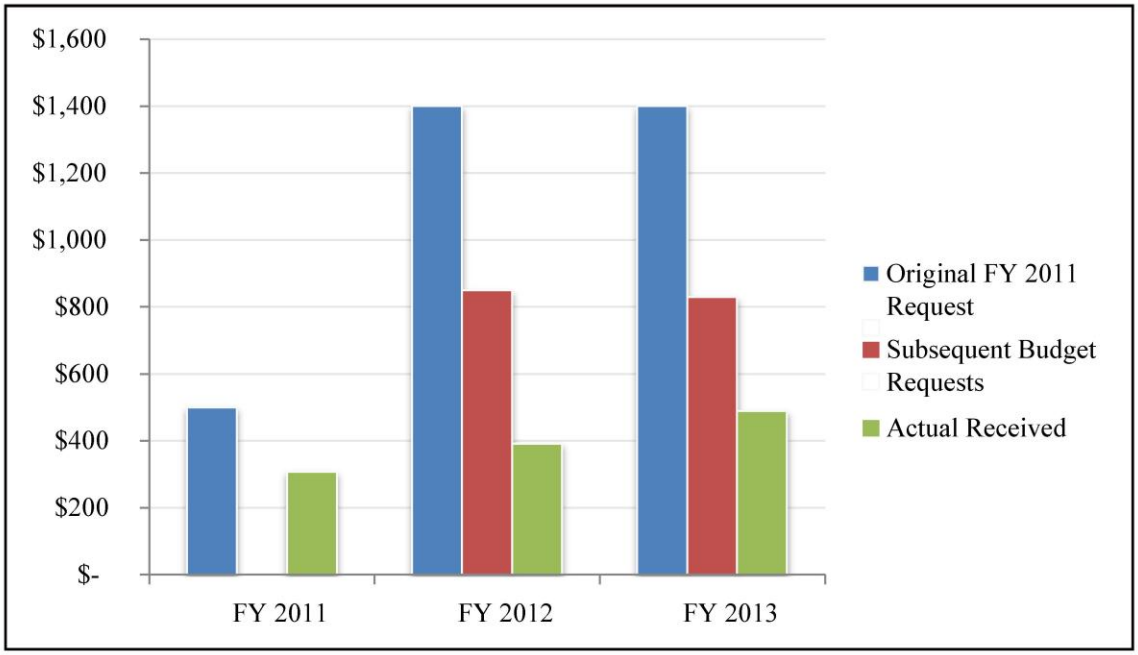
Throughout its existence, NASA's Commercial Crew Program has received budget appropriations that were substantially lower than requested. Perhaps the most tangible impact of these funding shortfalls has been the 2-year delay of the first crewed demonstration flight to the ISS by a commercial partner.

Specifically, for FY 2013, the Program received $525 million or 37 percent less than the President's budget request. The year before, the Commercial Crew Program requested $850 million but received $397 million, less than half its request. Overall, when

[22] By law, the ISS must be maintained until at least 2020, but NASA is examining the feasibility of extending the Station's life.

comparing actual funds received to the original FY 2011 budget request, which was based on a $6 billion program developed in 5 years, the Program has received 38 percent of its requested funding for FY 2011 through FY 2013 (see Figure 2).

Figure 2: Evolution of Commercial Crew President's Budget Requests from FYs 2011 through 2013 (Dollars in Millions)



Source: NASA OIG analysis of President's budget data.

For subsequent budget requests beginning in FY 2012, the Office of Management and Budget reduced the Program's annual appropriations request and created a "flat-line" budget profile by spreading funding evenly over subsequent fiscal years (see Table 3). Specifically, for FY 2013 Commercial Crew Program managers had to revise program schedules after their budget was reduced from the $830 million requested by the President to the $525 million appropriated by Congress.[23] Generally speaking, we determined that each year's budget decrement has resulted in an additional year of schedule delay. Even if the Program receives its full budget request in future years, the cumulative difference between the Program's initial budget requests and receipts over the life of the Program would be approximately $1.1 billion.

[23] At the end of March 2013, across-the-board budget reductions known as sequestration took effect, resulting in a 5 percent funding cut for this Program and most others across the Federal government. In addition, Congress imposed an additional 1.877 percent rescission against all Commerce, Justice, and Science agencies, which left the Program with $489 million in FY 2013. NASA subsequently submitted an operating plan in which it requested additional funds to address the shortfall and, as of August 2013, the operating plan was approved and the Program received $525 million – reprogrammed from other programs.

Table 3: Commercial Crew Program Budget Requests by FY (Dollars in millions)

	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	Total
FY09 Budget Request	$0	$0	$0	$0	$0						$0
FY10 Budget Request	$51	$0	$0	$0	$0	$0					$51
FY11 Budget Request	$51	$0	$500	$1,400	$1,400	$1,300	$1,200				$5,851
FY12 Budget Request	$51	$0	$321	$850	$850	$850	$850	$850			$4,623
FY13 Budget Request	$51	$0	$321	$397	$830	$830	$830	$830	$830		$4,920
FY14 Budget Request	$51	$0	$321	$397	$525	$821	$821	$821	$590	$371	$4,719
Total Shortfall	$0	$0	($179)	($1,003)	($875)	($479)	($379)	$821	$590	$371	**($1,133)**

*Prior years' actual received amounts are in grey. Total Shortfall amounts are based on actual received amounts versus the original FY11 request where appicable. Numbers in parentheses are negative.

Source: NASA OIG analysis of President's budget data.

Funding Shortfalls Led to Extended Use of Space Act Agreements and Delays to the First Crewed Launch. NASA's original budget estimate for the Commercial Crew Program projected that $1.4 billion would be required for FY 2012. Ultimately, NASA requested $850 million for the Program that year but received just $397 million.

NASA's first acquisition plan for developing the Commercial Crew Program anticipated the use of FAR-based contracts starting in late FY 2012 for the integration phase of development. During integration, NASA expected its partners to progress to a point where their system designs were mature. According to NASA officials, FY 2012 funding was insufficient to execute this plan. As a result, they continued to use funded Space Act Agreements to support the companies' development efforts.[24] Under this revised acquisition plan, NASA is also using FAR-based contracts to start certification activities and running that process parallel to activities under the Space Act Agreements. Even with this shift in procurement strategy, the budget reductions resulted in schedule delays, postponement of certification, and a delay in the completion of commercial crew development from FY 2016 to mid-FY 2017.

NASA officials told us that keeping multiple partners in the Program for as long as possible is essential to maintain redundant capability and competitiveness. For the next phase of development, including full system certification and demonstrations to the ISS, NASA plans to use a FAR-based contract.

However, continued funding shortfalls will only increase pressure on NASA to "down select" to a single company. Acknowledging this point in a March 2013 hearing, the NASA Administrator stated that funding profiles will affect the number of companies NASA will be able to fund during the final certification phase.[25]

[24] As noted earlier in this report, Space Act Agreements are considered less costly because partners share costs.

[25] Science Subcommittee, U.S. House of Representatives Appropriations Committee, "NASA Oversight Hearing," YouTube (March 20, 2013), http://www.youtube.com/watch?v=5NEW1GIekYk (accessed August 20, 2013).

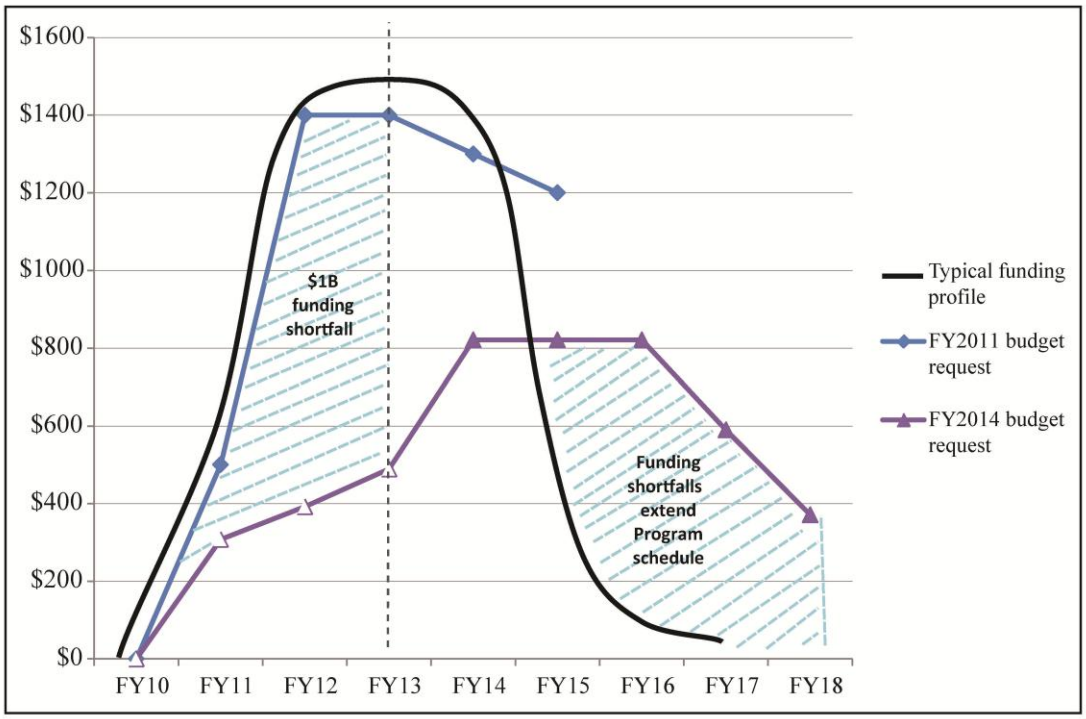
Although NASA has considered the possibility of continuing to use Space Act Agreements during the final phase of development, as noted earlier in this report, Agency officials told us they cannot impose specific requirements on partners under a Space Act Agreement in the same way they can with a FAR-based contract. Accordingly, they do not believe that Space Act Agreements would be suitable vehicles for certifying that particular systems meet NASA safety and human rating requirements.

Current Funding Plan Increases Risk of Further Cost Overruns, Schedule Delays, and Impediments to Competition. Decreased and flat-lined funding has already caused a 2-year delay in commercial crew development efforts. Moreover, the Program's anticipated funding for FY 2014 and beyond is not consistent with best acquisition practices and could manifest in additional problems down the road. Prior audit work by the GAO has shown that the most effective budget profile for large and complex space system development programs is steady funding in the early stages of development and increased funding during middle stages.[26] An absence of sufficient funding early in development increases cost risks and the potential for schedule delays because project managers have to defer development of critical technologies to a time when integration of those technologies may be more difficult or when the costs of material and labor may be greater. Shifting tasks to later project phases also results in higher fixed costs given the need to sustain a work force longer than originally planned or to add shifts in an attempt to make up for lost time. In addition, insufficient early funding for development decreases management's ability to identify and address key risks. Finally, insufficient funding may make it difficult to maintain two partners thereby eliminating the competition. Agency officials maintain that competition increases partner performance and helps drive down the price of future contracts.

A typical space system life cycle model shows a bell-shaped funding curve for research, development, testing, and evaluation because more resources are needed as development progresses and programmatic risks are identified and remediated (see Figure 3). However, while NASA's FY 2011 budget request for its Commercial Crew Program closely resembled the traditional bell curve and anticipated completing development in FY 2015, the Program's actual funding profile for FY 2012 and FY 2013 was flattened and the development schedule was extended. The FY 2014 budget request again reflects a bell curve, with development funding extended through FY 2018.

[26] GAO, "GAO Cost Estimating and Assessment Guide" (GAO-09-3SP, March 2009).

Figure 3: Program Evolution of Developmental Funding Budget Requests vs. Typical Funding Profile (Dollars in Millions)



Note: Solid white milestones reflect actual dollars received in previous years.

Source: NASA OIG analysis of President's Budget data and extrapolation to guidance from GAO's Cost Estimating and Assessment Guide.

If the shortfall in funding continues, NASA officials said it will be difficult for the Program to meet its goal of completing development by 2017. While the commercial partners could increase their contributions to offset the Government's reduced funding and help keep the Program on track, representatives from one company expressed uncertainty with regard to the continued development of their spacecraft in the absence of additional funding from the Agency. On average, the three Commercial Crew partners are contributing under 20 percent of the CCiCap development costs for their spaceflight systems.[27]

Two key advisory groups – the Aerospace Safety Advisory Panel (ASAP) and the National Research Council – recently published reports addressing the effects of funding shortfalls. In its 2012 Annual Report, the ASAP stated:

> From its inception, this program [Commercial Crew] has been funded at levels far below what would be expected for a traditional program. NASA's ability to successfully complete the certification process as currently planned and to begin flying [missions] by FY 17 will require increased funding for the program starting in FY 13… the ASAP is concerned about what tradeoffs NASA and the [partners] will take to accommodate future budget shortfall. There appear to be few options available to NASA when the

[27] For comparison, partner contributions for the cargo development program were roughly 50 percent.

> budget is reduced. These include stretching the schedule, reducing performance, and/or obtaining additional funding. Given NASA's budget history, it is unlikely there will be additional funding.[28]

The National Research Council made a similar observation in its 2012 report when addressing NASA programs in general:

> …there has been some instability at the programmatic level and the out-year projections in the President's budget are unreliable, which makes it difficult for program managers to plan activities that require multi-year planning. Numerous times the agency initiated new programs with the expectation that budgets would increase to support them, only to have no increases emerge…The approach to and pace of a number of NASA's programs, projects, and activities will not be sustainable if the NASA budget remains flat, as currently projected.[29]

Aligning Cost Estimates with Program Schedule May Enhance Management and Improve Transparency of Commercial Crew Program

According to NASA guidance, managers should develop year-by-year life cycle cost estimates for their programs before completing Preliminary Design Review.[30] A life cycle cost estimate refines a program's overall cost estimate by determining all possible costs required to develop, produce, deploy, and sustain a particular program and projecting them over time (by year). This policy is designed to prevent development delays in future years caused by inadequate funding levels.

NASA's Chief Engineer told us that NASA policies requiring life cycle cost estimates do not apply to development efforts that use Space Act Agreements, and that developing life cycle estimates for such programs has proven challenging. Therefore, despite completion of Preliminary Design Review by NASA's commercial crew partners, Agency officials have yet to develop a life cycle cost estimate for the Program. Instead, NASA developed independent government cost estimates that project the overall costs to complete development and certification.[31] An independent government cost estimate simply documents the government's assessment of the program's most probable overall cost without aligning the cost estimates to a schedule. The Chief Engineer did state that once a FAR-based contract is issued for CCtCap, which occurs around the same time the

[28] ASAP, "Annual Report for 2012" (January 9, 2013).

[29] Committee on NASA's Strategic Direction, Division on Engineering and Physical Sciences, National Research Council, "NASA's Strategic Direction and the Need for a National Consensus" (2012).

[30] NASA Procedural Requirements (NPR) 7120.5E, "NASA Space Flight Program and Project Management Requirements w/Changes 1-10" and NPR 7120.5 "NASA Space Flight Program and Project Management Handbook" (February 2010).

[31] An independent government cost estimate is conducted to check the reasonableness of a contractor's cost proposal and to make sure that the offered prices are within the budget range for a particular program. It documents the government's assessment of the program's most probable cost and ensures that enough funds are available to execute it. The Crew Program uses these types of estimates to inform budget planning efforts.

partners are expected to complete their Critical Design Reviews, the Program will become more traditional and a life cycle cost estimate will be feasible.

Because partnering with commercial companies through Space Act Agreements is a novel approach to developing human spaceflight transportation capabilities, NASA was faced with an array of challenges in developing cost estimates for the Commercial Crew Program. For example, Program officials noted that because of varying design approaches, each partner's estimated costs are different, making it difficult to complete a comprehensive life cycle cost estimate. In addition, NASA space system acquisition programs typically use the NASA/Air Force Cost Model to produce a life cycle estimate, which relies on historical information about NASA and Air Force space projects. However, because of the unique development approach used for this Program, little comparable historical data exists. Adding to the difficulty is that under a Space Act Agreement, developmental costs covered by the companies are not a part of Program costs and are generally proprietary. Given these factors, cost estimators could not fully rely on the model's early estimates.

We acknowledge the difficulties in establishing a comprehensive life cycle cost estimate for a program using a development approach that is evolving and for which limited comparable historical data exists. However, without a detailed cost estimate for each year of the program based upon a complete analysis of each subcomponent over time, it is difficult for NASA to calculate how much funding is required each year given that costs over time can fluctuate significantly. Furthermore, the lack of a comprehensive cost estimate makes it more difficult for NASA to manage its wider portfolio of spaceflight programs, particularly in a constrained budget environment.

Improved guidance requiring detailed cost estimates aligned with the program's schedule over time could help enhance the transparency of NASA's budget submissions. To this point, members of Congress and the ASAP have stated that in the absence of this type of information it is difficult to know with any level of confidence the amount of government money required to develop a viable commercial crew transportation capability.[32]

In early 2013, the private consulting group Booz Allen Hamilton (Booz Allen) completed an independent assessment of the Commercial Crew Program's government estimate that included costs from the end of CCDev2 through certification.[33] Overall, Booz Allen found that the Program's cost estimates were of high quality and followed standard cost estimating best practices. However, the assessment found that the estimates were optimistic, and that the Program was likely to experience cost growth. In addition, Booz Allen noted that without costs projected over the life of the Program, NASA officials will not be able to independently evaluate each partner's progress. Booz Allen recommended

[32] House Committee on Science, Space and Technology Hearing, "Recent Developments in NASA's Commercial Crew Acquisition Strategy" (September 14, 2012). (Representative Donna F. Edwards and Vice Admiral Joseph Dyer-ASAP Chair).

[33] Booz Allen, "Independent Cost Assessment of the Commercial Crew Program: Independent Cost Assessment Report" (March 1, 2013).

several efforts to improve the accuracy of the cost estimates, including using an integrated schedule and maintaining risk register data.[34]

In our judgment, NASA is now better positioned to develop improved guidance for cost estimating when systems are developed using Space Act Agreements in light of historical cost data received under the Commercial Crew Program.

Timeliness of NASA's Process for Considering Alternative Human Rating Requirements Remains a Concern

NASA's current process for considering partners' requests to use alternate standards or to deviate from NASA's human rating and certification requirements frequently does not result in timely decisions.[35] The Agency's current process was developed to ensure NASA management sufficiently considers dissenting opinions on safety-related issues. While we acknowledge the importance of considering all opinions on safety issues, an inability to address partners' requests in a timely manner risks costly redesign work or delays to the Program schedule. Although Program officials expected to process the majority of the partners' requests by mid-September 2013, the partners are expected to submit additional requests before the certification planning is completed.

Human Rating Requirements. "Human rating" is the process of assuring that a spacecraft or launch vehicle is capable of safely transporting human beings. Human rating concepts developed over the past 60 years include:

- using simpler designs to avoid complex components,
- using well-established and proven aerospace design standards,
- incorporating sufficient redundancy in all critical systems, and
- avoiding untried or unproven technology.

According to NASA, a human rated system must accommodate human needs; effectively utilize human capabilities; control hazards; manage safety risks; and, to the maximum extent possible, provide the capability to safely recover the crew from hazardous

[34] An integrated schedule is a time-based schedule containing the detailed tasks necessary to ensure successful program/contract execution. A risk register is a central repository for all risks identified by the project that includes information on probability, impact, and counter-measures.

[35] A partner may request an alternate standard that meets the intent of or is consistent with a NASA standard. Variances to requirements occur if a partner cannot meet a requirement, and are generally classified as exceptions, deviations, or waivers. NASA defines deviations as requests made during the formulation, planning, or design stages of a program to address expected situations and that provide temporary relief from a specific requirement in advance. NASA defines exceptions as permanent relief from a specific requirement, and they may be requested at any time during the life cycle of the program. NASA defines waivers as temporary relief from a specific requirement after the baseline system has been approved.

situations.[36] Compliance with these requirements leads to certification that the system is suitable for crewed spaceflight. Before securing transportation for its astronauts on a commercial spaceflight system, the Agency needs to review and approve the system to ensure it meets NASA's human rating requirements.

The OIG, GAO, and others have expressed concerns about NASA's approach to determining baseline human rating and safety requirements for commercial crew vehicles, and for ensuring that contractors adhere to those requirements. In order to stimulate innovative designs, NASA intentionally did not impose human rating and safety requirements on its commercial partners during early development. While such an approach may foster innovation, it also can raise concerns that partners may be developing systems that NASA will ultimately be unable to certify.

To address this challenge, in December 2011, NASA published a series of detailed requirements, certification, and management documents that provide its commercial partners with the Agency's specific safety and human rating objectives:

- Crew Transportation Plan (CCT-PLN-1100) defines the processes for Crew Transportation System certification and flight readiness.
- System Design Reference Missions (CCT-DRM-1110) defines reference missions to the ISS.
- Crew Transportation Technical Management Processes (CCT-PLN-1120) provides the technical management processes that support the certification effort.
- ISS Crew Transportation and Services Requirements Document (CCT-REQ-1130) establishes requirements that will be met to achieve certification to transport NASA crew.
- Crew Transportation Technical Standards and Design Evaluation Criteria (CCT-STD-1140) and Crew Transportation Operations Standards (CCT-STD-1150) are intended to guide the development of the crew transportation system.[37]

These documents outline the fundamental elements a system must satisfy to receive certification from NASA. According to NASA and partner personnel, the commercial partners have used these documents to ensure that they are integrating NASA's requirements into their transportation system designs. However, NASA has not yet certified whether any of the partners' systems meet the Agency's requirements.

[36] NPR 8705.2B, "Human-Rating Requirements for Space Systems (w/change 4 dated 8/21/2012)."

[37] In addition to these documents, prior to December 2011, NASA also published the Commercial Orbital Transportation Services ISS Interface Requirements Document (SSP 50808), which outlines requirements for docking with the Station. NASA originally released SSP 50808 in September 2007 to provide international partners guidance on docking with the ISS.

Figure 4 depicts NASA's strategy for ensuring the partners meet the Agency's human rating and safety requirements. In December 2012, NASA awarded CPC – the first of a two-phased, FAR-based contract under which the Agency plans to review the partners' transportation system designs to ensure they meet its safety and operational requirements.[38] In CPC, the partners provide products considered critical to establishing expectations for certification by NASA. The CPC statement of work provides criteria and requirements to guide the contractors' efforts toward NASA certification. These products include the following deliverables:

- *Alternate Standards* – The Contractor will deliver alternate standards proposed to satisfy the NASA "meet the intent of" standard requirements.

- *Hazard Reports* – The Contractor will deliver hazard reports for at least catastrophic hazards. The hazard reports will address all phases of the mission to the ISS. Hazard reports will include descriptions, effects, risk assessments and actions necessary to eliminate or control the hazard.

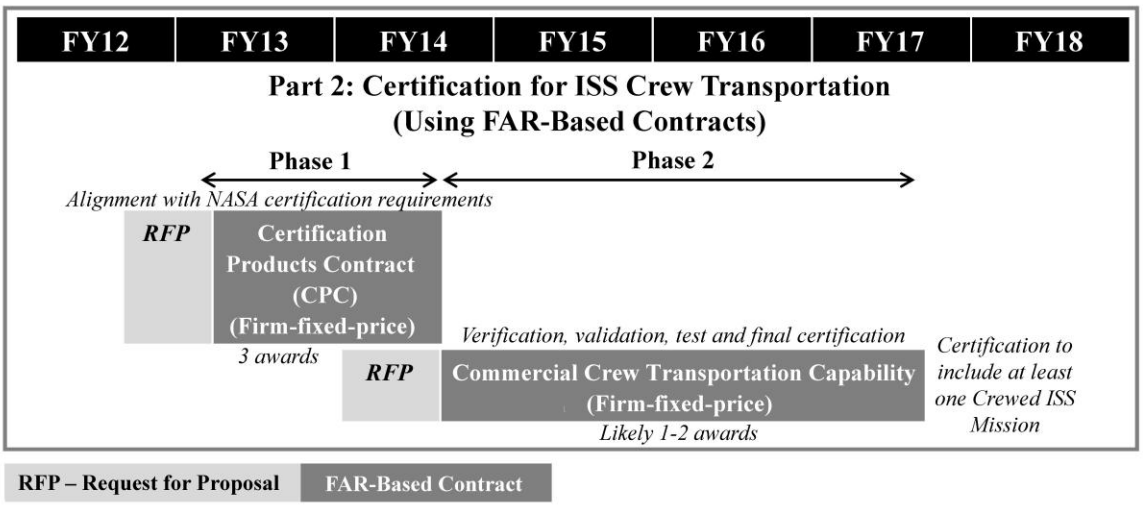
- *Verification and Validation Plan* – The Contractor will deliver a Verification and Validation Plan. The Plan will identify the verification and validation activities, methods, deliverables, and processes that result in objective evidence that all elements of the design, production, and operation meet the performance requirements and accomplish the intended design reference mission to the ISS when operated in the intended environment. The Contractor should deliver any proposed variances to meeting NASA's certification requirements.

- *Certification Plan* – The Contractor shall deliver a Certification Plan that will define an integrated strategy for certification of the complete system and will clearly define the order of execution and schedule.

During CCtCap, scheduled to start in the middle of 2014, NASA plans to enter into one or two firm-fixed-price contracts pursuant to which the Agency will endorse the partner's own internal certification in order to grant final certification of a crew transportation system or systems. This strategy anticipates the Agency certifying at least one operational crew transportation system in time for missions to the ISS by 2017.

[38] Phase I is CPC and Phase II is CCtCap.

Figure 4: Certification Strategy



Source: Commercial Crew Program Acquisition Strategy.

Process to Resolve Partner Requests for Alternate Standards and Requirements Variances. Given the partner's varying system designs, the Program has developed a process for assessing requests to use alternate standards and to vary from its stated requirements with a 90-day goal for NASA to respond to such requests. However, in the past, the process has taken as much as 9 months, and according to NASA officials, for other Agency programs such as the Ares I, even longer. The Commercial Crew Program office has acknowledged that this process can be lengthy and identified it as a significant risk to the Program. However, we found that the Program Office is not adequately tracking the timeliness of responses to partner requests.

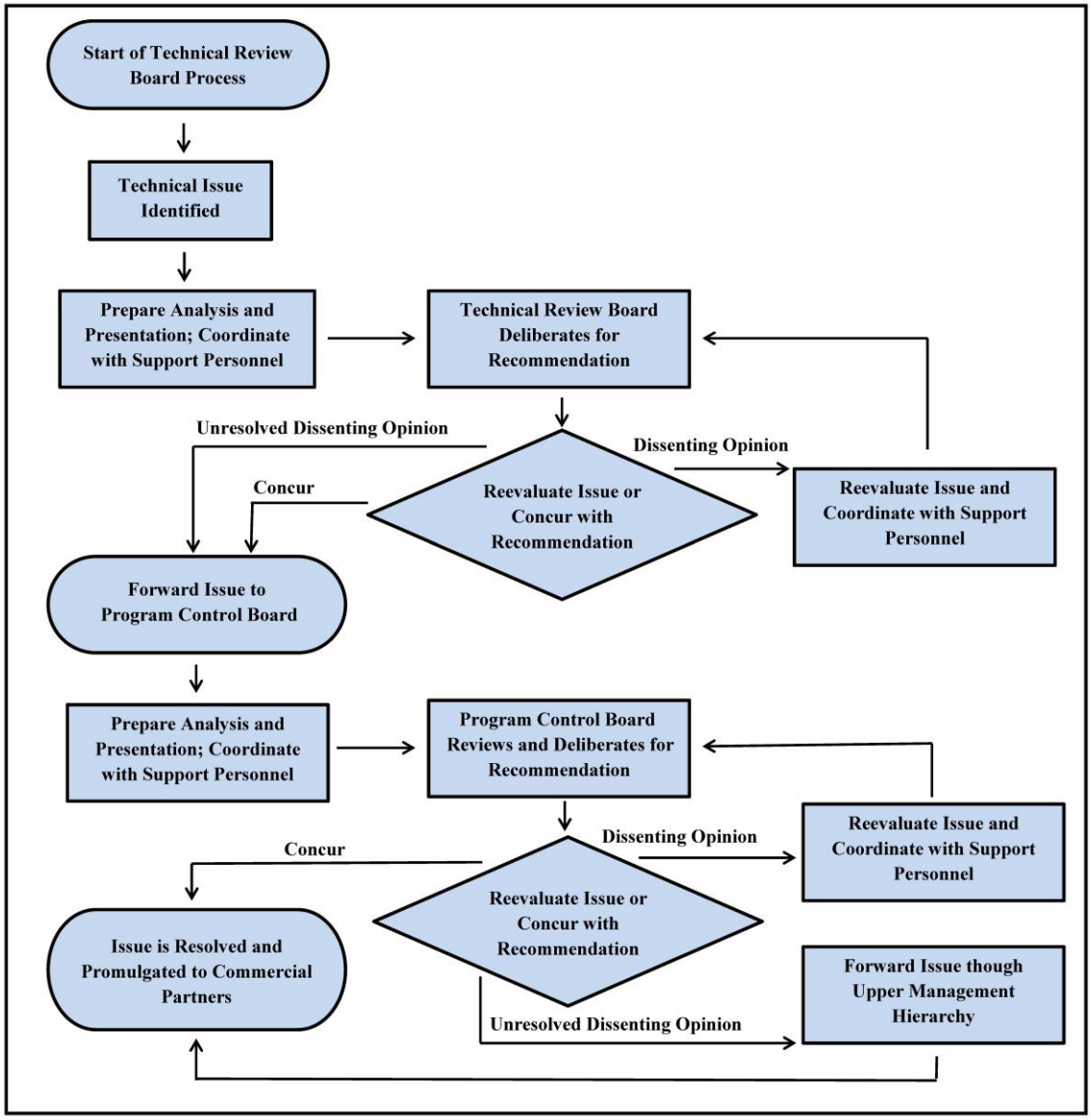
Requests related to Commercial Crew Program requirements are reviewed by the Commercial Crew Program Control Board while requests related to ISS requirements go to the Space Station Program Control Board. Requests can go to both boards if an integration issue exists.

Technical or safety requests of either type are first directed to a Technical Review Board for consideration and this Board makes recommendations to the full Program Control Board. Throughout the process, supporting organizations can provide dissenting opinions, which require additional analysis.[39] If a particular organization is not satisfied with the Program Control Board's decision, the issue can be elevated to a higher authority, including all the way to the NASA Administrator for final determination.

[39] The supporting organizations include the Commercial Crew Program Systems Engineering and Integration Office; Program Control and Integration; Partner Integration; Mission Planning and Integration; Spacecraft Systems; Launch Vehicle Systems; Launch and Recovery Systems; Commercial Crew Program Chief Engineer; Commercial Crew Program Chief Safety Officer; Engineering; Safety and Mission Assurance; Commercial Crew Program Chief Health and Medical Officer; Space and Life Sciences; Flight Crew; ISS; Mission Operations – Johnson Space Center; Ground Processing – Kennedy Space Center; and the FAA (Advisory Role).

Figure 5 depicts the general process used by both Boards.

Figure 5: Technical Review and Program Control Boards Process



Source: Commercial Crew Program process documentation and NPR 7120.5E.

This process was developed to ensure NASA management considers safety-related dissenting opinions when reaching a consensus, and officials said the process may take longer when the specific issue involves more risk to the mission. For example, in the original iteration of its human rating requirements, the Agency did not require pressure suits be tested to ensure they maintain a living environment.[40] However, in November 2011, NASA personnel questioned this omission, which resulted in the issue

[40] The pressure suits would include everything needed for survival such as breathing oxygen, pressure exerted on the body, and even a heating and cooling system.

being forwarded to the Technical Review Board and eventually to the full Program Control Board for review. During the review, dissenting opinions were elevated to the Program Control Board and senior NASA officials were consulted. In July 2012, NASA clarified the requirement and required the pressure suits be tested to ensure they maintain a living environment. According to Program officials, the 9 months it took to resolve this issue is not atypical for resolution of high-risk issues associated with human spaceflight programs.

As of July 2013, NASA has received 86 alternate standards or variances requests from its commercial crew partners. Of the requests that have been in the review process for more than 90-days, over 65 percent remain unresolved. According to Program personnel, part of the delay is attributable to the partners not providing complete information, requiring the Program Office to request additional data.

The Commercial Crew Program Office has acknowledged that the process for addressing requests for alternate standards or variances has been lengthy in the past. However, Program officials anticipated speeding up the pace of processing and completing the majority of the requests by mid-September 2013. Program officials also said that verbal feedback on the request is shared with the Partners long before the requests are formally closed.

We acknowledge the recent efforts the Agency has made in more timely processing requests for alternate standards or variances. Nonetheless, because the multi-step review process historically has been time consuming, and the partners are expected to submit additional requests before the certification planning is completed, resolving the current and any new requests in a timely manner is critical to Program success. For example, many of the program replies to the partner requests involve asking for more information – after a 90-120 day period has already passed.

In our judgment, greater visibility regarding the timeliness of NASA responses during program briefings would help prioritize and emphasize the importance of bringing resolution to the partner requests for alternate standards and variances within the 90-day goal. We found that although the Program Office regularly briefs NASA management on the progress of the partner requests, the briefings did not include a summary of the timeliness of NASA's responses, nor did they identify the number of requests over 90 days.

We acknowledge the need for the Agency to ensure that safety-related concerns are comprehensively considered. However, not resolving alternate standards and variance requests in a timely manner could adversely affect the Program. Specifically, partners may delay production of their final designs or move forward with requirements that are not fully defined. Previous reports by the OIG, GAO, and others have shown that requirement changes late in product development can lead to design rework that is both costly and time consuming.

Coordination of Spaceflight Safety Issues with Other Federal Agencies is Ongoing

NASA's foray into securing commercial transportation for its astronauts requires a greater level of coordination between the Agency and the FAA than has been the case with its previous crewed and uncrewed spaceflight missions. Although the two agencies have taken positive steps to coordinate their efforts, complex range safety, legal, and insurance issues remain unresolved.

NASA and FAA Responsibilities for Commercial Spaceflight Activities. For more than 50 years, NASA was solely responsible for the safe conduct of its space launches. However, because the Government will not own or control the operation of the space systems developed by NASA's commercial crew partners, their launch and reentry are deemed commercial activities subject to the jurisdiction of the FAA.[41]

The Commercial Space Launch Amendments Act of 2004 temporarily restricts the FAA's authority to regulate the commercial space industry. Specifically, until 2015, the FAA's authority is limited to regulating launches and reentries, and therefore at present the FAA does not license commercial spacecraft, requires no airworthiness certificate for these companies, and imposes no crew escape requirements during launch. Beginning in October 2015, the FAA is authorized to promulgate regulations to ensure crew and participant safety.[42] Eventually, oversight of the commercial spaceflight industry will parallel the way in which the FAA approaches airline safety, although NASA will continue to retain responsibility for ensuring the safety of its crews, workforce, and infrastructure during commercial launches carrying NASA astronauts.[43]

Because of these overlapping authorities, both NASA and the FAA must coordinate their efforts to avoid imposing conflicting requirements on commercial spaceflight operators. The NASA partner companies we spoke with said they are concerned about the impact conflicting requirements could have on their operations. Officials from one company said it is important that the FAA publish its regulations as soon as possible to enable each company in the market to operate under the safest conditions. They further explained that common sense regulation could help prevent an early accident that could result in over regulation – which could have a costly and negative effect on the fledgling industry. Other partners said they would prefer that the FAA postpone its regulations until both the industry and NASA requirements are fully developed because they do not want competing, overlapping, or contradictory requirements from NASA and the FAA.

Coordination Efforts are Progressing. As discussed in our 2011 audit report, NASA and the FAA took initial steps to coordinate their efforts by having discussions and co-

[41] 49 U.S. Code § 70101 et seq., Commercial Space Launch Act of 1984.

[42] 51 U.S. Code 509, paragraphs (a)(2) and (a)(5)(C) provided for the regulations to begin 8 years after the enactment of the Commercial Space Launch Amendments Act of 2004 (in 2012); this date was extended to begin October 1, 2015 by Public Law 112-95, February 14, 2012.

[43] NASA Policy Directive 8700.1, "NASA Policy for Safety and Mission Success" (October 28, 2008).

locating personnel at various NASA and FAA offices.[44] Since that time, NASA and the FAA have taken additional steps to coordinate their efforts. For example, in June 2012 the two agencies signed a Memorandum of Understanding agreeing to collaborate on several efforts, including:

- providing a stable framework for the U.S. space launch industry,
- avoiding conflicting requirements and multiple sets of standards,
- advancing both public safety and crew safety, and
- advancing the interests of NASA-certified U.S. commercial launch operators responsible for transporting U.S. and partner astronauts to the ISS.

NASA and the FAA are working to both achieve consistency between NASA and non-NASA flight activities and to avoid conflicts between FAA regulations and the Commercial Crew Program requirements. To that end, the agencies have developed a list of items requiring coordination, such as the authority to approve changes while in flight, including designating emergency landing sites. Although this list is still evolving, as of August 2013, the agencies have resolved 24 of 59 issues and are working to settle the remaining issues. However, many of the outstanding items are among the more complex issues facing the two agencies and, as the Commercial Crew Program has acknowledged, will require considerable technical and legal review as well as the agreement of both NASA's Commercial Crew Program Control Board and the FAA Office of Commercial Space Transportation. Examples of these complex issues include agreed-upon credentials for pilots and crew, financial responsibility for claims, and the claims waiver requirements.[45] Commercial Crew Program managers noted that NASA, the FAA, and the U.S. Air Force – which operates the launch ranges most often used by the commercial partners – must develop a process that encourages uniformity among Government oversight authorities in the implementation of requirements.

Mechanism Lacking for Official Resolution of Joint Issues. One hindrance to ongoing coordination between NASA and the FAA is the lack of an official mechanism to address joint issues and obtain documented resolution. NASA staff has acknowledged that documented decision-making is necessary for maintaining internal control of the resolution process. However, the process for documenting issue resolution through the Commercial Crew Program Control Board and the FAA Office of Commercial Space Transportation is time consuming and not firmly established. For example, the FAA participates in meetings of the Commercial Crew Program Control Board only as an observer/liaison and FAA representatives have indicated they do not view Board deliberations as binding to the FAA. Therefore, NASA staff members coordinating

[44] NASA OIG, "NASA's Challenges Certifying and Acquiring Commercial Crew Transportation Services" (IG-11-022, June 30, 2011).

[45] The FAA and NASA must decide how claims for loss of life, injuries, or property damage will be handled, and/or the waivers of claims for missions that are contractor-operated and owned but involve NASA missions.

resolution of requirements issues currently record the decisions from the Commercial Crew Program Control Board in addition to documentation of agreement of those decisions by the FAA Office of Commercial Space Transportation.

Figure 6: Multiple Agencies Routinely Involved in Commercial Spaceflight: SpaceX's Falcon 9 with Dragon Capsule Launches from Cape Canaveral Air Force Station En Route to the ISS on a NASA Resupply Mission

Source: NASA.

Furthermore, consistent application of safety principles is necessary so that crew safety is held to the same standard for Government or commercially-licensed activities. The Commercial Crew Program has initiated formation of a tri-party safety steering group involving NASA, FAA, and U.S. Air Force staff. The group will be chartered to promote consistency and uniformity among the various Government entities with whom commercial providers must work to provide commercial crew space transportation. As of August 2013, the "Commercial Human Spaceflight Launch and Re-Entry Steering Group" (steering group) had developed a draft charter. However, the steering group's authority and reporting structure remains to be established. Apart from the steering group's work, Commercial Crew Program officials have proposed developing a Commercial Crew Program/FAA Program Management Plan to document joint processes and information exchange for the execution of licensed missions.

Regulatory Issues Remain that Could Impact Mission Schedules. Without a formal process to resolve complex coordination issues, it will be difficult for NASA to influence the actions of the other Government entities that have a role in commercial crew spaceflight. Of greatest concern are issues involving safety, such as whether a change in a spacecraft's reentry trajectory would violate the spacecraft operator's license. An extreme example is a situation in which the weather is deteriorating and the FAA's license for the flight (provided 180 days in advance of the flight) may not allow for a landing at a place or time that would provide the crew with the best chance of a safe return. In such an event, proper FAA guidance and range responses would be critical to ensuring crew safety. Although air traffic controllers make these types of decisions routinely for changes in airline flights, a similar procedure does not currently exist for commercial space launches.

Other unresolved coordination matters involve legal and liability issues. These include:

- FAA licenses cover launch and reentry, but the definition of the "end of launch" and "beginning of reentry" for Commercial Crew Program missions remains to be resolved. For instance, end of launch could be considered when rocket stages separate, or in the case of expendable launch vehicles, the "last exercise of control" over the launch vehicle, which historically occurs with the venting of the tanks and discharging of batteries. A failure to define each term could result in confusion over which agency has control or decision making authority during flight.

- A question exists regarding the legality of NASA astronauts operating commercial vehicles given the statutory definition of "crew" as employees of the licensee.

- Current FAA regulations parallel U.S. Air Force range requirements. For past-crewed missions, NASA negotiated with the range for implementation of contingencies that specifically addressed the safety of crews, including procedures for emergency egress and landing. For FAA-licensed launches, NASA has no authority or official avenue to influence range safety policy or implementation.

Conclusion

NASA continues to make progress in commercial spaceflight development, as recently demonstrated by SpaceX's successful cargo resupply missions to the ISS and Orbital's maiden test flight of its cargo delivery rocket. However, the ability of commercial partners to successfully develop safe, reliable, and cost effective space transportation for human transportation to the ISS is far more complex and unproven.

Reduced budgets for NASA's Commercial Crew Program have forced the Agency to delay completion of the Program's development phase until 2017, and if this funding trend continues the risk of delay beyond 2017 increases significantly. As such, it is crucial that the Agency make a concerted effort to develop comprehensive and timely cost estimates for its Commercial Crew Program.

NASA's publication of commercial crew requirements and certification documents was a major step forward in the evolution of the Program, but the path to certifying a commercial partner's spaceflight system remains uncertain. Given that each partner has a varied business and technical approach to development, it is important that NASA utilize a process that both ensures safety-related concerns are sufficiently examined and that deviations, exceptions, and waivers are processed in a timely manner. Failure by NASA to confirm design requirements and provide timely certification guidance regarding deviations, exceptions, and waivers could impact contractors' ability to move forward with production of their spaceflight systems.

Finally, NASA's ability to obtain adequate funding from Congress and coordinate effectively with the FAA and Air Force to manage the commercial spaceflight industry are key factors underpinning the success of the Agency's crewed commercial spaceflight efforts. Failure to secure these capabilities will require NASA to negotiate for additional seats on the Soyuz, which by 2017 will cost over $70 million each. Moreover, given that the operational status of the ISS beyond 2020 is yet to be determined, delays beyond 2017 may call into question the viability of the Program.

Recommendations, Management's Response, and Evaluation of Management's Response

Recommendation 1. We recommended that NASA, to the extent practical, revise guidance to ensure that managers of space system programs developed using Space Act Agreements provide detailed cost estimates for each year of the program based upon a complete analysis of the program over time before preliminary designs are completed in order to increase the accuracy and transparency of Agency budget submissions.

Management's Response. NASA concurred with our recommendation, noting that it will review existing policies and guidelines to determine the appropriate mechanism for satisfying the intent of this recommendation. NASA stated that while it will be extremely challenging to prepare detailed cost estimates for each year based upon a complete analysis before preliminary designs are completed, the Agency will endeavor to increase the accuracy and transparency of Agency budget submissions for future use of funded Space Act Agreements. NASA expects to complete any required updates to its existing policies and guidelines by mid-calendar year 2014.

Evaluation of Management's Response. We consider NASA's proposed corrective actions responsive; therefore, the recommendation is resolved and will be closed upon completion and verification of the corrective actions.

Recommendation 2. We recommended that the Associate Administrator for the Human Exploration and Operations Mission Directorate examine whether more comprehensive costs estimates should be developed by the Commercial Crew Program before completion of the Critical Design Review.

Management's Response. The Associate Administrator concurred with our recommendation, noting that the Program currently employs a series of reviews involving both internal and external checks that continually examine the Commercial Crew Program's status and that these reviews can identify cost risks or other indicators that may suggest the need for more comprehensive cost estimates. The Associate Administrator stated that NASA will take additional actions to address our recommendation, including collaborating with the ISS Program to examine service costs and updating the Independent Government Cost Estimates for both the FY 2016-2020 budget cycle and after the CCtCap award. The Associate Administrator stated that all additional actions are expected to be completed by the end of calendar year 2014.

Evaluation of Management's Response. We consider the Associate Administrator's proposed corrective actions responsive; therefore, the recommendation is resolved and will be closed upon completion and verification of the corrective actions.

Recommendation 3. We recommended that the Associate Administrator for the Human Exploration and Operations Mission Directorate routinely track adherence to the 90-day goal for responding to contractor requests for alternate requirement standards and variances and explore ways to facilitate the process in order to avoid delays or additional costs in development efforts.

Management's Response. The Associate Administrator concurred with our recommendation, stating that while the Program did not meet the 90-day goal for some of the Round 1 dispositions, in many cases this was to allow extra time for the partners to re-deliver products or provide additional supplementary information. Furthermore, according to the Associate Administrator, the Program was successful in dispositioning all deliverables by the end of September. To address our recommendation, the Associate Administrator stated that the Program completed a workshop in September 2013 to evaluate the lessons learned from Round 1 of the CPC Contract and to develop improvements to increase timeliness for Round 2. He also stated that NASA will begin tracking disposition timeliness against the 90-day goal and consider deferring the next round of reports to allow time for the the Agency to focus on key requests that may influence the partners' designs. The Associate Administrator anticipates completing these actions by the end of calendar year 2013.

Evaluation of Management's Response. We consider the Associate Administrator's proposed corrective actions responsive; therefore, the recommendation is resolved and will be closed upon completion and verification of the corrective actions.

Recommendation 4. We recommended that the Associate Administrator for the Human Exploration and Operations Mission Directorate, in conjunction with the FAA and the U.S. Air Force, formally establish a tri-agency Safety Steering Group for resolution of issues involving crew and public safety during commercial spaceflight operations in order to ensure that the Agency expeditiously meets all spaceflight safety issues.

Management's Response. The Associate Administrator concurred with our recommendation, noting that while NASA and the FAA have ongoing and comprehensive interactions regarding safety requirements and regulations, expanding this collaboration to include the Air Force in a more formal setting would be beneficial. The Associate Administrator stated that NASA has recently taken action to address our recommendation including obtaining approval from the Program Control Board to develop a Safety Steering Group that includes FAA and Air Force leadership, developing a draft charter for the Steering Group, and holding preliminary meetings between NASA, the FAA, and the Air Force's 45th Space Wing. The Associate Administrator also stated that additional meetings with the 45th Space Wing are scheduled for January 2014.

Evaluation of Management's Response. We consider the Associate Administrator's proposed corrective actions responsive; therefore, the recommendation is resolved and will be closed upon completion and verification of the corrective actions.

APPENDIX A

Scope and Methodology

We performed this audit from August 2012 through September 2013 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. This audit focused on the Commercial Crew Program managed by NASA's Commercial Spaceflight Development Office within the Human Exploration and Operations Mission Directorate.

To determine the Agency's management of the Commercial Crew Program, progress made, and challenges hindering the successful implementation of the Program, we reviewed 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 Commercial Crew Program. We interviewed key personnel within NASA's Commercial Spaceflight Development Office and the Commercial Crew Program located at NASA Headquarters, Kennedy Space Center, Johnson Space Center, and commercial partners at corporate sites or by telephone.

To determine whether the Commercial Crew Program is on track to provide a system capable of reaching the ISS in 2017, we analyzed the Program's documents, including budget documents, schedule timelines, and performance requirements as designed by NASA and presented to the development partners. We compared planned budgeting levels to actual budgeting levels and reviewed NASA's contingency planning for lower funding levels. We reviewed NASA's contingency plans to manage transportation to and from the ISS beyond 2016 in the case of major programmatic delays.

In order to assess the process used to communicate human rating requirements to the commercial partners, we reviewed human rated certification plans to assess how insight and oversight is to be implemented, and interviewed key NASA and commercial partner personnel. We also interviewed NASA Partner Integration Teams and observed their interactions with the commercial partners, and reviewed the requirements baseline to determine the variability of requirements modifications. Furthermore, we tracked and analyzed the timeliness of NASA's responses to the companies' requests for variances and alternate standards. By doing this, we were able to determine exactly how long it took NASA to provide a disposition on each of the requests, and therefore provide observations based upon the 90-day goal in the CPC contract, and from information provided by the companies.

Finally, to determine whether NASA is effectively coordinating with the FAA and other Government agencies to resolve spaceflight issues, we interviewed NASA personnel responsible for this coordination, applicable regulations and U.S. laws, as well as FAA personnel associated with certification and licensing of commercial spaceflight operations.

Use of Computer-Processed Data. We used computer-processed data to perform this audit. We collected computer-processed cost data related to the Commercial Crew Program in the form of milestone payment data from the beginning of the Program through the end of August 2013. Program officials downloaded the data from NASA's financial management program (Business Warehouse) and provided the data in Microsoft Excel. For our audit objectives, we compared this data to information provided in the President's budget estimates. We also queried the financial management program ourselves in order to validate the information received from the Program office. Therefore, we assess that the cost data we received is sufficiently reliable, but we did not rely solely on the computer-processed data to support our findings, conclusions, or recommendations.

Review of Internal Controls

We reviewed NASA policies and procedures to determine NASA's internal control requirements for managing the Commercial Crew Program. We found that while the Commercial Crew Program exhibited several good internal control practices, NASA officials should not have exempted this Program from adhering to required policies such as annual statements of assurance, periodic reviews by NASA's Independent Program Assessment Office, or formal assessments of their acquisition procedures as required by the Office of Management and Budget (OMB). We acknowledge that using Space Act Agreements requires some adjustment in procedures, but new programs and new approaches to development generally require more oversight, not less. Complying with basic OMB and GAO guidance helps managers provide reasonable assurance that government resources are safeguarded and errors or fraud are avoided. Although program officials understood the basic concept of internal control, the programs were not required by the Human Exploration and Operations Mission Directorate to perform internal control assessments. During the course of this audit, corrections were made and the Commercial Crew Program plans to submit a FY 2013 statement of assurance concerning their internal control program. In addition, although the Commercial Crew Program has spent a total of over $1 billion in government funding, the OMB-directed acquisition assessment for projects over $250 million has yet to be conducted. Finally, even though commercial spaceflight development commenced 7 years ago, neither the Cargo nor the Crew programs have been reviewed by NASA's Independent Program Assessment Office.[46] During the course of this audit, the Independent Program Assessment Office began designing a review of the Commercial Crew Program.

[46] On April 26, 2007, NASA's Program Management Council decided not to conduct an Independent Program Assessment Office review of the Commercial Cargo Program because of the uniqueness of the Program. The Cargo Program, now consisting of the Commercial Orbital Transportation Services and Commercial Resupply Services, has spent a total of over $1.7 billion in NASA funding.

Prior Coverage

During the last 5 years, the NASA OIG and the GAO have issued 11 reports of particular relevance to the subject of this report. Unrestricted reports can be accessed over the Internet at http://oig.nasa.gov/audits/reports/FY13/index.html (NASA OIG) and http://www.gao.gov (GAO).

NASA Office of Inspector General

"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-11-12, February 17, 2011)

Government Accountability Office

"Commercial Space Launches: FAA Should Update How It Assesses Federal Liability Risk" (GAO-12-899, July 30, 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: Assessment 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: Commercial Partners Are Making Progress, but Face Aggressive Schedules to Demonstrate Critical Space Station Cargo Transport Capabilities" (GAO-09-618, June 16, 2009)

COMMERCIAL PARTNER TABLES

Table 4: List of CPC Recipients

Company	System	Total Funds Available	Total Funds Used (as of August 31, 2013)	Profile	Capability	Location
Sierra Nevada Corp	Dream Chaser	$10 million	$4 million	Piloted lifting-body spacecraft	7 astronauts or equivalent crew and cargo; runway landing	Louisville, CO
The Boeing Company	CST-100	$9.9 million	$4 million	Crew module and service module	7 astronauts or equivalent crew and cargo; dry surface landing	Houston, TX
Space Exploration Technologies (SpaceX)	Dragon	$9.6 million	$3.8 million	Free-flying, reusable spacecraft	7 astronauts; dry surface or ocean landing	Hawthorne, CA

Source: NASA OIG summary of Commercial Crew Program data.

Table 5: List of CCiCap Recipients

Company	System	Total Funds Available[a]	Total Funds Used (as of August 31, 2013)	Profile	Capability	Milestones Completed (as of August 31, 2013)	Location
The Boeing Company	CST-100	$480 million	$280.9 million	Crew module and service module	7 astronauts or equivalent crew and cargo; dry surface landing	8 of 20	Houston, TX
Space Exploration Technologies Corporation (SpaceX)	Dragon	$460 million	$249 million	Free-flying, reusable spacecraft	7 astronauts; dry surface or ocean landing	7 of 16	Hawthorne, CA
Sierra Nevada Corporation	Dream Chaser	$227.5 million	$107.5 million	Piloted lifting-body spacecraft	7 astronauts or equivalent crew and cargo; runway landing	4 of 12	Louisville, CO

[a] Total Funds Available includes optional milestones added in August 2013.

Source: NASA OIG summary of Commercial Crew Program data.

Table 6: List of CCDev2 Recipients

Company	System	Total Funds Available	Total Funds Used (as of June 30, 2013)	Profile	Capability	Milestones Completed (as of June 30, 2013)	Location
The Boeing Company	CST-100	$112.9 million	$112.9 million (100%)	Crew module and service module	7 astronauts or equivalent crew and cargo; dry surface landing	16 of 16	Houston, TX
Sierra Nevada Corp	Dream Chaser	$105.6 million	$97.6 million (92%)	Piloted lifting-body spacecraft	7 astronauts or equivalent crew and cargo; runway landing	14 of 15	Louisville, CO
Space Exploration Technologies (SpaceX)	Dragon	$75 million	$75 million (100%)	Free-flying, reusable spacecraft	7 astronauts; dry surface or ocean landing	11 of 11	Hawthorne, CA
Blue Origin	Space Vehicle	$22 million	$22 million (100%)	Biconical spacecraft; Atlas V rocket initially, then reusable booster stage	4 astronauts	11 of 11[a]	Kent, WA
Unfunded							
Alliant Techsystems Inc.	Liberty	n/a	n/a	Solid rocket boosters, Ariane 5 core stage, Vulcain 2 engine	44,500 lbs lift to low Earth orbit	5 of 5	Promontory, UT
Excalibur Almaz	Human Spacecraft	n/a	n/a	Human spacecraft, including a capsule, launch abort system, and expendable service module	3 astronauts or equivalent cargo	5 of 5	Houston, TX

United Launch Alliance	Atlas V	n/a	n/a	Atlas core stage, Centaur upper stage, and option for up to five solid rocket boosters	860,000 lbs of thrust from core stage at liftoff; ability to launch different crew spacecraft	5 of 5	Centennial, CO

[a] Three additional unfunded milestones were added in February 2013.

Source: NASA OIG summary of Commercial Crew Program data.

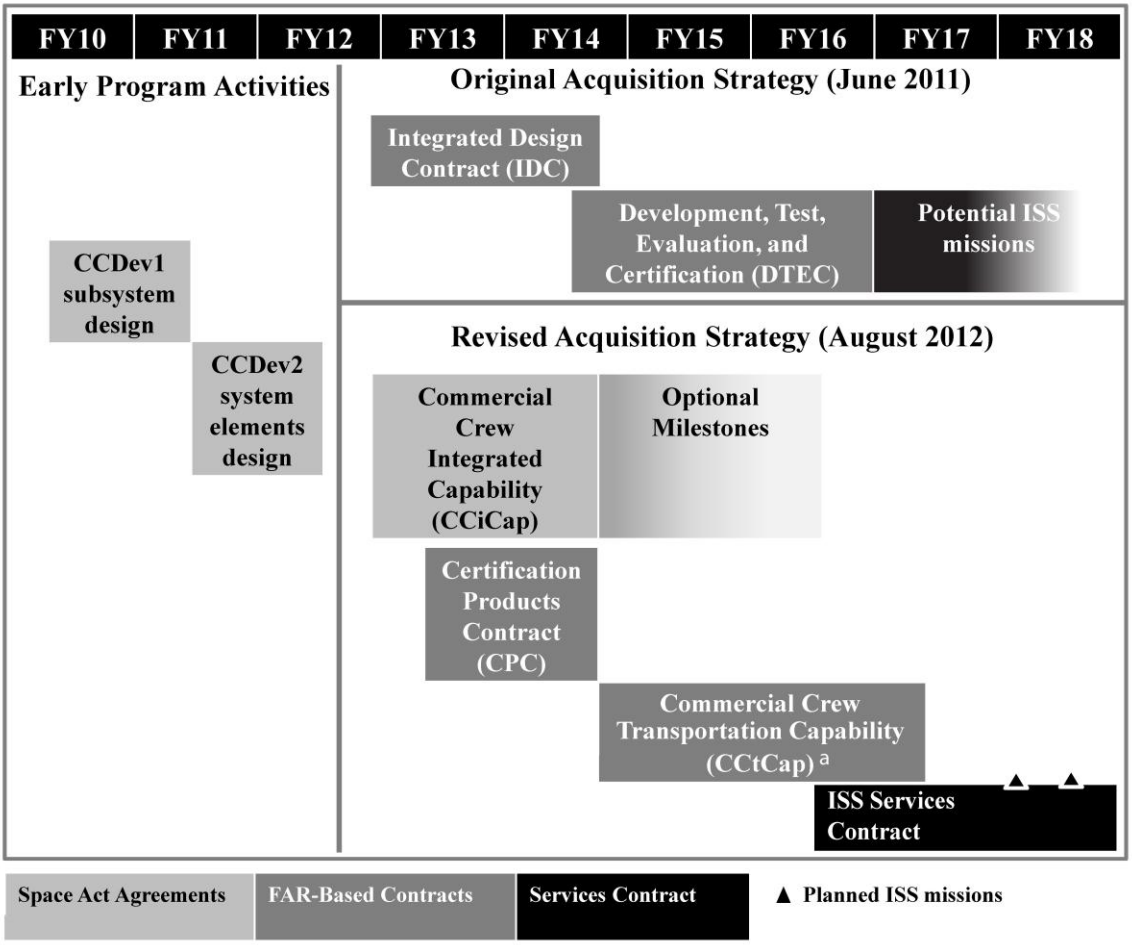
Table 7: List of CCDev1 Recipients

Company	System	Total Funds Spent	Profile	Capability	Milestones Completed (as of June 30, 2013)	Location
Sierra Nevada Corp	Dream Chaser	$20 million	Piloted lifting-body spacecraft	7 astronauts or equivalent crew and cargo; runway landing	4 of 4	Louisville, CO
The Boeing Company	CST-100	$18 million	Crew module and service module	7 astronauts or equivalent crew and cargo; dry surface landing	36 of 36	Houston, TX
United Launch Alliance	Atlas V	$6.7 million	Atlas core stage, Centaur upper stage, and option for up to five solid rocket boosters	860,000 pounds of thrust from core stage at liftoff; ability to launch different crew spacecraft	4 of 4	Centennial, CO
Blue Origin	Space Vehicle	$3.7 million	Biconical spacecraft; Atlas V rocket initially, then reusable booster stage	4 astronauts	7 of 7	Kent, WA
Paragon Space Development Corporation	Commercial Crew Transport-Air Revitalization System (CCT-ARS)	$1.44 million	n/a	Modular and reconfigurable life support system	5 of 5	Tucson, AZ

Source: NASA OIG summary of Commercial Crew Program data.

COMPARISON OF ORIGINAL AND REVISED ACQUISITION STRATEGIES FOR THE COMMERCIAL CREW PROGRAM

Figure 7: Comparison of Original and Revised Acquisition Strategies for the Crew Program



[a] A draft request for proposal for CCtCap, formerly known as CPC Phase 2, was released in July 2013.

Source: NASA OIG analysis of Program-supplied data.

MANAGEMENT COMMENTS

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

NOV - 7 2013

Reply to Attn of: Human Exploration and Operations Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Human Exploration and Operations Mission Directorate

SUBJECT: Response to OIG Draft Audit Report, "NASA's Management of Commercial Crew Program" (Assignment No. A-12-024-01)

The Human Exploration and Operations Mission Directorate (HEOMD) appreciates the opportunity to review your draft report entitled "NASA's Management of Commercial Crew Program" (Assignment No. A-12-024-01).

NASA's response to the recommendations, including planned corrective actions, follows:

Recommendation 1: Revise guidance, to the extent practical, to ensure that managers of space system programs developed using Space Act Agreements provide detailed cost estimates for each year of the program based upon a complete analysis of the program over time before preliminary designs are completed in order to increase the accuracy and transparency of Agency budget submissions.

Management's Response: NASA concurs with this recommendation. NASA will review existing policies and guidelines to determine the appropriate mechanism for satisfying the intent of this recommendation. While it will be extremely challenging to prepare detailed cost estimates for each year based upon a complete analysis before preliminary designs are completed, NASA will endeavor to increase the accuracy and transparency of Agency budget submissions for future use of funded Space Act Agreements. Any updates required to NASA's existing policies and guidelines will be accomplished by mid-calendar year 2014.

Recommendation 2: Examine whether more comprehensive costs estimates should be developed by the Commercial Crew Program before completion of the Critical Design Review.

Management's Response: NASA concurs with this recommendation. NASA employs a series of reviews involving both internal and external checks that continually examine the Commercial Crew Program's (CCP's) status as a normal course of business, and will continue to do so. These reviews, such as equivalent Key Decision Points, quarterlies, risk reviews, and independent reviews can identify cost risks or other indicators which may suggest that more comprehensive cost estimates are warranted.

Additional actions planned by NASA to address this recommendation include:

- Continue collaborating with the International Space Station Program to extend this examination to estimates of services costs.
- Examine and update CCP's Independent Government Estimates for the next budget cycle (FY16-20 budget formulation).
- Review and update CCP's Independent Government Estimates after Commercial Crew Transportation Capability contract is awarded to incorporate new cost, schedule, technical, and risk information.

All of these actions are planned to be completed by the end of calendar year 2014.

Recommendation 3: Routinely track adherence to the 90-day goal for responding to contractor requests for alternate requirement standards and variances and explore ways to facilitate the process in order to avoid delays or additional costs in development efforts.

Management's Response: NASA concurs with this recommendation. Round 1 of NASA's Certification Products Contracts involved over 400 deliverables spanning three different partners with varying designs and processes and formats resulting in thousands of NASA comments in response. While the program did not meet the internally established goal of 90 days for some of the Round 1 dispositions, in many cases it was a conscious decision to allow extra time for the partners to redeliver products or provide additional supplementary information to increase effectiveness of the review. Also, CCP was successful in dispositioning all deliverables by the end of September (unless a partner requested a deference of our control board review and disposition). In addition, the Program concluded a workshop in September to evaluate the lessons learned from Round 1 and develop process improvements to ensure more timely disposition of the Round 2 deliverables.

Additional actions planned by NASA to address this recommendation include:

- Adjust CCP's management reporting processes to track disposition performance against the 90 day goal for each item received after the Round 2 deadline of May 28, 2014.
- Consider contract changes to defer the next delivery of hazard reports by several weeks to allow the NASA team to focus on the timely disposition of variances, alternate standards, the verification and validation plans, and the certification plans that could more strongly influence the partners' designs.

All of these actions are planned to be completed by the end of calendar year 2013.

Recommendation 4: In conjunction with the FAA and the Air Force, formally establish a tri-agency Safety Steering Group for resolution of issues involving crew and public safety during commercial spaceflight operations in order to ensure that the Agency expeditiously meets all spaceflight safety issues.

Management's Response: NASA concurs with this recommendation. While NASA and the Federal Aviation Administration (FAA) have ongoing and comprehensive interactions regarding crew/public safety requirements and regulations, NASA agrees that expanding this collaboration

to include the Air Force in a more formal setting would be beneficial. Specific actions either recently completed or planned to address this recommendation include:

- The CCP Program Control Board approved the development of a Safety Steering Group including FAA and Air Force leadership.
- A proposed draft charter describing the purpose, objective, scope, and membership for the Commercial Human Spaceflight Launch and Re-entry Steering Group (LESG) was presented to the CCP Program Control Board on June 27, 2013.
- Preliminary, informal meetings were held with the Air Force 45th Space Wing, FAA, and CCP points of contact to introduce LESG concept (August, 2013).
- The CCP is currently scheduled to provide a CCP overview briefing to the new 45th Space Wing Commander in January 2014.

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 at (202) 358-1574.

William H. Gerstenmaier

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House Committee on Oversight and Government Reform
- Subcommittee on Government Operations

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

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