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AUDIT REPORT

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NASA'S CHALLENGES CERTIFYING AND ACQUIRING COMMERCIAL CREW TRANSPORTATION SERVICES

OFFICE OF INSPECTOR GENERAL

National Aeronautics and
Space Administration

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Paul K. Martin
Inspector General

Acronyms

CCDev	Commercial Crew Development
COTS	Commercial Orbital Transportation Services
CRS	Commercial Resupply Services
EELV	Evolved Expendable Launch Vehicle
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulation
FY	Fiscal Year
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements

OVERVIEW

NASA'S CHALLENGES CERTIFYING AND ACQUIRING COMMERCIAL CREW TRANSPORTATION SERVICES

The Issue

After more than 30 years and 130 flights, NASA's Space Shuttle fleet will retire this year, leaving the United States dependent on the Russian Soyuz vehicle for crew transportation to and from the International Space Station until the next generation of U.S. space vehicles is ready for flight.[1] To develop this next generation of vehicles, NASA is simultaneously embarking on two paths:

1. Developing a Government-owned multi-purpose crew vehicle and Space Launch System for human exploration beyond low Earth orbit;[2] and

2. Stimulating the development of a commercial space industry capable of providing NASA with safe, reliable, and cost-effective access to and from the International Space Station and low Earth orbit.[3]

While NASA has over 50 years of experience with contractor-built, Government-owned space vehicles, the Agency has never procured transportation for its astronauts aboard a commercially developed vehicle. Of primary concern in this new paradigm is how the Agency will work with its commercial partners to ensure that commercially developed vehicles meet NASA's safety and human-rating requirements. These requirements seek to ensure that spaceflight systems accommodate human needs, control hazards, manage safety risks, and, to the maximum extent possible, provide the capability to recover the crew safely from hazardous situations.[4]

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[1] With completion of STS-133 on March 9, 2011, Space Shuttle Discovery has flown its last mission and is the first vehicle in the Shuttle fleet to be retired. Space Shuttle Endeavour completed its last mission (STS-134) on June 1, 2011 and the remaining Space Shuttle, Atlantis, will complete its final mission later this year.

[2] "Low Earth orbit" is commonly defined as between 100 and 1,240 miles above the Earth's surface.

[3] The NASA Authorization Act of 2010 (Public Law 111-267) stipulated that NASA's new multi-purpose crew vehicle and Space Launch System are to expand human spaceflight beyond the Space Station and low Earth orbit no later than December 31, 2016. The vehicles will also serve as a backup in the event that commercial industry cannot provide Space Station crew transportation services at that time. The NASA Authorization Acts of 2005 (Public Law 109-155), 2008 (Public Law 110-422), and 2010 collectively directed NASA to use commercially developed systems to the maximum extent practicable for crew and cargo transportation to the Space Station.

[4] NASA Procedural Requirements 8705.2B, "Human-Rating Requirements for Space Systems (w/change 1 dated 12/7/2009)," May 6, 2008.

Given the importance of the shift in NASA's approach to acquiring human access to space, the Office of Inspector General examined the Agency's efforts to modify its existing safety and human-rating requirements to make them applicable to commercially developed vehicles. We also evaluated the overarching challenges associated with possible approaches NASA may use to certify and acquire commercial crew transportation services. Details of the audit scope and methodology are in Appendix A.

Results

NASA is making sustained progress toward acquiring commercial crew transportation services. For example, in 2009 the Agency initiated the Commercial Crew Development (CCDev) effort to focus on developing systems and concepts that will help establish an industry capable of transporting astronauts to low Earth orbit and the Space Station. The following year, NASA awarded $50 million in funded Space Act Agreements to encourage the development of system concepts and capabilities that could enable commercial crew transportation services.[5] In April 2011, the Agency announced a second round of CCDev awards (CCDev 2) totaling $269.3 million to accelerate the availability of U.S. commercial crew transportation capabilities. However, even with the additional funding planned, NASA faces multiple challenges and risks as it expands its Commercial Crew Transportation program. These include:

Modifying NASA's Existing Safety and Human-Rating Requirements for Commercially Developed Systems. On December 8, 2010, NASA issued a consolidated set of health and medical, engineering, and safety and mission assurance requirements that commercial partners will have to meet to obtain certification to transport astronauts to low Earth orbit titled, "Commercial Crew Transportation System Certification Requirements for NASA Low Earth Orbit Missions" (Certification Requirements). However, NASA has not finalized the processes Agency officials will use to verify that commercial partners have met these requirements and subsequently certify that a commercial partner's vehicle can safely transport NASA personnel. In May 2011, the Agency released for industry review and comment six draft documents (the 1100-series) that supplement the Certification Requirements relating to missions to the Space Station. These documents provide additional information to commercial partners regarding roles and responsibilities, technical management processes supporting certification, crew transportation system and Space Station services requirements, and the application of technical and operations standards.[6]

[5] Pursuant to the National Aeronautics and Space Act of 1958 and NASA policy (NASA Policy Directive 1050.1l, "Authority to Enter into Space Act Agreements," December 23, 2008), NASA may enter into Space Act Agreements to meet mission and program objectives. The agreements, which represent a set of legally enforceable promises, are classified as reimbursable, non-reimbursable, or funded. NASA may only enter into funded Space Act Agreements with domestic agencies, persons, corporations, or educational institutions when the Agency's objective cannot be accomplished through a contract, grant, or cooperative agreement.

[6] NASA plans to issue the baseline 1100-series documents by the end of the year.

Despite the absence of finalized requirements from NASA, the private sector is already designing and developing systems and vehicles to meet NASA's crew transportation needs and interested companies have provided input on NASA's commercial crew transportation requirements. Specifically, industry representatives have suggested that NASA (1) modify existing requirements to the greatest extent possible and ensure they are achievable so that industry fully understands what is expected; (2) coordinate with the Federal Aviation Administration (FAA) – which has regulatory oversight of U.S. companies providing commercial space transportation services – to ensure NASA requirements and FAA regulations are compatible; and (3) allow for flexibility so that changes in vehicle or system design are attainable within reasonable costs.[7]

Additionally, in response to the CCDev 2 announcement for proposals, NASA received multiple questions from industry representatives seeking clarification on the requirements published to date, the timing of release of additional requirements, and NASA's expectations for fulfilling the requirements. One industry representative questioned a draft requirement that commercial partner vehicles be able to provide a 95 percent abort effectiveness capability – a requirement NASA itself has never met.[8] NASA officials said they hope to strike a balance that will enable innovation and flexibility yet prescribe the minimum number of requirements deemed essential to ensure the safety of NASA's astronauts.

Selecting an Acquisition Strategy for Commercial Crew Transportation Services. NASA is still developing its acquisition strategy and has not settled on the specific mechanisms it will use for procuring commercial crew transportation services. The Commercial Crew Program Planning Office (Commercial Crew Office) plans to present its proposed acquisition strategy to Congress by late summer 2011. Mindful of national policy to limit the use of high-risk contracting vehicles such as noncompetitive and cost-reimbursement contracts, among the options NASA may consider is an acquisition strategy that relies on funded Space Act Agreements, competitive procurements, in particular fixed-price contracts, or a combination of both.[9]

Each of these possible approaches poses financial and programmatic challenges to NASA's efforts to procure crew transportation services. For example, the use of funded Space Act Agreements limits Government control compared to traditional procurement

[7] In August 2010, the FAA sponsored a commercial human spaceflight workshop attended by a representative from NASA's Commercial Crew Office and industry representatives. According to the FAA, the companies were selected for participation based on their demonstrated capabilities and interest in participating in the commercial human spaceflight transportation industry.

[8] Requirement 3.3.1.6 in the draft version of "International Space Station Crew Transportation and Services Requirements Document" (CCT-REQ-1130) states, "The CTS [Commercial Transportation System] shall provide an overall abort effectiveness of 0.95 . . .."

[9] A procurement contract is defined by the Federal Acquisition Regulation (48 C.F.R. § 2.101), while the Federal Grants and Cooperative Agreements Act of 1977 (Chiles Act) (31 U.S.C. § 6303) establishes the general criteria that Federal agencies must follow when deciding which legal instrument to use when entering into a funding relationship. The principal purpose of a procurement contract is to obtain property or services for the direct benefit or use of the Government.

contracts based on the Federal Acquisition Regulation. Moreover, according to Agency policy, NASA may only enter into funded Space Act Agreements when its objective cannot be accomplished through a contract, grant, or cooperative agreement. Further, if the expected deliverables meet NASA's transportation needs, a procurement contract is required.

Consistent with these principles, the primary purpose of CCDev is to stimulate the private sector and aid in the development of commercial human spaceflight capabilities that NASA could use to transport astronauts to low Earth orbit and the Space Station. As one potential customer of this private sector market, NASA expects the CCDev Space Act Agreements to result in commercial capabilities that consider the Agency's Certification Requirements. However, the Agency is not dictating specific system concepts or elements or mandating compliance with its requirements. Rather, CCDev participants are free to determine the system requirements and concepts they believe will best serve their target markets. Since crew transportation for NASA is the most viable segment of the human spaceflight market in the short term, it is in the companies' best interest to ensure compliance with NASA requirements if they hope to obtain NASA's business. Nevertheless, the lack of mandatory compliance with NASA's requirements presents some risk that differences between partner designs and Agency requirements could occur.

Similarly, the potential use of fixed-price contracts for crew transportation services also presents challenges. Traditionally, cost-reimbursement rather than fixed-price contracts have been used on projects in which costs and risks are not clearly defined. While fixed-price contracts lock in the Government's initial investment, proceeding in this manner would not eliminate cost risks. Some of NASA's potential commercial crew partners are building spacecraft for the first time and design and development are under way without fully defined and finalized requirements. In this type of environment, there is a risk that during the period of contract performance NASA's requirements may change so significantly that contractors can successfully argue that the Agency is changing the contract's scope, in which case NASA could be required to pay the contractor to make necessary modifications.

Finally, NASA must consider whether to continue purchasing additional seats on the Russian Soyuz vehicle as a contingency to possible delays in obtaining commercial crew transportation. Currently, NASA has purchased seats on the Soyuz vehicle to ensure continued U.S. access to the Space Station through June 2016. Because of the long lead-time required for procuring Soyuz seats and planning a mission to the Space Station, NASA would have to make the decision to purchase additional seats in 2013, approximately 3 years before commercial systems are expected to be ready.

Establishing the Appropriate Insight/Oversight Model for Commercial Partner Vehicle Development. In selecting the timing and appropriateness of potential procurement mechanisms, NASA must balance its role as a supporter of commercial partners with its responsibility to ensure that U.S. commercially developed vehicles are safe for NASA astronauts, meet the Agency's needs, and provide for a viable domestic alternative to the Soyuz vehicle. The Commercial Crew Office is developing the model

for NASA's insight and oversight of commercial companies.[10] According to NASA policy, "insight" means acquiring knowledge and an understanding of contractors' actions by monitoring selected metrics and milestones. Methods of achieving insight include reviewing documents, attending meetings and tests, and conducting compliance evaluations. "Oversight" combines technical insight of contractor activities with approvals that provide the contractor with formally documented authority to proceed or formal acceptance of plans, tests, or other criteria.

While commercial partners are designing their launch systems, NASA will function in an insight role, forming partnerships with companies to increase the Agency's understanding of their system designs. During this phase of the process, NASA may consider an approach that assigns a core team to follow a specific CCDev partner throughout the life cycle of its launch system. Once the CCDev initiative has ended, NASA may award contracts or continue to use funded Space Act Agreements for commercial vehicle development, test, and evaluation. The Agency would be both stimulating a commercial crew industry and assisting the commercial partners to develop safe, reliable, and cost-effective vehicles that meet NASA's Certification Requirements. While NASA will still need to maintain insight into the development of each vehicle, at this stage of the process the Agency may assume more of an oversight role in granting approval or direction to each partner on the path to certification. As of May 2011, NASA has not finalized the oversight model for this phase, including defining key decisions regarding what will be required of commercial partners to successfully pass each milestone. Selecting the appropriate level and mechanisms of insight and oversight is necessary to provide NASA with sufficient information to assess partners' technical, schedule, and cost risks and certify that commercially developed vehicles are safe for NASA astronauts without unduly affecting the commercial partners' ability to operate in a cost-effective manner.

Because NASA is not dictating specific system concepts or elements or mandating compliance with its requirements when using funded Space Act Agreements, companies may develop vehicles that deviate from Agency requirements. To mitigate this risk, NASA is considering an approach that would identify significant differences between design and requirements that may prevent a partner from obtaining NASA's certification in the later phases of the acquisition process. However, conducting such an analysis for CCDev partners may be perceived as an unfair competitive advantage for non-CCDev companies. In fact, in response to its October 2010 CCDev 2 announcement, NASA received at least one question on the possible relationship between CCDev awards and future contracts. An industry representative inquired whether NASA anticipates overlap between CCDev 2 and any future procurement, such as commercial crew demonstration or transportation services contracts. NASA responded that there is no relationship between the two phases of acquisition. Moreover, according to the Agency's Space Act Agreements Guide, such a relationship or perceived relationship can lead to claims of a conflict of interest. If NASA fails to address such potential conflicts or develop

[10] NASA Policy Directive 8610.23C, "Launch Vehicle Technical Oversight Policy," August 18, 2006.

appropriate mitigation plans, the Agency could face a bid protest, which could cause delays and jeopardize the success of NASA's commercial crew program.

Relying on an Emerging Industry and Uncertain Market Conditions to Achieve Cost Savings. In the NASA Authorization Act of 2010, Congress stated that commercial companies offer the potential of providing lower cost crew transportation services to support the Space Station. In fact, NASA's acquisition strategy for procuring crew transportation services is premised on competition and a healthy commercial human spaceflight industry, which would allow NASA to solicit bids from a number of partners and make informed, competitive procurement decisions that meet individual mission requirements and provide the best value for the taxpayer. However, the commercial human spaceflight industry is in its infancy, and the market beyond NASA's own crew transportation needs is uncertain. Many of the risks associated with achieving anticipated cost savings are largely out of NASA's control, particularly in the area of creating non-Government demand for commercial human spaceflight services. The NASA Authorization Act of 2010 directs the Agency to work with the FAA's Office of Commercial Space Transportation and assess the potential non-Government market for commercially developed crew and cargo transportation systems and capabilities. In April 2011, NASA and the FAA reported that over time the market for commercial crew and cargo services may emerge and provide significantly more customers, more flights, and potentially lower prices to the U.S. Government. The continuing challenge will be to determine at what point the market can sustain a number of commercial partners, allowing NASA to transition to the role of consumer and ultimately realize cost-effective commercial crew transportation.

Managing the Relationship Among Commercial Partners, the FAA, and NASA. The FAA is responsible for regulatory oversight of companies seeking to provide commercial human space transportation. To date, the FAA has issued regulations pertaining to launch and reentry activities that could affect the public safety. However, in December 2012 the FAA is authorized to begin proposing regulations concerning the safety of passengers and crew involved in commercial spaceflight. As previously discussed, NASA plans to impose its own set of requirements, standards, and processes that commercial partners must meet to obtain a certification before transporting Agency personnel. Accordingly, NASA must coordinate with the FAA to avoid an environment of conflicting requirements and multiple sets of standards for commercial companies seeking to transport Government and non-Government passengers to low Earth orbit. Toward that end, the FAA and NASA have expressed a spirit of cooperation, and both groups have agreed that the goal is FAA licensing of commercially developed vehicles used to transport NASA personnel. Additionally, the agencies are co-locating personnel at NASA Headquarters, FAA field offices, and Johnson and Kennedy Space Centers to optimize Government oversight of commercial partners through compatible requirements, standards, and processes.

Management Action

Separately managing each challenge associated with certifying and acquiring commercial crew transportation services is difficult enough, but because the challenges are inherently related this creates additional complications. For example, the degree and nature of requirements levied on commercial partners will have an impact on both NASA's chosen acquisition strategy and the insight/oversight model the Agency will use to verify that the requirements are met. Also, to mitigate risks associated with relying on a single commercial partner and to help achieve anticipated costs savings, NASA's acquisition strategy should encourage competition between multiple commercial partners. However, the viability of the commercial human spaceflight market is uncertain beyond NASA's mission requirements, and the costs the industry must bear – such as those associated with operating in an environment of multiple standards and requirements established by NASA and the FAA – may deter companies from entering such an uncertain market.

While we are not making specific recommendations for corrective action, we believe NASA must pay particular attention to the challenges highlighted in this report. Specifically, NASA should:

- clearly articulate to its commercial partners as soon as possible all requirements for commercially developed systems and the processes NASA will use for certifying such systems;

- maintain robust communication with the emerging commercial spaceflight industry to ensure that Agency contracting mechanisms include the appropriate balance between insight and oversight that will provide NASA with sufficient information to assess and certify commercial partners' systems while providing companies the flexibility to innovate;

- clearly articulate how it will mitigate potential conflicts of interest that may arise as a result of any analysis that could provide an unfair competitive advantage to a NASA partner; and

- expand coordination with the FAA to avoid the potentially serious business impacts that would result if commercial companies were required to operate in an environment that included inconsistent standards for NASA certification and FAA licensing of the same vehicle.

In response to a draft of this report, the Associate Administrator for Exploration Systems Mission Directorate agreed that NASA should pay particular attention to the challenges highlighted in the report. The Associate Administrator also noted that NASA's acquisition strategy for the Commercial Crew Program is still under consideration and subject to further change as the procurement process matures (see Appendix C for the Agency's response).

CONTENTS

INTRODUCTION

Background

The concept of human rating a spacecraft – that is, determining that a vehicle can safely carry humans into space – has evolved based on the knowledge and technology available at the time and the experience accrued since inception of the nation's human spaceflight program more than 50 years ago. As NASA looks to commercial companies to develop vehicles to transport its astronauts, human rating must be an integral part of all activities throughout the life-cycle of a system, including design, development, test and evaluation; program management and control; mission operations; sustaining engineering; and vehicle disposal.

What Is Human Rating? 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:

- avoiding complex components by using simpler designs;
- 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 situations.[11] Compliance with these requirements leads to a certification attesting that the system is suitable for manned spaceflight.

The Evolution of NASA's Human Spaceflight Programs. Although NASA astronauts have ridden on vehicles deemed suitable for manned spaceflight for 50 years, all of NASA's human spaceflight programs predate the Agency's current human-rating requirements and certification process. NASA's first three human spaceflight programs – the Mercury, Gemini, and Apollo Programs – included 27 manned flights between 1961

[11] NASA Procedural Requirements (NPR) 8705.2B, "Human-Rating Requirements for Space Systems (with change 1 dated 12/7/2009).

and 1972.[12] These programs were considered "man-rated" in accordance with the requirements in place at the time.[13]

Initiated in 1972, NASA's Space Shuttle Program generally followed the basic design philosophies and human safety criteria of its predecessor programs. These concepts included adding redundancies, placing a heavy emphasis on ground testing, and requiring close management review and control of all engineering and technical activities affecting the reliability and safety of flight hardware. In 2004, President Bush announced the planned retirement of the Shuttle Program, which was increasingly viewed as unsafe and too costly.

By 2006, NASA was conducting trade studies and selecting contractors for the Agency's next human spaceflight program, Constellation. Like its predecessors, the Constellation Program was to be a Government-owned system built to NASA standards by contractors under cost-reimbursable contracts and with extensive Government oversight. However, in contrast to NASA's previous human spaceflight programs, elements of the Constellation Program, including those intended to transport astronauts to low Earth orbit, were being designed as the first vehicles that would meet the human-rating requirements established in NPR 8705.2B.[14]

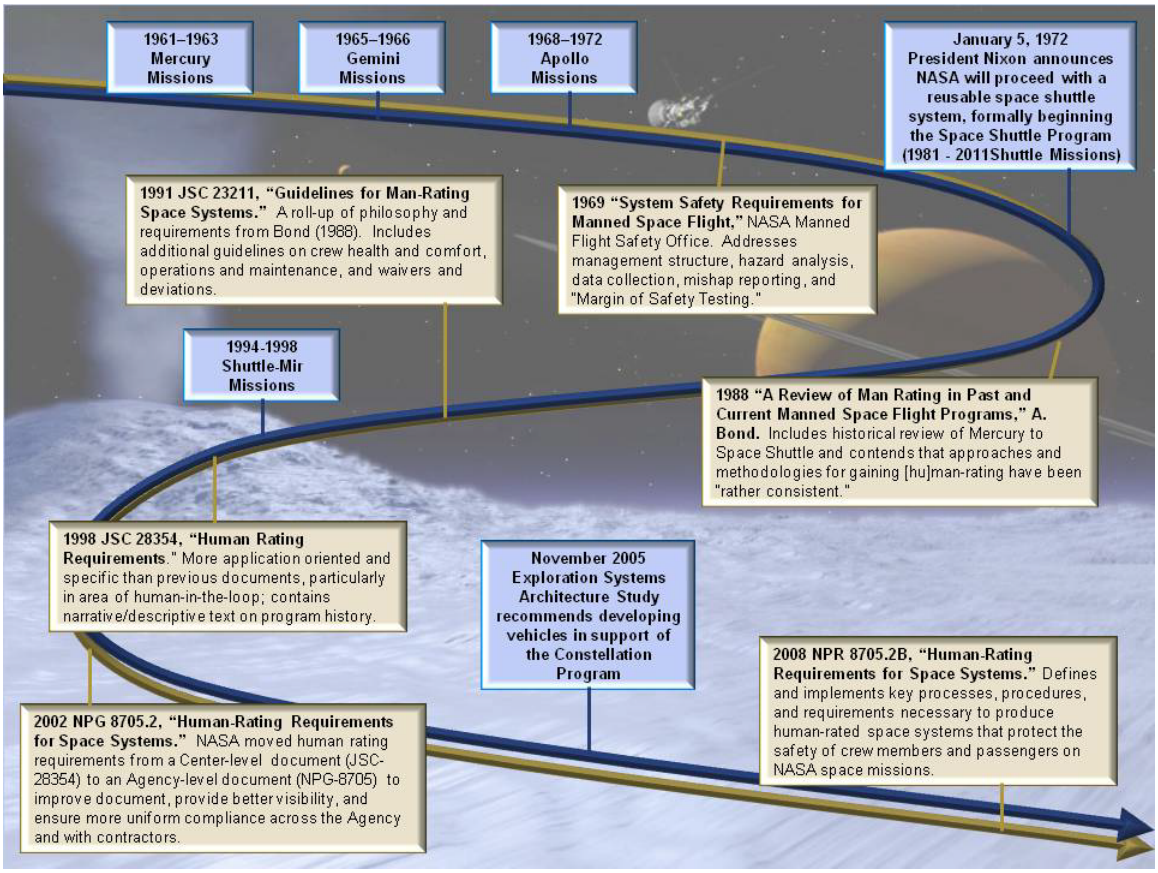
The chronology of NASA's human spaceflight programs and human-rating requirements is illustrated in Figure 1.

[12] Project Mercury included 6 manned flights between 1961 and 1963; Project Gemini resulted in 10 manned flights between 1965 and 1966; and the Apollo Program successfully completed 11 manned flights between 1968 and 1972.

[13] See, for example, "System Safety Requirements for Manned Space Flight," NASA Manned Flight Safety Office, January 1969.

[14] Notably, the Russian Soyuz vehicle has not obtained a NASA human-rating certification even though it carries NASA astronauts. Due to its successful operational history and demonstrated level of reliability and safety, NASA deemed the Soyuz safe for U.S. crews.

Figure 1. Selected Chronology of NASA's Human Spaceflight Programs and Human-Rating Requirements



Recent Policy Directives. In an October 2009 report, a committee established by the President to review the U.S. human spaceflight program concluded that "[t]he U.S. human spaceflight program appears to be on an unsustainable trajectory. . . . The United States needs a means of launching astronauts to low-Earth orbit, but it does not necessarily have to be provided by the government. . . . As we move from the complex, reusable Shuttle back to a simpler, smaller capsule, it is appropriate to consider turning this transport service over to the commercial sector."[15] In his fiscal year (FY) 2010 budget released the following February, President Obama proposed cancelling the Constellation Program in favor of relying on the nation's commercial companies to provide crew transportation services to the International Space Station and focusing NASA's attention on exploration beyond low Earth orbit. However, that proposal ran into stiff opposition in Congress. A compromise embodied in the NASA Authorization Act of 2010 requires that NASA use, to the extent practicable, commercially developed vehicles for transporting cargo and crew to the Space Station. At the same time, the Act

[15] Known as the "Review of U.S. Human Spaceflight Plans Committee" or Augustine Committee, the Committee was charged with conducting an independent review of the nation's human spaceflight program and providing alternatives that would ensure that the nation is pursuing the best trajectory for the future of human spaceflight – one that is safe, innovative, affordable, and sustainable.

directs NASA to develop a Space Launch System and multi-purpose crew vehicle using the Agency's traditional approach of Government-owned systems built to Agency standards by contractors.[16]

NASA's Investments in the Commercial Space Transportation Industry. NASA has funded aspects of the commercial space transportation industry since 2006, and over the past 5 years has initiated three activities to manage its investments: Commercial Orbital Transportation Services (COTS), Commercial Resupply Services (CRS), and Commercial Crew Development (CCDev).

In 2006, the Commercial Crew and Cargo Program Office announced the $500 million COTS Project with the purpose of helping industry develop space transportation capabilities for cargo. NASA structured the Project as a partnership with the commercial space industry, sharing the risks, costs, and rewards of developing new space transportation capabilities. NASA expected commercial partners participating in the project to develop their own technology solutions for an on-orbit cargo delivery capability that could potentially meet NASA's cargo needs and to raise additional funding to demonstrate their solutions. Once the partners have demonstrated the capability, NASA and other customers would be able to purchase space transportation services directly from them. NASA entered into Space Act Agreements under the COTS Project with Space Exploration Technologies Corporation (SpaceX) in August 2006, and with Orbital Sciences Corporation (Orbital) in February 2008.[17] In 2008, NASA awarded the two companies $3.5 billion in CRS contracts for 20 flights to provide cargo transportation services to support the Space Station through 2016, a task previously handled primarily by the Space Shuttles.

To stimulate the commercial human spaceflight industry, NASA initiated CCDev in 2009 to focus efforts on developing systems and concepts that will help establish an industry capable of transporting astronauts to low Earth orbit and the International Space Station. In 2010, NASA awarded the first round of funded Space Act Agreements under CCDev using $50 million in Recovery Act funds.[18] These awards were intended to assist commercial entities in the development of system concepts, key technologies, and capabilities that could be used in commercial crew space transportation systems. Shortly

[16] Public Law 111-267. Congress had previously expressed support for the U.S. space transportation industry in the NASA Authorization Acts of 2005 (Public Law 109-155) and 2008 (Public Law 110-422).

[17] On October 18, 2007, NASA terminated the $207 million COTS Space Act Agreement with Rocketplane Kistler due to the company's failure to meet agreed-upon milestones. NASA had already awarded Kistler about $32 million in milestone payments. NASA reopened bidding later that year for the remaining $175 million, a competition Orbital won.

[18] As stated in NASA Policy Directive (NPD) 1050.1l, "Authority to Enter into Space Act Agreements," December 23, 2008, and pursuant to the National Aeronautics and Space Act of 1958, NASA may enter into Space Act Agreements with people and organizations to meet mission and program objectives. The agreements, which represent a set of legally enforceable promises, are classified as either reimbursable, non-reimbursable, or funded. NASA may only enter into funded Space Act Agreements with domestic agencies, persons, corporations, or educational institutions when the Agency's objective cannot be accomplished through a contract, grant, or cooperative agreement.

after the 2010 Authorization Act became law, the Agency announced it was seeking proposals for a second round of funded Space Act Agreements (CCDev 2) to further mature commercial crew transportation system concepts and capabilities. On April 18, 2011, NASA awarded $269.3 million in CCDev 2 awards to four companies (see Table 1).

Finally, beginning in FY 2012 NASA plans to incorporate into follow-on awards the accomplishments and lessons learned from CCDev. Once commercial crew transportation capabilities have matured, NASA may award fixed-price contracts to commercial companies to purchase transportation services to meet its Space Station crew rotation and emergency return needs. Table 1 summarizes NASA's COTS, CRS, and CCDev agreements.

Table 1. NASA's COTS, CRS, and CCDev Agreements Space Act Agreements or Contracts

Activity	Award Year	Award Value (millions)	Company	Vehicles/Technologies
COTS	2006	$ 278.0	SpaceX	Dragon
COTS	2006	$ 207.0	Rocketplane Kistler[a]	K-1
COTS	2007	$ 175.0	Orbital	Cygnus
CRS[b]	2008	$1,600.0	SpaceX	Dragon (12 flights)
CRS[b]	2008	$1,900.0	Orbital	Cygnus (8 flights)
CCDev	2010	$ 20.0	Sierra Nevada	Continued work on lifting body spacecraft design, Dream Chaser
CCDev	2010	$ 18.0	Boeing	System concepts and technologies for CST-100
CCDev	2010	$ 6.7	United Launch Alliance	Atlas V and Delta IV early emergency detection system
CCDev	2010	$ 3.7	Blue Origin	Launch escape system and composite pressure vessel cabin
CCDev	2010	$ 1.4	Paragon Space	Life support subsystem
CCDev2	2011	$ 92.3	Boeing	System development and risk reduction demonstrations
CCDev2	2011	$ 80.0	Sierra Nevada	Further mature the Dream Chaser Crew Transportation System concept
CCDev2	2011	$ 75.0	SpaceX	Hardware demonstrations of the launch abort engine firings and cockpit prototype evaluations
CCDev2	2011	$ 22.0	Blue Origin	Facilitate development of the vehicle design and escape system

[a] Terminated on October 18, 2007, due to the company's failure to meet agreed-upon milestones.

[b] CRS awards are fixed-price indefinite delivery, indefinite quantity contracts with a period of performance from January 1, 2009, through December 31, 2016.

Source: FAA "2011 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports;" January 2011 and NASA's Selection Statement for Commercial Crew Development Round 2, April 18, 2011.

Objectives

Our objective in this project was to review NASA's efforts to modify its safety and human-rating requirements for application to commercially developed space vehicles. We also examined the overarching challenges associated with some possible approaches NASA may take to certify and acquire commercial crew transportation services.

CHALLENGES ASSOCIATED WITH CERTIFYING AND ACQUIRING COMMERCIAL CREW TRANSPORTATION SERVICES

Over the past 2 years, NASA has made sustained progress toward its goal of obtaining commercial crew transportation services to low Earth orbit. For example, in 2009 the Agency initiated Commercial Crew Development (CCDev) investments and in 2010 awarded $50 million in funded Space Act Agreements to five companies to develop and demonstrate technologies and systems that could enable commercial human spaceflight capabilities. In April 2011, the Agency announced a second round of CCDev awards totaling $269.3 million. However, NASA's effort to help develop a commercial space industry that could potentially meet the Agency's transportation needs to low Earth orbit faces significant challenges, including:

- modifying NASA's existing safety and human-rating requirements for commercially developed systems;
- selecting the acquisition strategy for commercial crew transportation services;
- establishing the appropriate insight/oversight model for commercial partner vehicle development;
- relying on an emerging industry and uncertain market conditions to achieve cost savings; and
- managing the relationship between commercial partners, the Federal Aviation Administration (FAA), and NASA.

The following sections examine each of these challenges in turn.

Modifying NASA's Existing Safety and Human-Rating Requirements for Commercially Developed Systems

NASA has never procured transportation for its astronauts aboard a commercially developed vehicle. To manage the risk inherent in this process, NASA's Commercial Crew Program Planning Office (Commercial Crew Office) is modifying a series of existing health and medical, engineering, and safety and mission assurance requirements for the commercial space industry. The Office is also developing but has not finalized the processes NASA will use to verify that these requirements have been met and to certify that a commercial partner's vehicle is capable of safely transporting Agency personnel.

Every requirement NASA imposes has a cost associated with it in time, money, or decreased innovation. Conversely, incurring these costs is often necessary to appropriately manage risk. Many of the requirements NASA will impose on its commercial partners are the same as those that the Agency applies to its own spaceflight programs. However, NASA still needs to determine if, when, and how it will oversee commercial partners' development efforts in order to ensure they meet Agency requirements.

NASA's goal is to maximize safety and reliability without burdening commercial partners with unnecessary demands that lead to higher development and operations costs. The challenge is achieving the appropriate balance of requirements and associated costs to meet the needs of all stakeholders. With sufficient industry feedback and input from NASA's Technical Authorities and managers of the Space Station, Space Shuttle, and Commercial Crew Programs, the Agency hopes to strike a balance that will prescribe the minimum number of requirements essential to ensuring the safety of NASA's astronauts while enabling innovation and flexibility on the part of the commercial providers.[19]

Commercial Crew Transportation System Certification Requirements. NASA is in the process of modifying its existing safety and human-rating requirements for commercially developed vehicles. In May 2010, the Agency released a draft version of the Commercial Human-Rating Plan. After incorporating industry comments, NASA renamed the document and released it in December 2010 as the "Commercial Crew Transportation System Certification Requirements for NASA Low Earth Orbit Missions" (Certification Requirements). This document contains a consolidated set of technical requirements, standards, and processes that commercial partners must meet to obtain NASA certification of their crew transportation systems.[20]

The Certification Requirements describe NASA's certification philosophy; the content and timing of the certification packages commercial companies will be required to deliver to NASA; and NASA's expectations for system safety, human control of the vehicle, and crew survival. In addition, the Requirements reference a set of 93 other documents, each containing additional requirements the companies must consider in order to obtain certification. NASA has categorized the underlying 93 documents into three types: Type 1 – mandatory, must be implemented as written; Type 2 – alternatives allowed with NASA approval; and Type 3 – suggested best practices. Each of the 93 documents

[19] NASA's Technical Authorities consist of Health and Medical, Engineering, and Safety and Mission Assurance personnel who provide independent oversight of programs and are responsible for the requirements associated with their discipline and all waivers to those requirements.

[20] NASA does not use the term "human rating" when referring to the Agency's certification of commercial systems, but instead has reserved the term for use with the Agency's own manned vehicles and systems. Instead, NASA will "certify" vehicles and systems produced by commercial partners when they are used to transport NASA astronauts.

reference other documents that set forth additional requirements. According to one estimate, NASA's Certification documents contain more than 4,000 requirements.[21]

Of the 93 underlying documents, the Agency's Health and Medical Technical Authority requires commercial partners to implement five Type 1 documents focusing on crew health and safety, human factors, and environmental standards; the Engineering and Safety and Mission Assurance Technical Authorities identify 70 Type 2 documents outlining requirements pertaining to design standards for space hardware and techniques for which substitutes are allowed with NASA approval; and the remaining 18 documents are considered best practices. We summarize the 93 documents in Table 2 below.

Table 2. Technical Authority Standards and Requirements Documents for Commercial Crew Transportation Systems

Document Type, Number in the Set, and Related Level of Enforcement	Technical Authority Discipline	Number of Related Documents
Type 1 Documents (5) – Mandatory		
	Health and Medical	5
	Engineering	0
	Safety and Mission Assurance	0
Type 2 Documents (70) – Alternatives Allowed with NASA Approval		
	Health and Medical	0
	Engineering	35
	Safety and Mission Assurance	35
Type 3 Documents (18) – Best Practices Suggested		
	Health and Medical	1
	Engineering	7
	Safety and Mission Assurance	10
Total		**93**

For a list of the 93 Technical Authority standards and requirements documents, see Appendix B.

Source: "Commercial Crew Transportation System Certification Requirements for NASA Low Earth Orbit Missions" (ESMD-CCTSCR-12.10) and correction provided by the Office of Safety and Mission Assurance.

The 1100-Series Documents. The Commercial Crew Office also intends to publish documents referred to as the "1100-series," which will tailor the Certification Requirements for crew transportation missions to the Space Station. In May 2011, the Commercial Crew Office publicly released in draft the following 1100-series documents for comment:

[21] Remarks presented by Thomas Martin, Chief Systems Engineer, Special Aerospace Services, LLC, at the Commercial Human Spaceflight Technical Forum, January 12–14, 2011.

- Crew Transportation Plan establishes the roles and interfaces between NASA and the commercial space transportation industry and describes the necessary elements for achieving certification to transport NASA crew to the Space Station.
- Crew Transportation System Design Reference Missions establishes the goals for the design of a system to transport humans to and from low Earth orbit.
- Crew Transportation Technical Management Process provides commercial partners a summary of NASA's expectations of the processes and products the Agency considers crucial to a successful development effort.
- ISS [International Space Station] Crew Transportation and Services Requirements Document provides the commercial space transportation industry with NASA's requirements for development of commercial services to deliver crew and a limited amount of cargo to the Space Station.
- Crew Transportation Technical Standards and Design Evaluation Criteria informs commercial partners of the specifications, standards, and processes that NASA considers critical to a successful design and provides guidance on the technical criteria NASA will use to assess the acceptability of proposed commercial designs.
- Crew Transportation Operations Standards establishes the minimum criteria and practices for space flight operations process.

NASA officials said they hope to issue the baseline 1100-series documents by December 2011.

Industry Comments and Concerns. The private sector has been participating in and commenting on NASA's certification requirements as they are being developed. For example, at an August 2010 commercial human spaceflight workshop hosted by the FAA and attended by representatives from industry and NASA, industry representatives suggested that NASA:

- modify existing requirements to the greatest extent possible and ensure they are achievable;
- develop mature, stable requirements as soon as possible and in coordination with the FAA, which has regulatory oversight of U.S. companies providing commercial space transportation services; and
- allow for flexibility in requirements so that changes in vehicle or system design are attainable within reasonable costs.[22]

[22] The following companies participated in the workshop: Bigelow Aerospace; The Boeing Company; Lockheed Martin Corporation; Orbital; Sierra Nevada Corporation; SpaceX; and United Space Alliance. According to the FAA, the companies were selected based on their demonstrated capabilities and interest in participating in the commercial human spaceflight transportation industry.

Additionally, NASA received numerous questions from industry representatives in response to its October 2010 CCDev 2 announcement, including questions about the requirements the Agency had published to date, the timing of the release of additional requirements, and NASA's expectations for requirements fulfillment. One industry representative questioned a draft requirement that commercial partner vehicles provide a 95 percent abort effectiveness capability, pointing out that this "seems to be a rather aggressive requirement given the fact that NASA's own calculations for the [Constellation Program] Ares I (which was supposed to be one of the safest crew vehicles NASA had ever designed) showed that this vehicle had an abort effectiveness of about 80 percent to 85 percent."[23] In response, NASA stated that it is not mandating compliance with requirements as part of CCDev 2 and, as discussed below, is simply informing industry as early as possible what may ultimately be required to obtain certification of a commercial system.

Selecting an Acquisition Strategy for Commercial Crew Transportation Services

NASA's Commercial Crew Office has not finalized the acquisition strategy it will use for procuring commercial crew transportation services, although NASA has stated that it plans to present its strategy to Congress by late summer 2011. Mindful of national policy to limit the use of high-risk contracting vehicles such as noncompetitive and cost-reimbursement contracts, among the options NASA may consider is an acquisition strategy that relies either on funded Space Act Agreements; competitive procurements guided by the Federal Acquisition Regulation (FAR), in particular fixed-price contracts; or some combination of both.

Each of these possible approaches poses financial and programmatic challenges to NASA's efforts to procure crew transportation services. In selecting procurement mechanisms, NASA must balance its role as a supporter of commercial partners with its responsibility to ensure that commercially developed vehicles are safe for NASA astronauts, meet the Agency's needs, and provide a viable domestic alternative to the Soyuz vehicle.

Challenges of Using Space Act Agreements. NASA may only enter into funded Space Act Agreements when it cannot accomplish its objective through a contract, grant, or cooperative agreement. Further, if the expected deliverables meet a NASA requirement, Federal policy states that a procurement contract is required.[24]

Consistent with these principles, the primary purpose of CCDev (which up to this point has been funded by Space Act Agreements) is to stimulate the private sector and aid in

[23] Requirement 3.3.1.6 in the draft version of "International Space Station Crew Transportation and Services Requirements Document" (CCT-REQ-1130) states, "The CTS [Commercial Transportation System] shall provide an overall abort effectiveness of 0.95 [to be confirmed] . . .."

[24] The Federal Grant and Cooperative Agreement Act of 1977.

the development of commercial human spaceflight capabilities that NASA could ultimately use to transport astronauts to low Earth orbit and the International Space Station. As one potential customer of the private sector, NASA expects the CCDev Space Act Agreements to result in commercial capabilities that consider the Agency's commercial crew transportation system certification requirements, but is not dictating specific system elements or mandating compliance with specific requirements. Rather, each participant operating under a CCDev Space Act Agreement is free to determine the system requirements and concepts that it believes best serve its target markets.

Although NASA is the biggest and most viable customer for these companies in the near term, because compliance with NASA's requirements is not mandatory it is possible that the companies' designs will not track all of NASA's requirements. To mitigate this risk, NASA may perform an analysis to identify shortfalls between the companies' designs and the Agency's requirements to improve the vehicle design or correct a known issue or defect. However, as discussed below, proceeding in this manner could create additional financial risks for the Agency.

Challenges of Using FAR-based Procurements, Specifically Fixed-Price Contracts. Cost increases associated with Government's use of cost-reimbursement contracts has focused attention on other procurement vehicles such as fixed-price contracts that might better contain costs. If NASA chooses to award fixed-price contracts, it will realize certain benefits, most notably locking in the Government's initial investment to a fixed amount. However, fixed-price contracts also create significant risks that the Commercial Crew Office will need to manage, including costs associated with unanticipated technical difficulties and yet-to-be-defined requirements.

The FAR lists several factors to consider when selecting and negotiating contract types. When the requirements are complex or unique, the Government usually assumes a greater portion of the risk by using contracting vehicles like cost-reimbursement contracts. This is especially true for complex research and development contracts where performance uncertainties or the likelihood of changes makes it difficult to accurately estimate performance costs in advance. Moreover, some of the companies that have shown interest in providing commercial crew services are building spacecraft for the first time and the requirements they will be expected to meet have not yet been fully defined. In this type of environment, there is a risk that during the period of contract performance NASA's requirements may change so significantly that contractors may assert the Agency is going beyond the contract's scope in which case NASA would be required to pay the contractor for necessary changes.

In addition, although fixed-price contracts provide the maximum incentive for contractors to perform effectively while controlling costs, they also place on the contractor the maximum risk of loss if it is unable to do so. This situation can create incentives for a contractor to "cut corners" to protect its profit margin.

Another challenge in a fixed-price environment is determining the true costs companies will face in meeting NASA requirements. For example, NASA has established a long-

term safety requirement for all future crewed space transportation systems, mandating that each system must eventually become safer than when initially developed.[25] Thus, each of NASA's commercial partners will be required to invest additional funds to develop and maintain a proactive continuous improvement program. In the fixed-price environment, a company's motivation to increase profit margins by cutting costs and creating efficiencies may conflict with the requirement to continually improve the safety of their system. Moreover, companies will need to account for the added costs of maintaining a continuous improvement program when contracting with NASA for Space Station transportation missions.

Soyuz Buy Decision. Another challenge facing NASA is determining whether and when to purchase additional seats on the Russian Soyuz vehicle as a contingency to possible delays in obtaining commercial crew transportation capabilities. Since 2005, NASA has negotiated with Roscosmos – the Russian Federal Space Agency – to purchase crew transportation services aboard the Soyuz vehicle. These services included the launch, return, and possible rescue of astronauts from the Space Station. To date, NASA has purchased 46 seats aboard Soyuz vehicles for launches planned through 2015. Since 2005, the average cost per seat has increased almost 175 percent, from $21.8 million for launches occurring in 2006, to $60 million for launches planned for 2015.[26]

As shown in Figure 2, the largest increase occurred for launches planned for the latter portion of 2011, when retirement of the Space Shuttle and the lack of a U.S. domestic transportation capability increased NASA's previous demand for Soyuz seats.[27] According to the Space Station External Integration Office, meeting this increased demand required upgrades to and modernization of Russia's manufacturing infrastructure, which resulted in a 57 percent increase in the cost per seat – from $27.7 million for launches in the first half of 2011 to $43.4 million for launches in the latter half of 2011. NASA determined that the 57 percent increase was reasonable and accurately reflected inflation and the effort required to sustain Russia's increased vehicle production rate to meet the Agency's increased demand for an extended period of time beyond 2011.

NASA has since agreed to three more contract modifications with Roscosmos for continued crew transportation, rescue, and related services for flights to and from the Space Station through 2015, with the cost per seat rising each year by an average of $4.34 million. The most recent contract modification purchased seats for launches in 2014 and 2015 with the final crew return mission occurring in June 2016. The cost per seat for the 2014 and 2015 launches is $55.6 million and $60 million, respectively.

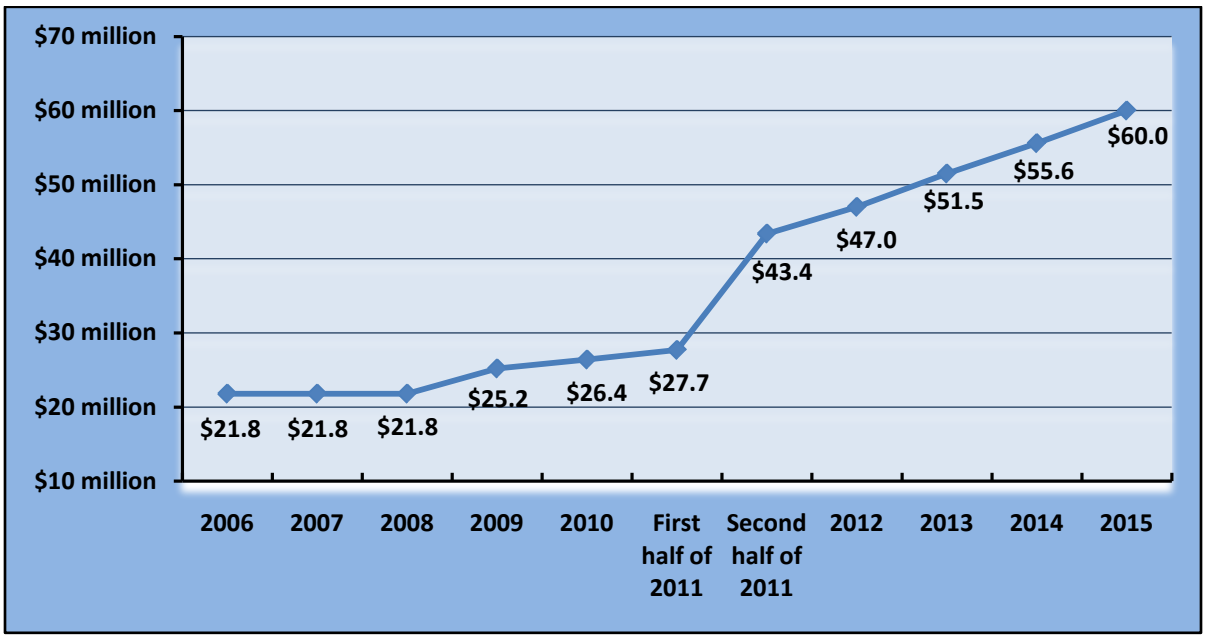
[25] The Agency will adopt safety goals and thresholds for crew transportation missions to the International Space Station. These goals and thresholds will be applied to acquisition programs involving commercial crew transportation capabilities and services as well as NASA Programs conducting such services.

[26] The costs cited are price per seat only and exclude any additional costs for cargo delivery, cargo return, and trash disposal capabilities.

[27] NASA purchased one Soyuz seat per year in 2007 and 2008 and six per year from 2009 to 2015.

The increases in the yearly cost per seat for U.S. crew transportation services aboard the Soyuz vehicle are shown in Figure 2.

Figure 2. Yearly Cost (per Seat) for U.S. Crew Transportation Services Aboard the Soyuz Vehicle for Launches through 2015



Source: NASA International Space Station External Integration Office, Johnson Space Center, May 2011.

Procurement of these additional Soyuz seats is intended to bridge the gap between the end of the Space Shuttle Program and the availability of U.S. commercially developed vehicles, which is planned for late 2016. However, if the commercial partners incur schedule slippage, technical or financial delays, or significant difficulty in the early stages of obtaining NASA's certification of their vehicles, NASA may have to purchase additional Soyuz seats to ensure continued U.S. access to the Space Station beyond June 2016. Because of the long lead-time required for procuring Soyuz seats and planning a mission to the Space Station, NASA would have to make the decision to purchase additional Soyuz seats for flights in 2016 and beyond by spring 2013, at least 3 years before commercial partners are expected to be ready to provide transportation services. Alternatively, NASA may decide not to purchase additional Soyuz seats and risk having no crew transportation capabilities to the Space Station after June 2016 if its partners encounter unexpected delays.

Establishing the Appropriate Insight/Oversight Model for Commercial Partner Vehicle Development

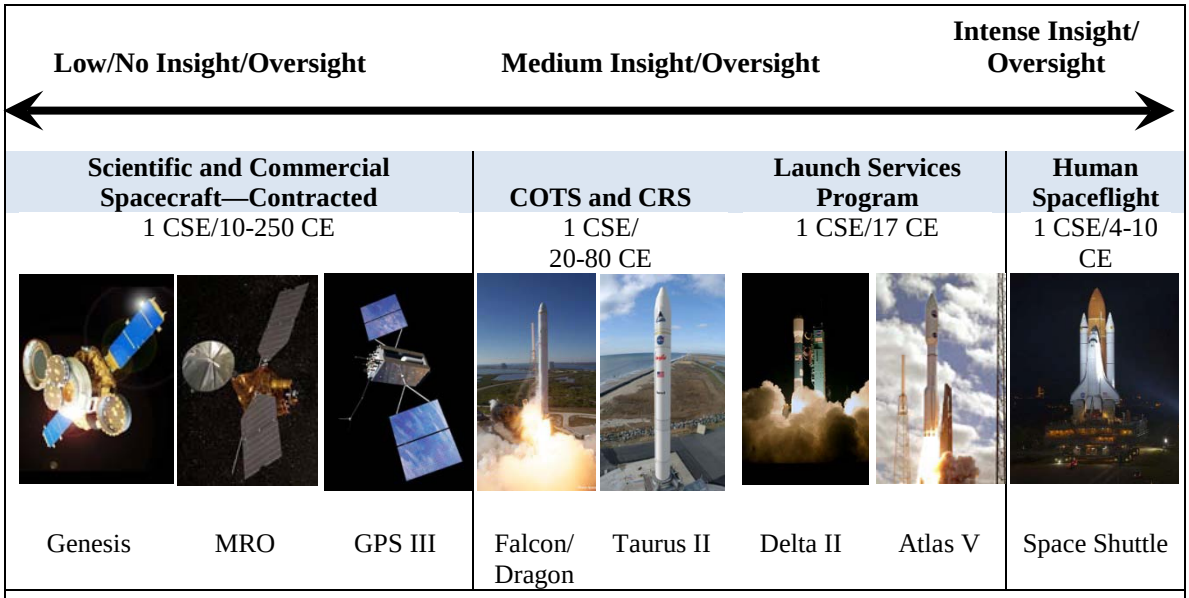
The Commercial Crew Office is developing the model for NASA's insight and oversight of commercial companies' efforts to develop crew transportation systems.[28] As defined by NASA, "insight" means acquiring knowledge and understanding of contractors' actions by monitoring selected metrics or milestones. Methods of achieving insight include review of documentation, attendance at meetings, tests, and compliance evaluations. In contrast, "oversight" combines technical insight of contractor activities with approvals that provide the contractor with formally documented authority to proceed or formal acceptance of plans, tests, or success criteria.

The primary difference between models of insight versus oversight is that insight provides NASA with knowledge without having the authority for decision-making and approval, whereas oversight provides for knowledge and authority to make approval decisions. Selecting the appropriate level and mechanisms of insight and oversight is necessary to provide NASA with information sufficient to assess commercial partners' technical, schedule, and cost risks and certify that commercially developed vehicles are safe for NASA astronauts without unduly affecting the commercial partners' ability to operate in a cost-effective manner. As discussed above, because NASA is not dictating specific system concepts or elements or mandating compliance with its requirements in funded Space Act Agreements, companies may develop vehicles that deviate from Agency requirements. To mitigate this risk, NASA's insight/oversight approach could include an analysis to identify significant differences between design and requirements that would potentially prevent a partner from obtaining NASA's certification in the later phases of the acquisition process.

Spectrum of Insight/Oversight Models. Throughout its history, NASA has utilized a wide spectrum of insight/oversight models. One method of measuring the Government's level of insight versus oversight is a program's ratio of civil service employees to contractor employees. As shown in Figure 3, insight/oversight models for NASA programs range from low (1 civil service employee to every 250 contractor employees for development of scientific and commercial spacecraft) to intense (1 civil service employee to every 4 contractor employees for the development and operation of human spaceflight programs).

[28] NPD 8610.23C, "Launch Vehicle Technical Oversight Policy," August 18, 2006.

Figure 3. Spectrum of Insight/Oversight Models



Spacecraft shown are only examples of multiple spacecraft in the category.

CE – contractor employee; CSE – civil service employee; GPS – Global Positioning Satellite
MRO – Mars Reconnaissance Orbiter

Source: Adapted from Hale, W., and F. Bauer, "Government Insight/Oversight for Commercial Crew Transportation," Rev. N, March 10, 2010. At http://www.nasa.gov/pdf/469245main_GovernmentInsightForCommercialCrewTransportation.pdf (accessed June 17, 2011).

Government insight/oversight also includes the mechanisms by which civil service employees (1) assess commercial partners' technical, schedule, and cost risks; (2) establish, apply, and modify technical requirements; and (3) evaluate the competency and adequacy of the technical work performed by commercial partners. Examples of NASA oversight are requiring Government approval of partners' documents and drawings; mission-unique hardware design, analysis, manufacture, and testing; spacecraft handling procedures; and launch go/no-go decisions. NASA insight could include Government monitoring and review but not approval of commercial partners' work practices and documentation; vehicle walk-down inspections; failure analysis; and anomaly resolutions. Whichever methodology it adopts, NASA must tread a delicate balance between insight/oversight activities that will provide sufficient evidence that partners have met the Certification Requirements to ensure that commercially developed vehicles are safe for NASA astronauts without unnecessarily driving up costs.

Insight in the Design Phase. While commercial partners are designing their launch systems as part of CCDev, NASA is considering the appropriate level of insight to increase its understanding of the companies' system design. The depth of this insight could be critical for accurately assessing technical, schedule, and cost risks, and for

establishing an analytical approach NASA may use to monitor and assess each partner's designs.

NASA is considering an approach that assigns a core team to follow a specific CCDev partner throughout the life-cycle of its launch system. To gain the best possible understanding of a partner's system, one or more of the team members may acquire an office at the commercial partner's production facility. NASA may augment the team when needed with subject matter experts to help resolve major issues and provide additional support for key milestone reviews such as design reviews and flight readiness reviews. NASA could also assign additional experts to support the more challenging, higher risk areas such as launch abort systems. This type of solution would require coordination between the Commercial Crew Office and NASA's institutional pool of experts.

Each insight team may be tasked with performing an independent analysis of the partner's design in order to assess differences between that design and NASA's Certification Requirements. These findings could enable NASA to assess the ability of each design to meet the Agency's Certification Requirements prior to the actual awarding of contracts for transportation services.

Oversight in the Development, Test, and Evaluation Phase. Once the design phase has ended, NASA may award contracts, Space Act Agreements, or both for commercial vehicle development, test, and evaluation. At that point, the Agency will be both stimulating a commercial crew industry and assisting with the development of safe, reliable, and cost-effective commercial vehicles that meet NASA's Certification Requirements. While NASA would still need to maintain insight into the development of each vehicle, at that stage in the process the Agency may assume more of an oversight role in granting approval or direction to companies as they move toward certification. As of May 2011, NASA had not finalized the oversight model for this phase, including defining key milestones regarding what will be required of commercial companies.

Establishing an insight/oversight model, however, is not without risks, particularly with respect to ensuring fair and open competition if, for example, the Agency were to transition from Space Act Agreements in the design phase to fixed-price contracts in the development, test, and evaluation phase. NASA would need to ensure it structured its insight during the design phase of CCDev so as not to give participants an unfair competitive advantage over non-participants. For example, although NASA's solicitation for vehicle development and crew transportation services would be open to non-participants, if NASA identifies differences in partners' designs and NASA requirements, only CCDev partners would have received that analysis, which could increase the likelihood that their vehicles will meet contract requirements.

NASA has received at least one question in response to the CCDev 2 announcement for proposals regarding the relationship between CCDev awards and future contracts. An industry representative inquired whether NASA anticipates overlap between CCDev 2 and any future procurement of commercial crew demonstration or transportation services.

NASA responded that there is no relationship between the two phases of acquisition. However, if NASA provides its CCDev partners information relevant to the differences between their designs and NASA requirements, non-CCDev companies may perceive that as an unfair competitive advantage. According to the Agency's Space Act Agreements Guide, such a relationship or perceived relationship could raise conflict of interest concerns. If NASA fails to address such potential conflicts or develop appropriate mitigation plans, the Agency could be faced with a bid protest, which could cause delays in the procurement.

Relying on an Emerging Industry and Uncertain Market Conditions to Achieve Cost Savings

NASA's acquisition strategy to procure safe, reliable, and cost-effective crew transportation services is premised on competition in the near term and a healthy commercial human spaceflight industry in the longer term. Competition will both incentivize performance and mitigate the risk that reliance on a single provider may pose. Engaging with multiple companies lessens the impact should any one company fail to meet NASA's Certification Requirements or secure the funds necessary to continue in the industry. A healthy commercial space transportation industry will allow NASA to solicit bids from a number of companies and make competitive procurement decisions that meet individual mission requirements while providing the best value for the taxpayer.

However, the commercial space industry is in its infancy and, according to a 2010 FAA report, there is currently insufficient demand to support a viable commercial human spaceflight market.[29] The report highlighted a number of steps that NASA and the FAA need to take to develop a commercial crew transportation market, including:

- Act as the anchor tenant customer for the foreseeable future, including guaranteeing a market greater than 5 years of Space Station support;
- Provide mature, stable requirements, including human-rating certification requirements, as soon as possible; and
- Ensure that NASA and the FAA agree on a coherent set of requirements and regulations that enable commercial crew transportation systems to serve both Government and non-Government customers.

The Importance of Government Investments. Creating an environment where competition exists in the development of commercial crew transportation services will require a large investment and support from the Federal Government on both the supply and demand sides of the business model. Although there appears to be a great deal of speculation and excitement surrounding commercial spaceflight, in the near term the market for non-Government commercial human spaceflight services is limited and the

[29] FAA, "Report of the Commercial Human Spaceflight Workshop," August 4-6, 2010.

future market is largely unknown. Similarly, NASA's need for crew transportation to the Space Station, as currently defined, is relatively limited and could potentially result in only two flights per year. Therefore, because of the large initial investment required by industry to enter into the commercial crew transportation business, NASA will most likely be a significant financial partner and supporter of those companies for some time to come.

Lessons Learned from the Evolved Expendable Launch Vehicle Program. Historically, past predictions of the demand for commercial launch vehicles have been overly optimistic. Moreover, competition in a demand-constrained environment can have unintended consequences. For example, Lockheed Martin and the Boeing Company were rival launch vehicle service providers in the Department of Defense's Evolved Expendable Launch Vehicle (EELV) Program.[30] When expected demand for EELV launch vehicles did not materialize, estimated prices for launch services increased 77 percent in 1 year. In an effort to provide more cost-effective and reliable launch vehicles in the face of limited demand for their services, the companies combined their EELV operations in December 2006 to form United Launch Alliance, LLC. The formation of United Launch Alliance eliminated competition and forced the Government to rely on a single provider of launch services to meet its intermediate- and heavy-class launch vehicle requirements. Consequently, near-term limited demand can stifle competition – a cornerstone of NASA's commercial crew services goals.

Impacts of Near-Term Limited Demand. Because of the near-term limited demand for commercial crew transportation services, it is likely that NASA's commercial partners will attempt to augment their business with commercial and Government satellite launches. For example, SpaceX is developing rockets that can transport satellites to orbit, including a rocket to compete with United Launch Alliance in the EELV market. However, FAA predictions for satellite launch vehicle demand through 2019 remain flat or slightly decline, although the FAA points out that opportunities for growth in the overall launch vehicle market could occur if a viable, commercial human spaceflight market emerges.[31] In spite of the current limited market demand, new companies have entered or expressed interest in the commercial crew industry.

In the NASA Authorization Act of 2010, Congress stated that commercial space transportation services have the potential of broadening availability and access to space travel while lowering costs. However, many of the risks associated with achieving the anticipated cost savings are largely out of NASA's control, particularly in the area of creating demand for non-Governmental commercial human spaceflight services. The Act directed the Agency to work with the FAA's Office of Commercial Space Transportation and assess the potential non-Government market for commercially developed crew and cargo transportation systems and capabilities. In April 2011, NASA and the FAA

[30] The Department of Defense initiated the Evolved Expendable Launch Vehicle Program in 1995. The Program consists of the Atlas V (formerly provided by Lockheed) and Delta IV (formerly provided by Boeing) families of launch vehicles.

[31] FAA "2010 Commercial Space Transportation Forecasts," May 2010.

reported that over time the non-Government market for commercial crew and cargo services may emerge and provide significantly more customers, more flights, and potentially lower prices to the U.S. Government. [32] For example, the clearly identifiable market for regular Space Station cargo delivery and crew rotation provides a foundation for private sector development efforts to succeed. However, without a successful Commercial Crew Program, the prospects for a stable commercial non-Government market are lessened considerably. The continuing challenge will be determining at what point the market can sustain a number of commercial companies, allowing NASA to transition from the role of partner in the development of commercial services to one of a consumer benefitting from cost-effective commercial crew transportation services.

Managing the Relationship Among Commercial Partners, the FAA, and NASA

Although U.S. human space travel has historically been managed by NASA, the FAA is responsible for providing regulatory oversight of companies seeking to provide commercial human space transportation. To date, the FAA has issued regulations pertaining to launch and reentry activities that could affect public safety. However, in December 2012 the FAA is authorized to begin proposing regulations concerning the safety of passengers and crew involved in commercial spaceflight. As previously discussed, NASA plans to impose its own set of requirements, standards, and processes that commercial partners must meet to obtain a certification before transporting Agency personnel. Accordingly, NASA must coordinate with the FAA to avoid creating multiple sets of standards and requirements for commercial companies seeking NASA certification and FAA licensing on the same vehicle.

History of FAA Regulating Commercial Spaceflight. In accordance with the Commercial Space Launch Act of 1984, the FAA is responsible for overseeing, licensing, and regulating launch and reentry activities undertaken by U.S. commercial space companies. The FAA also has authority over launch and reentry sites operated by U.S. business entities. The FAA's primary role is to ensure the safety of the public. Its regulatory oversight includes developing and issuing regulations; granting licenses, permits, and safety approvals; and conducting safety inspections during every licensed launch.

The Commercial Space Launch Amendments Act of 2004 expanded the FAA's role by establishing a regulatory framework for commercial human spaceflight. This law established an "informed consent" protocol for carrying spaceflight passengers. Informed consent is the process of notifying spaceflight passengers in writing of the risks associated with spaceflight, and passengers will be required to agree in writing to accept those risks. Before granting a launch license, the FAA must also approve the commercial operator's vehicle hardware and software. Additionally, the operator must assess critical

[32] "Commercial Market Assessment for Crew and Cargo Systems Pursuant to Section 403 of the NASA Authorization Act of 2010 (P.L. 111-267)," April 27, 2011.

hazards and risks posed by its launch operations and propose to the FAA how they will mitigate them.

Except for informed consent, the 2004 Commercial Space Act specifically prohibited the FAA from imposing regulations related to crew and passenger safety on commercial spaceflights for a period of 8 years after enactment.[33] Therefore, beginning in December 2012 (unless specifically prohibited by new legislation), the FAA will be able to begin proposing regulations concerning the safety of passengers and crew involved in commercial spaceflight. The FAA has indicated that it anticipates issuing regulations establishing requirements for launch vehicle maintenance; crew rest and safety; spaceflight participant safety and training; and vehicle re-entry. FAA officials foresee establishing a minimum set of requirements to help ensure safety of the crew and the public.

Before taking effect, any proposed FAA regulations must undergo an official Notice of Proposed Rulemaking process, which allows the public, industry, and other Government agencies to comment on the proposed regulation. This rulemaking process can take many months to complete, which in turn could delay the enactment of any new FAA regulations until sometime in 2013. In anticipation of this time lag, the FAA plans to begin an introductory dialogue with the commercial space industry in the spring of 2012 to conceptualize the regulatory environment as soon as possible so that industry may consider this information when designing vehicles.

Need for Timely NASA and FAA Coordination. The FAA and NASA have already demonstrated that they can collectively provide Government reviews for cargo transport demonstration missions to the Space Station. In December 2010, SpaceX was the first commercial entity to use an FAA-issued reentry permit for a test flight of its Dragon capsule as part of NASA's COTS Project. Similarly, all future commercial resupply flights to the Space Station conducted by SpaceX or Orbital will require FAA licenses.

What remains unclear is the extent of the Government oversight – either FAA, NASA, or a combination of both – that will be imposed for commercial crew missions to the Space Station. Industry officials have expressed concern that there may be two inconsistent Government environments: one encompassing FAA regulations for any non-NASA related flights and a different set of requirements imposed through NASA certification.

To illustrate the difficulty this could pose to a commercial company, consider the following scenario: a company launching space tourists to low Earth orbit falls under FAA regulations and restrictions. However, if the company uses the same vehicle to carry NASA personnel to the Space Station it may be required to meet different and possibly inconsistent NASA standards. To avoid this scenario, timely coordination among NASA, the FAA, and commercial spaceflight companies is essential.

[33] The exception would be if there was a high-risk incident, serious injury, or fatality, at which point the FAA could react accordingly and enact additional regulations.

Some of these discussions are already taking place. For example, NASA has agreed that the goal is for FAA to license commercially developed vehicles used to transport NASA personnel. In addition, the agencies are co-locating personnel at NASA Headquarters, FAA field offices, and the Johnson and Kennedy Space Centers, and this co-location should assist in coordination. Most notably, at Kennedy, the FAA has co-located personnel with NASA's Commercial Crew Planning Office until its Technical Center for Commercial Spaceflight is established. As expressed by the two agencies, the goal of these and other actions is to optimize Government oversight of commercial spaceflight companies through compatible requirements, standards, and processes.

Conclusion

NASA is making progress toward its goal of stimulating a commercial space transportation industry that will enable the Agency to acquire safe, reliable, and cost-effective astronaut transportation to low Earth orbit. However, the challenges to successful completion of this process are numerous, interrelated, and ongoing. For example, establishing the appropriate level and mechanisms for Government insight and oversight of commercial partners' operations will be influenced by the acquisition strategy NASA chooses. In addition, establishing cost-effective transportation and a price point relative to what transportation might cost on a NASA-developed or Soyuz vehicle is reliant upon a market that is currently under development. Furthermore, how successfully NASA and the FAA coordinate their respective roles in this process will impact the speed of development and the ultimate cost to NASA for commercial transport of its astronauts.

Following retirement of the Space Shuttle Program in summer 2011, the United States will no longer have its own capability to access low Earth orbit and the International Space Station, and instead will depend upon Russia to provide crew transportation services. Currently, the only other option in development is the Government-owned and -operated Multi-Purpose Crew Vehicle and Space Launch System that the 2010 Authorization Act set as a goal to be fully operational by December 31, 2016.[34] However, NASA has indicated that this system is unlikely to be ready by that date. Consequently, NASA faces an imperative to nurture development of a U.S. commercial transportation service to reestablish the nation's ability to access low Earth orbit and the Space Station as soon as possible.

[34] The Authorization Act requires NASA to design the Multi-Purpose Crew Vehicle and the Space Launch System for beyond-earth-orbit exploration missions, and to be available as an alternate means of transporting crew and cargo to the International Space Station in the event that commercial crew and international partners are unable to do so.

Management Action

While we are not making specific recommendations for corrective action, we believe NASA must pay particular attention to the challenges highlighted in this report. Specifically, NASA should:

- clearly articulate to its commercial partners as soon as possible all requirements for commercially developed systems and the processes NASA will use for certifying such systems;

- maintain robust communication with the emerging commercial spaceflight industry to ensure that Agency contracting mechanisms include the appropriate balance between insight and oversight that will provide NASA with sufficient information to assess and certify commercial partners' systems while providing companies the flexibility to be innovative;

- clearly articulate how it will mitigate potential conflicts of interest that may arise as a result of analysis that could provide an unfair competitive advantage to a NASA partner; and

- expand coordination with the FAA to avoid the potentially serious business impacts that would result if commercial companies were required to operate in an environment that included inconsistent sets of standards for NASA certification and FAA licensing of the same vehicle.

In response to a draft of this report, the Associate Administrator for Exploration Systems Mission Directorate agreed that NASA should pay particular attention to the challenges highlighted in the report and stated that the Agency will be making progress in each of the areas as the Commercial Crew Program matures. The Associate Administrator also reiterated that the Agency's acquisition strategy for the Commercial Crew Program has not been decided and is subject to further change as the procurement process matures.

APPENDIX A

Scope and Methodology

We performed this audit from June 2010 through May 2011 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.

Our overall audit objective was to review the development and implementation of NASA's safety and human-rating standards for the commercial space industry. In particular, we focused on NASA's development of the human-rating standards for commercial vehicles. We also evaluated how commercial space transportation providers intend to implement NASA's safety and human-rating requirements. We met with representatives of a commercial space transportation company and officials from NASA's Office of Safety and Mission Assurance Commercial Crew and Cargo Program Office. We identified and reviewed relevant Federal laws and regulations, NASA policies, procedures, plans, and guidance, and other criteria (see detailed list of items reviewed below).

During much of our audit field work, NASA was in a "blackout period" with industry between October 25, 2010, when the Agency released the Announcement for Proposals for the second round of CCDev proposals until NASA announced final awards on April 18, 2011. To avoid jeopardizing this procurement activity, the OIG did not communicate with the 42 companies that NASA had identified as Interested Parties during the blackout period.

As part of the audit, we:

- attended commercial crew planning checkpoint meetings;
- acquired transcripts of congressional testimony by NASA's Administrator and FAA's Commercial Space official;
- interviewed key personnel within NASA's Office of Safety and Mission Assurance;
- interviewed NASA's Chief Engineer;
- coordinated with the NASA Advisory Council's Commercial Space Committee;

- interviewed members of the Aerospace Safety Advisory Panel;
- interviewed personnel at SpaceX and toured their facility; and
- interviewed Air Force Chief Engineer for Wing Safety at Patrick Air Force Base in Florida;

In addition, we reviewed information on the FAA website related to the commercial space industry.

We identified and reviewed the following as applicable to our audit objectives:

Federal Laws, Regulations, Policies, and Guidance

- Public Law (P.L), 85 - 568; 72 Stat. 426, "The National Aeronautics and Space Act of 1958" as Amended (Space Act), July 29, 1958
- P.L. 108 – 492, "Commercial Space Launch Amendments Act of 2004," December 23, 2004
- P.L. 109 - 155, "NASA Authorization Act of 2005," December 30, 2005
- P.L. 110 - 422, "NASA Authorization Act of 2008," October 15, 2008
- P.L. 111 - 267, "NASA Authorization Act of 2010," October 11, 2010

NASA Policy and Procedures

- NASA Advisory Implementing Instruction 1050 – 1A, "Space Act Agreements Guide," August 15, 2008
- NASA Advisory Implementing Instruction 1050 – 1B, "Space Act Agreements Guide," June 10, 2011
- NPD 1050.1I, "Authority to Enter into Space Act Agreements", December 23, 2008
- NPD 8610.23C, "Launch Vehicle Technical Oversight Policy," August 18, 2006
- NPD 8700.1E, "NASA Policy for Safety and Mission Success," October 28, 2008
- NPD 8700.3B, "Safety and Mission Assurance (SMA) Policy for NASA Spacecraft, Instruments, and Launch Services," October 28, 2008
- NPR 8705.5, "Probabilistic Risk Assessment (PRA) Procedures for NASA Programs and Projects," July 12, 2004

- NPR 8705.2B "Human-Rating Requirements for Space Systems (w/change 1 dated 12/7/2009)," May 6, 2008

- "Commercial Crew Transportation System Certification Requirements for NASA Low Earth Orbit Missions," ESMD-CCTSCR-12.10, Revision Basic, December 8, 2010

- CCT-1001, Commercial Human-Rating Plan (Draft), May 21, 2010

We also reviewed the following documents and presentations:

- "Commercial Market Assessment for Crew and Cargo Systems Pursuant to Section 403 of the NASA Authorization Act of 2010 (P.L. 111-267)," April 27, 2011

- The Vision for Space Exploration, NASA, February 2004

- FY 2012 NASA Proposed Budget,

- Congressional Testimonies on Human Spaceflight from the NASA Administrator, Chairman of the Review of US Spaceflight Plans Committee; the Chairman of the Aerospace Safety Advisory Panel; the Director, Office of Science and Technology Policy for the Executive Office of the President of the United States; and Former Astronauts to the United States Senate Committee on Commerce, Science, and Transportation and/or to the United States House of Representatives Committee on Science and Technology

- Commercial Human Rating Plan Overview

- Briefing to the Aerospace Safety Advisory Panel, "NPR 8705.2B, Human-Rating Requirements for Space Systems," October 22, 2008

- Government Insight/Oversight for Commercial Crew Transportation

- Commercial Crew Insight/Oversight Model Recommendations

- Briefing to the Agency Program Management Council, "Safety Risk Tolerance for the Human Spaceflight," August 27, 2010

- FAA 2010 Commercial Space Transportation Forecasts, May 2010

- Letter from Former Columbia Accident Investigation Board Members to US Senator, Regarding Crew Safety

- Space Act Agreements and articles discussing the agreements regarding the commercial crew space industry

- Various articles from various space industry websites, addressing commercial space industry issues

Use of Computer-Processed Data. We did not rely upon computer-processed data to perform this review.

Review of Internal Controls

We reviewed internal controls related to the development and implementation of NASA's safety and human-rating standards for the commercial space industry. Generally, we concluded that the internal controls related to the commercial space industry were adequate.

Prior Coverage

During the last 5 years, the NASA Office of Inspector General (OIG) and the Government Accountability Office (GAO) issued three 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/FY11 (NASA OIG) and http://www.gao.gov (GAO).

NASA Office of Inspector General

"NASA's Management of Ares I Human-Rating Requirements" (IG-09-016, May 21, 2009)."

Government Accountability Office

GAO Report GAO-09-618, "NASA: Commercial Partners are Making Progress, But Face Aggressive Schedules to Demonstrate Critical Space Station Cargo Transport Capabilities," June 16, 2009.

GAO Report GAO-10-286T, "Commercial Space Transportation: Development of the Commercial Space Launch Industry Presents Safety Oversight Challenges for FAA and Raises Issues Affecting Federal Roles," December 2, 2009.

TECHNICAL AUTHORITY STANDARDS AND REQUIREMENTS

Type 1 - Mandatory Technical Authority Standards and Requirements Documents for Commercial Crew Transportation Systems		
Technical Authority	**Document Number**	**Document Name**
Health and Medical (1)	NASA-Standard-3001 Volume 1	NASA Space Flight Human System Standard Volume 1: Crew Health
(2)	NASA-Standard-3001 Volume 2	NASA Space Flight Human System Standard Volume 2: Human Factors, Habitability, and Environmental Health
(3)	FAA HFDS	Human Factors Design Standard
(4)	MIL-STD-1472	Human Engineering, Design Criteria for Military Systems, Equipment, and Facilities
(5)	NASA-Standard-3000 Volume I – II	Man-Systems Integration Standards.
Engineering (0)	None	
Safety and Mission Assurance (0)	None	

Type 2 - Technical Authority Standards and Requirements Documents for Commercial Crew Transportation Systems - Alternatives Allowed with NASA Approval		
Technical Authority	**Document Number**	**Document Name**
Health and Medical (0)		None
Engineering (1)	NASA-STD-0005	NASA Configuration Management (CM) Standard
(2)	NASA-STD-4003	Electrical Bonding For NASA Launch Vehicles, Spacecraft, Payloads, And Flight Equipment
(3)	NASA-STD-4005	Low Earth Orbit Spacecraft Charging Design Standard
(4)	NASA-STD-5005	Standard for the Design and Fabrication of Ground Support Equipment
(5)	NASA-STD-5017	Design and Development Requirements for Mechanisms

Type 2 - Technical Authority Standards and Requirements Documents for Commercial Crew Transportation Systems - Alternatives Allowed with NASA Approval		
Technical Authority	**Document Number**	**Document Name**
(6)	NASA-STD-5019	Fracture Control Requirements For Spaceflight Hardware
(7)	NASA-STD-6016	Standard Manned Spacecraft Requirements for Materials and Processes
(8)	NPR 2810.1	Security of Information Technology
(9)	NPR 7120.5	NASA Space Flight Program and Project Management Requirements
(10)	NPR 7123.1	NASA Systems Engineering Processes and Requirements
(11)	NPR 7150.2	NASA Software Engineering Requirements
(12)	JSC 65828	Structural Design Requirements and Factors of Safety for Spaceflight Hardware
(13)	JSC 65829	Loads and Structural Dynamics Requirements for Spaceflight Hardware
(14)	JSC 62809	Human Rated Spacecraft Pyrotechnic Specification
(15)	JSC 65827	Thermal Protection System Design Standard for Spacecraft
(16)	JSC 20793	Crewed Space Vehicle Battery Safety Requirements
(17)	JSC 62550	Strength Design and Verification Criteria for Glass, Ceramics, and Windows in Human Spaceflight Applications
(18)	JSC 65830	Interim Requirements and Standard Practices for Mechanical Joints with Threaded Fasteners in Spaceflight Hardware
(19)	JSC 65985	Deployable Aerodynamic Decelerator Requirements for Human Spaceflight
(20)	MIL-STD-461	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
(21)	MIL-STD-464	Electromagnetic Environmental Effects Requirements for Systems
(22)	MIL-STD-981	Design, Manufacturing and Quality Standards for Custom Electromagnetic Devices for Space Applications
(23)	MIL-STD-1540E/ Aerospace Report No. TR-2004 (8583) -1 Rev. A	Test Requirements for Launch, Upper-Stage, and Space Vehicles

Type 2 - Technical Authority Standards and Requirements Documents for Commercial Crew Transportation Systems - Alternatives Allowed with NASA Approval		
Technical Authority	**Document Number**	**Document Name**
(24)	AIAA S-111-2005	Qualification and Quality Requirements for Space Solar Cells
(25)	AIAA-S-112-2005	Qualification and Quality Requirements for Space Solar Panels
(26)	ANSI/ESD S20.20-1999	ESD Association Standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies
(27)	IPC-2221	Generic Standard on Printed Board Design
(28)	IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards
(29)	IPC-6011 1996	Generic Performance Specification for Rigid Printed Boards
(30)	IPC-6012	Qualification and Performance Specification for Rigid Printed Boards
(31)	IPC-CM-770E	Component Mounting Guidelines for Printed Boards
(32)	SAE ARP 5412A	Aircraft Lightning Environment and Related Test Waveforms
(33)	SAE ARP 5413	Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning
(34)	SAE ARP 5414A	Aircraft Lightning Zoning
(35)	SAE ARP 5577	Aircraft Lightning Direct Effects Certification
Safety and Mission Assurance (1)	NPD 8700.1	NASA Policy for Safety and Mission Success
(2)	NPD 8710.5	Policy for Pressure Vessels and Pressurized Systems
(3)	NPD 8730.1	Metrology and Calibration
(4)	NPD 8730.2	NASA Parts Policy
(5)	NPR 8000.4	Risk Management Procedures and Guidelines
(6)	NPR 8621.1	NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping
(7)	NPR 8705.5	Probabilistic Risk Assessment (PRA) Procedures for NASA Programs and Projects
(8)	NPR 8705.6	Safety and Mission Assurance Audits, Reviews, and Assessments
(9)	NPR 8715.3	NASA General Safety Program Requirements
(10)	NPR 8715.5	Range Safety Program
(11)	NPR 8715.6	NASA Procedural Requirements for Limiting Orbital Debris

Type 2 - Technical Authority Standards and Requirements Documents for Commercial Crew Transportation Systems - Alternatives Allowed with NASA Approval		
Technical Authority	**Document Number**	**Document Name**
(12)	NPR 8735.1	Procedures for Exchanging Parts, Materials, and Safety Problem Data Utilizing the Government-Industry Data Exchange Program (GIDEP) and NASA Advisories
(13)	NPR 8735.2	Management of Government Quality Assurance Functions for NASA Contracts
(14)	NASA-STD 8709.20	Management of Safety and Mission Assurance Technical Authority (SMA TA) Requirements
(15)	NASA-STD 8719.12	Safety Standard for Explosives, Propellants, and Pyrotechnics
(16)	NASA-STD 8719.13	NASA Software Safety Standard
(17)	NASA-STD 8719.14	Process for Limiting Orbital Debris
(18)	NASA-STD 8719.17	NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems (PV/S)
(19)	NASA-STD 8739.1	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
(20)	NASA-STD 8739.4	Crimping, Interconnecting Cables, Harnesses, and Wiring
(21)	NASA-STD 8739.5	Fiber Optic Terminations, Cable Assemblies, and Installation
(22)	NASA-STD 8739.8	Software Assurance Standard
(23)	ANSI Z117.1	Safety Requirements for Confined Spaces
(24)	ANSI Z136.2	Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources
(25)	ANSI/AIAA S-080	Space Systems-Metallic Pressure Vessels, Pressurized Structures, and Pressure Components
(26)	ANSI/AIAA S-081	Space Systems – Composite Overwrapped Pressure Vessels (COPV)
(27)	ANSI/ESD S20.20	Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
(28)	ANSI/NCSL Z540.3-2006	Requirements for the Calibration of Measuring and Test Equipment
(29)	ASTM Manual 36	Safe Use of Oxygen and Oxygen Systems: Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation
(30)	GEIA-STD-005-1	Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-Free Solder
(31)	IEEE 730-2002	IEEE Standard for Software Quality Assurance Plans

Type 2 - Technical Authority Standards and Requirements Documents for Commercial Crew Transportation Systems - Alternatives Allowed with NASA Approval		
Technical Authority	**Document Number**	**Document Name**
(32)	IPC J-STD-001D	J-STD 001D, Requirements for Soldered Electrical and Electronic Assemblies
(33)	IPC J-STD-001DS Amendment 1	Space Applications Electronic Hardware Addendum to J-STD 001D, Requirements for Soldered Electrical and Electronic Assemblies
(34)	SAE/AS5553	Counterfeit Electronic Parts; Avoidance, Detection, Mitigation, and Disposition
(35)	SAE/AS9100	Quality Management Systems – Aerospace-Requirements

Type 3 - Technical Authority Standards and Requirements Documents for Commercial Crew Transportation Systems - Best Practices		
Technical Authority	**Document Number**	**Document Name**
Health and Medical (1)	NASA/SP-2010-3407	Human Integration Design Handbook
Engineering(1)	GSFC-STD-1000	Goddard Space Flight Center Rules for the Design, Development, Verification, and Operation of Flight Systems
(2)	JPR 8080.5	JSC Design and Procedural Standards
(3)	KSC-DE-512	Facility, System, and Equipment General Design Requirements
(4)	KSC-NE-9439	KSC Design Engineering Handbook for Design and Development of Ground Systems
(5)	NESC-RP-06-108/05-173-E	Design, Development Test and Evaluation (DDT&E) Considerations for Safe and Reliable Human Rated Spacecraft Systems
(6)	RTCA DO-160E	Environmental Conditions and Test Procedures for Airborne Equipment
(7)	SAE ARP 5416	Aircraft Lightning Test Methods
Safety and Mission Assurance (1)	NPD 8700.3	SMA Policy for NASA Spacecraft, Instruments, and Launch Services
(2)	NPD 8720.1	NASA Reliability and Maintainability (R&M) Program Policy
(3)	NPR 8715.3	NASA General Safety Program Requirements
(4)	ANSI/ISO/IEC 17025-2000	General Requirements for Competence of Testing and Calibration Laboratories

Type 3 - Technical Authority Standards and Requirements Documents for Commercial Crew Transportation Systems - Best Practices		
Technical Authority	**Document Number**	**Document Name**
(5)	ANSI/NCSL Z540.1-1994 (R2002)	General Requirements for Calibration Laboratories and Measuring and Test Equipment
(6)	AS 9003	Inspection and Test Quality System
(7)	NASA-STD 2202-93	Software Formal Inspections Standard
(8)	GIDEP S0300-BT-PRO-010	GIDEP Operations Manual
(9)	GIDEP S0300-BU-GYD-010	Government-Industry Data Exchange (GIDEP) Requirements Guide
(10)	GSFC-STD-1000	Goddard Space Flight Center Rules for the Design, Development, Verification, and Operation of Flight Systems

Acronyms:

AIAA	American Institute of Aeronautics and Astronautics
ANSI	American National Standards Institute
ARP	Aerospace Recommended Practice
AS	Aerospace Standards
ASTM	American Society for Testing and Materials
CM	Component Mounting
ESD	Electrostatic Discharge
FAA	Federal Aviation Administration
GEIA	Government Electronics and Information Technology Association
GIDEP	Government Industry Data Exchange Program
GSFC	Goddard Space Flight Center
HFDS	Human Factors Design Standard
IEEE	Institute of Electrical and Electronics Engineers
IEC	International Electrotechnical Commission
IPC	Association Connecting Electronics Industries
ISO	International Organization for Standardization
JPR	Johnson Procedural Requirements
JSC	Johnson Space Center
KSC	Kennedy Space Center
MIL	Military
NCSL	National Conference of Standards Laboratories
NESC	NASA Engineering and Safety Center
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
RTCA	Radio Technical Committee for Aeronautics
SAE	SAE International
STD	Standard

MANAGEMENT COMMENTS

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

June 29, 2011

Reply to Attn of: Exploration Systems Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Exploration Systems Mission Directorate

SUBJECT: Office of Inspector General (OIG) Draft Report, "NASA's Challenges Certifying and Acquiring Commercial Crew Transportation Services" (Assignment No. A-10-010-00)

The Exploration Systems Mission Directorate (ESMD) appreciates the opportunity to review and provide comments on the OIG draft report entitled, "NASA's Challenges Certifying and Acquiring Commercial Crew Transportation Services," (Assignment No. A-10-010-00) dated May 24, 2011.

In the draft report, the OIG lists four challenges that ESMD will be facing as NASA's Commercial Crew Program (CCP) develops. NASA concurs with the OIG that NASA should pay particular attention to the challenges highlighted in the draft report. As the CCP matures, the Agency will be making progress in each of the areas highlighted.

The draft report also refers to challenges and risks associated with the expansion of the Program as the Agency transitions from Commercial Crew Development (CCDev) to the CCP. Among these challenges is the selection of an acquisition strategy. As acknowledged in the draft report, the acquisition strategy has not been decided, and is still under consideration and in formulation by the Agency, and is subject to further change as the procurement process matures.

Thank you for the opportunity to provide a written response to the subject draft audit report.

Douglas R. Cooke

cc:
ESMD/Dr. Leshin
Mr. McAlister
SOMD/Mr. Gerstenmaier
Ms. Cline
Ms. Mumford
OGC/Mr. Wholley
Ms. Graham
HQ/Office of Procurement/Mr. McNally
KSC/Mr. Cabana
Mr. Mango

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Major Contributors to the Report:

Rebecca Sharek, Director, Space Operations Directorate
Raymond Tolomeo, Director, Science and Aeronautics Research Directorate
Loretta Atkinson, Project Manager
Frank Martin, Aerospace Technologist
Larry Neu, Aerospace Technologist
Eugene Bauer, Auditor

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