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AUDIT REPORT

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COMMERCIAL CARGO: NASA'S MANAGEMENT OF COMMERCIAL ORBITAL TRANSPORTATION SERVICES AND ISS COMMERCIAL RESUPPLY CONTRACTS

OFFICE OF INSPECTOR GENERAL

National Aeronautics and
Space Administration

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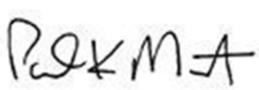

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Inspector General

Acronyms

ATV	Automated Transfer Vehicle
CDR	Critical Design Review
COTS	Commercial Orbital Transportation Services
CRS	Commercial Resupply Services
FAR	Federal Acquisition Regulation
FY	Fiscal Year
GAO	Government Accountability Office
GPS	Global Positioning System
HTV	H-II Transfer Vehicle
ISS	International Space Station
LIDAR	Light Detection and Ranging
OIG	Office of Inspector General
PDR	Preliminary Design Review

OVERVIEW

COMMERCIAL CARGO: NASA'S MANAGEMENT OF COMMERCIAL ORBITAL TRANSPORTATION SERVICES AND ISS COMMERCIAL RESUPPLY CONTRACTS

The Issue

In anticipation of the Space Shuttle's retirement, the NASA Authorization Act of 2005 directed NASA to develop cargo transportation capabilities to the International Space Station (ISS or Station) by fostering the commercial spaceflight industry. Reliable cargo transportation capabilities to the ISS are essential to ensure that critical life-sustaining supplies are provided to support the Station's crews and to maximize utilization of the ISS as a research lab by delivering and returning experiment-related materials to Earth. In the absence of commercial capabilities, NASA would need to rely on the spacecraft of international partners from Europe and Japan to resupply the ISS.

NASA's goals for its commercial cargo effort are to:

- implement U.S. Space Exploration policy with an investment to stimulate commercial enterprises in space;
- facilitate U.S. private industry demonstration of space cargo transportation capabilities with the goal of achieving reliable, cost effective access to low Earth orbit; and
- create a market environment in which commercial space transportation services are available to Government and private sector customers.

Given that the ISS is scheduled to be decommissioned in 2020, if NASA expects commercial partners to play a significant role in servicing the ISS, timely and successful development of their transportation capabilities is crucial.[1]

To foster commercial cargo capabilities and procure ISS resupply missions, NASA used a combination of Space Act Agreements as part of its Commercial Orbital Transportation Services (COTS) Program and fixed-price contracts structured in accordance with the Federal Acquisition Regulation (FAR) as part of its Commercial Resupply Services

[1] By law, the ISS must be maintained until at least 2020; however, NASA is examining and Congress is considering the feasibility of extending the Station's life.

(CRS) Contract.[2] For the COTS Program, NASA collaborated with and provided funding to two private companies – Space Exploration Technologies Corporation (SpaceX) and Orbital Sciences Corporation (Orbital) – to further the companies' development of spaceflight cargo capabilities.[3] SpaceX and Orbital have shared costs with NASA by contributing more than 50 percent of the funds needed for spacecraft development.

In 2008, NASA awarded $3.5 billion in fixed-price contracts to SpaceX ($1.6 billion for 12 missions) and Orbital ($1.9 billion for 8 missions) to procure resupply services to the ISS.[4] In October 2012 and March 2013, SpaceX successfully completed two resupply missions. Orbital plans to undertake its first resupply mission in late 2013. NASA officials stress that the success of both SpaceX and Orbital is critical to the sustainability and utilization of the ISS.

NASA's commercial cargo program is at a critical stage with Orbital poised to come online later this year and the scheduled decommissioning of the ISS in 2020 rapidly approaching. Meanwhile, NASA is using a similar acquisition strategy – a combination of Space Act Agreements and FAR-based, fixed-price contracts – to pursue commercial transportation services to the ISS for its astronauts.[5] To this end, the successes and challenges experienced by NASA's commercial cargo program will prove to be instructive to its commercial crew effort.

Given the importance of the commercial cargo program to the continued viability of the ISS, we examined NASA's management of the program. Details of the audit's scope and methodology are in Appendix A.

Results

Following a nearly 3-year delay early in development, SpaceX successfully completed its final system demonstration flight and two resupply missions to the ISS. Although each flight experienced some anomalies, none were serious enough to substantially impact the missions. During the final demonstration flight, SpaceX needed to adjust its Dragon capsule's guidance system, causing a short delay in the capsule's final approach to the ISS. During its first cargo mission, SpaceX encountered a failure on one of the nine

[2] Space Act Agreements are a form of "Other Transaction Authority" provided in the National Aeronautics and Space Act of 1958 (as amended) that allows NASA to establish a set of legally enforceable commitments between the Agency and a partner per NASA Policy Directive 1050.1I, "Authority to Enter Into Space Act Agreements," December 23, 2008.

[3] SpaceX's transportation system includes a rocket booster system (Falcon 9) and capsule (Dragon), while Orbital's system includes a rocket booster (Antares) and capsule (Cygnus).

[4] NASA has issued task orders and work plans under the FAR-based contracts that outline schedules, payment information, and milestones for the 20 resupply missions. To date, NASA has given SpaceX authority and partial funding to proceed with 7 missions and Orbital authority and partial funding for 6 missions.

[5] The Office of Inspector General is also conducting an audit of NASA's Commercial Crew Program and will issue a report later this year.

Merlin engines in its Falcon 9 rocket, several hardware failures caused by radiation exposure, three instances of sensors losing functionality in the Dragon's thrusters, and the loss of all three coolant pumps due to a water leak after splashdown in the ocean. All radiation effects were resolved with no mission impact, the faulty temperature sensors represented a loss of redundancy only, and the failure of the coolant pumps did not affect the science experiments on board in the return payload. However, these issues contributed to a 2-month delay of the launch of the second cargo mission, which was moved from January to March 2013.

During the second cargo mission, a malfunction initially limited the operation of three of the four thruster pods used to boost the Dragon to a higher orbit and perform the final maneuvers necessary to rendezvous with the ISS. The problem was corrected and the Dragon berthed with the ISS one day later than scheduled with no operational impact to the mission. As of the end of fiscal year (FY) 2012, NASA had paid SpaceX $858 million for development and cargo resupply services under both its funded Space Act Agreement and FAR-based contract.

Like SpaceX, Orbital has experienced delays of over 2 years in its COTS Program, including an early change from an unpressurized to pressurized capsule and construction delays on its Wallops Island, Virginia, launch facility. NASA has paid Orbital a total of $910 million as of the end of FY 2012, including funding for both development efforts under its COTS Space Act Agreement and CRS contract. Under the current payment schedule, the company is on track to receive up to 70 percent of the funds associated with six of its eight CRS missions prior to having flown a demonstration flight.[6]

Orbital successfully completed a maiden test flight of its Antares rocket on April 21, 2013, but the full demonstration flight required under the COTS Program most recently scheduled for June 2013 has slipped to August or September 2013. NASA and Orbital officials noted the maiden flight has reduced technical risk and that the costs of any system modifications needed as a result of the demonstration flight will be borne by Orbital given that the CRS contract is fixed price. Nevertheless, the possibility remains that the demonstration flight could expose issues that require costly rework and redesign, resulting in major adjustments to the current CRS launch schedule.

Out of a need to ensure a redundant cargo capacity, NASA funded development of SpaceX's and Orbital's spaceflight capabilities under the COTS Program while concurrently funding fabrication of the companies' spacecraft under the CRS contracts. As a general matter, procuring rocket systems prior to a successful system demonstration flight substantially increases financial risk as major technical problems may be encountered during final testing and demonstration. Although CRS activities are not contractually tied to a successful demonstration flight, as Orbital's COTS development activities slipped so did the anticipated launch dates for its CRS missions. Although we do not second guess NASA's decision to concurrently fund up to three rocket systems given the critical need for

[6] As of May 2013, Orbital officials stated they had received 70 percent of payments for Missions 1 through 3, 50 percent for Mission 4, and 40 percent for Mission 5.

additional ISS resupply capabilities, in the case of Orbital, NASA will fully or partially fund six rocket systems under the CRS contract before Orbital has fully demonstrated its spaceflight system.[7]

In our judgment, NASA has been too slow to adjust its payment schedule to Orbital under the CRS contract given the substantial slippage in the launch schedule for the company's resupply missions. As such, given the risks inherent in concurrent development, we question NASA's decision to pay Orbital approximately $150 million for costs associated with their fourth and fifth resupply missions. We believe NASA should have deferred this amount to future fiscal years in order to avoid spending funds too far in advance of each mission's launch dates. During the course of our review, NASA took steps to adjust its payment schedule in light of the development delays by negotiating a contract modification in December 2012 for Mission 6 that tied payment to a successful Antares maiden test flight. In our view, NASA instead should have tied payment for this mission to a successful full system demonstration flight. Finally, Orbital requested to begin work on resupply Mission 7 by May 2013, a request from our perspective that, if approved, would result in an additional estimated $70 million in premature payments to the company in FY 2013.[8]

We discussed with program officials our concerns about these advance procurements and they recognized the need to slow down the pace of NASA's payment for Orbital's rocket systems production. For example, officials said they tied future Mission 4 and 5 payments to an adjusted launch schedule and completion of ISS integration activities by the company.[9] While we appreciate that NASA has taken these steps, we believe the Agency has accepted too much financial risk by funding Orbital's fabrication of rocket systems for Missions 4, 5, and 6 so far in advance of the time needed to meet the ISS resupply schedule and prior to Orbital completing a successful system demonstration flight.

Management Action

To reduce the Agency's financial risk, we recommended that the Associate Administrator for Human Exploration and Operations Mission Directorate ensure that contractual agreements for the commercial cargo providers are updated to reflect the lead times required to meet any revised launch dates. If launch dates slip, NASA should adjust contract work plans to ensure that the authorized lead times and NASA payments reflect the revised schedules. In response to our draft report, the Associate Administrator concurred with our recommendation. We consider the Associate Administrator's

[7] As a point of comparison, NASA had funded or partially funded four missions before SpaceX's first demonstration mission and five missions before the second demonstration mission.

[8] As of June 2013, NASA officials informed us that they have delayed authority to proceed for Mission 7 due to slippages in the CRS launch schedule.

[9] Per the CRS contract, ISS integration is "the activities required to ensure that SSP 50808 (ISS requirements document) have been met; necessary hardware and software developments to interface with the ISS have been completed; and joint on-orbit integrated operations plans have been finalized." Orbital reported completing ISS integration in March 2013.

proposed actions to be responsive to our recommendation and will close the recommendation upon completion and verification of the corrective actions.

While the Associate Administrator concurred with the recommendation, he disagreed that NASA has accepted too much financial risk in the way it has implemented the Orbital CRS contract. He stated that NASA determined that the programmatic risks of not starting hardware development needed for cargo resupply were substantially greater than the financial risks posed to the Agency by doing so. He further stated that NASA uses existing payment cap protections and other contractual provisions to reduce financial risks and align payments with technical performance.

We agree that balancing programmatic and financial risk is critical to ensure the success of the commercial cargo program. However, as outlined in the report we continue to believe that NASA has been too slow to adjust its payment schedule to Orbital given the substantial slippage in the launch schedule for the company's resupply missions.

CONTENTS

INTRODUCTION

Background

In 2004, President George W. Bush announced the Vision for Space Exploration, which, among other initiatives, directed NASA to pursue access to the International Space Station (ISS) and low Earth orbit for both crew and cargo by means of commercial partners. Congress responded by enacting the NASA Authorization Act of 2005, which directed the Agency to facilitate agreements with U.S. companies for the research and development of commercial spaceflight capabilities. That same year, NASA created the Commercial Crew and Cargo Program Office to stimulate efforts within the private sector to develop safe, reliable, and cost-effective transportation capabilities.

Between 2006 and 2012, NASA spent $743 million on commercial cargo development efforts through its Commercial Orbital Transportation Services (COTS) Program. In addition, since 2009 the Agency has made $1.1 billion in payments in connection with two fixed-price contracts for cargo transportation services to and from the ISS through its Commercial Resupply Services (CRS) Contract. Two companies – Space Exploration Technologies Corporation (SpaceX) and Orbital Sciences Corporation (Orbital) – received development funds under the COTS Program and are also executing task orders and work plans under the CRS contracts.[10]

Space Act Agreements. The National Aeronautics and Space Act of 1958 (as amended) gives NASA authority to utilize agreements to work with nongovernment entities other than the standard contracts governed by the Federal Acquisition Regulation (FAR). One of the most frequently used of these "Other Transaction Authorities" is Space Act Agreements, which establish a set of legally enforceable commitments between NASA and a partner but do not incorporate an extensive list of requirements routinely found in FAR contracts.[11] In Space Act Agreements, NASA agrees to provide funding, goods, services, facilities, or equipment that the partner uses to accomplish stated objectives. In return, the partner may advance technologies that support NASA's mission, share information, or reimburse NASA for the support provided. As of March 2013, NASA reported over 1,500 active Space Act Agreements with various private companies, educational institutions, state and Federal government organizations, and foreign governments and entities.

[10] As defined in the Federal Acquisition Regulation, a task order is an order for services defined in a contract. NASA uses a document called a work plan to describe the ways in which the contractor will execute the task order.

[11] We use the term "partner" to describe the commercial companies that perform work with NASA under a Space Act Agreement.

The Space Act provides authority for reimbursable, nonreimbursable (unfunded), and funded agreements, and NASA has utilized all three types of agreements in its commercial cargo development program. In a funded agreement, NASA transfers appropriated funds to a partner to accomplish a specific objective. The Agency may use funded agreements only if it cannot achieve its objectives through other types of instruments, including traditional FAR-based contracts. In nonreimbursable agreements, each party bears the cost of its participation with no exchange of funds, while in reimbursable agreements a partner reimburses NASA for support provided such as test facilities, supplies, or engineering expertise.[12]

Commercial Orbital Transportation Services. NASA's commercial cargo development program – known as COTS – aims to stimulate efforts within the private sector to develop and demonstrate safe, reliable, and cost-effective cargo transportation capabilities to the ISS and low Earth orbit. In 2006, NASA announced it would begin this effort by competitively funding multiple Space Act Agreements. That year, NASA entered into Space Act Agreements with SpaceX and Rocketplane Kistler for $278 million and $207 million, respectively. However, because Rocketplane Kistler failed to achieve several financial and technical milestones, NASA terminated its Agreement with the company in 2007 after expending $32.1 million. In February 2008, NASA recompeted the opportunity and entered into a Space Act Agreement with Orbital worth up to $170 million. In fiscal year (FY) 2011, NASA added additional milestones to the SpaceX and Orbital Agreements, bringing the total value of the respective Agreements to $396 million and $288 million.

Both SpaceX and Orbital were expected to contribute their own funds to the commercial cargo development efforts and to date have contributed more than 50 percent of overall development costs. In essence, this means that NASA and the companies share financial, schedule, and technical risks associated with the Program. In addition, both agreements called for the companies to demonstrate a cargo resupply capability in less than 3 years – a substantially shorter timeframe than the average 5 to 6 years NASA officials told us such efforts typically take to complete.

As a part of the Space Act Agreement negotiations, NASA and the companies agreed to a series of developmental milestones that tied payments to events such as design reviews, testing, and ultimately full system demonstration flights. Once NASA and the company agree that a particular milestone has been accomplished, NASA pays the company a predetermined amount associated with that milestone.

A key milestone in the Space Act Agreements for both companies is a full system demonstration flight, which includes successful launch and rendezvous with the ISS. For SpaceX, the full system demonstration flight also included successful delivery of cargo to and the return of cargo from the ISS.[13] Initially, SpaceX proposed to conduct three

[12] NASA Policy Directive 1050.1I, "Authority to Enter into Space Act Agreements," December 23, 2008.

[13] SpaceX's Dragon capsule returns to Earth, while Orbital's Cygnus capsule will burn up upon reentry and therefore can only be used to dispose of unneeded materials from the ISS.

demonstration flights of its rocket systems under the COTS Agreement. Ultimately, SpaceX self-funded the maiden flight of its Falcon 9-Dragon transportation system. That mission was followed by two demonstration missions under the COTS Agreement, one of which included berthing with the ISS. Given the success of these demonstration flights, NASA determined that SpaceX had met or exceeded all of the technical objectives in the COTS Agreement and thus did not require the company to perform a third demonstration mission.

Orbital's Space Act Agreement includes a single system demonstration flight currently planned for August or September 2013. In 2011, NASA added a milestone to the Agreement linked to a maiden test flight of Orbital's Antares rocket. Orbital successfully completed this test flight on April 21, 2013.

Commercial Resupply Services Contracts. In December 2008, while SpaceX's and Orbital's development efforts were still underway pursuant to their COTS Space Act Agreements, NASA entered into a separate set of FAR-based, firm-fixed-price contracts with the companies for a series of resupply missions to the ISS. Worth a total of $3.5 billion, these contracts are for 20 cargo resupply missions through at least 2016: 12 by SpaceX and 8 by Orbital. (See Appendix B for more information concerning the CRS contracts.) Under the contracts, NASA and the companies agreed to a price per mission for the delivery to and return of cargo and disposable items from the ISS. Because costs are expected to rise over the life of the program, annual increases to the price per mission are factored into the contracts.

NASA uses task orders and work plans to manage the CRS contracts. Task orders are issued to the companies for specific projects related to a mission. To date, NASA has issued 26 task orders: 18 to SpaceX and 8 to Orbital.[14] For both companies, Task Order 1 describes the basic requirements for the 20 resupply missions. Work plans are published for each mission and identify the milestone dates tied to specific payments by NASA to the companies. Each work plan is designed to allow sufficient lead time to build the vehicle to meet the ISS resupply schedule. Because NASA wanted to start resupply missions as soon as possible, NASA initiated its FAR-based resupply contracts with the understanding that the companies would receive authority and funds to build rocket systems prior to completing their first demonstration flights. Due to the imminent need for cargo missions and the lead time necessary to fabricate the systems, NASA accepted the risk associated with building vehicles before a successful demonstration flight. The partners sought to help mitigate this risk by testing individual systems and components prior to the demonstration flight.

When SpaceX received its CRS contract award in 2008, its COTS efforts had been underway for 28 months and the company had completed its system design reviews. In contrast, NASA's Space Act Agreement with Orbital had been in place for just 10 months and its system designs were still preliminary when Orbital was awarded its CRS contract in 2008. Moreover, once the requirements of the CRS contract were

[14] Examples of task orders include conducting studies and designing new equipment for future missions.

finalized, Orbital altered its COTS demonstration mission design for an unpressurized capsule to address NASA's request for a pressurized capsule.[15]

The CRS contracts were not directly tied to the milestones outlined in the companies' COTS Agreements. Rather, they were tied to a launch schedule that anticipated the companies' development efforts would be completed with full demonstration flights approximately 2-3 years later. However, as developmental efforts began to slip and completion of COTS milestones was delayed, this assumption turned out to be incorrect. Moreover, although NASA has authority under the CRS contract to adjust the payment schedule based on revised launch dates, we found this was not routinely done in a timely manner.

SpaceX launches from Cape Canaveral Air Force Station in Florida, adjacent to NASA's Kennedy Space Center. Following a series of delays, SpaceX flew a successful maiden flight of its Falcon 9-Dragon system in June 2010, a full system demonstration of its launch system in December 2010, a demonstration flight to the ISS in May 2012, and two resupply missions to the ISS in October 2012 and March 2013.

Orbital's rocket system launches from a newly constructed pad at Wallops Flight Facility in Virginia. Orbital conducted a successful hot fire test of its Antares engines in February 2013 and a test flight of its Antares rocket in April 2013. A demonstration mission of its full system to the ISS is planned for August or September 2013. Orbital's first resupply mission to the ISS is scheduled for the last quarter of calendar year 2013. Figure 1 provides a summary of both companies' spaceflight systems.

[15] In accordance with its Space Act Agreement, Orbital began building an unpressurized capsule in February 2008. In December 2008, Orbital accepted a contract award for the CRS missions with a requirement for a pressurized capsule, which necessitated a change in design and delayed development of its system. This issue is discussed in more detail in the Results section.

Figure 1: Commercial Orbital Transportation Services – Orbital and SpaceX

	Orbital Sciences Corporation	Space Exploration Technologies Corporation
		
Launch Vehicle/Capsule	Antares/Cygnus	Falcon 9/Dragon
Launch Site	Wallops Flight Facility, VA	Canaveral AFS, FL
Operational Status	Maiden test flight: APR 13; Demonstration: AUG/SEP 13	Maiden test flight: JUNE 10; Demonstrations: DEC 10 and MAY 12; 2 of 12 CRS missions to ISS completed
Cargo Capability To ISS From ISS	 1,700-2,700 Kilograms 2,000 kilograms (Disposed)[a]	 3,310 Kilograms 3,310 Kilograms[b]

[a] Orbital's Cygnus capsule will have the capacity to carry 1,700 kilograms in its first three resupply missions and 2,700 kilograms on the remaining five missions. In addition, up to 2,000 kilograms of trash from the ISS can be disposed of by loading on the capsule, which will burn up upon reentry.
[b] SpaceX can return up to 2,500 kg of cargo to Earth, or a total of 3,310 kg of pressurized (return) and unpressurized (disposal) cargo on a single mission.

Source: NASA Office of Inspector General (OIG) presentation of company and Program information.

ISS Cargo Transportation Providers. In addition to the SpaceX and Orbital vehicles, NASA has access to two other vehicles to transport supplies to the ISS: the European Space Agency Automated Transfer Vehicle (ATV) and the Japanese Aerospace

Exploration Agency H-II Transfer Vehicle (HTV).[16] The international partners and NASA worked together to produce a schedule that meets ISS needs and maximizes each vehicle's capabilities. NASA officials stated that because European cargo missions are scheduled to end in mid-2014, these vehicles would not provide sufficient capability to meet the Agency's ISS cargo transportation needs beginning in 2015. In addition, Program officials said the last two scheduled HTV flights in 2015 and 2016 are slated to carry 24 primary batteries for the ISS, which significantly reduces the available pressurized resupply capability of these flights.

SpaceX is the sole transportation provider capable of returning equipment, supplies, and research experiments to Earth, as all the other vehicles (including Orbital's Cygnus) are designed to disintegrate upon reentering the Earth's atmosphere. Figure 2 provides the projected schedule for cargo resupply flights to the ISS through 2016. Missions beyond 2016 are not yet scheduled.

Figure 2: ISS Cargo Mission Schedule as of May 2013

	2012	2013	2014	2015	2016
Orbital Cargo Missions (Cygnus)		D Aug/Sep; 1 Nov	2 Jan; 3 May; 4 Oct	5 Feb; 6 Sep	7 Mar; 8 Sep
SpaceX Cargo Missions (Dragon)	D May; 1 Oct	2 Mar; 3 Nov	4 Apr; 5 Aug; 6 Nov	7 Feb; 8 Apr; 9 Aug	10 Jan; 11 Apr; 12 Aug
European Cargo Missions (ATV)	3 Mar	4 June	5 Apr		
Japanese Cargo Missions (HTV)	3 Jul	4 Aug	5 Jul	6 Jul	7 Jul
Russian Cargo Missions (Progress)*	46 Jan; 47 Apr; 48 Aug; 49 Oct	50 Feb; 51 Apr; 52 Jul; 53 Oct	54 Feb; 55 Apr; 56 Jul; 57 Oct	58 Feb; 59 Apr; 60 Jul; 61 Oct	62 Feb; 63 Apr; 64 Jul; 65 Oct

*At this time, the United States does not procure cargo resupply services from Russia.

ATV – Automated Transfer Vehicle
HTV – H-II Transfer Vehicle

Numbers represent launch number.
D is for demonstration launch.

Source: NASA OIG presentation of Program information.

NASA barters with the European Space Agency and the Japanese Aerospace Exploration Agency for cargo transportation on their vehicles.[17] As of January 2013, the Europeans

[16] The Russian Space Agency (Roscosmos) uses its "Progress" vehicle to resupply its segment of the ISS, but the United States does not have a current resupply agreement with Russia.

[17] Barter agreements involve the exchange of goods or services rather than money. The framework for cooperation was established in the January 1998 ISS Intergovernmental Agreement with specific details for barter agreements in subsequent Memorandums of Understanding between NASA and partner countries.

have flown three of five planned cargo missions on the current schedule, while the Japanese have flown three of seven planned missions.

The costs per mission for cargo resupply both by SpaceX and by Orbital are expected to be lower than the costs associated with the European and Japanese vehicles. Table 1 compares the average cost per mission and capabilities of all ISS cargo service providers.

Table 1: Cargo Transportation Average Price per Mission and Capability

	Contract award (billions)	Number of missions on contract	Average price per mission (millions)	Potential pressurized and/or unpressurized payload delivered to ISS per mission	Payload returned from ISS or disposed per mission
Orbital	$1.9	8	$237.5	1,700 kg standard[a] 2,700 kg enhanced	2,000 kg (disposed[b])
SpaceX	$1.6	12	$133.3	3,310 kg	2,500 kg pressurized (returned[c]) 3,310 kg (pressurized + unpressurized[d])
International Partner Capabilities[e]					
JAXA–HTV	-	-	$400 - 450	6,000 kg max [5,200 kg (pressurized) 1,500 kg (unpressurized)]	< 6,000 kg (disposed)
ESA–ATV	-	-	$450 - 500	7,667 kg	6,500 kg (disposed)

[a] Orbital's first three resupply missions will use the standard Cygnus cargo module; the rest will use the enhanced module, which can hold an additional 1,000 kilograms (kg) of cargo.
[b] Orbital's return capability consists of waste disposal only.
[c] SpaceX has the ability to return cargo such as science experiments to Earth intact.
[d] SpaceX also has the ability to return a combination of pressurized and unpressurized cargo, part of which returns to Earth intact, and the rest is disposed.
[e] Average price per mission for JAXA and ESA was taken from open source publications, and is not the price NASA pays due to barter agreements.

Source: NASA OIG analysis of Program information.

Objectives

Given the importance of NASA's commercial cargo program to support the ISS through the remainder of its scheduled lifespan, we assessed the program's progress to date and the Agency's overall management approach. Specifically, we assessed the extent to which the Agency and its commercial partners are on track to resupply the ISS. See Appendix A for details of the audit's scope and methodology, our review of internal controls, and a list of prior audit coverage.

SPACEX SUCCESSFULLY COMPLETED ITS DEMONSTRATION FLIGHTS AND TWO RESUPPLY MISSIONS TO THE ISS

Following a nearly 3-year delay in development, SpaceX successfully completed its final system demonstration flight and two resupply missions to the ISS as of April 2013. Although each flight experienced technical anomalies, none were serious enough to substantially impact the missions and, according to ISS Program officials, were fewer in number and complexity than what program managers encountered during other space programs. For example, during the second demonstration flight SpaceX needed to adjust Dragon's guidance system prior to its final approach to the ISS. During the company's first cargo mission, SpaceX experienced a failure in one of its nine engines, several hardware failures in the Dragon caused by radiation exposure, three instances of sensors losing functionality in the Dragon's thrusters, and the loss of all three coolant pumps due to a water leak after splashdown in the ocean. All radiation effects were resolved with no mission impact, the faulty temperature sensors represented a loss of redundancy only, and failure of the coolant pumps did not lead to loss of science experiments on the return payload. However, these issues contributed to a 2-month delay for the second cargo mission, which slipped from January to March 2013. During the second cargo mission, a malfunction initially limited operation of three of the four thruster pods used to boost the Dragon to a higher orbit and perform the final maneuvers necessary to rendezvous with the ISS. The problem was quickly corrected, and the Dragon berthed with the ISS one day later than scheduled with no operational impact.

SpaceX Successfully Demonstrated its System Albeit Nearly 3 Years Later than Originally Scheduled

NASA awarded SpaceX a $278 million Space Act Agreement as part of the COTS Program in August 2006, and 2 years later a $1.6 billion firm-fixed-price CRS contract for 12 resupply flights to the ISS. In FY 2011, NASA added milestones to the Space Act Agreement, bringing its total value to $396 million. With its May 2012 demonstration flight, SpaceX satisfied all requirements of the Space Act Agreement and received its final milestone payment in August 2012.

Launch contracts are typically paid in increments tied to the successful completion of production milestones. As of the end of FY 2012, NASA had paid SpaceX $462 million on its CRS contract (see Table 2). This included full payment for the company's first ISS resupply mission and partial funding for completed milestones associated with the next five missions. Work on a seventh mission began in December 2012.

Table 2: Summary of COTS and CRS Funding for SpaceX

	Agreement type	Total award (millions)	Total spent [a] (millions)	Percent spent
Commercial Orbital Transportation Services **(COTS)**	Space Act Agreement	$396	$396	100%
Commercial Resupply Services **(CRS)**	Fixed-price contract	$1,600	$462	29%
	Total	$1,996	$858	43%

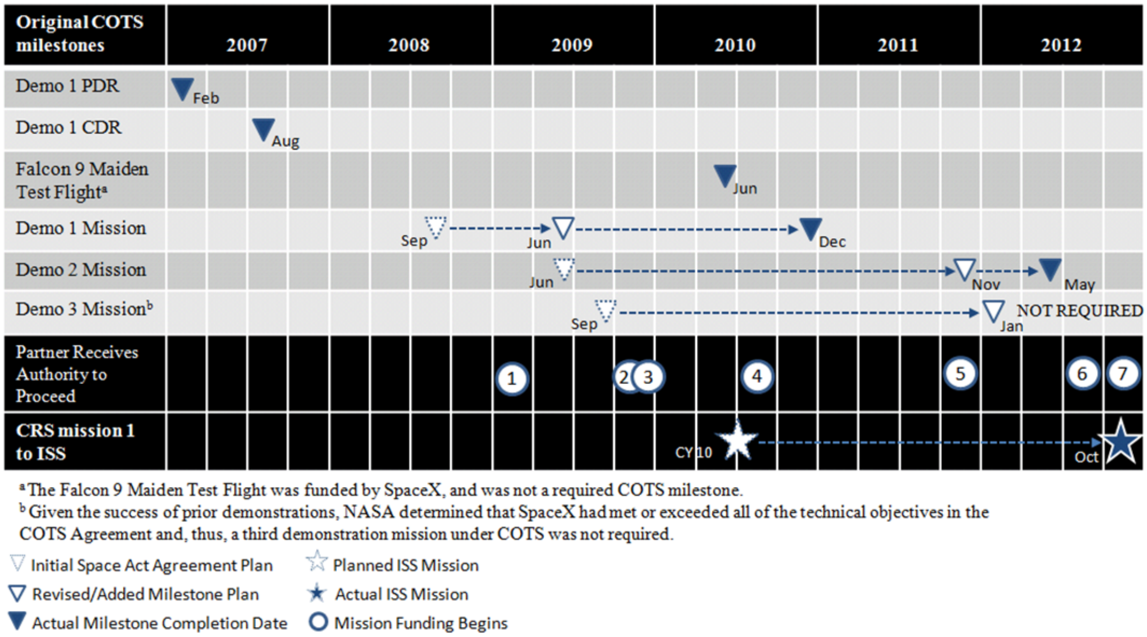
[a] Dollars as of the end of FY 2012.

Source: NASA OIG analysis of Program information.

Originally, SpaceX was scheduled to conduct three demonstration missions under its Space Act Agreement, with the final mission scheduled for September 2009.[18] However, technical issues – including those related to design and software development – caused SpaceX to delay its first COTS demonstration flight until December 2010. Given the success of this flight and the second COTS demonstration, NASA did not require a third COTS demonstration, thereby finalizing the company's obligations under its COTS Agreement. The delay in the final demonstration mission shifted the schedule for the company's first resupply mission from mid-2010 to October 2012 (see Figure 3). The company's second mission successfully launched on March 1, 2013, berthed to the ISS with the assistance of the Station's robotic arm, and returned to Earth on March 26, 2013.

[18] Under the original Space Act Agreement, the final SpaceX COTS demonstration was the only flight that included an actual berthing with the ISS.

Figure 3: Key Milestones and Test Event Delays for SpaceX

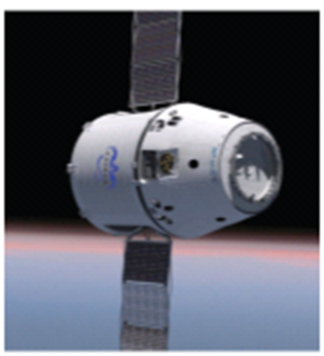


[a] The Falcon 9 Maiden Test Flight was funded by SpaceX, and was not a required COTS milestone.
[b] Given the success of prior demonstrations, NASA determined that SpaceX had met or exceeded all of the technical objectives in the COTS Agreement and, thus, a third demonstration mission under COTS was not required.

Source: NASA OIG analysis of Program information.

COTS Demonstration Flight Was Successful

Figure 4: SpaceX's Dragon Capsule



Source: NASA.

SpaceX's May 2012 flight successfully demonstrated the company's ability to launch the Dragon capsule (see Figure 4) and to approach and berth with the ISS. During the flight, SpaceX experienced a minor technical issue with the Dragon's Light Detection and Ranging (LIDAR) guidance system used in conjunction with a thermal imaging sensor to guide the capsule toward the ISS. As the Dragon capsule made its way to the ISS, SpaceX halted its progress due to unanticipated LIDAR reflections from the ISS structure that were removed by reducing the field of view of the sensor. This action allowed the Dragon capsule to properly analyze the distance from the ISS, safely approach the Station, and attach to a docking port with the help of the Station's robotic grappling arm. The LIDAR guidance system functioned correctly during SpaceX's October 2012 resupply flight.

Technical Issues During SpaceX Mission 1

In October 2012, SpaceX launched CRS Mission 1, the first of its 12 cargo resupply flights to the ISS. Mission 1 carried approximately 450 kilograms of supplies, including

166 scientific investigations.[19] In addition, the mission carried a secondary payload – a communications satellite for the company ORBCOMM. As is common, the flight experienced several minor technical issues, none of which affected the success of the NASA cargo mission.

First Stage Engine Failure. SpaceX's Falcon 9 first stage is powered by nine Merlin engines. Approximately 79 seconds into launch, Falcon 9 experienced a failure in one engine, which automatically shut down. The Falcon 9 is designed to operate in the event of the failure of one engine, and the Dragon capsule remained on course to its rendezvous with the ISS. However, the engine failure resulted in the loss of the prototype ORBCOMM communications satellite, which deployed at a lower than expected altitude and was unable to reach its operational orbit.[20] SpaceX subsequently conducted an investigation and NASA received a report on the failure in February 2013.

For the second CRS mission, SpaceX used engines that had been thoroughly inspected to preclude recurrence of the problem. Moreover, SpaceX officials stated that the upgraded engine that will be used in future flights does not use the same production process.

Flight Computer Malfunction and Radiation Events. In order to decrease computing power, facilitate ability to upgrade, and increase processor speed, SpaceX decided not to use radiation-hardened parts, and instead chose to address radiation effects through a radiation-tolerant avionics system and design recovery strategies if a failure were to occur.[21] For example, to compensate for the danger of a radiation-induced malfunction, SpaceX uses three redundant computers to ensure that one or more remain operational.

Following its successful berthing to the ISS in October 2012, the Dragon experienced a number of radiation-related malfunctions. First, following a wave of solar radiation, one of the capsule's three computers desynchronized from the other two. After the malfunctioning computer successfully rebooted, SpaceX technicians decided not to resynchronize it with the other computers operating the capsule. Because the capsule was able to operate at full capability with only two computers – the minimum required by NASA – Agency officials said that re-synchronizing the failed computer was not worth the risk, and the mission proceeded using the two computer systems. NASA and SpaceX subsequently developed contingency plans to address this situation were it to occur on

[19] While the Dragon can carry 3,310 kilograms of pressurized up mass, the amount of mass carried is dependent on the cargo's density given the available volume. Furthermore, previous resupply missions by international partners had reduced the amount of cargo that SpaceX needed to deliver to the ISS on this first mission. The higher priority need for this mission was to return cargo back to Earth.

[20] A planned second burn of the Falcon 9 second stage was cancelled by NASA in order to meet ISS safety requirements. This burn would have been needed to place the satellite into the correct orbit. While the second stage had sufficient propellant for the second burn, the amount available was just below the level NASA required to meet its acceptable risk criteria.

[21] Hardening against the effects of radiation involves using special radiation-resistant materials when fabricating computer processors and components, and then insulating and shielding the systems from the effects of radiation.

SpaceX Missions 2 or 3. The Dragon capsule that SpaceX is preparing for Mission 4 will be able to resynchronize its computers without rebooting.

In addition to the malfunction of the flight computer, radiation also caused the temporary loss of one of three Global Positioning System (GPS) sensors, the propulsion and trunk computers, and an ethernet switch. Once the Dragon reached orbit and prior to berthing with the ISS, the GPS sensor suffered a radiation hit and lost power. However, technicians were able to quickly restore power and restart the sensor. While berthed to the ISS, the propulsion and trunk computers as well as an ethernet switch lost power due to radiation exposure. Both systems fully recovered following a restart.

Figure 5: Dragon Splashdown to End Cargo Mission 1, October 28, 2012

Source: NASA.

Capsule Thruster Sensor Malfunctions. The Dragon capsule uses thrusters to control attitude and maneuvering capabilities once it has entered low Earth orbit. During CRS Mission 1, sensors on two thrusters malfunctioned. On Thruster 3, a sensor reading drifted for a short period. SpaceX technicians monitored the thruster for the remainder of the flight and did not report any additional or undesired drift. On Thruster 4, a temperature sensor reading also had a similar error.

NASA officials said that each of the sensors had backups, which alleviated any maneuvering issues. In addition, the malfunctioning sensors did not fall below NASA-required performance thresholds, allowing the thrusters to continue normal operations.

Electrical Power Lost After Splashdown. The Dragon capsule returned from CRS Mission 1 on October 28, 2012, with 393 kilograms of scientific experiments and 235 kilograms of hardware. After splashdown in the Pacific Ocean (see Figure 5) and before the Dragon capsule could be lifted onto the recovery ship, water leaked into external portions of the capsule, which prompted SpaceX officials to turn off electrical power to several components, avoiding potential damage. As a result, three coolant pumps that maintain temperatures inside the cabin were shut off, although temperatures remained within required limits. In addition, electrical power to the General Laboratory Active Cryogenic ISS Experiment Refrigerator (GLACIER) refrigeration system was turned off. The refrigerator was storing temperature-sensitive samples from investigations conducted on the ISS. Although temperatures inside the refrigerator rose 30 degrees from the desired temperature of minus 95 degrees Celsius, none of the materials stored inside this device were damaged.

NASA officials explained that the water seepage was caused by the loss of air pressure in portions of the capsule during deorbit, creating a vacuum at splashdown. The capsule used during the company's May 2012 demonstration flight also experienced seepage after splashdown and SpaceX began to take steps to address the problem following that flight. However, by the time of the demonstration flight, the vehicles for use in CRS Missions 1 and 2 were nearly complete and little could be done to modify them. Accordingly, SpaceX modified the storage containers for the second flight in an attempt to increase their resistance to water seepage. SpaceX has since modified the design of the capsule for the third mission to guard against water intrusion.

As a result of the technical issues experienced on CRS Mission 1, SpaceX and NASA rescheduled the second resupply mission from January to March 2013. None of these issues turned out to be major problems, and NASA officials did not consider the 2-month delay substantial or indicative of future negative performance issues.

Technical Issue Briefly Delayed Berthing with ISS During SpaceX Mission 2

On March 1, 2013, SpaceX launched the second of its 12 CRS missions to the ISS with 677 kilograms of supplies, including 160 scientific experiments. At approximately 9 minutes into launch, a minor issue occurred with the Dragon capsule's oxidizer tank pressure. This malfunction limited the operation of three of the four thruster pods used to boost the capsule to a higher orbit and perform the final maneuvers necessary to rendezvous with the ISS. SpaceX delayed deployment of the Dragon's solar array for 90 minutes until technicians determined that deployment would not exacerbate the thruster problem.

NASA has a firm requirement that at least three thruster pods be operational before the Dragon can approach the ISS. Accordingly, SpaceX delayed further ascent until it corrected the thruster problem. Approximately 5 hours after launch, SpaceX engineers corrected the issue with the oxidizer tanks and their associated plumbing, thereby returning all four thruster pods to normal operation. The Dragon recomputed its ascent and rendezvous profiles and resumed its approach to the ISS.

The Dragon successfully berthed to the ISS on March 3 – one day later than scheduled. This delay did not adversely affect any experiments aboard the Dragon capsule. The capsule remained at the ISS until March 26, when it returned to Earth with 1,370 kilograms of science samples.

NASA PAID ORBITAL SIGNIFICANT FUNDING UNDER THE RESUPPLY CONTRACT FOR SIX MISSIONS EVEN THOUGH THE COMPANY HAS YET TO COMPLETE ITS FIRST FLIGHT TO THE ISS

Like SpaceX, Orbital has experienced delays in its COTS development program, including postponement of critical system reviews and flight tests. Despite these delays, NASA has paid Orbital a total of $910 million as of the end of FY 2012, including funding for both COTS development efforts and cargo resupply services under its CRS contract. As of May 2013, the company is on track to receive up to 70 percent of the funds associated with six of its eight CRS resupply missions prior to having flown a demonstration flight.[22] Given the risks inherent in concurrent development and production, we question NASA's decision to pay Orbital approximately $150 million for costs associated with Orbital's fourth and fifth resupply missions and believe NASA paid these funds too far in advance of the missions' launch dates. These actions increased NASA's financial risk in the event that the system demonstration flight reveals the need for design changes and modifications to Orbital's rocket system. Moreover, in December 2012 NASA gave Orbital authority to proceed on Mission 6 with payments contingent upon a successful maiden test flight of the company's Antares rocket. In our view, NASA instead should have made payment for this mission contingent upon a successful full system demonstration flight. Finally, as part of their Launch on Need proposal, Orbital requested to begin work on resupply Mission 7 by May 2013, a request that if approved would result in an additional estimated $70 million in payments for a mission that is not scheduled to launch until 2016.[23] During the course of this audit, Orbital successfully completed its Antares maiden test flight, which company officials state reduces the risk that the demonstration flight will reveal major technical issues.

Orbital Successfully Completed its Antares Maiden Flight but Has Yet to Demonstrate a Flight to the ISS

Orbital's Antares-Cygnus rocket system is the most complex and technically challenging rocket system the company has attempted. Antares is both the largest rocket the

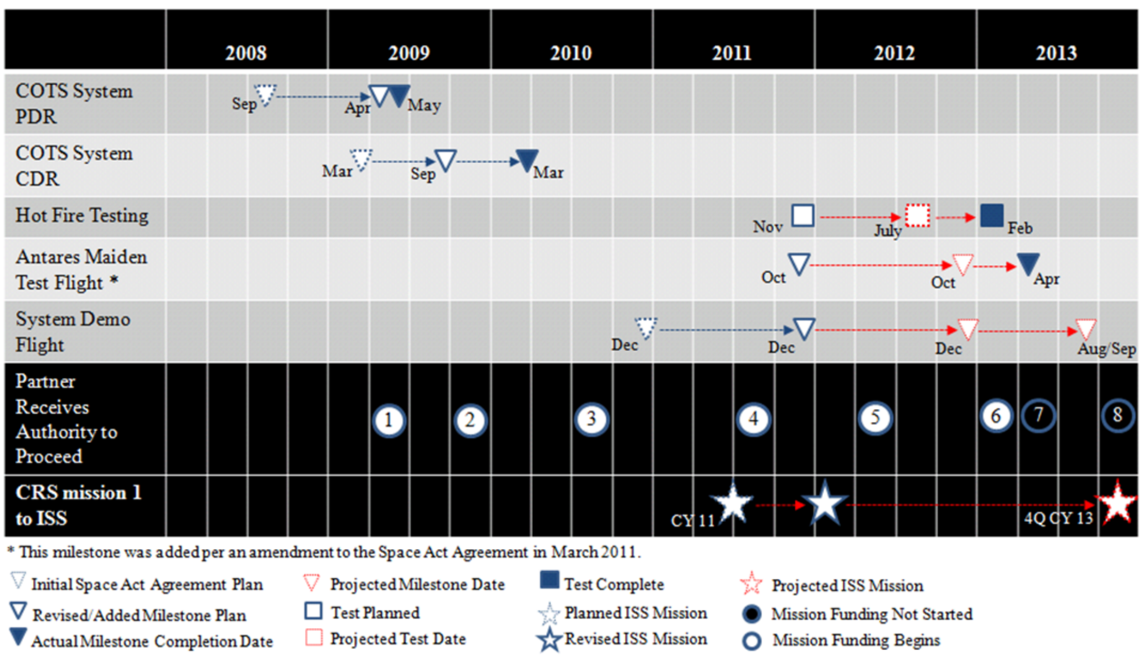
[22] Orbital officials stated that as of May 2013 the company has received 70 percent of the payments associated with Missions 1 through 3, 50 percent for Mission 4, and 40 percent for Mission 5.

[23] Launch on Need capability means that the contractor has a "rolling spare" vehicle readily available in the event NASA needs a launch earlier than is planned in the current launch schedule. As of June 2013, NASA officials informed us that they have delayed the Authority to Proceed for Mission 7 due to slippages in the CRS launch schedule.

company has built and its first powered by first-stage liquid-fueled engines.[24] In addition, Orbital officials told us that two-thirds of the company's launch system is composed of significantly modified heritage subsystems or new subsystems, which in their view reduces technical risk. However, we have previously reported that the use of heritage technologies often requires significant modification before they are suitable for integration into new products.

Under the original terms of its Space Act Agreement, Orbital had planned its key milestone – a system demonstration mission to the ISS – for December 2010. Once it became clear that the company would not meet this timeline, NASA amended the Agreement in March 2011 to add a milestone for a maiden test flight of the Antares rocket (see Figure 6). Orbital successfully completed this test flight on April 21, 2013.

Figure 6: Key Milestones and Test Event Delays for Orbital



Source: NASA OIG analysis of Program information.

[24] There are two basic types of rockets: solid propellant fueled and liquid propellant fueled. Liquid-fueled rockets are considered more complicated to operate because they require pumps and fuel lines, which tend to make them heavier than solid-fueled engines. Although a liquid-fueled rocket has its complications, there are also advantages. For example, unlike a solid-fueled rocket, which, once ignited, burns until all fuel has been exhausted, a liquid-fueled rocket has valves and pipes that direct (or shut off) the fuel, making it easier to control the amount of the thrust.

Due to technical issues, Orbital's system demonstration flight has been delayed repeatedly and is now scheduled for August or September 2013.[25] Orbital's key milestone delays are as follows:

- *System Preliminary Design Review (PDR)* was delayed 8 months. The PDR is an important review to demonstrate that a system's preliminary design meets all requirements with acceptable risk and within cost and schedule constraints. The PDR establishes the basis for proceeding with detailed design and demonstrates that the correct design option was selected, interfaces have been identified, and verification methods have been described. In its Space Act Agreement, Orbital agreed to develop an unpressurized cargo module; however, NASA's CRS contract calls for pressurized cargo missions. At Orbital's request, NASA modified the Space Act Agreement to include demonstration of a pressurized cargo capability. This major change caused the delay in completing the PDR.

- *System Critical Design Review (CDR)* was delayed 12 months. The purpose of CDR is to demonstrate that the design is sufficiently mature to proceed with full-scale fabrication, assembly, integration, and testing. The CDR should indicate that the technical effort is on track to meet mission performance requirements within the identified cost and schedule constraints. A portion of the delay in getting to CDR was caused by the delayed PDR. The rest of the delay was due to technical issues associated with hardware and electronic systems for the spacecraft. Contrary to industry best practices, Orbital began ordering parts for fabrication of its first two launch vehicles before CDR was successfully completed. Spacecraft designs are not frozen until CDR and are subject to change until that time. Once CDR is completed, all parts specified and designed are ordered and fabricated. Due to early fabrication of the first two launch vehicles and subsequent requirements changes, Orbital's first enhanced cargo module will not be available until Mission 4.[26]

- The *Hot Fire Test* was delayed 15 months. This test was performed on February 22, 2013 to demonstrate the readiness of the rocket's first stage and launch pad fueling systems. The test involved firing Antares' dual AJ26 rocket engines – generating a combined total thrust of 680,000 pounds for approximately 29 seconds – while the first stage was held down on the pad. COTS Program officials told us this delay in testing stemmed primarily from an engine failure during prior testing due to a fuel pipe structural failure caused by

[25] Orbital originally proposed in its COTS agreement to develop, test, and demonstrate the entire system in 2 years. NASA Program officials told us they knew this was an optimistic and aggressive schedule and would likely slip, but they nonetheless approved Orbital to work toward that goal.

[26] The enhanced cargo module provides the capability to increase delivery of cargo to the ISS from 1,700 kilograms to 2,700 kilograms. NASA and Orbital originally planned to use an enhanced cargo module for Mission 3; however, subsequent changes in requirements associated with the vehicle visiting the ISS made it necessary to slip the enhanced capability to Mission 4.

stress corrosion, and improvements to the liquid-fuel-capable launch facility at Wallops that were not completed until September 2012.[27]

- The *Maiden Test Flight* of Antares was delayed 18 months. This test flight took place on April 21, 2013, and included a launch of the Antares vehicle carrying a payload simulator in place of the actual Cygnus capsule. The delay for this test flight stems from the Wallops launch pad construction and engine issues mentioned above. After the successful hot fire test, this maiden test flight was Orbital's second-to-last major milestone under its COTS Agreement. In December 2012, NASA granted Orbital authority to proceed with its sixth launch vehicle with payment contingent on completion of this maiden test flight. Despite the delays, the maiden flight of Antares successfully demonstrated all operational aspects of the new launch site and the new rocket, including the ascent to space and delivery of the Cygnus simulator to a target orbit. According to Orbital officials, this reduced significant technical risk associated with the System Demonstration Flight.

- The *System Demonstration Flight* has been delayed at least 33 months. Under Orbital's current plan, the demonstration flight is expected to include: (1) launch of the Cygnus capsule; (2) check-out of Cygnus systems in low Earth orbit; (3) rendezvous, proximity operations, capture, and berth with the ISS; (4) crew entrance and check-out of Cygnus systems while berthed to the ISS; (5) release and departure of Cygnus; and (6) deorbit and re-entry. A large portion of the delay (12 months) can be attributed to the PDR and CDR delays; however, COTS Program officials told us the remaining 21-month delay stemmed primarily from the engine and launch facility issues discussed above combined with systems integration testing that identified issues with individual systems within the Cygnus capsule. In addition, Orbital decided to replace one of the engines on the demonstration launch vehicle due to an internal propellant seal leak observed in prior acceptance testing. Assuming that this flight occurs as planned in August or September 2013, NASA will have paid towards the production of at least six of the eight Orbital vehicles specified in the CRS contract before the company has demonstrated its full flight system.

Under NASA's current schedule, Orbital completed its Antares maiden flight test and plans to undertake its demonstration flight and first cargo mission to the ISS within 7 months. In contrast, SpaceX conducted its Falcon 9 maiden test flight more than 6 months before its first demonstration flight, and an additional 17 months passed between the company's first and second demonstration flights. We acknowledge that technical issues and schedule slippage are common in complex development programs; however, the 3 months between the launch system's August/September demonstration flight and Orbital's first resupply mission to the ISS planned for the last quarter of calendar year 2013 leaves little time to correct any significant issues discovered during

[27] The launch facility at Wallops, known as the Mid-Atlantic Regional Spaceport, is overseen by the Virginia Commercial Space Flight Authority.

the demonstration. Even so, Orbital officials stated that a 3-month turnaround time is achievable because the company has considerable experience in launching multiple missions in a short timeframe and have the space systems readily available.

Continued Funding of Orbital's CRS Contract Despite Substantial Launch Delays Increases NASA's Financial Risk

NASA increased its financial risk by funding production of multiple Orbital spaceflight systems while Orbital's development efforts were still under way. According to best practices for space system acquisition, production of a flight system should not occur until the system has been successfully demonstrated in a relevant environment.[28] The purpose of these practices is to minimize the concurrency between product development and production of a system.[29] Previous reviews by the NASA OIG and the Government Accountability Office (GAO) have found that committing to production before system development is complete is a high-risk strategy that often results in performance shortfalls, cost increases, schedule delays, and test problems.[30]

We understand that NASA accepted the risks of concurrent development with both SpaceX and Orbital out of a need to ensure a redundant cargo capacity to meet the ISS resupply schedule, and we do not second guess the Agency's decision to concurrently fund up to three spaceflight systems for each company. However, in the case of Orbital, we believe that NASA has leaned too far forward by continuing to fund the company's CRS missions when Orbital did not meet major developmental milestones specified in its Space Act Agreement, which in turn delayed launch dates for its CRS resupply missions.

In the Orbital CRS contract, each cargo mission has 10 milestones, the first 7 of which are tied to rocket system fabrication for items such as long lead procurement and integration and testing. The final three milestones, representing 30 percent of the remaining funds, are dependent on successful launch activities such as cargo integration review, launch, and delivery. As a result, NASA is paying Orbital 70 percent of the funds associated with the company's first three CRS missions and 40 to 50 percent of the

[28] GAO, "Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes" (GAO/NSIAD-99-162, July 30, 1999). Technology readiness level 6 – demonstration of a prototype in a relevant environment – is the level of technology maturity that constitutes low risk for beginning system fabrication for production models.

[29] Concurrency is broadly defined as the overlap between technology development and product development or between product development and production. While some concurrency is understandable, committing to product development before requirements are understood and technologies mature or committing to production and fielding before development is complete is a high-risk strategy that often results in performance shortfalls, unexpected cost increases, schedule delays, and test problems. It can also create pressure to keep producing to avoid work stoppages. GAO, "Missile Defense: Opportunity Exists to Strengthen Acquisitions by Reducing Concurrency" (GAO-12-486, April 2012).

[30] GAO, "NASA: Assessments of Selected Large-Scale Projects" (GAO-12-207SP, March 1, 2012) and NASA OIG, "NASA's Challenges to Meeting Cost, Schedule, and Performance Goals" (IG-12-021, September 27, 2012)

funds associated with Missions 4 and 5 – all before Orbital demonstrates that its system can successfully launch and rendezvous with the ISS.

As of the end of FY 2012, NASA paid Orbital $633 million under the CRS contract toward activities associated with building five rocket systems, three of which were substantially complete by December 2012.[31] This funding represents 33 percent of the total funding NASA agreed to pay Orbital for its 8 resupply missions. In contrast, NASA paid SpaceX approximately $100 million toward three missions under its CRS contract prior to the company's Falcon 9 maiden test flight, and a total of about $300 million prior to its successful demonstration flights. Table 3 summarizes the funding Orbital has received from NASA.[32]

Table 3: Summary of COTS and CRS Funding for Orbital

	Agreement type	Total award (millions)	Total spent [a] (millions)	Percent spent
Commercial Orbital Transportation Services **(COTS)**	Space Act Agreement	$288	$276	96%
Commercial Resupply Services **(CRS)**	Fixed-price contract	$1,900	$633	33%
	Total	**$2,188**	**$910**	**42%**

[a] Dollars as of the end of FY 2012.

Source: NASA OIG analysis of Program information.

We question NASA's decision to continue funding milestones for up to six Orbital CRS missions given the financial risk to the Agency if major modifications are required to the company's launch system after the demonstration flight. Funding so many missions in advance of a demonstration flight increases NASA's financial and programmatic risk. Under the original CRS contract, NASA was scheduled to fund work on three missions before Orbital completed its demonstration flight. However, even though most key development milestones under the Space Act Agreement and therefore the launch dates for Orbital's CRS flights have been delayed, NASA only recently adjusted Orbital's CRS payment schedule to reflect these delays.[33]

Moreover, as a result of the schedule delays and its decision not to adjust the payment schedule accordingly, NASA has funded all of Orbital's missions months or even years earlier than necessary to fly to the ISS, according to the Agency's revised flight schedule.

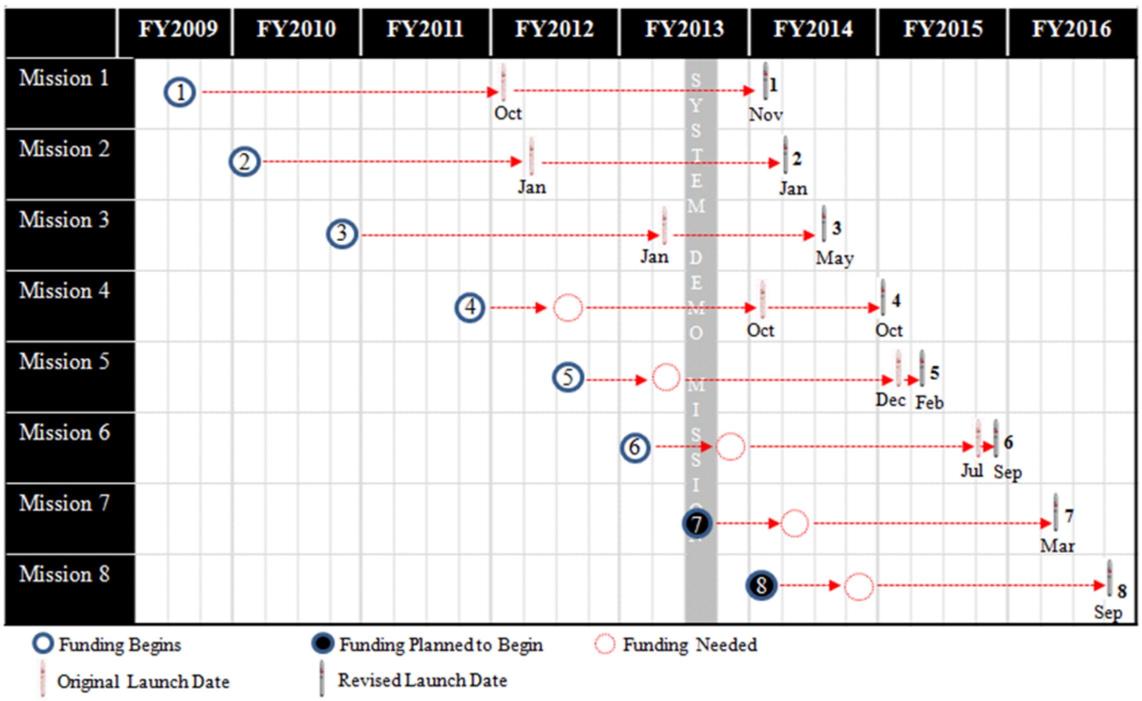
[31] The payments to Orbital are used for all costs related to the entire program including spacecraft hardware, ground systems, and program reviews.

[32] As a point of comparison, SpaceX began work on flight hardware for its first three missions before its Falcon 9 maiden test flight in June 2010. At the same point in its development cycle – prior to its April 2013 Antares test flight – Orbital had begun work on six of its eight missions.

[33] Although there are no contractual ties between the CRS contract and the COTS Space Act Agreements, in December 2012 NASA negotiated with Orbital to tie payment for Mission 6 to the completion of the Antares maiden test flight.

Standard lead times for development of similar space systems is 24-30 months, and the SpaceX and CRS contracts specify lead times consistent with this standard. However, NASA funded and Orbital began fabricating systems for the company's first six missions an average of 41 months before they are now scheduled to fly. Figure 7 summarizes the relationship between fabrication and current mission schedules.

Figure 7: CRS Funding and Fabrication Schedule



Source: NASA OIG analysis of Program information.

In our judgment, funding Missions 1, 2, and 3 was reasonable despite the program delays and schedule changes because NASA officials had a need to start CRS missions to the ISS immediately following COTS demonstration flights. However, we question NASA's decision to pay Orbital approximately $150 million in FY 2011 through FY 2013 toward the systems for Missions 4 and 5, which are not scheduled to fly until FY 2015. At the time these funding decisions were made, NASA Program officials were well aware of the extent of slippage in both Orbital's COTS milestones and its CRS launch dates.

Furthermore, so far in FY 2013, NASA has spent approximately $10 million on Mission 4, and we estimate the Agency will spend an additional estimated $70 million on Missions 4, 5, and 6 by the end of FY 2013. In addition, Orbital has requested as part of their Launch on Need proposal to begin work on Mission 7 in May 2013 and Mission 8 in November 2013. We estimate that should NASA ultimately agree to this request it would constitute a premature expenditure of an additional estimated $70 million in FY 2013 and roughly $60 million in FY 2014, based on NASA's current ISS flight manifest.

Table 4 summarizes the amounts NASA has paid or is scheduled to pay Orbital per mission under the CRS contract. In our judgment, delaying authority to proceed until closer to when missions are scheduled to launch would better protect NASA's financial interest against the possibility that Orbital is ultimately unable to successfully demonstrate its launch system or the demonstration flight shows that major modifications to the system are required.

Table 4: Summary of Potential CRS Savings per Fiscal Year

	FY 2011 (millions)	FY 2012 (millions)	FY 2013 (millions)	Additional Request for FY 2013 (millions)	FY 2014 (millions)	Total (millions)
Spent Dollars That Could Have Been Deferred	$45	$95	$10			**$150**
Dollars to Defer from FY 2013 to FY 2014			$70	$70		**$140**
Dollars to Defer from FY 2014 to FY 2015					$100	**$100**

Source: NASA OIG analysis of Program information.

Balancing and Managing Financial Risk

NASA officials acknowledged the financial risk associated with funding Orbital's development of spaceflight capabilities while concurrently funding the fabrication of six launch vehicles. However, in their view the programmatic risks of not having reliable transportation capabilities to service the ISS outweighed the financial risk. To this end, NASA program officials said they funded Orbital for six missions because NASA required a Launch on Need capability in case cargo resupply missions from either SpaceX or the Agency's international partners became unavailable. In addition, NASA Program officials said upgrades to Orbital hardware on Missions 4 through 8 required a longer lead time to build.

NASA officials also explained their rationale for accepting this level of financial risk as a way to ensure a second private company was financially "healthy" enough to participate in the CRS activities. The officials said that despite the milestone delays under Orbital's Space Act Agreement, they currently see no major technical problems with the company's launch system or capsule. Further, NASA Program officials noted that to reduce risk, they have linked 20 percent of the payment for each mission to milestones Orbital can meet only by successfully completing deliveries to the ISS. In addition, they said they have been holding both SpaceX and Orbital to their original mission pricing as a means of holding the contractors accountable for the schedule delays, which helps reduce the Government's financial risk.

According to Orbital officials, the successful Antares maiden flight in April 2013 has reduced the risk that the full demonstration flight will reveal major technical issues with the company's system. Given this flight and the completion of ISS integration, which took place in March 2013, Orbital officials said they have demonstrated the capability to execute ISS resupply missions. In addition, Orbital officials stress that because the CRS resupply contract is fixed-price, any technical changes that result in additional costs will be borne by Orbital alone. They also point out that in the event the contract needs to be terminated for cause, all CRS payments are recoverable.

Nevertheless, we maintain that by buying services – valued at almost $1 billion – for a system that has not been fully demonstrated, NASA has incurred an unnecessary risk. In our view, continuing work on Orbital's fourth and fifth rocket systems and beginning work on Missions 6 through 8 in the absence of a successful system demonstration flight introduces unnecessary financial risk to NASA, particularly given that the start-work dates for these missions are well in advance of the current launch schedule. The current manifest indicates that Orbital's Mission 6 is not scheduled to launch until FY 2015, with Missions 7 and 8 not scheduled to launch until at least FY 2016.

Despite their confidence in Orbital's system, Program officials acknowledged our concern about the level of financial risk NASA was accepting given that the company's system demonstration flight has slipped to August or September 2013. In addition, during the course of our audit we discussed with NASA and Orbital officials our concerns regarding the Agency's increased financial risk associated with paying towards rocket systems so far in advance of when they are needed to meet the ISS flight manifest. NASA officials generally agreed with our assessment, and took action to reduce the Agency's financial risk. For example, NASA officials enforced a section of the CRS contract that enables them to hold funding for Missions 4 and 5 at 50 percent as a result of launch schedule delays. Furthermore, although NASA granted Orbital authority to proceed with Mission 6 in December 2012, payments for the mission were withheld until the completion of the Antares maiden test flight.

While we acknowledge these positive steps toward mitigating NASA's financial risk, we believe that going forward, NASA should ensure that contractual plans and agreements are updated to reflect the lead times required to meet revised launch dates. If launch dates slip, NASA should adjust the contracts to ensure that the authorized lead times – and NASA payments – reflect the revised schedules.

Conclusion

Since 2006, NASA has worked with its commercial partners to develop commercial capabilities to transport cargo to low Earth orbit. In 2008, NASA entered into contracts with two companies to utilize those capabilities by delivering cargo to the ISS. To date, SpaceX has successfully completed the COTS Program and flown two CRS missions to the ISS, while Orbital prepares to demonstrate its complete flight system. While we are encouraged by the successful maiden test flight of Orbital's Antares rocket, we remain concerned about the financial risk NASA is taking by funding systems for Orbital missions so far in advance of expected launch dates and before the company has completed a total spacecraft system demonstration flight to the ISS. With six systems either substantially complete or in production, NASA has invested considerable Agency resources in Orbital's current system design prior to a successful demonstration flight.

Consequently, we question NASA's decision to continue to fund or begin funding Orbital's fourth, fifth, and sixth resupply missions. While we acknowledge that Orbital's testing to date is meeting expectations, if the system ultimately is unable to successfully launch, rendezvous, and berth with the ISS, NASA may not be able to recover the approximately $150 million it has invested in these later missions.[34] In addition, if NASA executes its current FY 2013-2014 spending plan, it will prematurely authorize payment of an additional estimated $240 million to Orbital for these missions. We believe that this level of risk is unnecessary given that NASA has other options for resupplying the ISS, including SpaceX and other international partners.

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

We recommended that going forward, the NASA Associate Administrator for the Human Exploration and Operations Mission Directorate ensure that contractual agreements for the commercial cargo providers are updated as appropriate to reflect lead times required to meet new launch dates. If launch dates slip, NASA should adjust contract work plans to ensure that the authorized lead times – and NASA payments – reflect the revised schedules.

Management's Response. Although the Associate Administrator disagrees that NASA has accepted too much financial risk in the way it has implemented the Orbital CRS contract, he nevertheless concurred with our recommendation to ensure CRS contracts are updated to reflect the lead times required to meet any revised launch dates. He stated that NASA will work closely with CRS contractors to update work plans in an iterative process, including reviewing and updating the plans at quarterly meetings, and will document the logic behind any decision not to update a particular work plan. He noted that the next quarterly meetings are scheduled for July for SpaceX and August for Orbital.

With regard to our finding regarding financial risk, the Associate Administrator stated that NASA determined that the programmatic risks of not starting hardware development needed for cargo resupply were substantially greater than the financial risks posed to the Agency by doing so. He further stated that NASA uses existing

[34] NASA officials have stated that CRS payments are commercial interim payments that would be fully recoverable in the event of termination of the entire contract for cause (per FAR 52.212-4[m] "Termination for Cause"). However, our analysis indicates that Orbital will receive additional funds associated with the contract before the demonstration flight now scheduled for August or September 2013. It may be very difficult to recover these funds in the event of a Termination for Cause.

payment cap protections and other contractual provisions to reduce financial risks and align payments with technical performance.

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

With regard to the Associate Administrator's comments regarding our finding of financial risk, we agree that balancing programmatic and financial risk is critical to ensure the success of the commercial cargo program. However, as outlined in the report, we continue to believe that NASA has been too slow to adjust its payment schedule to Orbital given the substantial slippage in the launch schedule for the company's resupply missions.

Scope and Methodology

We performed this audit from July 2012 through April 2013 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We assessed that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. This audit focused on the COTS Program managed by NASA's Commercial Spaceflight Development Office, and the CRS contract managed by NASA's International Space Station Program, both within the Human Exploration and Operations Mission Directorate.

To determine the Agency's management of the COTS Program and CRS contracts, progress made, and challenges hindering the successful implementation of the Program and contracts, we reviewed laws, regulations, and policies in order to determine compliance with required guidance and best practices. We obtained and reviewed prior reports related to NASA's ability to address the development and collaboration challenges of the COTS Program. We interviewed key personnel within NASA's Commercial Spaceflight Development Office and the COTS Program located at NASA Headquarters, Kennedy Space Center, Johnson Space Center, and commercial partners at their corporate sites.

To determine whether both the commercial partners were on track to provide a system capable of resupplying the ISS, we analyzed schedule timelines and partner performance under both COTS and CRS to date.

We reviewed CRS contracts and interviewed key NASA personnel to determine whether NASA was properly managing the work plans for CRS. We compared contract payment milestones to milestones in the Space Act Agreements and in NASA guidance and analyzed the differences.

To determine whether the Space Act Agreements used in cargo development are readily adaptable to other programs such as commercial crew development, we interviewed program managers and officials from both the commercial crew and cargo programs, along with their supervisors and supporting teams.

Use of Computer-Processed Data. We used computer-processed data to perform this audit. We collected computer-processed milestone payment cost data for the COTS Program and the CRS contracts from the beginning of the Program through the end of FY 2012. Program officials downloaded the data from NASA's financial management program and provided the data in Microsoft Excel. In order to verify the accuracy of this data, we corroborated the information provided with documentation such as the original

COTS Space Act Agreements and amendments, the CRS contracts, task orders, work plans, and budget data. We analyzed this data to enable us to evaluate partner and contractor performance, identify risks to the Program, and quantify NASA's investment to date. We assessed that the cost data we received was sufficiently reliable, but we did not rely solely on the computer-processed data to support our findings, conclusions, or recommendations.

Review of Internal Controls

We reviewed NASA policies and procedures to determine internal control requirements for management of the COTS Program. The results of this review will be provided in a separate memorandum to NASA management.

Prior Coverage

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

NASA Office of Inspector General

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

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

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

Government Accountability Office

"Commercial Space Launches: FAA Should Update How It Assesses Federal Liability Risk" (GAO-12-899, July 30, 2012)

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

"Missile Defense: Opportunity Exists to Strengthen Acquisitions by Reducing Concurrency" (GAO-12-486, April 2012)

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

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

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

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

"NASA: Commercial Partners Are Making Progress, but Face Aggressive Schedules to Demonstrate Critical Space Station Cargo Transport Capabilities" (GAO-09-618, June 16, 2009)

COMMERCIAL PARTNER TABLE

Table 5: List of COTS Recipients and CRS Awards

Company	Orbital Sciences Corporation (Orbital)	Space Exploration Technologies Corporation (SpaceX)
System	Cygnus/Antares	Dragon/Falcon 9
Total COTS Funds Available	$288 million	$396 million
Total COTS Funds Used (Percentage of Total Funds)	$276 million (96%)	$396 million (100%)
Total Potential Value of CRS Contract	$1.9 billion	$1.6 billion
Total CRS Funds Used (Percentage of Total Funds)	$633 million (33%)	$462 million (29%)
Capability	Internal pressurized cargo delivery and disposal	Internal pressurized cargo delivery return; unpressurized cargo delivery and disposal
Payload to ISS	1,700 kg (standard) 2,700 kg (enhanced)	3,310 kg
Payload from ISS	2,000 kg (disposed)	3,310 kg (returned, pressurized + unpressurized)
Number of Flights Ordered	8	12
Number of Flights Completed	0	2
Planned Missions by Fiscal Year	2013 – 2 2014 – 2 2015 – 2 2016 – 2	2012 – 1 2013 – 2 2014 – 3 2015 – 3 2016 – 3

Source: NASA OIG analysis of Program information.

MANAGEMENT COMMENTS

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

June 11, 2013

Reply to Attn of: Human Exploration and Operations Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Human Exploration and Operations Mission Directorate

SUBJECT: Response to OIG Audit Report, "Commercial Cargo: NASA's Management of Commercial Orbital Transportation Services and ISS Commercial Resupply Contracts" (Assignment No. A-12-024-00)

The Human Exploration and Operations Mission Directorate (HEOMD) appreciates the opportunity to review your audit report entitled "Commercial Cargo: NASA's Management of Commercial Orbital Transportation Services and ISS Commercial Resupply Contracts" (Assignment No. A-12-024-00). The open dialogue during the review process was very valuable. NASA appreciates the effort by the Office of the Inspector General (OIG) to protect sensitive but unclassified (SBU) contractor data. It appears that all of the Agency's issues related to SBU contractor data have been addressed, and we presume that those of both Orbital and SpaceX have also been dealt with appropriately.

This letter addresses measures that NASA continues to take to mitigate the financial risks of the Commercial Resupply Service (CRS) contracts. The OIG report states (page IV) that the Agency has accepted too much financial risk by authorizing Orbital to proceed well in advance of the time needed to meet the International Space Station (ISS) resupply schedule. NASA disagrees with this conclusion. NASA determined that the programmatic risks of not being able to resupply the ISS by not starting hardware development needed for cargo resupply were substantially greater than the financial risks. ISS was at risk if cargo was not provided. Through the contract, NASA had several ways to mitigate financial risk as follows. NASA uses existing payment cap protections and other contractual provisions to reduce financial risks and align payments with technical performance. Specific payment cap provisions in the contract include:

- ISS Integration: contractor payments capped until ISS integration is demonstrated in compliance with Space Shuttle Program 50808.
- Mission Integration Review: contractor payments capped until successful completion of the MIR which is determined by the Government.

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- Cargo Delivery: final milestone payment is held until mission success is determined by the Government.

Other contractual protections which further reduce NASA's financial risk, clause II.A.6, Resupply Mission Payments, Milestone Events, and Completion Criteria, assure that:

- all interim CRS payments would be fully recoverable in the event of termination of the entire contract for cause.
- the contractor forfeits the final 20 percent mission payment in the case of a failed mission in lieu of other termination for cause provisions.
- the Government may defer or cancel payment schedules if the contractor fails to make substantial progress on milestone events required under the contract.

Other key clauses include clause II.A.3, Security for Cargo Resupply Service Payment Financing, which requires adequate security for Government financing and clause II.A.2, Limitation of Funds (Fixed-Price Contract), which limits NASA's total financial obligation to the amount provided on the contract to date.

The OIG report includes the following recommendation which is addressed to the Associate Administrator for Human Exploration and Operations Mission Directorate:

Recommendation 1: Going forward, we recommend that the NASA Associate Administrator for the Human Exploration and Operations Mission Directorate ensure that contractual agreements for the commercial cargo providers are updated as appropriate to reflect the lead times required to meet new launch dates. If launch dates slip, NASA should adjust the contracts to ensure that the authorized lead times - and NASA payments - reflect the revised schedules.

Management's Response: NASA concurs with the recommendation. NASA will work closely with the CRS contractors to update work plans in an iterative process. NASA will update work plans for all authorized missions within the coming months. NASA may choose to not update the work plans but will document the logic for that decision. NASA will review work plans at every Quarterly meeting. The next meetings are scheduled in July for SpaceX and August for Orbital.

NASA manages the CRS contracts to meet the cargo delivery needs of the ISS and to limit the financial risk to the Government. The CRS contracts provide for the necessary contract protections to balance programmatic requirements and meet the Agency's obligations to the Nation and to our International Partners. NASA will continue to pursue contract consideration when appropriate and hold the CRS contractors to their original mission prices. These actions demonstrate that NASA has operated within proper contract bounds as good stewards of the U.S. taxpayers' funds while still enabling critical logistics capabilities for the safe operation and full utilization of the ISS.

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

William H. Gerstenmaier

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