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NASA's Response to Orbital's October 2014 Launch Failure: Impacts on Commercial Resupply of the International Space Station

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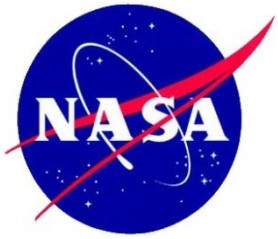

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RESULTS IN BRIEF

NASA's Response to Orbital's October 2014 Launch Failure: Impacts on Commercial Resupply of the International Space Station

September 17, 2015 IG-15-023 (A-15-006-00)

WHY WE PERFORMED THIS REVIEW

On October 28, 2014, the third in a series of NASA-contracted resupply missions to the International Space Station (ISS or Station) by Orbital Sciences Corporation (Orbital) failed during lift-off, causing the vehicle to crash near the launch pad and destroying the company's Antares rocket and Cygnus spacecraft as well as all cargo aboard.[1] The Virginia Commercial Space Flight Authority's (VCSFA) launch pad and supporting facilities at NASA's Wallops Flight Facility (Wallops) on Virginia's Eastern Shore also sustained damage. In the aftermath of the failure, Orbital suspended its cargo resupply missions until completion of an investigation and acceptance by NASA of the company's Return to Flight Plan.

NASA's $1.9 billion Commercial Resupply Services (CRS-1) contract with Orbital required the company to transport 18.6 metric tons of supplies and equipment (upmass) to the Station over eight flights by the end of 2016. Orbital's Return to Flight Plan – approved by NASA in January 2015 – calls for the company to deliver its remaining 13 metric tons to the ISS by flying four rather than the five flights planned under the original schedule. Two of these flights will use another company's rocket, the Atlas V, while the remaining flights will use a revamped model of Orbital's Antares rocket.

We examined NASA's response to Orbital's October 2014 launch failure and its impacts on commercial resupply of the ISS. As part of this review, we assessed the technical and operational risks of Orbital's Return to Flight Plan, NASA's efforts to reduce the financial risk associated with its contract with Orbital, the progress of repairs at Wallops, and the procedure for investigating the cause of the failure.

WHAT WE FOUND

Orbital's Return to Flight Plan contains technical and operational risks and may be difficult to execute as designed and on the timetable proposed. First, although the Atlas V has a strong flight record and is a suitable rocket for Orbital missions, the company will be integrating its Cygnus capsule with the Atlas rocket for the first time. Second, Orbital must accelerate development of its modified Antares launch system, refitting it with new engines for two planned launches in 2016. This tight schedule does not include a test flight for the modified system and provides limited opportunities for qualification and certification testing. Third, although NASA has increased monitoring of Orbital's milestone plan and RD-181 engine testing for the modified Antares, the Agency has not conducted detailed technical assessments of the modified system and the associated qualification testing results. Finally, we believe Orbital's plan to drop one of its scheduled resupply flights may disadvantage NASA by decreasing the Agency's flexibility in choosing the type and size of cargo the company transports to the ISS.

In addition, although NASA will not pay Orbital more than the fixed price of $1.9 billion agreed to for the original eight flights, the Agency did not take advantage of provisions in the contract that could have reduced its costs by up to $84 million. Specifically, when flight schedules slipped such that Orbital was making multiple flights in a year, NASA did not invoke a contract provision allowing for an adjustment to the mission pricing worth as much as $21 million, but

[1] On June 28, 2015, a mission by NASA's other commercial cargo provider, Space Exploration Technologies Corporation, exploded shortly after takeoff. This report does not examine the impact of that loss, which occurred after we had completed our audit work; however, we plan to conduct a similar audit on NASA's response to this loss.

instead received other nonmonetary considerations with an assessed value of only $2 million. Agency officials contend that invoking this provision may have reopened negotiations on pricing and potentially given Orbital the opportunity to press for higher prices, which could have resulted in the Agency ultimately paying more. However, negotiations and modifications to the contract were already underway as a result of the schedule delays, and we believe it would have been in NASA's interest to at least broach the issue with Orbital. Further, when calculating the cost to NASA for the remaining four flights, Orbital did not use the per-kilogram pricing in the original contract and instead divided the price for the cancelled eighth mission by its contractual upmass requirement to arrive at a revised price per-kilogram. By accepting this pricing structure, NASA committed to paying $65 million more for these missions than the Agency would have paid if the original pricing had been used. While Orbital offered NASA some consideration in exchange for the adjustments made in its Return to Flight Plan, we question the value of these services. In addition, NASA recently took actions that will limit its ability to slow milestone payments caused by schedule delays for future cargo resupply missions, effectively increasing the Agency's financial risk for its follow-on commercial resupply contract.

Further, the Space Act Agreement between NASA and VCSFA specified that VCSFA was required to obtain insurance at no cost to NASA to cover claims for liability and damage to NASA property, have insurance for its own property, and waive all claims against the Government for any damage arising under the Agreement. However, although NASA officials stated that VCSFA intended to self-insure for damages resulting from launch operations, it is not clear from correspondence between VCSFA and NASA that this issue was understood or agreed upon by both parties. As a result, $5 million of NASA funds intended for other space operations projects were used to help fund the repairs.

Finally, although Orbital's Accident Investigation Board satisfies the requirements of the company's Federal Aviation Administration license and the CRS-1 contract, the company's investigation lacks the level of independence required of NASA Mishap Investigation Boards.

WHAT WE RECOMMENDED

In order to reduce schedule, performance, and financial risks in NASA's CRS-1 contract and any similar future contracts, we made several recommendations, including that the Associate Administrator for Human Exploration and Operations complete a detailed technical assessment of Orbital's revamped Antares rocket; use available contractual provisions to ensure the best value to the Government when making equitable adjustments due to a contractor's deficiency; ensure mission pricing and payment are continually updated; and continue to incorporate lessons learned during CRS-1 into follow-on contracts and during the evaluation of return to flight plans. Further, in order to protect the United States against claims for damages caused by commercial spaceflight operations, we recommended the NASA General Counsel establish procedures to ensure that insurance policies adhere to agreement requirements and provide adequate financial liability and damage coverage. Finally, to address concerns regarding the independence of accident investigation boards, we recommended the Associate Administrator for Human Exploration and Operations consider whether relevant contract provisions should be revised to more closely align with NASA Mishap Investigation Board procedures.

In response to a draft of our report, the Associate Administrator concurred with six of seven recommendations and described corrective actions the Agency has or will take. Our recommendation about protecting NASA against claims for damages remains unresolved.

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Acronyms

AIB	Accident Investigation Board
ATP	Authorization to Proceed
CRS	Commercial Resupply Services
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulation
ISS	International Space Station
kg	Kilogram
MARS	Mid-Atlantic Regional Spaceport
MIR	Mission Integration Review
OIG	Office of Inspector General
VCSFA	Virginia Commercial Space Flight Authority

INTRODUCTION

On October 28, 2014, Orbital Sciences Corporation (Orbital) launched its third in a series of eight planned cargo resupply missions (Orb-3) to the International Space Station (ISS or Station).[1] However, seconds after liftoff, the vehicle encountered propulsion problems that required initiation of the Flight Termination System, causing the vehicle to crash near the launch pad and destroying Orbital's Antares rocket and Cygnus spacecraft as well as all cargo aboard. The Virginia Commercial Space Flight Authority's (VCSFA) launch pad and supporting facilities at NASA's Wallops Flight Facility (Wallops) on Virginia's Eastern Shore also sustained damage. In the aftermath of the mishap, Orbital suspended its resupply missions until completion of an investigation into the cause of the failure and acceptance by NASA of the company's Return to Flight Plan.

In light of these events and because Orbital is one of only two private companies transporting supplies, we examined NASA's response to Orbital's launch failure and its impacts on commercial resupply of the ISS.[2] As part of this review, we assessed the technical and operational risks of Orbital's Return to Flight Plan, NASA's efforts to reduce the financial risk associated with its contract with Orbital, the progress of repairs at Wallops, and the procedures for investigating the cause of the failure. See Appendix A for details on the scope and methodology.

Background

Between 2006 and 2008, NASA entered into a series of funded Space Act Agreements with Orbital, Space Exploration Technologies Corporation (SpaceX), and other private companies to stimulate development by U.S. corporations of transportation systems capable of providing cargo delivery services to the ISS. In addition to receiving more than $700 million from NASA, Orbital and SpaceX committed their own resources to this effort, ultimately contributing more than 50 percent of the development costs of their respective spaceflight systems.

In 2008, while development efforts were still underway, NASA awarded fixed-price contracts valued at $1.9 billion and $1.6 billion to Orbital and SpaceX, respectively, for a series of cargo resupply missions to the ISS (Commercial Resupply Services [CRS-1] contracts). The contracted services include delivery of supplies and equipment (upmass) to the Station and, depending on the mission, return of equipment and experiments (downmass) to Earth and/or disposal of waste. NASA selected two companies to ensure redundancy if one was unable to perform.[3]

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[1] In February 2015, Orbital merged with Alliant Techsystems, Incorporated. The new company is known as Orbital ATK but for ease of reference we refer to the corporation as Orbital throughout this report.

[2] On June 28, 2015, a mission by NASA's other commercial cargo provider, Space Exploration Technologies Corporation (SpaceX), exploded shortly after takeoff. This report does not examine the impact of that loss, which occurred after we had completed our audit work; however, we plan to conduct a similar audit on NASA's response to this loss.

[3] In addition, NASA barters with the Japan Aerospace Exploration Agency for cargo transportation on its H-II Transfer Vehicle and can place a small amount of upmass on the Russian Space Agency's Soyuz capsule and Progress cargo vehicle. In the past, NASA sent cargo to the ISS on the European Space Agency's Automated Transfer Vehicle, which made its final delivery to the ISS in July 2014.

Key Features of Orbital and SpaceX CRS-1 Contracts

NASA implements the Orbital and SpaceX CRS-1 contracts through a series of task orders and work plans detailing specific objectives for each cargo resupply mission, and identifying the milestones each company must meet to secure payment, criteria by which the Agency determines whether a particular milestone has been achieved, launch dates, and payment allocations for milestone completion. Once NASA and Orbital or SpaceX agree a particular milestone has been accomplished, NASA pays the company a predetermined amount associated with the milestone. The first milestone for both companies is authorization from the NASA Contracting Officer to begin work on the mission, known as "authorization to proceed" (ATP). The final two milestones for both companies are launch and delivery of cargo to the ISS. Reflecting a standard practice in the launch industry, if Orbital or SpaceX fails to deliver their cargo they forfeit the final payment – in this case, 20 percent of the total mission cost for each company.

NASA guaranteed to purchase a minimum of 20 metric tons (approximately 44,000 pounds) of upmass from each company to be delivered in 8 missions for Orbital and 12 missions for SpaceX between 2010 and 2015.[4] Orbital, whose capsule disintegrates upon atmospheric reentry, agreed to provide trash disposal services that match its upmass capability, while SpaceX, whose capsule returns to Earth, agreed to carry at least three metric tons of downmass back to Earth.

The CRS-1 contracts provide two options for pricing resupply missions: (1) using tables that set gradually increasing prices depending on the year of launch and provide a discount when multiple missions are flown in a single year (mission pricing) or (2) by kilogram (mass pricing).[5] With the exception of the companies' demonstration flights for which mass pricing was used, NASA has used mission pricing for both Orbital and SpaceX CRS-1 contracted missions.

In 2009, NASA issued the first in a series of task orders accompanying the CRS-1 contracts to detail the expected upmass and cost of each mission. The original contracts required Orbital to transport 19.3 metric tons over 8 missions and SpaceX 39.7 metric tons over 12 missions.[6] These values were reduced in subsequent discussions between NASA and the companies to 18.6 and 35.4 metric tons for Orbital and SpaceX, respectively, in exchange for the companies providing additional cargo containers and berthing capabilities requested by NASA.

To further ensure redundancy of resupply services to the ISS, NASA modified the Orbital and SpaceX CRS-1 contracts in 2011 and 2012, respectively, to provide for a "launch-on-need" capability. Essentially, this provision requires Orbital and SpaceX to be prepared to fly a resupply mission earlier than scheduled in the event of an interruption in service from another cargo provider. Orbital's launch-on-need provision requires the company to provide a cargo resupply mission within 3 months of

[4] The purpose of the guarantee was to ensure a minimum payment to each company sufficient to create a business case for providing cargo service. The guarantee means that as long as it provides a vehicle capable of carrying the agreed-upon weight for each mission, the company meets its contractual requirements regardless of the amount of cargo NASA actually presents for transport.

[5] The pricing tables contain separate figures for pressurized and unpressurized capsules, standard and enhanced capsules, and returned or disposed downmass.

[6] NASA originally ordered 8 flights from Orbital (1 each in 2011 and 2012, and 2 each in 2013 through 2015) and 12 flights from SpaceX (1 each in 2010 and 2011, 2 in 2012, 3 each in 2013 and 2014, and 2 in 2015).

a request from NASA, while both companies are required to provide a mission no earlier than 2 months after its last resupply flight. To ensure provision of this service, NASA agreed to lengthen the time between ATP and launch for Orbital from 24 to 31 months and advanced SpaceX more than $100 million, which will be credited towards future missions if the launch-on-need capability is not utilized.

The CRS-1 contracts place much of the risk of an unsuccessful mission on NASA. However, this is not unusual for Government contracts relating to space operations given the expense and risks involved in spaceflight and the limited number of capable contractors. Because of the relationship between level of risk and price, shifting more of the risk to the contractor would likely increase contract price. To this end, the CRS-1 contracts do not require Orbital or SpaceX to re-fly failed missions or carry upmass from a failed mission on future flights, nor do they make the companies liable for any cargo destroyed as a result of a launch failure or other anomaly. While Orbital or SpaceX would forfeit the cargo delivery milestone payment (20 percent) as a penalty for a mission failure, NASA is not entitled to recover milestone payments already made for a failed launch and can only recover milestone payments made toward missions not yet flown if it terminates the contract for cause.[7]

Cargo Delivery Capability

Orbital flew a demonstration mission in September 2013 and launched its first resupply mission (Orb-1) on January 9, 2014, which delivered approximately 1,462 kilograms (kg) of cargo to the ISS. Orbital's second resupply mission (Orb-2) launched on July 13, 2014, and delivered approximately 1,664 kg. Orb-3 – the failed mission – carried approximately 2,293 kg of cargo. All three missions launched from VCSFA's launch pad at Wallops, which is the only launch pad currently configured for the Antares rocket. At the time of the Orb-3 failure, the five remaining rockets Orbital planned to use to meet the terms of its CRS-1 contract were in various stages of construction.

As noted previously, on June 28, 2015, a SpaceX resupply mission exploded shortly after liftoff. Prior to this incident, the company had successfully flown a demonstration mission and six resupply missions to the ISS. For the first two resupply missions, the spacecraft did not meet its planned lift capability of 3,310 kg and carried much less cargo than expected – 450 kg and 865 kg, respectively. As compensation for the shortfall, SpaceX agreed to provide additional capabilities in future missions, including the ability to reallocate power between internal and external payloads and waste processing at its rocket-development facility in McGregor, Texas. Since these early flights, SpaceX's capability has increased, with the company transporting more than 2,300 kg of cargo on its fifth resupply mission. The failed mission was carrying 2,393 kg of cargo, including 676 kg of crew supplies, 529 kg of science investigations, 526 kg of docking equipment, 461 kg of vehicle hardware, 166 kg of EVA (extravehicular activity) equipment, and 35 kg of computer resources. Among the lost equipment was one of the adapters needed to dock the commercial spacecraft NASA hopes will begin transporting astronauts to the Station in 2017 and replacement parts for the Station's water purification system.

[7] Under a termination for cause scenario, the Government may terminate all or a portion of a commercial contract if the contractor fails to comply with contract terms or cannot provide the Government with adequate assurances of future performance. We inquired with another Government agency that procures launch services to insert payloads into orbit and were informed that the agency typically structures its contracts similarly to the CRS-1 contracts with a relatively small final payment tied to successful launch and the contractor retaining prior milestone payments in the event of a mishap.

Because of delays by Orbital and SpaceX in developing and testing their spacecraft and as part of the Agency's overall acquisition and flight schedule planning, NASA adjusted both companies' launch schedules and moved some resupply flights. Between September and December 2014, NASA extended SpaceX's CRS-1 contract into 2017 and issued task orders for three additional missions. Similarly, in December 2014 and June 2015, NASA extended Orbital's contract into 2018, first adding one mission (Orb-8E) and then two more (Orb-9E and -10E).[8] As of June 2015, Orbital had successfully completed two cargo resupply missions and received $1.6 billion – including payments for Orb-3, Orb-8E, and Orb-9E – from NASA, while SpaceX had completed six resupply missions and received $1.4 billion.

Orbital's Return to Flight Plan

In December 2014, 2 months after the Orb-3 failure, Orbital publicly announced plans for resuming ISS cargo resupply missions and meeting its obligations under the CRS-1 contract, stating it would "fulfill its commitment to NASA for ISS cargo deliveries with high levels of safety and reliability and minimum disruption to schedules." The company indicated it planned to accomplish the remaining cargo upmass deliveries under the original agreement by the end of 2016 at no additional cost to NASA. Orbital provided NASA a Return to Flight Plan in mid-December, and on January 23, 2015, NASA approved the Plan with minor adjustments and modified its contract with Orbital accordingly.

Orbital plans to meet its obligation to deliver the company's remaining upmass to the ISS by cancelling Orb-8 and flying four flights rather than the five planned under the original cargo resupply schedule (see Figure 1 for the revised resupply schedule).[9] To accomplish this goal, the company will have to carry a heavier payload than originally planned on each of the remaining four flights. For two of these flights, Orbital plans to launch its Cygnus capsule from Cape Canaveral Air Station in Florida aboard Atlas V rockets purchased from the United Launch Alliance, the first of which is scheduled to launch in December 2015.[10] According to Orbital, the Atlas' greater lift capacity will allow the Cygnus capsule to carry nearly 30 percent more cargo than was possible in earlier missions that used Orbital's Antares rocket.

[8] As a result of these additions, contract values increased to over $2 billion for both Orbital and SpaceX.

[9] The remaining upmass excludes the amount lost on the failed Orb-3 flight.

[10] United Launch Alliance is a joint venture between Lockheed Martin Corporation and The Boeing Company that provides launch services to the U.S. Government. Orbital plans to use a revamped Antares rocket for the remainder of its CRS-1 missions. As part of its Return to Flight Plan, Orbital proposed to use an Atlas V launch vehicle for Orb-4 and provided NASA the option of using an additional Atlas V for a second mission. In August 2015, Orbital announced its intent to exercise this option and plans to use an Atlas V for Orb-6 scheduled for launch in March 2016.

Figure 1: ISS Cargo Resupply Mission Schedule, as of September 2015

	2013				2014				2015				2016				2017			
Orbital Cargo Missions (Cygnus)			D[a] Sept		1 Jan		2 July	3[b] Oct				4 Dec	5/6 Mar/ Mar			7 Oct		8E June		9E Oct
SpaceX Cargo Missions (Dragon)	2 Mar					3 Apr	4 Sept		5 Jan	6/7[b] Apr/ June		8 Nov	9/10 Jan/ Feb	11 June	12 Aug		13 Feb	14 Apr	15 Aug	
European Cargo Missions (Automated Transfer Vehicle)		4 June					5 July													
Japanese Cargo Missions (H-II Transfer Vehicle)		4 Aug									5 Aug					6 Nov				
Russian Cargo Missions (Progress)[c]	50 Feb	51 Apr	52 July	53 Nov	54 Feb	55 Apr	56 July	57 Oct	58 Feb	59[b] Apr	60 July	61/62 Oct/ Nov	63 Feb	64 Apr	65 Aug	66 Oct		67 May	68 July	

Source: NASA Office of Inspector General (OIG) analysis of ISS Program information.

Note: This does not reflect SpaceX mission changes due to the June 28, 2015, launch failure. Also, Orb-10E is expected to launch in April 2018, with ATP expected in April 2016.

[a] Demonstration launch.
[b] Red shading indicates a failed mission.
[c] As of September 2015, the Russian Soyuz capsule and Progress cargo vehicle only fly small amounts of U.S. cargo, averaging 59 kg per flight on the past six missions.

Orbital plans to fly its remaining CRS-1 missions using a modified version of the company's Antares rocket – the Antares 230. The original Antares rocket – the Antares 130 – used refurbished Soviet-era engines known as the AJ-26 for its first stage. Before the Orb-3 failure, Orbital was seeking to replace the AJ-26 due to reliability concerns and limited inventory. After the failure, Orbital accelerated this process; however, a lack of American-made engines meeting Orbital's immediate needs necessitated the company look overseas for a replacement. Orbital's preferred choice was the Russian-made RD-180 engine used in the Atlas V system, but because United Launch Alliance has exclusive rights to that engine it was not a viable option. For the Antares 230 configuration, Orbital instead chose another Russian-made engine, the RD-181. In contrast to the Atlas V's RD-180 design, which uses a single engine to direct thrust out of two nozzles, the Antares 230 will use two RD-181 engines positioned next to each other. Although neither Orbital nor NASA has experience with the RD-181, the engine designs, components, and manufacturing processes are similar to those used with the RD-180.

The Cygnus' upmass capability depends on both the capsule's useable volume – the space available to pack the cargo – and the weight the rocket can lift. Orbital planned to use two different cargo capsules over the course of the CRS-1 contract: the "Standard Cygnus" and the "Enhanced Cygnus." The baseline Standard Cygnus has a payload capability of 2,000 kg and the Enhanced Cygnus a payload capability of 2,700 kg. While the Standard Cygnus was used on the demonstration flight and the Orb-1, Orb-2, and Orb-3 missions, the Enhanced Cygnus is expected to be introduced beginning with the Orb-4 mission.[11] Beginning with the Orb-3 mission, Orbital utilized a more efficient cargo packing approach, which increased the Cygnus' volume above the baseline estimate and therefore increased its upmass capability to almost 2,300 kg. Specifically, Orbital increased the number of storage containers in two previously unused areas: a row in the middle of the module and four rows along the sides of the module. Further, after the October failure and as part of its Return to Flight Plan, Orbital added an additional layer of cargo at the front of the Enhanced Cygnus for future missions.

For the Orb-4 and Orb-6 missions, Orbital plans to use the Enhanced Cygnus atop an Atlas V rocket, which can lift up to 3,513 kg. For Orb-5, Orb-7, and the extended missions, Orbital plans to use the Antares 230 configuration. Given the flight profile of the Antares 230 with the RD-181 engines, NASA and Orbital anticipate an increase in useable volume of 18 percent and a payload capability of 3,200 kg. Orbital projects that the first Antares 230 rocket will be ready for launch in March 2016 with a second launch available in October 2016. Table 1 summarizes the key information for the various launch system configurations Orbital has utilized or plans to utilize in the future.

Table 1: Orbital Launch Systems Summary

Launch System	Engine	Pressurized Cargo Module	Volume (m^3)[a]	Maximum Upmass Capability (kg)
Antares 130	AJ-26	Standard Cygnus	18.7	2,000
Antares 230	RD-181	Enhanced Cygnus	26.2	3,200
Atlas V	RD-180	Enhanced Cygnus	26.2	3,513

Source: NASA OIG analysis of commercial cargo program data.

[a] m^3 - cubic meters

Federal Aviation Administration Oversight, Orbital's Accident Investigation Board, and NASA's Independent Review Team

According to Agency policy, NASA is responsible for forming a Mishap Investigation Board to determine the root cause of a failure of any NASA-owned launch vehicle.[12] The policy requires the majority of Mishap Investigation Board members be independent from the investigated activity, the chairperson be independent of the underlying program, no member be involved in the direct management of the

[11] Orb-3 was originally expected to be the first mission to use the Enhanced Cygnus, but a change requested by NASA required use of the Standard Cygnus.

[12] NASA Procedural Requirements 8621.1B, "NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping w/Change 7 (07/15/2013)," May 23, 2006. The objective of a mishap investigation is to improve safety by identifying what happened, where it happened, when it happened, why it happened, and what should be done to prevent recurrence and reduce the number and severity of mishaps.

activity under investigation or have a vested interest in the outcome of the investigation, and no contractor be involved in the investigation. However, because the Antares rocket is owned and operated by Orbital rather than NASA, regulations and procedures that apply to NASA launches do not apply to Orbital's CRS-1 flights. Rather, Orbital received a commercial space launch license from the Federal Aviation Administration (FAA) pursuant to the Commercial Space Launch Act.[13] Among other things, the FAA's licensing procedure assesses the potential risks posed by a commercial launch to public safety, public property, and national security. While Orbital's FAA commercial space launch license required the company to develop and submit to the FAA for approval an Accident Investigation Plan for responding to launch accidents, the FAA did not impose any specific independence requirements for the investigative process.

The CRS-1 contract also addresses accident investigations and provides that Orbital lead the investigation of any accident that occurs after launch but before the spacecraft reaches the joint operations point with the ISS. Consistent with this provision, Orbital's Accident Investigation Plan provides that the company will conduct an investigation of any mishap that damages NASA payloads or Orbital property within the launch facility, provided no third party is involved. Accordingly, Orbital formed a permanent Accident Investigation Board (AIB) chaired and staffed primarily by Orbital employees, along with two NASA members, to provide for FAA oversight of the overall process. According to FAA officials, the AIB must complete its Orb-3 investigation and Orbital must implement any recommendations before the FAA will approve another Antares launch. As of September 2015, the AIB had not released its report; however, Orbital has publicly stated that the liquid oxygen and kerosene turbo pump in one of the Antares engines was the direct cause of the Orb-3 failure.[14]

In addition to Orbital's effort to determine the cause of the failure, in late November 2014, NASA formed an Independent Review Team led by the manager of NASA's White Sands Test Facility.[15] The Review Team is not designed to replace Orbital's AIB, but rather charged with independently examining the causes and physical evidence from the Orb-3 failure to learn from the event. As of September 2015, the Review Team had not completed its investigation.[16]

Orb-3 Cargo

The 2,293 kg of cargo destroyed on Orb-3 included crew supplies (748 kg), science investigations (727 kg), vehicle hardware (637 kg), spacewalk equipment (66 kg), computer resources (37 kg), and 78 kg of packaging. The crew supplies consisted of flight control equipment, food, and flight procedure books. NASA equipment onboard included a specialized camera for spectral analysis of meteors, a food growth chamber, sensor suite and telemetry for reentry break up, an external leak locator, and a Shutter Actuation System that allows ground crew to open and close the Station's Window Observation Research

[13] Recodified at Title 51, U.S. Code Chapter 509, "Commercial Space Launch Activities" (2012).

[14] NASA defines the direct cause, more formally known as the proximate cause, as the events that occurred, including any conditions that existed immediately before the undesired outcome, that directly resulted in its occurrence and, if eliminated or modified, would have prevented the undesired outcome. In contrast, the root cause is one of typically multiple factors that contributed to or created the proximate cause and subsequent undesired outcome and, if eliminated or modified, would have prevented the undesired outcome.

[15] Aerojet Rocketdyne, supplier of the AJ-26 rocket engine, also formed its own separate investigation into the Orb-3 failure.

[16] In August 2015, NASA announced it is performing an independent analysis of the June 2015 SpaceX failure.

Facility shutter without assistance from the crew, thus freeing up crew members for other projects. Orb-3 also carried experiments from NASA and the Center for Advancement of Science in Space, including a human health study to examine blood flow in space, biological and specimen samples for testing in microgravity, and a large number of high school science experiments.[17]

Damage to Launch Facility at Wallops

In 1997, VCSFA entered into a reimbursable Space Act Agreement with NASA for the use of land and facilities on Wallops to develop and operate a commercial spaceport.[18] This agreement led to establishment of the Mid-Atlantic Regional Spaceport (MARS), which features two launch facilities on the southern section of Wallops. In 2008, Orbital chose MARS as the launch site for its ISS resupply missions.

The Orb-3 failure damaged a VCSFA-owned launch pad and several surrounding structures (see Figure 2). A construction contractor retained by VCSFA estimated hazardous material removal, environmental cleanup, and repairs to the launch pad and surrounding facilities would cost approximately $15.2 million and take until October 2015 to complete. In addition, NASA property on site – mostly small buildings – sustained an estimated $1 million in damage. NASA, VCSFA, and Orbital have each committed funds to repair the launch facilities. Orbital's FAA launch license required the company to have insurance to cover damage to Government property and third-party injury and property damage. Therefore, Orbital's insurance is covering the estimated $1 million in damage to NASA property and NASA has provided supplementary funding to help VCSFA with repairs.

[17] The Center for Advancement of Science in Space is a nonprofit organization working under a cooperative agreement with NASA to manage non-NASA research on the ISS. The Center reported it spent $174,800 on experiments lost in the Orb-3 failure.

[18] In 1995, the Virginia General Assembly created VCSFA to promote commercial space activity, economic development, and aerospace research in the state of Virginia. Funding for VCSFA operations, personnel, site maintenance, and infrastructure is provided by Virginia's Transportation Trust Fund.

Figure 2: Damage to VCSFA Launch Complex at Wallops

Source: NASA/Terry Zaperach.

As of September 2015, MARS reported to NASA that repairs to the launch pad and its supporting systems would be substantially complete by September 30, 2015, with performance testing of the facilities continuing through October. In addition to repairs required as a result of the Orb-3 failure, previously planned upgrades to the pad's hydraulic system are being made, along with other modifications necessary to accommodate the Antares 230 configuration. The MARS pad repair and upgrade schedule currently provides a 3-month margin for the planned February 1, 2016, testing of the Antares 230 first stage.

No Immediate Safety Issues for Astronauts Onboard the ISS

According to Agency officials, despite three failed cargo resupply missions over 8 months, the ISS crew is in no immediate danger of running out of food or water.[19] Current projections indicate that even without further resupply, food supplies on Station will be sufficient until January 17, 2016, and water supplies until June 1, 2016. NASA planned for the possibility of an interruption in cargo delivery service to the ISS in a variety of ways, including contracting with and negotiating the launch-on-need capability with Orbital and SpaceX, making agreements with international partners to carry cargo, and maintaining a 6-month reserve supply of food on Station.[20]

[19] In addition to Orbital's October 2014 failure and SpaceX's June 2015 failure, a Russian Progress cargo mission also failed to reach the ISS in April 2015.

[20] Without replenishment, the 6-month reserve supply will be depleted by the middle of January 2016. Accordingly, it is important that the remaining resupply flights occur on or close to the current flight schedule to maintain a six-person crew.

Prior to the Orb-3 failure, SpaceX had five missions scheduled for 2015. After the failure, NASA made minor adjustments in SpaceX's schedule to compress the time between missions 7, 8, and 9; reshuffled its cargo delivery manifests; and flew some replacement items on SpaceX's January and April 2015 missions, including food and crew provisions, waste and hygiene supplies, experiments, systems hardware, equipment for conducting space walks, and computer resources.

The failure of SpaceX's June 2015 mission leaves NASA with even fewer options for transporting cargo to and from the Station. With the exception of Japan's mission, which successfully delivered more than 4.5 tons of cargo to the ISS in August 2015, NASA will have to rely on the Russian Progress until Orbital and SpaceX return to flight. However, U.S. cargo on Russian rockets has averaged only 59 kg per flight on the past six missions.[21]

[21] The Russian Soyuz capsule and Progress cargo vehicle only fly small amounts of U.S. cargo.

ORBITAL FACES RISKS EXECUTING ITS PLAN TO RESUME RESUPPLY MISSIONS

We found that Orbital's Return to Flight Plan contains technical and operational risks and may be difficult to execute as designed and on the timetable proposed. First, although the Atlas V has a strong flight record and is a suitable rocket for Orbital's next ISS cargo delivery, the company will be integrating its Cygnus capsule with the Atlas rocket for the first time. Second, Orbital must accelerate development of the modified Antares launch system, refitting it with new engines for two planned launches in 2016. This tight schedule does not include a test flight for the modified system and provides limited opportunities for qualification and certification testing.[22] Third, although NASA has increased monitoring of Orbital's milestone plan and RD-181 engine testing for the modified Antares, the Agency has not conducted detailed independent technical assessments of the modified system and the associated qualification testing results. Finally, we believe Orbital's proposal – agreed to by NASA – to drop one of its five planned resupply flights and carry the promised cargo in four missions may disadvantage NASA by decreasing the Agency's flexibility in choosing the type and size of cargo that Orbital transports to the ISS.

Orbital's Aggressive Schedule Limits Testing and Evaluation

Orbital's Return to Flight Plan envisions flying the Cygnus capsule on two Atlas V rockets and two modified Antares rockets before the end of 2016. To meet this ambitious schedule, Orbital and NASA face multiple challenges, including flying Cygnus for the first time on an Atlas V rocket and integrating new engines into the Antares 230 rocket. Despite these challenges and even though as of June 2015 NASA had paid Orbital $1.6 billion on the CRS-1 contract, the Agency has not fully utilized provisions in the CRS-1 contract that would allow it to increase monitoring and oversight through a detailed independent technical assessment of the company's efforts to fulfill its contract obligations.

Using Atlas V for Next ISS Cargo Deliveries Reduces Some Risk

For the Orb-4 mission planned for December 2015 and the Orb-6 mission planned for March 2016, Orbital plans to launch the Cygnus capsule on an Atlas V rocket. Given the time needed to ready the Antares for a return to flight, using the Atlas V with its long history of reliability is a credible solution. However, although NASA officials view the Cygnus/Atlas V combination as low-risk, the Orb-4 mission will nevertheless be the first to use this combination and Orbital will be integrating the two systems relatively quickly.

[22] In NASA development programs, qualification testing is time intensive and conducted on all elements, components, and subsystems to verify performance of the flight hardware. A certification plan is used to conduct integrated tests of the system to ensure it performs together as designed.

Integration and Schedule Challenges with Modified Antares Rocket

Orbital plans to integrate the RD-181 engines with the Antares 230 by modifying the rocket's first stage and launch software. However, with the first flight of the new rocket scheduled approximately 8 months after the RD-181 engines arrive in the United States from Russia, Orbital has set an aggressive launch schedule that allows limited time for testing and evaluation of the fully-integrated Antares configuration. Although it is based on related technologies, the RD-181 is not identical to the RD-180 engine used on the Atlas V. The NASA Launch Services Program Chief Engineer cautioned against assuming similarity between the two engines as each combination of vehicle and engine creates unique interface characteristics.[23] However, NASA is not requiring a test flight or conducting an independent assessment of Orbital's qualification test plan.

In past audits of spaceflight programs, we have found project managers are often overly optimistic about the effort required to modify heritage technologies – in this case, incorporating the RD-181 engines into Antares – and underestimate the time needed to address known and unknown risks by assuming that most risks will not materialize. For example, in a 2012 audit, we found that the Kepler and Mars Science Laboratory projects experienced time-consuming and expensive integration challenges when NASA attempted to adapt previously flown technologies to new requirements.[24] More recently, the Government Accountability Office found that NASA could experience schedule pressure while attempting to integrate heritage hardware – such as the Space Shuttle main engines or Constellation solid rocket boosters – into the Space Launch System.[25]

Prior to using the RD-181 engine, Orbital must modify the Antares first stage structure, steering mechanisms, fuel tanks and lines, and flight control software to accommodate the new engine. The extent of these modifications, coupled with Orbital's aggressive launch schedule, will limit the time available to conduct qualification testing of the new engines and other components. Notably, with the first two RD-181 engines having been delivered to the United States in July 2015, Orbital plans two types of stage tests at Wallops – cold-flow and hot-fire – but does not plan to conduct a full "Test-Like-You-Fly" launch profile hot-fire test or a demonstration flight before the planned Orb-5 launch in March 2016.[26] Further, Orbital will have limited time to update and test launch control software for the new engine specifications if it plans to meet a March 2016 launch date.

In 2012, NASA conducted a detailed technical assessment of the AJ-26 engine Orbital used in its original Antares 130 configuration and identified the risk that the engine had not been rigorously tested in Test-Like-You-Fly conditions. Specifically, NASA determined the configuration and operation of the AJ-26 engine was substantially different from the NK-33 engine on which it was based. In addition,

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[23] NASA's Launch Services Program provides engineering, procurement, and launch support for the Agency's rocket launch needs. As part of its services, the Launch Service Program is capable of assessing qualification test plans to examine all components of the launch vehicle, including the engines and pumps, to determine what testing should occur to mitigate identified risks.

[24] NASA OIG, "NASA's Challenges To Meeting Cost, Schedule, and Performance Goals" (IG-12-021, September 27, 2012).

[25] Government Accountability Office, "Space Launch System: Resources Need to be Matched to Requirements to Decrease Risk and Support Long Term Affordability" (GAO-14-631, July 23, 2014).

[26] Cold-flow testing pushes propellant through the tanks and engine to test tank pressurization, adequate chilling, and safe offloading of propellants. A hot-fire test ignites the engine for a brief period at launch thrust levels without the launch vehicle leaving the ground. Test-Like-You-Fly tests the engines for the duration of the full launch profile.

limited test data was available at the thrust level used in the AJ-26 engines, and combining two of the AJ-26s into the Antares 130 first stage further increased the need for a Test-Like-You-Fly approach. Ultimately, after consulting with Orbital, NASA accepted the heightened risks associated with the engines and proceeded with Orbital's flight plan.[27]

Moving forward, Orbital must address return to flight schedule pressures that may limit testing of the Antares first stage and the lack of detailed information on the RD-181 engines that could complicate integration. Any significant delays will require NASA to investigate other cargo resupply options, including relying more heavily on the Agency's international partners for resupply. Even if Orbital is able to launch the Antares 230 as planned in March 2016, the flight will carry a greater risk profile given the limited testing of the new configuration. NASA officials said they factored this in during their Return to Flight negotiations with Orbital and plan to limit the flight to carry only nonessential payloads to the ISS.

In Light of Increased Risk NASA Should Increase Technical Assessments

Under the CRS-1 contract, NASA has the authority to offer insight, require approvals, and conduct technical assessments of the contractor's flight systems, including a technical evaluation of the Antares 230 qualification testing. According to Agency officials, since the failure NASA has monitored the company's RD-181 testing and participated in Orbital's June 2015 Critical Design Review of the Antares 230 system, which identified no major issues.[28] NASA officials also said they reviewed Orbital's Antares 230 qualification test plan and related documents and initially withheld 8 percent of the associated milestone payment until they determined the plan was complete. On May 27, 2015, Orbital published updated versions of the test plan documents, but as of September 2015, NASA has not conducted a detailed technical assessment of the qualification test plan or the results of the testing performed.

Despite the higher risk tolerance NASA accepts in its CRS contract, we question whether the Agency should be doing more to monitor Orbital's return to flight efforts. Because many of the contract milestones Orbital met for missions Orb-4 through Orb-8 were accomplished using the AJ-26 engine rather than the RD-181 engine, they have not been evaluated for risks associated with integrating the RD-181 engine and its components. Further, even though NASA has insight into Orbital's testing activities to meet future milestones, we believe the Agency faces increased risk by not conducting a detailed and independent technical assessment of the Antares 230 qualification testing.

[27] Over the past 4 years, AJ-26 engines experienced two significant failures on U.S. test stands, both resulting in fires stemming from structural failures of the engine. The first failure in 2011 resulted from a cracked intake fuel pipe caused by corrosion. After inspection of other AJ-26 engines revealed similar corrosion cracks, Orbital and its engine subcontractor Aerojet Rocketdyne took corrective steps by welding the weakened metals. Similarly, a liquid oxygen turbo pump failed in a May 2014 test of an AJ-26 engine planned for use in the Orb-4 launch.

[28] Critical Design Review is a process that determines whether a system is sufficiently mature to proceed with fabrication, assembly, integration, and testing.

Orbital's Return to Flight Plan Reduces Flexibility for ISS Resupply

Although Orbital claims it can transport its remaining 13 metric tons of upmass before the end of 2016 in four rather than five missions, the loss of one flight provides NASA with less flexibility in choosing the type and size of cargo the company can carry – choices that may ultimately result in a reduction in the amount of supplies and research-related materials Orbital delivers to the ISS. The ISS Program projected the Station's upmass demand would exceed transportation capability by more than 3.6 metric tons in fiscal year 2015, much of which can be attributed to Orbital not planning to fly its next mission until December 2015. This shortfall comes at a critical time as NASA seeks to maintain food and water reserves, replenish spare parts, complete installation of the docking adapter, and fully utilize the ISS research laboratories.

ISS Program officials told us that in their view Orbital's plan to fly one fewer flight benefits the Agency because the astronauts will not be required to plan and execute logistics for that flight – a time-consuming activity. In addition, they contend that the steps the company has taken to increase the cargo capacity of its capsule together with the improved lift of the Atlas V and Antares 230 rockets will provide NASA with essentially the same cargo capacity as the original five flights. However, even if this is true, in our view providing the equivalent weight and volumetric capability does not fully account for the flexibility a fifth flight would have provided, particularly given NASA's decision to fly only nonessential payloads on the system's first return flight.

Although, as discussed previously, Orbital has added cargo containers in multiple locations in the Enhanced Cygnus, most of these containers are smaller than the containers in the original storage areas. Accordingly, NASA will have access to fewer large containers than it would have under the original five-flight plan, which affects the type of goods that can be transported to the ISS. We acknowledge that Orbital's new packing strategy and the utilization of two Atlas V rockets will increase the volume available in the remaining missions. However, in our judgment, the cancellation of Orb-8 results in decreased flexibility in the type and size of cargo that can be transported and, therefore may disadvantage NASA. Our concerns are compounded by the fact that with the exception of Orb-3, both Orbital and SpaceX resupply missions have generally not carried the maximum required upmass due to volumetric or performance constraints.

NASA Missed Opportunities to Save Money on Orbital's Cargo Resupply Services Both Before and After the October Mishap

Although under the revised contract NASA will not pay Orbital more than the fixed price of $1.9 billion agreed to for the original eight flights under the CRS-1 contract, the Agency did not take advantage of provisions in the contract that could have reduced its costs by up to $84 million.[29] Specifically, when flight schedules slipped such that Orbital was making multiple flights a year, NASA did not invoke a contract provision allowing for an adjustment to the mission pricing worth as much as $21 million, but instead received other nonmonetary considerations with an assessed value of only $2 million. Agency officials contend that invoking this provision may have reopened negotiations on pricing and potentially given Orbital the opportunity to press for higher prices, which could have resulted in the Agency ultimately paying more. However, negotiations and modifications to the contract were already underway as a result of the schedule delays, and we believe it would have been in NASA's interest to at least broach the issue with Orbital. Further, when calculating the cost to NASA for the remaining four flights Orbital did not use the per-kilogram pricing in the original contract. By accepting Orbital's proposed pricing structure, NASA committed to paying $65 million more for these missions than the Agency would have paid if the original pricing had been used. While Orbital offered NASA some consideration in exchange for the adjustments made in its Return to Flight Plan, we question the value of these services. Moreover, NASA recently took actions that will limit its ability to slow milestone payments caused by schedule delays for future cargo resupply missions, effectively increasing the Agency's financial risk for the follow-on CRS-2 contract.[30]

NASA Did Not Seek Price Reductions for Delayed Orbital Cargo Launches

We found that NASA could have pressed Orbital for discounts in the price it paid for the Orb-1 and Orb-2 missions when schedule delays caused by the company pushed both those flights into 2014. In the event of a launch delay beyond 30 days – regardless of cause – the CRS-1 contract instructs the NASA Contracting Officer to request information from the company about the effect of the delay on price, schedule, or other contract terms relating to the affected mission. The contract further provides that this exchange between NASA and the company "may result in an equitable adjustment to the price of all affected CLINs [contract line item numbers] in the task order (if any), change in the delivery schedule,

[29] Detailed calculations supporting the $84 million figure were provided to Program officials but have been removed from our final report since detailed mission pricing information and contract cost tables are considered proprietary or procurement sensitive.

[30] CRS-2 is the follow-on contract to CRS-1. This new cargo resupply contract is expected to be awarded in November 2015, and the contractor(s) will perform cargo resupply missions beginning as early as 2018 and continuing through 2024.

and change in the period of performance."[31] If NASA and Orbital fail to agree to an adjustment, the Contracting Officer may unilaterally adjust the task order. Moreover, according to the contract "nothing in this clause shall excuse the Contractor from proceeding with the contract as extended." Table 2 reflects delays in Orbital's cargo resupply mission flight schedule from the launch plan originally negotiated in 2009 to the launch plan in place immediately prior to the Orb-3 failure.[32] These slippages were mainly caused by almost 3 years of developmental delays of Orbital's launch system.

Table 2: Original 2009 Negotiated Launch Plan Compared to Launch Plan as of August 2014

Mission	Calendar Year					
	2011	2012	2013	2014	2015	2016
Original 2009 Schedule	1	1	2	2	2	--
August 2014 Schedule	0	0	0	3	2	3

Source: NASA OIG analysis of ISS Program information.

Task Order 1 of Orbital's CRS-1 contract details the number of missions per year and the price per mission. Prices rise for flights in later years and a discount is offered for multiple flights in one year.[33] Program officials told us that NASA protected its financial interests in the event of launch delays caused by Orbital by locking in the lower rates applicable to the original year a flight was scheduled rather than paying the higher rates applicable to the actual launch year. For example, even though Orb-1 and Orb-2 were both launched in 2014 instead of 2011 and 2012, respectively, as originally planned, NASA paid Orbital at the negotiated rate for the earlier years. However, we found that had NASA agreed to pay for Orb-1 and Orb-2 at the 2014 rate with the multiple flight discount factored in, the price for these flights would have been $21 million less than the 2011 and 2012 rates – funds that we believe could have been put to better use.[34] Although we realize Orbital may not have agreed to the full discount, we are concerned NASA did not negotiate with the company for a reduced price given the extensive launch delays.[35]

Agency officials contend that doing as we suggest could have reopened contract-pricing negotiations, thereby giving Orbital the opportunity to press for higher prices, which could ultimately have resulted in NASA paying more. Specifically, officials were concerned that adjusting the prices for the first two missions would have led Orbital to request upward adjustments for the remainder of the original eight missions. They explained that in lieu of price adjustments, NASA received other considerations, including modifications to components of the spacecraft, analyses and tests on cabin fans, and accommodation of late changes to cargo manifests. However, ISS procurement officials' assessed the

[31] Contract line item numbers specify prices and delivery schedules or performance periods for individual contract deliverables.

[32] Because schedule slips occur, NASA continuously updates launch plans.

[33] Program officials assert that a discount is offered only when initially ordering multiple flights in the same year to capitalize on economies of scale. However, per the contract provision cited above, we believe once these missions slipped multiple times NASA had the option to negotiate for a better price using the multiple flight discount as a benchmark.

[34] While NASA could have saved money by adjusting Orbital mission prices to reflect the year in which the launch actually occurred, the opposite is true for SpaceX. The Agency benefitted by holding SpaceX to the mission costs for the year in which the missions were originally planned since mission pricing tables are different for each company according to their individual contracts with NASA.

[35] For this analysis, we did not apply the multi-mission discount to Orb-3, which also occurred in 2014, because it was credited to Orbital as an enhanced mission due to requirements changes from NASA.

value of these items at approximately $2 million, significantly less than the $21 million difference in the rates. Moreover, even if Orbital had pressed for higher prices, nothing in the contract required NASA to accept the company's proposal. Accordingly – with potentially $19 million at stake – we remain concerned that NASA did not invoke available contract provisions to obtain either a price adjustment or, at a minimum, additional nonmonetary consideration.

NASA Agreed to Higher Per-Kilogram Pricing than Outlined in Original Contract for Remaining Orbital Flights

In its Return to Flight Plan, Orbital cancelled Orb-8 and allocated that flight's cargo upmass requirement of 2,621 kg across the remaining four scheduled flights to satisfy its overall upmass obligation to NASA. To price the four flights, Orbital proposed and NASA agreed to allocate Orb-8's contractual value across the flights on a per-kilogram basis.[36] Accordingly, Orbital divided Orb-8's mission price by its contractual upmass requirement to arrive at a revised price per-kilogram. We found that Orbital's recalculated price per-kilogram was higher than the kilogram pricing in the original CRS-1 contract. As an alternative to accepting Orbital's recalculation of the cost for delivering additional cargo on Orb-4 through Orb-7, NASA could have negotiated with Orbital and pressed them to adhere to the kilogram pricing tables in the original CRS-1 contract. We calculated that doing this could have saved NASA up to $65 million – funds that we believe could have been put to better use.

NASA Program officials noted they did not press Orbital to adhere to the contract's original kilogram pricing structure because per-kilogram pricing was only used for the demonstration mission, while all commercial resupply missions used mission pricing. However, because additional kilograms were being added in a manner similar to the demonstration mission, we believe it would have been reasonable for NASA to invoke the per-kilogram pricing in the original contract when negotiating with Orbital regarding its proposed Return to Flight Plan.

Questionable Value of Orbital's Considerations

As part of its proposed Return to Flight Plan, Orbital offered NASA several items and services that were not part of the original contract. Specifically, NASA received 600 kg of cargo, extended berthing of the Cygnus at the ISS from 30 to 60 days, Orbital's agreement to utilize new systems and databases, and incorporation of design changes for future missions, including updating attitude rates and radiated emissions requirements at no additional cost. We question whether the value of these services is sufficient to compensate the Agency for the lost flexibility or align with the financial concessions to which NASA may have been entitled.

[36] Adding Orb-8E, Orb-9E, and Orb-10E and extending the contract's performance period into 2018 were not considered in Orbital's Return to Flight Plan.

Cargo Credit

Orbital offered to give NASA 600 kg of cargo credit – that is, upmass for which the Agency will not pay. Of this amount, 200 kg is credited toward the Orb-8E mission and the remaining 400 kg toward cargo that Orbital carried on its demonstration flight in September 2013.

In order for Orbital to meet its overall contractual upmass requirements, NASA and Orbital agreed to shift some of the requirements from the eight CRS-1 missions to the demonstration flight and, accordingly, Orbital did not bill NASA for the additional 400 kg delivered to the ISS during that flight.[37] As part of Orbital's Return to Flight Plan, NASA is now formally relieved of this obligation. However, since the demonstration upmass was to count toward Orbital's total contractual upmass requirement, we question whether this is something NASA would have been required to pay. Moreover, we found that NASA agreed to assign a price for the credit that was $11 million higher than it should have been had NASA used the original demonstration mission pricing values.

Extended ISS Berthing

Orbital offered to extend berthing of the Cygnus at the ISS from 30 to 60 days for four of the remaining Antares missions – Orb-5 through Orb-8E – which would enable greater flexibility in loading and offloading ISS supplies and trash disposal. However, NASA's most recent integrated launch schedule shows that Cygnus is to remain berthed 49 days or less for these missions, with one of the four missions currently planned to remain on Station for 21 days. Consequently, NASA is only taking partial advantage of this concession.[38]

Additional Capabilities

As part of the Return to Flight negotiations, Orbital offered to use new systems and databases, such as NASA's new ISS Hazard System, to support the ISS Program's Safety Review Panel processes.[39] The company also agreed to process exceptions to requirements using a new system (as opposed to using a paper process that involves e-mail exchanges) and to implement seven requirements changes such as updates to attitude rates, radiated emission requirements, and cleanliness.[40] These were changes NASA

[37] For the demonstration mission, Orbital was paid to deliver 300 kg to the Station with an option for NASA to add up to an additional 500 kg, which would be credited against the company's total upmass requirement under the CRS-1 contract. NASA exercised this option and asked Orbital to deliver an additional 388 kg during the demonstration flight for a mission total of 688 kg.

[38] NASA officials asserted that regardless of whether the Agency uses this capability, having this flexibility is a significant benefit to the Program. Officials also stated that berth time is constantly being reassessed and changed.

[39] The ISS Program safety team has changed their processes to include using a new ISS Hazard System as part of the standard process for executing the extensive three-phase Safety Review Panel Process. This new system is a significant change for how the entire process is executed, from how deliveries are made to how hazard reports are reviewed and approved to how meeting requests are generated.

[40] These changes refer to the interface and performance requirements for cargo transportation services to the ISS, including ground systems supporting vehicle flights to the ISS, and design requirements on the vehicle to ensure safe integration with the ISS.

did not formally request, but nonetheless accepted. NASA procurement officials we spoke with were uncertain whether the Agency would have issued a contract modification for these capabilities if Orbital had not offered them as part of the overall package in its Return to Flight Plan. In addition, two of the seven total changes have been waived or deferred to a future contract modification.[41] Accordingly, Orbital has no current obligation to provide these services.

Advanced Funding Continues Under Orbital's Return to Flight Plan

In addition to not taking advantage of contract provisions that could have saved the Agency money, NASA continues to take financial risks by paying Orbital for missions far in advance of actual flight.[42] This is largely the result of Orbital structuring its Return to Flight Plan so that Orb-8 – the most expensive planned mission on a price-per-kilogram basis – is cancelled and its costs distributed over the remaining four flights. Consequently, NASA paid Orbital over $50 million after receiving credit for milestone payments already made on Orb-8 (40 percent of total mission costs) and after calculating the additional payments needed for milestones already completed on Orb-4 through Orb-7.[43]

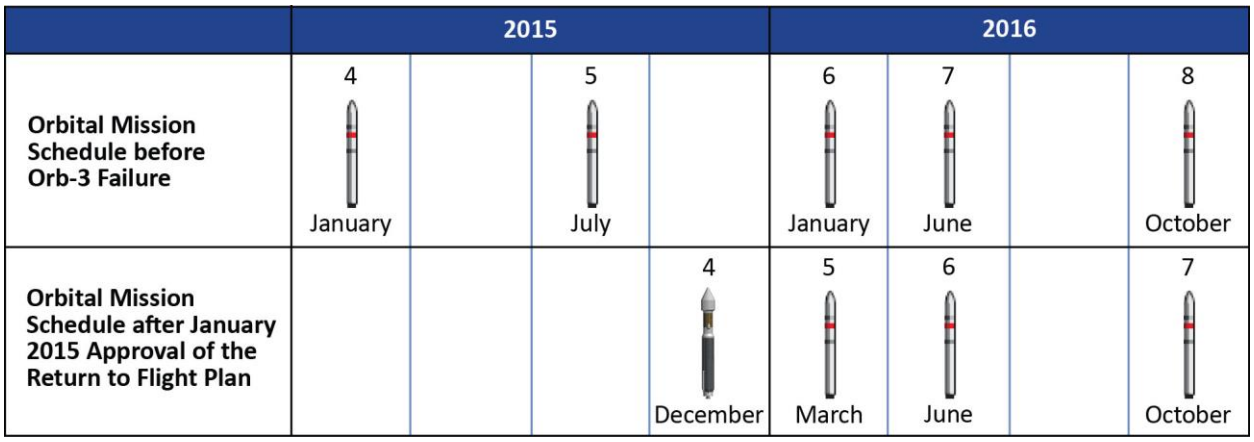
Had NASA insisted that the next mission on the schedule – Orb-4 – be cancelled and the cost of that mission distributed across the remaining flights, the Agency would have had a credit instead of a balance due. Figure 3 shows that Orb-4 was originally scheduled for launch in January 2015 and in the aftermath of the mission failure, the remaining missions were expected to launch in almost the same timeframe as reflected in the August 2014 updated schedule (the most up-to-date launch schedule prior to the Orb-3 failure).

[41] NASA officials clarified that they will continue to receive updates for one of these changes, but if the updates require design changes to the Cygnus, those design changes (and cost) will be addressed under a separate modification.

[42] In a June 2013 report (Commercial Cargo: NASA's Management of Commercial Orbital Transportation Services and ISS Commercial Resupply Contracts [IG-13-016, June 13, 2013]), we noted that despite almost 3 years of delays in the development of transportation services, corresponding shifts in the milestone payments tied to the delayed launch dates were not made for Orbital's eight missions. NASA was slow to adjust its payment plan to reflect the delays and from our perspective paid Orbital too far in advance of when services were actually needed, thereby increasing financial risk to both NASA and Orbital. We also found that these payments – for up to six rockets at that time – were made before Orbital completed a test flight and demonstration of its rocket. As a result of our report, NASA agreed to ensure CRS contracts were updated to reflect the lead times required to meet revised launch dates.

[43] NASA Program officials told us that a portion of the payment originally planned for June was not paid until August 2015 since the Orb-4 mission date slipped from October to December 2015.

Figure 3: Orbital's Mission Schedule Before the Orb-3 Failure and After NASA's Approval of Orbital's Return to Flight Plan in January 2015



Source: NASA OIG analysis of ISS Program information.

At the time the Return to Flight Plan was approved, NASA had already paid Orbital 70 percent of the total mission costs for Orb-4. If that mission had been cancelled, the associated funding would have been a credit applied toward milestones already completed for Orb-5 through Orb-8. Under this scenario, NASA would not have owed any payments to Orbital in June 2015, but instead would have had a credit balance of approximately $30 million to apply to future mission milestones.

Although the total cost of all the missions is the same in both scenarios, NASA could have taken steps to pay Orbital when the company was closer to demonstrating its ability to return Antares to flight instead of paying significantly more upfront for a revamped launch system that has yet to fly. If NASA is agreeing to cancel a mission and reallocate the funds to pay for additional upmass capability on remaining missions, it would have been in the Agency's best interests to cancel Orb-4 to avoid additional advanced payments to Orbital, which has received almost $1.6 billion of the more than $2 billion contract value after flying only 2 successful missions of the 10 currently planned.

NASA is Reducing Financial Safeguards Associated with Milestone Payments

We found that NASA has agreed to changes in the Orbital contract that will limit the Agency's ability to slow future milestone payments in response to schedule delays, effectively increasing NASA's financial risk. The original terms of the CRS-1 contract called for milestone payments to be tied to a mission's launch date. Therefore, when delays occurred, milestone payments would correspondingly be delayed; however, in 2012, NASA and Orbital agreed to modify the contract and instead tie select milestones to ATP to support the launch-on-need capability. Through the life of the contract, Orbital has averaged 54 months from ATP to launch. Based on the planned launch dates in Orbital's Return to Flight Plan and work plans for the extended missions, the time from ATP to launch will average 38 months.

Placing a percentage cap on the amount eligible for payment up to and including the Mission Integration Review (MIR) at 50 percent of the total cost of the mission is another contractual mechanism in the CRS-1 contract that helped control the timing of payment disbursements.[44] If the contractor cannot satisfy the criteria of the MIR, additional milestone payments are deferred and the 50 percent cap is enforced until the MIR is complete. The Request for Proposals for CRS-2 officially increases the MIR hold to 60 percent of the total cost of the mission, further shifting the financial risk for a delayed or failed mission to NASA if the contractor cannot perform as expected. NASA officials told us that although the MIR increase results in more funds paid prior to successful completion of the mission milestone, increasing the cap from 50 percent to 60 percent offers advantages for both the contractor and Agency. For the contractor, it provides relief from financial pressures created by payments withheld for work already performed and costs already incurred.

NASA officials said these benefits are achieved with no additional cost risk to the Agency since the milestone payments will not be made until the Contracting Officer Representative has certified that the work required for that milestone has been completed. However, since Program officials have historically been slow to adjust payment schedules in light of launch schedule delays, and because more milestones are now tied to ATP rather than launch date, we remain concerned about this increase in advanced funding.

[44] The MIR provides NASA with a current mission integration status. NASA utilizes the information presented at this review to determine if the planned delivery date is achievable and if integration efforts should continue.

NASA NOT LIABLE BUT NONETHELESS HELPING PAY FOR REPAIRS AT WALLOPS

The Space Act Agreement between NASA and VCSFA required VCSFA to waive all claims against the Federal Government for any damage arising under the Agreement and to obtain insurance to cover damages to VCSFA property. However, although NASA officials stated that VCSFA intended to self-insure for damages resulting from launch operations, it is not clear from correspondence between VCSFA and NASA that this issue was understood or agreed upon by both parties. As a result, $5 million of NASA funds intended for other space operations projects were used to fund repairs to VCSFA property.

Insurance Requirements for Orbital and VCSFA

Orbital was required by the FAA to obtain a launch license and insurance to cover Government property and third-party injury and property damage.[45] Moreover, to obtain the license, Orbital was required to sign a cross waiver with VCSFA stating that each party bore the risk of any damage to their own property during the launch and could not sue the other for losses or insure the other's property. NASA officials stated Orbital will pay roughly $1 million for the damage to Agency property caused by the Orb-3 failure.

VCSFA obtained an FAA launch site operator license, but the license did not compel VCSFA to obtain insurance for its own property or to cover third-party liability. However, the 1997 Space Act Agreement between NASA and VCSFA specified that VCSFA was required to obtain insurance at no cost to NASA to cover claims for liability and damage to NASA property, have insurance for its own property, and waive all claims against the Government for any damage arising under the Agreement. VCSFA was to deliver proof of insurance to the Chief Counsel at Goddard Space Flight Center, after which NASA would determine if the policy was acceptable prior to the commencement of Agreement activities.[46] Although VCSFA obtained a commercial aviation general liability insurance policy, the Goddard Chief Counsel raised concerns about the type of damages covered under that VCSFA policy. VCSFA informed the Chief Counsel that it intended to "self-insure" against damage. We reviewed the policy in effect at the time of the Orbital mishap and found that while it covers damage from aircraft and aviation operations, it explicitly excludes spacecraft and launch vehicles.

[45] Title 14, Code of Federal Regulations, Chapter III, Subchapter C, Part 413.3 (a) (1)-(4) states a person must obtain a license from the FAA to (1) launch a launch vehicle from the United States, (2) operate a launch site within the United States, (3) reenter a reentry vehicle in the United States, or (4) operate a reentry site within the United States.

[46] These requirements remain in effect.

Disagreement with VCSFA Regarding Funding Repairs at Wallops

Despite the provisions in its Space Act Agreement regarding insurance and liability, VCSFA asked NASA to pay for repairs to the VCSFA launch facility damaged in the Orb-3 failure. On November 11, 2014 – 2 weeks after the launch failure – four Virginia congressmen wrote the Chairman of the House Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies requesting $20 million for repair work at Wallops. The following month, Congress passed the Consolidated and Further Continuing Appropriations Act, 2015.[47] The explanatory statement that accompanied the Act directed NASA to reallocate $20 million from the Agency's budget request toward its 21st Century Space Launch Complex Program – a line item that encompasses Wallops.[48]

Despite this congressional direction, disagreements remained over who should pay for the launch pad repairs. In February 2015, the NASA Associate Administrator for Human Exploration and Operations initiated an exchange of correspondence with the VCSFA Executive Director citing the Space Act Agreement insurance requirements. VCSFA responded it had satisfied NASA insurance requirements and claimed the need to insure launch pads was not communicated by the Agency. The Associate Administrator has since expressed his commitment to the relationship with VCSFA, but continued to articulate concern with VCSFA's understanding of the legal responsibilities among NASA, Orbital, and VCSFA with respect to repairing the launch pad.

To satisfy the intent of Congress and avoid delays, on March 13, 2015, NASA issued a notice of intent to noncompetitively increase the value of its existing contract with VCSFA by $5 million.[49] According to NASA officials, the funding will come from other programs within the Space Operations budget, which includes the ISS and the Space Communications and Navigation Program.[50] VCSFA officials reported that as of September 2015, repairs to the launch pad and its supporting systems would be substantially complete by September 30, 2015, with performance testing of the facilities continuing through October.

In light of the Wallops experience, we are concerned regarding future enforcement of liability and insurance provisions for commercial cargo and crew programs. In our judgment, the requirements were clear – NASA was not financially responsible for damage to Agency property or the property of VCSFA. Nevertheless, after the Orb-3 failure, the Virginia congressional delegation took steps to make $20 million of NASA's budget available to help fund Wallops repairs – funds that we believe could be put to better use. As NASA continues to rely on commercial companies to provide cargo, and soon crew, transportation services to the ISS, it is important to ensure all parties comply with procedures regarding obtaining (or waiving) insurance and clarifying who pays for what in the event of a mishap.

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[47] Consolidated and Further Continuing Appropriations Act, 2015, Pub. L. No. 113–235 (2014).

[48] NASA's 21st Century Space Launch Complex Program aims to modernize and transform NASA's launch and range complexes, including Wallops and the Kennedy Space Center, to support current and future NASA programs, other U.S. Government agencies, and commercial industry.

[49] On December 8, 2014, NASA and VCSFA entered into a fixed-price indefinite-delivery, indefinite-quantity contract known as MARS III for launch site services at Wallops.

[50] In an April 2014 report, we detailed NASA's funding challenges associated with the Space Communications and Navigation Program. NASA OIG, "Space Communications and Navigation: NASA's Management of the Space Network," (IG-14-018, April 29, 2014).

ORB-3 ACCIDENT INVESTIGATION BOARD LACKS LEVEL OF INDEPENDENCE REQUIRED OF NASA MISHAP BOARDS

Although Orbital's AIB meets its FAA licensure requirements and CRS-1 contract obligations, the company's investigation lacks the level of independence required of NASA Mishap Investigation Boards. For example, the Orbital employee who chairs the Board is a former manager of the company's Antares Program, a majority of its members are Orbital employees, and a NASA member participated in the risk analysis required prior to the Orb-3 launch.

NASA Policy and Standard Practice Call for Independent Accident Investigations

To ensure impartial investigation of an accident, instill trust and confidence in identifying deficiencies, and make recommendations to prevent recurrence of the event, NASA Mishap Investigation Boards are constructed to be independent and free from conflicts of interest. NASA's policy for mishap investigations states "it is difficult to conduct an unbiased investigation of one's own actions," and therefore establishes independence standards for Mishap Investigation Board members, including that a majority of members be independent from the investigated activity and the chairperson independent of the underlying program.[51] The National Transportation Safety Board and U.S. Air Force also have independence requirements for their investigation boards.[52] In a 2008 speech, a member of the National Transportation Safety Board stressed the importance of independence by stating, "one of the most critical elements in achieving investigative integrity is independence of accident investigations."[53]

The Orb-3 AIB Does Not Meet NASA Standards

Under the CRS-1 contract, Orbital leads investigations into accidents that – like Orb-3 – occur after launch but before reaching the ISS. By structuring the contract in this manner, NASA deviated from its practice of requiring Board member independence. For example, four of seven AIB members are Orbital employees, including the chairperson who is a former manager of the Taurus II and Antares Programs and

[51] NASA Procedural Requirements 8621.1B, Paragraph 4.2.7.

[52] The National Transportation Safety Board is an independent Federal agency and has no authority to regulate, fund, or be involved in commercial space transportation activities. National Transportation Safety Board members and staff must be independent from the accident investigation. The U.S. Air Force conducts two types of investigations – a Safety Investigation Board and an Accident Investigation Board – both of which must be independent.

[53] Robert Sumwalt, National Transportation Safety Board Member, remarks to the International Society of Air Safety Investigators, Mid-Atlantic Regional Chapter, May 1, 2008, Washington, DC.

was involved in risk analysis and testing decisions for the Antares and AJ-26 engines.[54] Of the other three Board members, two are current NASA employees – one of whom had responsibility for the risk analysis used to approve the Orb-3 launch and for reviewing Orbital's Return to Flight Plan for technical feasibility. In our judgment, the lack of independence standards in the CRS-1 contract and the Orb-3 AIB raises questions about the investigative process that could potentially impact the AIB's analysis. In November 2014, NASA formed its own team to independently validate the AIB findings and to assess the risk of Orbital's Return to Flight Plan. However, Orbital and NASA have already made modifications to the CRS-1 contract based on the preliminary results from the AIB investigation.

The risk of conflicts within any commercial-entity-established AIB exist for all NASA-sponsored commercial space launches. In a November 2013 report, we recommended NASA better coordinate safety issues with the FAA to avoid imposing conflicting requirements on commercial spaceflight operators while ensuring the safety of its crews, workforce, and infrastructure during commercial launches carrying NASA astronauts.[55] In our discussions with FAA officials following the Orb-3 failure, they stated NASA can implement additional independence requirements for accident investigations through its contracts with commercial operators as long as they do not conflict with FAA regulations.

[54] In December 2011, Orbital renamed their Taurus II rocket Antares to avoid confusion with the company's Taurus XL line of launch vehicles.

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

CONCLUSION

Reliable cargo transportation is essential to the safe and successful operation of the ISS as a research platform for both NASA and other government and private entities that utilize the Station. Two recent commercial cargo resupply launch failures underscore the importance of contracting with multiple providers to ensure redundancy if one provider is unable to perform. However, in seeking redundancy NASA should not lose sight of its responsibility to ensure proper stewardship of Agency funds. Accordingly, as NASA incorporates Orbital's Return to Flight Plan into ISS cargo resupply operations and makes decisions about how to proceed, it should use all available contractual options to ensure not only a safe and timely return to flight, but also the best possible return on its investment in the CRS-1 contract.

NASA missed opportunities to seek lower prices from Orbital both before and after the Orb-3 failure and we question the value of the consideration Orbital offered in its Return to Flight Plan in exchange for NASA's agreement to accept one less resupply flight from the company. In addition, by accepting Orbital's plan to eliminate one flight, NASA has reduced its flexibility in sending cargo to the ISS. Finally, as performance under the CRS-1 contract ends with the last resupply mission scheduled to take place in 2018, NASA is currently evaluating proposals from commercial companies for the follow-on CRS-2 contract expected to be awarded in November 2015. Continuing to apply the lessons learned from CRS-1 and the Orb-3 failure will help protect the Agency and taxpayer's investment in commercial space activities.

RECOMMENDATIONS, MANAGEMENT'S RESPONSE, AND OUR EVALUATION

In order to reduce schedule, performance, and financial risks in NASA's CRS contracts, we recommended the Associate Administrator for Human Exploration and Operations, in conjunction with the CRS-1 Contracting Officer, ensure the ISS Program

1. complete a detailed technical assessment of the Antares 230, including the qualification test results and risk mitigation plan before the Antares returns to flight;
2. establish a decision point for asking Orbital to provide a second Atlas V mission, thereby increasing the likelihood the company will meet its upmass requirements on a reasonable schedule;[56] and
3. use available contract provisions to ensure the best value to the Government when making equitable adjustments due to a contractor's deficiency.

In order to reduce risk in future CRS contracts, we recommended the Associate Administrator for Human Exploration and Operations, in conjunction with the CRS-1 and CRS-2 Contracting Officers,

4. ensure mission pricing and payment are continually updated to take advantage of discounts available for flying multiple missions in a single calendar year, using per-mission or per-kilogram pricing tables already established in the contract, and
5. continue to incorporate lessons learned during CRS-1 into follow-on contracts and during the evaluation of Return to Flight Plans. For example, limit percentage of mission payment to 50 percent at the Mission Integration Review (or lower), rather than the currently contemplated 60 percent and tie more payments to the launch date instead of the ATP.

In order to prevent claims against the United States for damages caused by commercial spaceflight operations, we recommended the NASA General Counsel

6. establish procedures to ensure that insurance policies adhere to agreement requirements and provide adequate financial liability and damage coverage.

To address concerns about the independence of accident investigation boards for NASA-sponsored commercial spaceflights, we recommended the Associate Administrator for Human Exploration and Operations, in conjunction with the CRS-1 and CRS-2 Contracting Officers

7. consider whether contract provisions relating to the boards should be revised to more closely align with NASA Mishap Investigation Board procedures (NASA Procedural Requirements 8621.1B, Chapter 4).

[56] This recommendation was made before Orbital announced in August 2015 that it would exercise the option to contract for an additional Atlas V rocket to launch Orb-6.

In response to a draft of our report, the Associate Administrator concurred with recommendations 1, 2, 3, 4, 5, and 7 and described corrective actions the Agency has taken or will take to address them. Agency officials did not concur with recommendation 6.

We find the actions the Agency describes responsive to recommendations 1, 2, 3, 5, and 7 and will close these recommendations upon reviewing relevant contract documentation and verifying that the Agency has completed the described actions.

We do not find NASA's comments responsive to recommendation 4. Specifically, we are troubled that despite our findings that the Agency failed to take advantage of contractual mechanisms that could have saved it millions of dollars, NASA's comments do not suggest it intends to do anything differently in the future to ensure it receives the best value. Accordingly, we are leaving the recommendation unresolved pending our review of NASA's actions regarding future contract modifications.

Although Agency officials did not concur with recommendation 6, we believe NASA can take additional steps to help ensure clarity regarding who is responsible for paying for repairs in the event of a launch mishap. Specifically, NASA officials stated that VCSFA intended to self-insure for damage resulting from launch operations; however, it is not clear from correspondence between VCSFA and NASA that this issue was understood or agreed upon by both parties. This lack of clarity may have contributed to NASA's decision to divert money intended for other projects to repair VCSFA property. Accordingly, we continue to urge NASA to assess whether it should take additional steps to ensure liability provisions and insurance requirements relating to launch failures are clear to all parties. This recommendation is unresolved pending further Agency response.

Management's full response to our report is reproduced in Appendix B. Technical comments provided by management have also been incorporated, as appropriate.

Major contributors to this report include, Ridge Bowman, Space Operations Director; Raymond Tolomeo, Science and Aeronautics Research Director; Kevin Fagedes, Project Manager; Loretta Atkinson, Project Manager; Letisha Antone, Team Lead; David Balajthy; Sarah Beckwith; Cedric Campbell, Associate Counsel; Sashka Mannion; and Robert Proudfoot.

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

Paul K. Martin
Inspector General

APPENDIX A: SCOPE AND METHODOLOGY

We performed this audit from February 2015 through August 2015 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.

To assess the technical and operational risks of Orbital's Return to Flight Plan, we reviewed the NASA processes and guidance for conducting oversight over CRS contracts. We also reviewed risk assessments from Orbital and NASA; interviewed officials from the ISS Program Office, Wallops, MARS, and the Launch Services Program; and analyzed the CRS-1 contract and NASA policies for additional oversight controls. In particular, we reviewed the following documents:

- Orbital's CRS-1 contract – December 2008, modifications to the contract, task orders, and work plans
- SpaceX's CRS-1 contract – December 2008, modifications to the contract, task orders, and work plans
- Orbital's Taurus II Qualification Plan, September 9, 2011
- NASA's AJ-26 Engine Test Evaluation, January 19, 2012
- NASA's AJ-26 E17 Failure Investigation Overview, July 10, 2014
- NASA's AJ-26 Bearing Wear Assessment, September 30, 2014
- Orbital's Return to Flight Plan (Initial Draft), November 21, 2014
- Orbital's Approved CRS Return to Flight Plan Proposal (Final Proposal), December 17, 2014
- ISS Flight Assessment – Capability vs. Demand and Flight Rate – Pressurized, March 10, 2015
- ISS Status Update Presentation to NASA Advisory Council, April 2015
- Orbital's response to OIG questions, May 8, 2015
- Orbital's Antares Propulsion Upgrade Stage Test Plan (Rev A), May 27, 2015
- Orbital's Antares Qualification Plan for Commercial Resupply Services (Rev G), May 27, 2015
- Orbital's Antares 230 Main Propulsion System Verification Plan for CRS, May 28, 2015
- ISS Stage Operations Readiness Review Consumables Status Report, June 1, 2015
- ISS flight plans
- NASA's Antares Orb-3 Launch Vehicle Assessment

To examine NASA's efforts to reduce the financial risk associated with its contract with Orbital, we reviewed NASA criteria to determine how NASA is managing the CRS-1 contract. We analyzed Federal procurement law and contract documentation, and we interviewed personnel from the ISS Program Office and Office of General Counsel. In particular, we reviewed the following contract documents:

- Orbital's Return to Flight Plan (Initial Draft), November 21, 2014
- Orbital's Approved CRS Return to Flight Plan Proposal (Final Proposal), December 17, 2014
- Orbital Responses to NASA Requests For Clarification, December 17, 2014
- NASA's Price Reasonableness Determination, January 22, 2015
- NASA's Findings and Determinations for CRS-1 Contract Modification #66, January 22, 2015
- NASA's CRS-1 Return to Flight Contract Modification #66, January 23, 2015
- Orbital's Response to OIG Questions, May 8, 2015
- Orbital and SpaceX contract documents, modifications to the contract, task orders, and work plans

To examine the progress of repairs at Wallops, we reviewed NASA policies and guidance for Space Act Agreements, policies for NASA-sponsored commercial space launches, and Federal appropriations law and processes. We also reviewed NASA's policies for Space Act Agreements, Federal law and regulations for commercial space launches, and correspondence between NASA and VCSFA. We visited Wallops and conducted interviews with NASA and VCSFA staff. We also interviewed Office of General Counsel personnel. In particular, we reviewed the following documents:

- Space Act Agreement Between NASA and VCSFA, April 7, 2007
- License Number: LSO 02-007 (Rev 2), FAA Office of Commercial Space Transportation, "Commercial Space Transportation License" (to VCSFA to operate launch pad at Wallops), December 19, 2012
- License Number: LLO 14-091, FAA Office of Commercial Space Transportation, "Commercial Space Transportation License" (to Orbital for Orb-3 Launch), June 12, 2014
- Wallops Return to Flight – Projected Cash Flow Requirements, VCSFA, November 25, 2014
- VCSFA Insurance Policy, policy period: March 21, 2014 to March 21, 2015

To review the procedure for investigating the cause of Orbital's failure, we examined NASA policies, FAA regulations, and Federal procurement law for requirements and best practices. We also reviewed NASA mishap procedures, Federal law and regulations for commercial space launches, and Federal procurement law and decisions. We also interviewed officials from the Office of Safety and Mission Assurance and the FAA Office of Commercial Space Transportation. In particular, we reviewed the following documents:

- Statement of Pamela Melroy (Colonel, United States Air Force, Ret.), Director of Field Operations for FAA Commercial Space Transportation, before the U.S. Senate Committee on Commerce, Science, and Transportation, Subcommittee on Science and Space, June 20, 2012
- Orbital Launch Vehicle Mishap Investigation and Reporting Plan, Revision D, Orbital, November 12, 2013
- William Gerstenmaier, Associate Administrator for Human Exploration and Operations Mission Directorate, NASA, "Independent Review Team of the Orb-3 Accident," November 26, 2014

Laws, Regulations, Policies, and Requirements

We identified and reviewed applicable Federal, Agency, and Center level regulations and guidance.

Federal Laws, Regulations, Policies, and Guidance

- Federal Acquisition Regulation (FAR) 9.504, "Contracting Officer Responsibilities," October 25, 1991
- Aetna Gov't Health Plans, Inc.; Foundation Health Fed. Servs., Inc., Comp. Gen. B-254397.15 et al., July 27, 1995
- FAA, Associate Administrator for Commercial Space Transportation, "Advisory Circular: License Application Procedures," August 16, 1999
- FAR 2.101, "Definitions," January 10, 2001
- Government Accountability Office, *Principles of Federal Appropriations Law*, Third Edition, Volume II, February 2006
- Executive Order 13457, "Protecting American Taxpayers From Government Spending on Wasteful Earmarks," January 29, 2008
- FAA, Associate Administrator for Commercial Space Transportation, "Safety Approval Guide for Applicants," September 28, 2009
- Nortel Gov't Solutions Inc., Comp. Gen. B-299522.6, December 30, 2008
- FAR 3.11, "Preventing Personal Conflicts of Interest for Contractor Employees Performing Acquisition Functions," November 2, 2011
- U.S. Senate Report 113-181, Departments of Commerce and Justice, and Science, and Related Agencies Appropriations Bill, June 5, 2014
- House of Representatives, "Explanatory Statement Submitted by Mr. Rogers of Kentucky, Chairman of the House Committee on Appropriations Regarding the House Amendment to the Senate Amendment on H.R. 83," December 11, 2014
- Consolidated and Further Continuing Appropriations Act, 2015, Pub. L. No. 113235, 2014
- Code of Federal Regulations, Title 14, Chapter III, "Commercial Space Transportation, Federal Aviation Administration, Department Of Transportation"
- U.S. Code, Title 51, Chapter 509, "Commercial Space Launch Activities"

NASA Policies and Procedures

- NASA Procedural Requirements 8621.1B, "NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating and Recordkeeping w/Change 7 (07/15/2013)," May 23, 2006
- NASA Guide on Organizational Conflicts of Interest, March 2010
- NASA Policy Directive 8610.23C, "Launch Vehicle Technical Oversight Policy," March 6, 2012
- NASA Policy Directive 8610.7D, "Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions," August 27, 2012

- Space Act Agreements Guide, NASA Advisory Implementing Instruction 1050-1C, February 25, 2013
- NASA Policy Directive 1000.5B, "Policy for NASA Acquisition," December 19, 2013
- NASA FAR Supplement 1809.5, "Organizational Conflicts of Interest," July 29, 2014
- NASA Procedural Requirements 8705.4, "Risk Classification for NASA Payloads," October 2, 2014

Use of Computer-Processed Data

We used computer-processed financial data to perform this audit, and that data was used to materially support findings, conclusions, and recommendations. In order to assess the quality and reliability of the financial data, we verified the information through independent calculations and corroboration with Program documents and the input of various Program officials.

Review of Internal Controls

We reviewed and assessed controls associated with the audit objectives and concluded that the ISS Program has a comprehensive set of management tools (identified in a detailed Program Plan) that it uses to provide internal controls for the ISS Program. To facilitate internal controls, the ISS Program uses a broad set of control boards, panels, and working groups that addresses a myriad of risks. However, as shown in our findings, we did not find the normal analyses by the supporting teams when evaluating Orbital's Return to Flight Plan. This resulted in the approval of a Plan containing technical, operational, and financial risks that were not fully identified. Implementing our recommendations will address these risks.

Prior Coverage

During the last 5 years, the OIG and Government Accountability Office have issued 10 reports of significant relevance to the subject of this report. Unrestricted reports can be accessed at http://oig.nasa.gov/audits/reports/FY15 and http://www.gao.gov, respectively.

NASA Office of Inspector General

Extending the Operational Life of the International Space Station Until 2024 (IG-14-031, September 18, 2014)

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

Space Communications and Navigation: NASA's Management of the Space Network (IG-14-018, April 29, 2014)

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

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

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

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

Government Accountability Office

NASA Assessments of Selected Large-Scale Projects (GAO-15-320SP, March 26, 2015)

Space Launch System: Resources Need to be Matched to Requirements to Decrease Risk and Support Long Term Affordability (GAO-14-631, July 23, 2014).

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

APPENDIX B: MANAGEMENT'S COMMENTS

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

September 14, 2015

Reply to Attn of:

Human Exploration and Operations Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Human Exploration and Operations Mission Directorate

SUBJECT: Response to OIG Draft Report "NASA's Response to Orbital's October 2014 Launch Failure: Impacts on Commercial Resupply of the International Space Station" (A-15-006-00)

NASA appreciates the opportunity to review the Office of Inspector General (OIG) draft report entitled "NASA's Response to Orbital's October 2014 Launch Failure: Impacts on Commercial Resupply of the International Space Station" (A-15-006-00) dated August 12, 2015. NASA also appreciates the efforts of the OIG in protecting data that is Sensitive But Unclassified (SBU) and identifying additional areas considered SBU data.

In the draft report, the OIG makes a total of seven recommendations; six recommendations are addressed to the Associate Administrator for Human Exploration and Operations Mission Directorate (HEOMD), in conjunction with the Commercial Resupply Services (CRS)-1 and -2 Contracting Officers, and one recommendation is addressed to the NASA General Counsel regarding the Orbital October 2014 launch failure. NASA's response to the OIG's recommendations, including planned corrective actions, follows:

In order to reduce schedule, performance, and financial risks in NASA's CRS contracts, the OIG recommends the Associate Administrator for HEOMD, in conjunction with the CRS-1 Contracting Officer, ensure the ISS Program:

Recommendation 1: Complete a detailed technical assessment of the Antares 230, including the Qualification Test results and risk mitigation plan before the Antares returns to flight.

Management's Response: Concur. NASA expects full delivery of the qualification rationale by the Cargo Integration Review at Launch minus four months, and, per our normal activity, will provide a risk assessment in the same timeframe of the Stage Operations Readiness Review which occurs at Launch minus one month.

Estimated Completion Date: Launch minus one month, which is currently expected to be May 1, 2016. It should be noted that Orbital is currently protecting for a March 2016 launch of Cygnus/Antares 230; however, NASA believes June 2016 is more likely.

Recommendation 2: Establish a decision point for asking Orbital to provide a second Atlas V mission, thereby increasing the likelihood the company will meet its upmass requirements on a reasonable schedule.

Management's Response: Concur. Orbital ATK has secured a second Atlas V rocket and launch is planned for March 2016. This CRS mission, designated Orb 6, will have the same capabilities as the Orb-4 mission.

Estimated Completion Date: Action complete.

Recommendation 3: Use available contract provisions to ensure the best value to the Government when making equitable adjustments due to a contractor's deficiency.

Management's Response: Concur. NASA has always used all available contract provisions when making equitable adjustments and will continue to do so. Use of available contract provisions when making equitable adjustments for mission price updates are addressed in our response to Recommendation 4. With regard to the OIG's assertion that NASA should require additional insight, NASA has invoked every provision within the contract to provide insight and oversight and has a sufficient level of insight to determine readiness of flight in support of their commercial services.

Estimated Completion Date: Action complete.

In order to reduce risk in future CRS contracts, the OIG recommends the Associate Administrator for HEOMD, in conjunction with the CRS-1 and CRS-2 Contracting Officers:

Recommendation 4: Ensure mission pricing and payment are continually updated to take advantage of discounts available for flying multiple missions in a single calendar year, using per-mission or per-kilogram pricing tables already established in the contract.

Management's Response: Concur. NASA obtained appropriate contractual consideration on behalf of the U.S. taxpayers in all instances based on the facts and timing of each contract transaction. NASA has administered the CRS-1 contracts consistent with all CRS-1 contract terms and conditions and consistent with Federal Acquisition Regulations (FAR) for FAR Part 12 Commercial Fixed Price Contracts.

Despite the lengthy delays in mission launch dates, NASA held the contractor to the original mission prices established in 2008. For example, for Orbital Mission-1, NASA paid the original mission price for a launch based on an October 2010 initial

launch date which actually occurred in January 2014 at no increase to the mission price. During operation of the CRS contracts, the Government ensured that when a mission slipped, the Government received adequate consideration for those adjustments. In many cases, the consideration received was of greater value to the Government than the schedule slippage, not just of essentially equal value when schedule slippage reduced the number of flights in a calendar year.

NASA did, indeed, consider a wide variety of alternative opportunities to obtain other or additional value as consideration for schedule changes. Each of those other opportunities presented considerable or even significant risk to NASA, and, thus, NASA deemed them less beneficial than the approaches NASA selected and has successfully executed.

Estimated Completion Date: December 31, 2015.

Recommendation 5: Continue to incorporate lessons learned during CRS-1 into follow-on contracts and during the evaluation of Return to Flight Plans. For example, limit percentage of mission payment to 50 percent at the Mission Integration Review (or lower), rather than the currently contemplated 60 percent and tie more payments to the launch date instead of the Authorization to Proceeed (ATP).

Management's Response: Concur. NASA will continue to incorporate lessons learned during CRS-1 into follow-on contracts and during the evaluation of Return to Flight Plans.

Note that NASA engaged the commercial industry as part of CRS-1 to ensure that some of the milestones are production-based milestones rather than mission-readiness milestones. To make production milestones based on the launch date, as the OIG suggests, would be arbitrarily incentivizing the contractor to stop processing activities on the spacecraft and wait until the "launch minus" date to occur so as to incur costs as close as possible to receipt of associated milestone payments. This would add unacceptable performance and schedule risk to the overall mission as testing issues and failures would be uncovered much later in the flow with less time to recover. While the auditor's preference has some benefit, it is in the Government's overall best interest and provides NASA with best value to incentivize the contractor to perform as much spacecraft integration and test activities as early as possible. Then, when the spacecraft is complete, it can go into storage and will be ready for the mission at the appropriate time. This allows the discovery of issues and problems at the earliest possible time, which allows for a better chance to resolve them without affecting the overall mission success or schedule. The contractor performs work on these production-based milestones independent of the launch date and should be compensated at that time. Had NASA done otherwise in CRS-1, or proposed to do otherwise in CRS-2, it is near certain that the cost-incurrence/ payment-received disconnect would have resulted in less-favorable prices as the contractors naturally reacted to that disconnect. That is the primary reason for production-based milestones to be tied to ATP versus launch. Similar inquiries with

industry support NASA's decision to hold the Mission Integration Review (MIR) cap at 60 percent.

Estimated Completion Date: December 31, 2015.

In order to prevent claims against the United States for damages caused by commercial spaceflight operations, the OIG recommends the NASA General Counsel:

Recommendation 6: Establish procedures to ensure that insurance policies adhere to agreement requirements and provide adequate financial liability and damage coverage.

Management's Response: Non-concur. Procedures are in place for reviewing financial protection requirements under agreements such as the agreement between NASA and the Virginia Commercial Space Flight Authority (VCSFA). Those procedures were followed for the agreement between NASA and VCSFA. The insurance policies obtained by Orbital and VCSFA did, in fact, fully comply with the requirements of the agreement. There was no requirement for VCSFA to obtain commercial insurance covering VCSFA's own property during launch operations; risk management for such potential property loss or damage is a business decision for which the agreement partner itself is responsible. VCSFA obtained commercial insurance covering its property during day-to-day activities at the site and indicated that it would self-insure for launch operations. After considering VCSFA's explanation of their insurance coverage, NASA deemed it to be satisfactory since NASA-owned property was covered under the agreement, and there were no circumstances under which NASA could be held liable for damage to VCSFA-owned property under the Agreement. This analysis proved accurate when the damage occurred because the damage to NASA property was covered by Orbital's commercial insurer, and NASA was not liable for damage to VCSFA property. NASA was not required to contribute funds to the recovery effort at the site, but rather made an appropriate programmatic and policy-based decision to do so. Accordingly, NASA will continue to enforce existing requirements and procedures to ensure its commercial partners meet their responsibilities pursuant to liability and risk allocation provisions in agreements.

Estimated Completion Date: Not applicable

To address concerns about the independence of accident investigation boards for NASA-sponsored commercial spaceflights, the OIG recommends the Associate Administrator for HEOMD, in conjunction with the CRS-1 and CRS-2 Contracting Officers:

Recommendation 7: Consider whether contract provisions relating to the boards should be revised to more closely align with NASA Mishap Investigation Board Procedures (NASA Procedural Requirement 8621.1B, Chapter 4).

Management's Response: Concur. NASA will consider updates to the relevant contract provisions while taking into consideration existing Federal Aviation Administration procedures and NASA strategic goals and objectives.

Estimated Completion Date: Prior to the CRS-2 contract announcement, currently planned for early November 2015.

We have reviewed the draft report for information that we believe should not be publicly released and have communicated our concerns regarding the release of information to the OIG.

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

William H. Gerstenmaier

cc:
Office of General Counsel/Ms. Thompson-King
Office of Procurement/Mr. McNally

APPENDIX C: REPORT DISTRIBUTION

National Aeronautics and Space Administration

Administrator
Deputy Administrator
Associate Administrator
Deputy Associate Administrator
Chief of Staff
Executive Officer
Chief Engineer
Chief Financial Officer
Deputy Chief Financial Officer
Chief, Safety and Mission Assurance
General Counsel
Associate Administrator, Human Exploration and Operations
Assistant Administrator, Procurement
Director, International Space Station Program
Program Manager, International Space Station Program
Deputy Program Manager, International Space Station Program
Director, Goddard Space Flight Center
Director, Johnson Space Center
Director, Kennedy Space Center
Director, Marshall Space Flight Center
Director, Stennis Space Center
Director, Wallops Flight Facility

Non-NASA Organizations and Individuals

Office of Management and Budget
    Deputy Associate Director, Energy and Space Programs Division

Government Accountability Office
    Director, Office of Acquisition and Sourcing Management

Congressional Committees and Subcommittees, Chairman and Ranking Member

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

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

Senate Committee on Homeland Security and Governmental Affairs

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

House Committee on Oversight and Government Reform
Subcommittee on Government Operations

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

(Assignment No. A-15-006-00)