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Office of Inspector General

Office of Audits

AUDIT OF COMMERCIAL RESUPPLY SERVICES TO THE INTERNATIONAL SPACE STATION

April 26, 2018

Report No. IG-18-016

Office of Inspector General

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RESULTS IN BRIEF

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April 26, 2018 IG-18-016 (A-17-013-00)

WHY WE PERFORMED THIS AUDIT

Since the Space Shuttle's final flight in 2011, NASA has embarked on a new approach to transport supplies, equipment, and science research to and from the International Space Station (ISS or Station) using private companies. Through its first round of Commercial Resupply Services contracts (CRS-1), NASA awarded a total of 31 missions to Orbital ATK and Space Exploration Technologies Corporation (SpaceX) worth $5.9 billion, or an average cost of $191.3 million per mission.[1] As a follow-on to CRS-1, NASA awarded a second round of cargo resupply contracts known as CRS-2 to Orbital ATK, SpaceX, and the Sierra Nevada Corporation (Sierra Nevada) with a maximum total value of $14 billion – more than double the value of the CRS-1 contracts. As of December 2017, NASA has awarded $2.6 billion in task orders for eight CRS-2 missions and related integration costs.

Cargo missions are key to the successful utilization of the ISS and continued reliance on commercial operators to provide this vital service could play a major role in NASA's future plans as it searches for cheaper and more efficient methods to explore space. Costing more than 30 percent of the ISS Program's annual budget, NASA officials view the commercial resupply contracts as successful and cost effective. In this audit, we examined the CRS contracts for resupplying the Station through 2024 with a special emphasis on the CRS-2 contracts. Specifically, we examined (1) the extent to which CRS-2 contracts provide best value to NASA, (2) CRS-2 costs, and (3) technical and schedule risks to CRS-2 contractors. In meeting these objectives, we reviewed applicable Federal laws, regulations, and guidelines; evaluated NASA's CRS contracts; interviewed officials from NASA and the commercial companies; analyzed spending on CRS; and reviewed relevant documentation.

WHAT WE FOUND

During the CRS-2 solicitation and award process, NASA followed Federal procurement rules and applied lessons learned from the CRS-1 contract to provide the ISS Program with better cargo capabilities, more transport flexibility, added insurance coverage for NASA payloads, and clearer Government insight into subcontractor activities. We found that NASA could obtain additional savings by competing future cargo resupply missions after meeting the minimum of six flights guaranteed for each contractor. However, despite a requirement to compete task orders among all contractors, NASA approved sole-source awards for all 31 CRS-1 missions and the 8 CRS-2 missions awarded as of December 2017. With the addition of a third contractor under CRS-2, we believe NASA has more flexibility to compete task orders or possibly open the contract to new entrants through its On-Ramp clause that allows NASA to recompete contracts with new contractors for any missions beyond the guaranteed six. In addition, we believe NASA could realize substantial savings if Sierra Nevada uses a less expensive launch vehicle than the Atlas V currently planned for the company's first two missions.

[1] Total awards include per-mission pricing, contract modifications based on requirements changes, and payload integration costs. The average per-mission cost is a NASA Office of Inspector General calculation derived by dividing the total awards by the total missions.

Initial 2016 projections showed the CRS-2 contract was approximately $400 million more expensive than CRS-1 while delivering roughly 6,000 kilograms less upmass capability (i.e., delivery of supplies and equipment to the Station). The higher costs for CRS-2 are primarily driven by increased prices from SpaceX, the impact of selecting three contractors, and the $700 million in integration costs awarded to date. Of those integration costs, we question as premature $4.4 million paid to Sierra Nevada to begin certifying its second Dream Chaser configuration. We believe ISS Program officials should have delayed these payments until after the first Dream Chaser configuration is successfully demonstrated. In light of the CRS-2 contract's overall higher costs, the ISS Program is considering changing the cadence for upcoming CRS-2 flights to potentially save $300 million by taking advantage of pricing discounts without decreasing the number of missions. By the end of 2017, NASA had ordered 8 CRS-2 missions that followed this strategy; however, it is unclear whether the Agency will continue this pattern for the remaining 13 CRS-2 missions.

Although less risky than the CRS-1 missions, all three contractors face technical and schedule risks as they prepare for their CRS-2 missions. Development and launch of the Dream Chaser spacecraft poses the greatest technical and schedule risk to NASA due to its lack of flight history and Sierra Nevada's plan to not conduct a demonstration flight. Additionally, Sierra Nevada intends to only build one Dream Chaser and this raises concerns about potential schedule delays if an anomaly or failure occurs. For SpaceX, certification of the company's unproven cargo version of its Dragon 2 spacecraft for CRS-2 missions carries risk while the company works to resolve ongoing concerns related to software traceability and systems engineering processes. And finally, while Orbital ATK's planned use of a slightly modified Cygnus spacecraft for CRS-2 missions reduces risk, the company plans to rely on the relatively new Antares 230 configuration that could be affected by congressional bans on Russian engines.

What We Recommended

To obtain the best value for its cargo resupply missions and mitigate technical risks, we recommended the Associate Administrator for Human Exploration and Operations Mission Directorate ensure the ISS Program: (1) incorporates, to the extent practicable, the ISS Program Planning and Control Office's proposed mission cadences into the Planning, Programming, Budgeting, and Execution process for fiscal year 2020 to take advantage of contractor discounts for multiple missions through 2024; (2) ensures appropriate pacing of expenditures for integration costs to avoid paying for configurations too far in advance of when they may be used; (3) clarifies whether Sierra Nevada will deliver a second Dream Chaser spacecraft for CRS-2 missions and, if not, incorporates the risk of having only a single vehicle into the ISS Program risk management database; (4) ensures that the Agency negotiates monetary discounts, as required by the CRS contracts, in the event contractors use an alternate launch vehicle or a previously flown vehicle; and (5) decides by January 2020 whether to compete task orders beyond the minimum guarantee of six for each contractor through the existing contract or through the On-Ramp clause.

We provided a draft of this report to NASA management who concurred with our recommendations and described planned corrective actions. We consider the proposed actions responsive for four of the five recommendations and will close them upon their completion and verification. With regard to Recommendation 3, the Agency did not directly answer the question whether Sierra Nevada will deliver a second Dream Chaser spacecraft for CRS-2 missions. Therefore, we consider this recommendation unresolved pending further discussion with the Agency.

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Acronyms

CCiCap	Commercial Crew Integrated Capability
CCtCap	Commercial Crew Transportation Capability
COTS	Commercial Orbital Transportation Services
CRS	Commercial Resupply Services
CTBE	Cargo Transfer Bag Equivalents
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulation
IDIQ	Indefinite-Delivery, Indefinite-Quantity
ISS	International Space Station
kg	Kilogram
LSP	Launch Services Program
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
OIG	Office of Inspector General
RFP	Request for Proposal
SSP	Space Station Program
ULA	United Launch Alliance

INTRODUCTION

Since the last flight of the Space Shuttle in 2011, NASA has relied on commercial contractors to deliver cargo to the International Space Station (ISS or Station) through Commercial Resupply Services (CRS) contracts. The first round of these cargo resupply contracts, known as CRS-1, was awarded in 2008 to Orbital ATK and Space Exploration Technologies Corporation (SpaceX). As of December 2017, NASA has awarded $5.9 billion for 31 cargo missions. Of those missions, 20 of 22 have successfully delivered cargo to the ISS while 9 more missions are planned through early 2020. While generally successful, the CRS-1 contractors have experienced launch failures, schedule delays, and capability limitations. In January 2016, NASA awarded a second round of cargo resupply contracts, known as CRS-2, to Orbital ATK, SpaceX, and the Sierra Nevada Corporation (Sierra Nevada) with a total contract value of $14 billion – more than double the value of all CRS-1 contracts. As of December 2017, NASA has awarded $2.6 billion in task orders for eight CRS-2 missions and related integration costs.

Reliable transportation of supplies, equipment, and other cargo is key to the successful utilization of the ISS, and over the past 6 years, NASA increasingly has relied on commercial companies for most of the Agency's deliveries to the Station.[1] While cargo transportation costs account for over 30 percent of the ISS Program's $3 to $4 billion annual budget, NASA officials have viewed commercial transportation as a cost effective and successful approach to delivering cargo to the ISS.

Given the expense and importance of commercial cargo transportation to sustaining the ISS, we examined the CRS contracts for resupplying the Station through 2024 with a special emphasis on the CRS-2 contracts. Specifically, the audit examined (1) the extent to which CRS-2 contracts provide best value to NASA, (2) CRS-2 costs, and (3) technical and schedule risks to CRS-2 contractors. See Appendix A for details on the audit's scope and methodology.

Background

Between 2006 and 2008, NASA entered into a series of funded Commercial Orbital Transportation Services (COTS) Space Act Agreements with Orbital ATK and SpaceX to stimulate U.S. commercial development of transportation systems capable of providing cargo delivery services to the ISS.[2] According to NASA officials, Orbital ATK and SpaceX ultimately contributed more than 50 percent of the development costs of their respective spaceflight systems while receiving more than $700 million from NASA under these agreements.[3]

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1 Russia and Japan have spacecraft that deliver cargo to the ISS that NASA has used when needed. Until 2014, the European Space Agency also transported cargo.

2 The National Aeronautics and Space Act of 1958 granted NASA broad authority to enter into "other transactions" commonly referred to as Space Act Agreements, which can be reimbursable, nonreimbursable, funded, or international. 51 U.S.C. § 20113(e) (2016). Space Act Agreements establish a set of legally enforceable commitments between NASA and a second party requiring a commitment of Agency resources, including personnel, funding, services, equipment, expertise, information, or facilities.

3 A third company – Rocketplane Kistler – was terminated in 2007 from COTS after receiving $32.1 million in NASA funding but failing to meet financial obligations.

ISS Cargo and Crew Transportation Contracts

In 2008, while development efforts were still underway, NASA awarded fixed-price contracts with task orders initially valued at $1.9 billion and $1.6 billion to Orbital ATK and SpaceX, respectively, for 20 cargo resupply missions to the ISS through 2016.[4] Additional CRS-1 task orders were subsequently issued to the companies for missions through January 2020 for a total of 31 missions. These CRS-1 contracts provide for delivery of supplies and equipment to the Station (referred to as upmass) and, depending on the mission, the return of equipment and experiments to Earth or the disposal of waste (downmass). SpaceX began cargo resupply flights to the ISS in 2012 and Orbital ATK followed with its first mission in 2014. NASA selected two companies to ensure redundancy if one was unable to perform due to technical or other reasons. In January 2016, NASA selected Orbital ATK, SpaceX, and Sierra Nevada for the second round of resupply contracts to deliver cargo through 2024.

In addition to its commercial cargo efforts, NASA is working with private companies to develop commercial crew vehicles to reduce NASA's reliance on the Russian Soyuz to transport astronauts to the ISS.[5] Spacecraft designs from The Boeing Company (Boeing), Sierra Nevada, and SpaceX were selected in 2012 for further development through the Commercial Crew Integrated Capability (CCiCap) agreements. In 2014, NASA awarded Boeing and SpaceX Commercial Crew Transportation Capability (CCtCap) contracts to complete vehicle certifications, conduct demonstration flights, and transport crew to the ISS. Through 2017, NASA has spent about $6.3 billion on commercial cargo activities and about $3.9 billion on commercial crew activities.[6] Figure 1 displays a commercial cargo and crew development timeline highlighting demonstration and first flights for each contractor.

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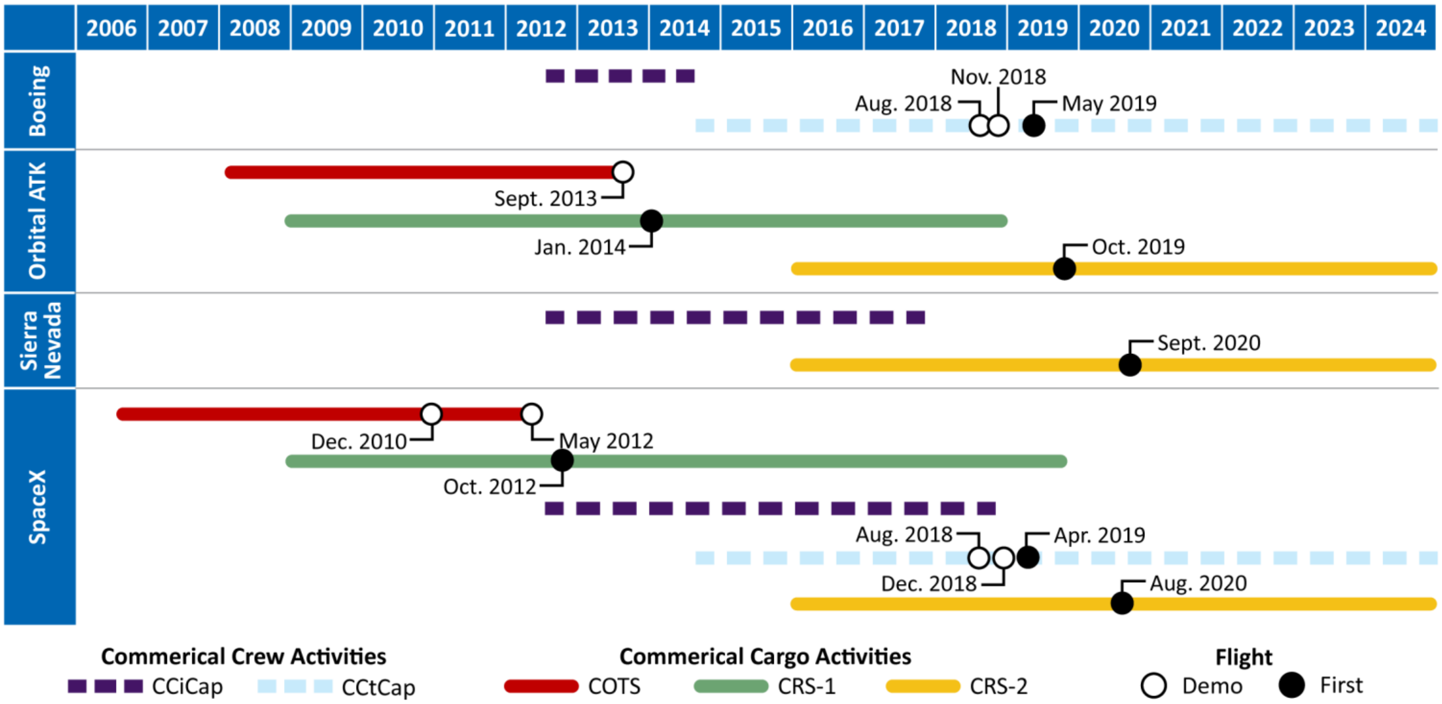
4 The maximum not-to-exceed value for each of these contracts was $3.1 billion.

5 Since retirement of the Space Shuttle in 2011, NASA has been paying Russia's space agency for seats on the Soyuz spacecraft to transport crew to the ISS. Between 2006 and 2018, NASA will pay the Russian Federal Space Agency $3.5 billion to ferry 63 NASA and partner astronauts to and from the ISS at prices ranging from $21.8 million to $81.9 million for each round trip.

6 These numbers do not reflect amounts NASA paid to Russia for crew transportation aboard the Soyuz.

Figure 1: Timeline of Commercial Cargo and Crew Activities



Source: NASA Office of Inspector General (OIG) presentation of ISS Program documentation.

Note: For commercial crew, the first two rounds of Space Act Agreements – Commercial Crew Development 1 and Commercial Crew Development 2 – are not shown.

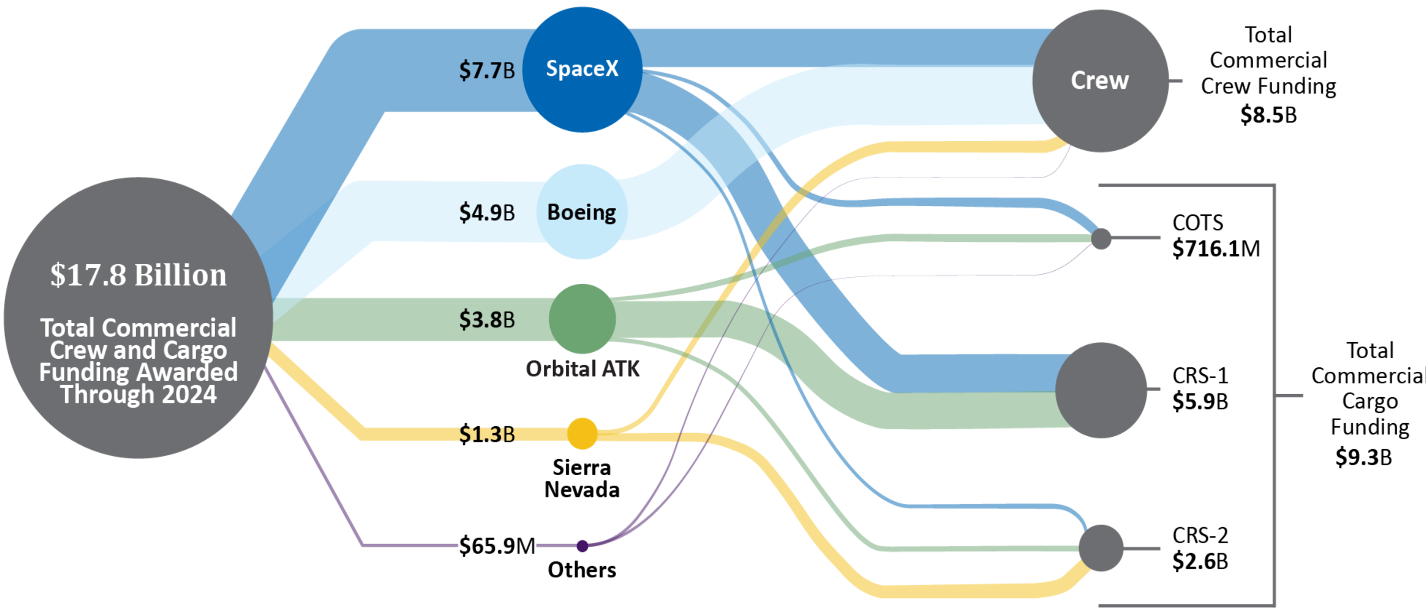
Together, commercial cargo and crew transportation efforts account for about 50 percent of total ISS annual spending.[7] With the CRS-2 contract award, NASA plans to award more than $20 billion in commercial transportation of cargo and crew to the ISS through 2024. To date, NASA has awarded $17.8 billion towards this total – $9.3 billion for cargo and $8.5 billion for crew activities.[8] This funding helped pay for development of two launch vehicles (Falcon 9 and Antares), four spacecraft for cargo deliveries (Cygnus, Dragon 1, Dragon 2, and Dream Chaser), and two spacecraft for crew transportation (Starliner and Dragon 2). For cargo, NASA purchased transportation services on 2 out of 3 demonstration flights and 39 missions and plans to buy at least 10 more for a total of 49 missions through 2024.[9] With respect to crew, 4 commercial crew demonstration flights and up to 12 crewed missions are planned through 2024. Figure 2 provides a summary of cargo and crew awards by activity and contractor.

[7] ISS Program funding does not include commercial crew development activities funded separately through the Commercial Crew Program.

[8] A NASA award includes past and future expenditures that have already been committed through a contract task order or Space Act Agreement milestone. This does not include minimum mission guarantee costs that are not yet on task orders.

[9] As of December 2017, NASA has committed to 8 CRS-2 missions but the Agency must purchase at least 10 more to meet the minimum order requirements, which in turn will increase the Agency's funding beyond $20 billion when those task orders are awarded.

Figure 2: NASA's Awards for Commercial Cargo and Crew Activities Through 2024



Source: NASA OIG analysis of Agency commercial activities and awards.

Note: Amounts are rounded. Total overall funding awards may not equal the sum of the rounded amounts. M denotes millions; B denotes billions. For additional information about NASA's commercial cargo and crew transportation awards, see Appendix B. These amounts represent total awards through December 2017 for activities that will take place through 2024.

As shown in Figure 2, SpaceX has received the most awards of all contractors with $7.7 billion for cargo and crew activities, followed by Boeing at $4.9 billion for crew transportation, Orbital ATK at $3.8 billion for cargo, and Sierra Nevada at $1.3 billion for cargo and crew. For CRS-2, NASA has awarded $2.6 billion in task orders for initial ISS certification activities and eight cargo missions as of December 2017, with the majority of mission task orders not yet awarded.

NASA's Impact on Commercial Launch Market

NASA's funding of commercial cargo and crew transportation to the ISS, which is planned to exceed $20 billion through 2024, has affected the commercial launch vehicle market by facilitating the introduction of competition and contributing to the development of new domestic capabilities, resulting in cheaper access to space for commercial and Government customers. NASA officials, including the Associate Administrator for Human Exploration and Operations Mission Directorate, have said development of new launch vehicles, such as SpaceX's Falcon 9, created competition for NASA commercial launches that previously were awarded only to United Launch Alliance (ULA) for its Atlas V launch vehicle.[10] These officials believe competition has contributed to lower prices for NASA launches. To that point, NASA officials reviewed past launch pricing and found the cost for a basic Atlas V

[10] ULA is a joint venture between the Lockheed Martin Corporation and Boeing that, up until the qualification of SpaceX's Falcon 9 (version 1.1), provided all large payload launch services for U.S. Government launch customers, including NASA, the U.S. Department of Defense, and the National Reconnaissance Office. ULA flies the Atlas V, Delta II, and Delta IV launch vehicles.

configuration decreased by roughly $20 million per launch after the Falcon 9 became eligible in 2013 to compete for launch services contracts through the Agency's Launch Services Program (LSP).[11] See Appendix C for more details on NASA's analysis of the impact new commercial launch capabilities have had on the commercial launch market.

New launch capabilities developed through CRS activities are also attracting commercial customers to use domestic launch companies when several years ago they likely would have relied on Russian or European providers. Additionally, the development of multiple companies with commercial launch capabilities has enabled domestic companies to reach space at more competitive prices.

NASA's Technical Management Process for CRS-1 and CRS-2

NASA's technical management process for the CRS contracts consists mainly of insight with some limited Agency oversight as the spacecraft approaches the ISS.[12] The CRS contractors develop the launch vehicle and spacecraft designs and are responsible for the launch, mission, and mitigation of risks. For activities near the Station, NASA works to ensure the spacecraft meets ISS safety requirements and determine if the contractor has provided adequate assurances that it can safely transport cargo to the ISS. This approach differs from the processes the Agency uses for its traditional cost-plus contracts and commercial launch services contracts acquired through LSP.

Traditional Contract and Risk Classification Approach

Traditionally, NASA has used cost-plus contracts to design, develop, and build new and unproven space capabilities such as the Space Shuttle, elements of the Constellation Program, the Space Launch System heavy-lift rocket, and the Orion Multi-Purpose Crew Vehicle.[13] Using this approach, NASA approves all designs, manages all development and schedules, and owns the vehicle once delivered by the contractor. While this process gives NASA maximum control over the contractor's design and final product, the majority of the cost, schedule, and outcome risks are borne by the Federal Government.

NASA's spaceflight program management policy outlines the process for managing traditional NASA missions.[14] As part of this process, all NASA-owned payloads – including projects using traditional cost-plus contracting – must have a risk classification ranging from Class A (least risk tolerant) to Class D (most risk tolerant) as part of NASA's risk management policies.[15] The payload classification allows

[11] LSP – part of the Human Exploration and Operations Mission Directorate – procures launches under NASA launch services contracts for non-defense-related Government payloads and satellites.

[12] Oversight is the process in which NASA approves and directly manages contractor activities while insight occurs when the Agency monitors contractor activities but does not require specific approvals for most decisions.

[13] In anticipation of the Shuttle Program's retirement, NASA established the Constellation Program in 2005 to develop a crew exploration vehicle, crew launch vehicle, and heavy-lift launch vehicle to enable a return to the Moon as a stepping-stone to future exploration of Mars and other destinations. However, in October 2010 the Constellation Program was canceled.

[14] NASA Procedural Requirements (NPR) 7120.5E, "NASA Space Flight Program and Project Management Requirements with Changes 1-15," August 14, 2012. This policy applies to all NASA spaceflight programs and projects.

[15] NPR 8705.4, "Risk Classification for NASA Payloads," October 2, 2014.

NASA to better internally communicate the risk posture of a mission and for the Agency to appropriately mitigate identified risks. Examples of Class A payloads – generally extremely expensive, complex, one-of-a kind systems – are the Cassini spacecraft that traveled to Saturn and the James Webb Space Telescope scheduled for launch in 2020.[16]

Launch Services Program's Commercial Approach

Formed in 1998, LSP provides acquisition, technical, mission integration, and launch management support to launch science payloads into space. LSP uses commercial fixed-price launch services contracts with less invasive and costly terms than traditional NASA contracts.[17] Over the last 20 years, LSP has awarded contracts totaling almost $8 billion to launch 86 missions with only two mission failures – a success rate of almost 98 percent.

To facilitate NASA's adoption of a new commercial approach for launch contracts, LSP developed policies to certify launch vehicles for Agency missions, perform risk management, and conduct technical oversight through insight and approval of the contractor. LSP policy holds the contractor responsible for launch vehicle management, identifies a certification process based on launch vehicle risk categorization, and develops an acquisition strategy to balance launch risks with mission needs.[18] LSP categorizes specific launch vehicle configurations as high, medium, or low risk based on past flight history, vehicle maturity, and technical knowledge of the vehicle. This launch vehicle risk certification and the NASA payload risk classification (Class A through D) determine which type of launch vehicle configurations may be used for a particular payload.[19]

Requirements under Commercial Resupply Services Contracts

In contrast to the traditional NASA cost-plus contract approach or the more commercial LSP model, the ISS Program does not perform a payload risk classification, categorize launch vehicles by risk, or conduct certain oversight approvals such as making a decision to proceed or delay on the day of the launch. Prior to the CRS-1 contract award in 2008, the ISS Program reviewed LSP policies and purposefully adopted a tailored approach that reduced oversight requirements. Like LSP, contractors hired for ISS cargo missions are responsible for mission success but have fewer specific approvals than both LSP and traditional approaches. Additionally, because they are commercial launches, CRS missions are licensed through the Federal Aviation Administration (FAA) in contrast to other NASA launches.[20]

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16 The successor to the Hubble Space Telescope, the James Webb Space Telescope is designed to help understand the origin of the first stars and galaxies in the universe, the evolution of stars, and the formation of stellar systems. After multi-year delays that increased its life-cycle costs to $8.8 billion, the telescope is scheduled to launch on an Ariane 5 rocket from French Guiana in 2020.

17 Passed in the same year LSP was created, the Commercial Space Act allows launch services to be purchased through Federal commercial contracting regulations. Commercial Space Act of 1998, Pub. L. No. 105-303 (1998).

18 NASA Policy Directive (NPD) 8610.7, "Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions," January 31, 2008.

19 NPD 8610.7 and NPR 8705.4.

20 FAA licensing requirements do not apply to NASA launches like the Space Shuttle, Space Launch System, or LSP-procured commercial vehicles because they are carried out by the U.S. Government on its own behalf. 14 C.F.R. § 400.2(a). In contrast, the CRS-1 and CRS-2 cargo services procured by NASA require FAA approval because they are carried out by a commercial vendor who owns the launch vehicle and spacecraft.

In addition, instead of adopting all of LSP's risk management and technical oversight policies, the ISS Program set reduced requirements in the contracts and focused approvals on certification requirements for the spacecraft and cargo. If NASA does not receive adequate assurance that its cargo will be safe on a given mission, the Agency may delay the mission with no penalty to the Government.

Launch Vehicle Assessments

Through its insight authority in the CRS contracts, the ISS Program conducts a Launch Vehicle Assessment prior to each mission to determine if the risk of flying cargo on a given mission is acceptable. Unlike the LSP risk categorization of high, medium, or low for specific launch vehicle configurations, the CRS contracts do not apply these risk categories before conducting cargo missions. Instead, the ISS Program's Launch Vehicle Assessment summarizes launch risks, post-flight reviews from previous missions, and insight activities into contractor activities to determine whether to place cargo on the launch vehicle. Additionally, the contractor must provide launch vehicle designs and configuration change updates for each launch and focused Test-Like-You-Fly qualification reviews for propulsion, flight controls, software, and separation systems as needed.[21]

Spacecraft Certifications

In addition to the insight provisions for the launch vehicle, the contractor's spacecraft must meet all certification design requirements in the CRS contracts.[22] Specifically, NASA must approve contractor compliance with 444 requirements ranging from specific internal atmosphere ranges to broader safety requirements for avionics and navigation used to rendezvous with the ISS. NASA must also approve certification requirements associated with the loading and transport of cargo, including packing methods or power levels needed for science experiments.[23] Although each CRS mission is not given a payload risk classification (Class A through D) to identify the criticality of each mission, NASA does make decisions to limit risk by placing essential and one-of-a-kind cargo on particular launch vehicles.

The CRS-2 contract requires contractors to submit spacecraft and cargo transportation certifications for NASA approval as part of the initial ISS integration certification process. In addition to the approvals required before the contractor's first mission, the certification process requires the contractor to periodically report design and implementation progress. The CRS-2 contract does not require demonstration flights for any spacecraft, including the unproven Dragon 2 or Dream Chaser Cargo System, although it is noteworthy that under COTS both Orbital ATK and SpaceX conducted demonstration flights before their first CRS-1 missions.

Insurance Requirements

The FAA requires companies to purchase third-party liability insurance to cover potential damage to private property and injury to the public during launches, and property insurance for non-launch-related Federal Government property. The amount of insurance for each launch is set by the FAA with the Federal Government self-insuring for a portion of losses beyond this coverage. For CRS-1, NASA

[21] Test-Like-You-Fly requires launch vehicles to be tested in as-close-as-possible mission conditions to better understand and mitigate technical risks.

[22] Space Station Program (SSP) 50808, "International Space Station (ISS) to Commercial Orbital Transportation Services (COTS) Interface Requirements Document (IRD)," Revision F, September 2014.

[23] SSP 50833, "ISS Cargo Transport Requirements Document," Revision B, February 2015.

payloads are not insured by the contractor. Instead, in order to mitigate the risk of losing cargo, the Agency may withhold at least 20 percent of the overall mission payment when a failure occurs. For CRS-2, in addition to potentially withholding at least 20 percent of milestone payments, NASA requires the three contractors to purchase up to $100 million in property insurance to cover the value of the cargo in case of damage or loss.

Commercial Crew Requirements

Similar to its acquisition of commercial cargo services, NASA's Commercial Crew Program seeks to procure transportation to and from the ISS for up to four crew per mission using fixed-price contracts with modified oversight and insight requirements. In 2011, the Agency updated the human-rating certification requirements for Space Shuttle missions to streamline new requirements for commercial crew missions. In addition to meeting these requirements, spacecraft developed by Boeing and SpaceX to carry crew must meet the same vehicle interface certifications required for cargo missions.[24]

Status of CRS-1 Contracts

The selection of Orbital ATK and SpaceX in 2008 for the CRS-1 contract was the first time NASA utilized its new commercial contracting approach that incorporated less oversight and higher risk tolerance. For NASA, CRS-1 represented a risky procurement strategy with many unknowns – the launch vehicles and spacecraft were unproven and had not flown demonstration flights at the time of the contract award; the fixed-price contract approach was new for ISS cargo delivery services; and program management requirements were reduced for risk management, payload risk classification, and oversight and insight authorities.

Both companies experienced mission failures and schedule delays – issues that NASA managers said were expected given the complexities involved in producing new launch vehicles and spacecraft. Orbital ATK encountered the first CRS-1 failure when its third mission (Orb-3) failed seconds after liftoff on October 28, 2014.[25] Eight months later, SpaceX's seventh CRS-1 mission (SpX-7) failed during launch on June 28, 2015.[26] Another failure of the Falcon 9 launch vehicle in September 2016 during a static fire test for a non-NASA customer also impacted the CRS-1 schedule.[27]

Despite these setbacks, NASA officials generally view the CRS-1 contracts as successful, with roughly 45,000 kilograms (kg) of cargo delivered to the ISS from October 2012 through December 2017 and another 33,000 kg in upmass capability planned for delivery through the final CRS-1 mission in 2020. We reviewed the CRS-1 contracts and determined NASA has awarded 31 missions and contract modifications

[24] SSP 50808 and SSP 50833. Commercial crew vehicles must also meet (1) Crew Transportation System Design Reference Missions (CCT-DRM-1110), (2) ISS Crew Transportation Certification and Services Requirements Document (CCT-REQ-1130), (3) NASA's Crew Transportation Technical Standards and Design Evaluation Criteria (CCT-STD-1140), (4) NASA's Crew Transportation Operations Standards (CCT-STD-1150), and (5) Crew Transportation Technical Management Processes (CCT-PLN-1120).

[25] For more information about the Orbital ATK failure, see NASA OIG, "NASA's Response to Orbital's October 2014 Launch Failure: Impacts on Commercial Resupply of the International Space Station" (IG-15-023, September 17, 2015).

[26] For more information about the SpaceX failure, see NASA OIG, "NASA's Response to SpaceX's June 2015 Launch Failure: Impacts on Commercial Resupply of the International Space Station" (IG-16-025, June 28, 2016).

[27] The failure destroyed AMOS-6, a private communications satellite owned by Spacecom.

worth $5.93 billion, or an average cost of $191.3 million per mission.[28] Of these missions, SpaceX is scheduled to complete 20 with a total payment of $3.04 billion, or an average cost of $152.1 million per mission. Orbital ATK is scheduled to complete 11 missions with a total payment of $2.89 billion, or an average cost of $262.6 million per mission.[29] Through December 2017, NASA has spent $5.12 billion on CRS-1 activities and is projected to spend an additional $810 million through completion of the final cargo resupply mission in 2020.

Orbital ATK – Past CRS-1 Challenges

Challenges faced by Orbital ATK during CRS-1 include schedule delays and the failure of a 1970s Russian rocket engine the company modified for early CRS missions. NASA and Orbital ATK both determined a failed turbopump caused the Orb-3 failure that destroyed the rocket and $51 million in ISS cargo. The failure also resulted in $15 million in damage to the launch pad at the Wallops Flight Facility (Wallops) owned by the state of Virginia. In the NASA investigation of the failure, the Agency concluded that Orbital ATK could have better understood the turbopump design in the 40-year-old Russian engines it was using – modified and renamed AJ-26 engines – to identify and mitigate risks.[30] Orbital ATK's upgrade to its Antares 230 launch vehicle with newer RD-181 rocket engines after the Orb-3 failure took nearly 2 years. To meet its cargo resupply commitments in the interim, the company purchased three Atlas V rockets to launch its Cygnus spacecraft to the ISS.

SpaceX – Past CRS-1 Challenges

SpaceX also faced a variety of challenges during CRS-1 including volume restrictions for its Dragon 1 spacecraft and systems engineering concerns related to design changes to its Falcon 9 launch vehicle. Throughout CRS-1, NASA and SpaceX struggled to fully utilize Dragon 1's pressurized upmass capability of 3,310 kg due to the interior dimensions of the capsule, volume limitations, and the sizes and shapes of the various Cargo Transfer Bag Equivalents (CTBE).[31] For the 13 CRS-1 missions completed through 2017, the pressurized component of cargo has ranged from 450 kg (14 percent of the spacecraft's total upmass capability) to as much as 2,024 kg (61 percent of total upmass capability). The overall pressurized average for all completed missions was less than 50 percent.[32] If unpressurized upmass is included, past SpaceX CRS-1 missions have averaged about 2,200 kg in total upmass delivered or 66 percent of total upmass capability.

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[28] Total awards include per-mission pricing, contract modifications based on requirements changes, and payload integration costs. The average per-mission cost is a NASA OIG calculation derived by dividing the total awards by the total missions and do not reflect each contractor's competition sensitive and proprietary per-mission pricing.

[29] For SpaceX and Orbital ATK, the average prices-per-mission are NASA OIG calculations derived by dividing total contract awards by the number of missions; these figures do not reflect actual per-mission pricing.

[30] NASA, "NASA Independent Review Team: Orb-3 Accident Investigation Report (Executive Summary)," October 9, 2015. In contrast, Orbital ATK maintains the cause of the failure was a manufacturing defect stemming from the engine's original construction in Russia in the 1970s.

[31] Dragon 1 maximum combined pressurized and unpressurized upmass is 3,310 kg, which can be all pressurized, all unpressurized, or anywhere in between. Upmass is the cargo carried internally or externally on a spacecraft while pressurized upmass is carried within the spacecraft.

[32] Decisions by NASA can also impact full utilization of CRS spacecraft upmass capabilities. Large items with less mass, such as a spacesuit, can limit full upmass utilization for a mission while still providing significant value to ISS operations.

As a result of the SpX-7 failure, NASA lost $118 million in cargo, including a spacesuit and one of two international docking adapters required for crewed commercial spacecraft to dock with the ISS. The launch failure was traced to SpaceX's modification of its original second stage helium tank configuration to use a commercial-off-the-shelf rod end not designed to operate in cryogenic temperatures.[33] For the AMOS-6 failure, SpaceX changed its helium and liquid oxygen loading procedures using incorrect modeling and without extensive testing, resulting in undetected buckling of one of the second stage helium tanks that caused rapid depressurization during propellant loading. SpaceX responded to these failures by conducting extensive reviews, improving quality controls, and updating its processes for modifying rocket designs.

CRS-2 Selection and Capabilities

As a follow-on to the first round of commercial cargo resupply missions, in January 2016, NASA selected Orbital ATK, Sierra Nevada, and SpaceX for the CRS-2 contracts. Similar to its approach with CRS-1, NASA used the authority in the Commercial Space Act of 1998 to procure the CRS-2 missions as commercial items under the Federal Acquisition Regulation (FAR).[34] Additionally, NASA used an indefinite-delivery, indefinite-quantity (IDIQ), firm-fixed-price contract to maximize its flexibility while limiting risks of cost increases. An IDIQ contract allows the Government to compete and select contractors even though exact dates or quantities of future deliveries are not known when the contract is awarded. This approach is not unique to CRS – LSP also procures commercial launches through an IDIQ contract and each task order is subsequently competed among pre-approved contractors.

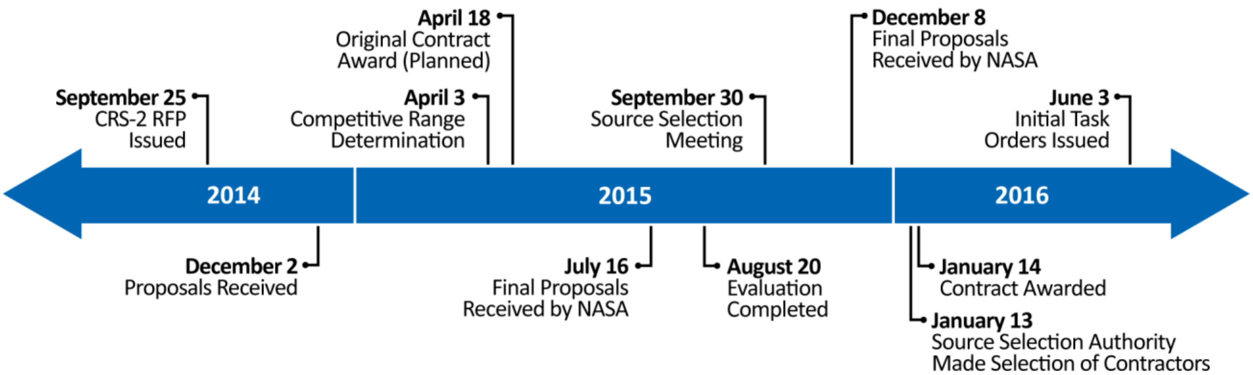
When NASA issued the CRS-2 request for proposal (RFP) in September 2014, it received interest from five companies – Lockheed Martin Corporation (Lockheed Martin), Boeing, Orbital ATK, Sierra Nevada, and SpaceX. NASA made a competitive range determination to remove Boeing and Lockheed Martin from the competition and further considered proposals from the three remaining companies.[35] Orbital ATK, Sierra Nevada, and SpaceX were awarded CRS-2 contracts in January 2016 with initial task orders awarded in June 2016. Figure 3 illustrates the timeline of key CRS-2 events.

[33] In March 2018, NASA released a public summary of LSP independent findings on the SpX-7 failure. NASA, "NASA Independent Review Team: SpaceX CRS-7 Accident Investigation Report (Public Summary)," March 12, 2018.

[34] Section 202(a), Pub. L. No. 105-303.

[35] Competitive range determinations identify proposals that have a reasonable chance of being selected for a contract award based on technical and price criteria. FAR 2.101(a)(7).

Figure 3: CRS-2 Proposal and Selection Timeline



Source: NASA OIG analysis of CRS-2 contract information.

Each of the three companies is guaranteed at least six cargo missions under the CRS-2 contract. As of December 2017, NASA had awarded $2.6 billion on three contracts with a combined, not-to-exceed value of $14 billion. NASA officials explained that selecting three companies rather than two for CRS-2 increases cargo capabilities and ensures more redundancy in the event of a contractor failure or schedule delay.

CRS-2 Contractor Capabilities

Table 1 outlines capabilities for each CRS-2 contractor, including pressurized upmass, unpressurized upmass, returned downmass, and disposed downmass. Pressurized cargo is accessible inside the spacecraft by ISS crew while unpressurized cargo is exposed to the vacuum of space and can only be accessed externally by the ISS robotic arm. Returned downmass lands on Earth's surface inside the spacecraft and is accessible within hours. Disposed downmass burns up during atmospheric reentry. Docking occurs when a spacecraft rendezvous with the ISS under its own power while berthing requires the Station's robotic arm to grab the approaching spacecraft.

Table 1: CRS-2 Contractor Capabilities

	Orbital ATK	Sierra Nevada	SpaceX
			
Spacecraft	Cygnus (options for stretched or unpressurized versions)	Dream Chaser Cargo System	Dragon 2 (option for Dragon 1)
Launch Vehicle	Antares 230 (option for Atlas V)	Atlas V (other vehicles possible after second launch)	Falcon 9 (option for previously flown)
Berthing or Docking	Berthing	Berthing (option for docking)	Docking (option for berthing)
Useable Pressurized Volume	12.9 m^3	17.7 m^3 Dream Chaser: 7.1 m^3 Cargo Module: 10.6 m^3	8.6 m^3
Upmass Per Mission (Total kg)	3,754 kg	5,500 kg [a]	3,307 kg
Upmass Pressurized (total available)	3,754 kg	5,000 kg	2,507 kg
Upmass Unpressurized (total available)	0	1,500 kg	800 kg
Downmass	Cygnus: 3,754 kg (disposed)	Dream Chaser: 1,750 kg (returned) Cargo Module: 3,250 kg (disposed)	Dragon 2: 2,507 kg (returned) Trunk: 800 kg (disposed)

Source: NASA OIG analysis of ISS Program information.

Note: m^3 = cubic meters.

[a] The total upmass for the Dream Chaser cannot exceed 5,500 kg. For example, if the pressurized upmass is full at 5,000 kg, only 500 kg in unpressurized cargo can be flown.

Orbital ATK

Orbital ATK will use its Cygnus spacecraft to deliver up to 3,754 kg of upmass and disposal downmass inside its pressurized cargo module.[36] The Cygnus will launch aboard an Antares 230 launch vehicle and berth with the ISS. The Cygnus does not have unpressurized upmass capabilities outside its pressurized cargo module, but Orbital ATK plans to add hardware mounts outside the spacecraft to attach unpressurized downmass for disposal.

[36] Orbital ATK proposed other options for a larger Cygnus spacecraft capable of carrying up to 4,954 kg on an Atlas V launch vehicle and an unpressurized Cygnus variant capable of carrying up to 2,700 kg of unpressurized upmass. As of January 2018, NASA has not chosen to pursue either option.

Sierra Nevada

Sierra Nevada plans to use the Dream Chaser Cargo System to deliver a total upmass of 5,500 kg, which includes a mix of up to 5,000 kg of pressurized upmass and up to 1,500 kg of unpressurized upmass to the ISS to meet the total upmass capability. Sierra Nevada's cargo delivery system combines the Dream Chaser, initially designed for the commercial crew program as a reusable lifting body spacecraft capable of landing on airport runways, and its new cargo module, a pressurized attachment to the Dream Chaser. Downmass capabilities include 1,750 kg of return downmass in the Dream Chaser and 3,250 kg of disposal downmass inside the cargo module. The spacecraft is capable of either docking or berthing with the ISS, but a new cargo module with ISS docking or berthing hatch is required for each mission because they burn up during atmospheric reentry. For at least its first two CRS-2 missions, Sierra Nevada plans to use an Atlas V to launch the Dream Chaser Cargo System, but the company is considering alternative launch vehicles for subsequent missions.

SpaceX

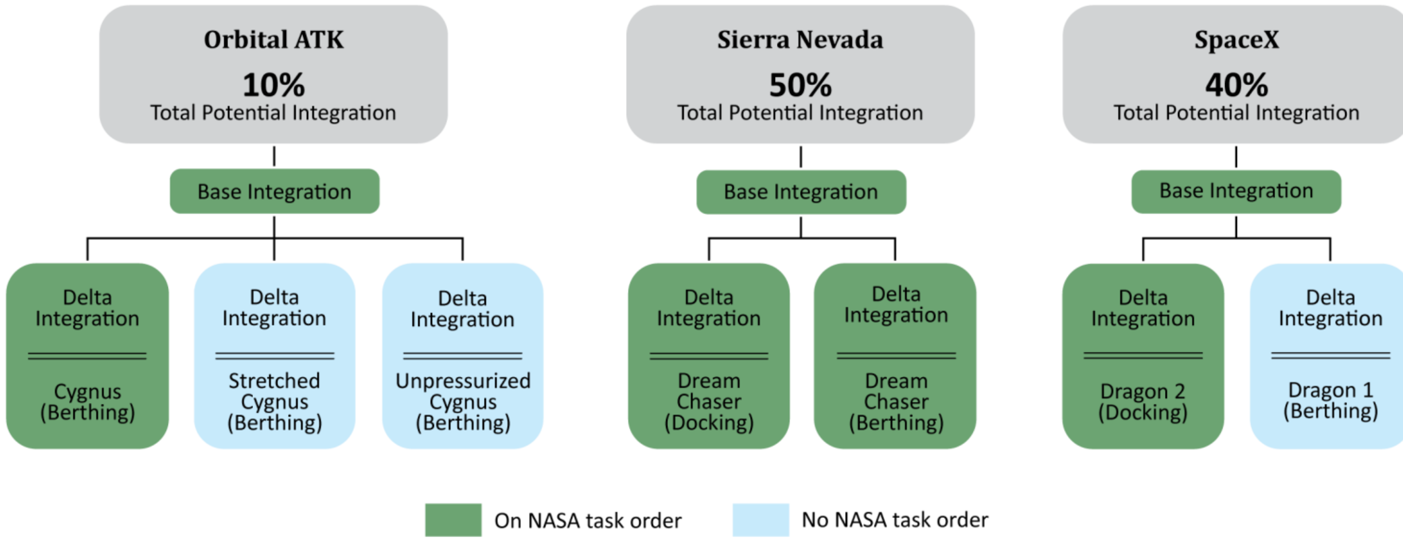
SpaceX plans to launch its Dragon 2 spacecraft aboard its Falcon 9 launch vehicle to deliver up to 3,307 kg of upmass. The Dragon 2 was initially designed for crew missions, but with modifications, the spacecraft can also be used to transport cargo. The vehicle has a pressurized capsule that can carry up to 2,507 kg of upmass and returned downmass along with an external trunk below the capsule that can carry up to 800 kg of additional unpressurized upmass and downmass. For the CRS-2 contract, SpaceX also proposed using the Dragon 1 spacecraft used for its CRS-1 missions, but NASA selected the Dragon 2 due to lower integration costs and per-mission pricing. However, the docking configuration for Dragon 2 has limitations regarding the size of the hatch such that larger items including spacesuits and large cargo bags cannot fit.[37]

CRS-2 Integration Costs

Task orders for the CRS-2 contracts are divided into two types: initial ISS certification that includes all potential spacecraft integration options, and at least 18 individual cargo missions. Initial integration certification pricing is divided into two parts – base integration, which is paid one time regardless of the spacecraft configuration, and delta integration, which is paid when additional spacecraft configuration options are selected by NASA. For example, in 2016, NASA began paying the base and delta integration for the SpaceX Dragon 2 spacecraft to dock with the ISS, but the Agency has not awarded a task order to develop the Dragon 1 berthing option so no delta integration funding has been obligated for that capability. Of the total available money for potential spacecraft integration options under the CRS-2 contracts, approximately 10 percent is available for three Orbital ATK configuration options, 40 percent for two SpaceX configurations, and the remaining 50 percent for two Sierra Nevada configuration options. Figure 4 details all integration options and identifies the integration activities currently on task order.

[37] To address this limitation, SpaceX is proposing to unpack large cargo bags inside the Dragon or only carrying spacesuit parts that fit through the docking hatch. However, such alternatives will likely require additional crew time and complicate ISS spacecraft logistics.

Figure 4: Allocation of Potential CRS-2 Integration Funding by Contractor



Source: NASA OIG analysis of ISS Program information.

As of December 2017, NASA has awarded roughly $700 million in task orders to pay integration costs associated with Orbital ATK's Cygnus berthing capability, Sierra Nevada's Dream Chaser docking and berthing capabilities, and SpaceX's Dragon 2 docking capability.[38] Prior to their first CRS-2 missions, each contractor must complete seven initial integration certification milestones over two and a half years, with at least the first milestone completed before the ISS Program will grant authority to proceed for the company's first mission. The three contractors are leveraging past work conducted under the CRS-1 contract and Commercial Crew Program in order to complete these milestones. As of December 2017, Orbital ATK completed five milestones and was awarded its first three CRS-2 missions, the first of which is scheduled for October 2019; Sierra Nevada completed three integration milestones and was awarded its first CRS-2 mission for September 2020; and SpaceX completed four integration milestones and was awarded its first four CRS-2 missions with the first mission scheduled for August 2020.

NASA pays each contractor a fixed-price for individual cargo resupply missions through seven milestone payments that can vary by timing or percentage. However, NASA will not pay more than 80 percent of mission costs prior to launch and final milestone payments are not made if cargo is not delivered and the mission is not completed. Individual mission prices include payload loading and processing, launch services, cargo delivery, and disposal or return of science experiments and cargo from the ISS. Changes in requirements, technical deficiencies, or schedule delays may result in an equitable adjustment in the contract.[39]

[38] The $700 million in integration task orders was awarded as of December 2017 and does not reflect the respective percentages of total available integration costs listed in Figure 4 for all three contractors. Additional funds remain available for the option of added integration costs in the future. Payments for the delta integration for Sierra Nevada's docking capability were on hold as of July 2017 until the Agency decides whether to proceed with that capability.

[39] Under an equitable adjustment, either party may be compensated for changes outside the agreed-upon requirements, price, or schedule. If the contractor is delayed beyond a certain period or cannot technically perform, NASA may negotiate for price reductions or additional benefits. Likewise, if NASA changes the certification requirements, delays a mission, or receives additional benefits, the contractor may negotiate for additional payments, a more flexible schedule, or a reduced capability on a future mission.

CRS-2 Met Acquisition Requirements and Enhanced Mission Capabilities but Opportunities Remain for Cost Savings Through Competition

We found NASA followed Federal procurement rules during the CRS-2 solicitation and award process to review price reasonableness and make competitive range determinations for all five proposals. Moreover, in this follow-on cargo resupply contract, NASA applied lessons learned from the CRS-1 contract to acquire more robust cargo capabilities, including a density requirement to maximize each vehicle's upmass, transport flexibility using three different spacecraft launching on at least three different launch vehicles, insurance coverage for NASA payload losses, and clearer Government insight into contractor (or subcontractor) activities. While we found these changes positive, we also determined that NASA could obtain additional value by competing future cargo missions among the three contractors and using the contract's On-Ramp clause to allow new entrants to compete.

CRS-2 Source Selection Complied with Federal Regulations

NASA used the IDIQ, firm-fixed-price contract structure to maximize flexibility while limiting risks of cost increases. For all five submitted CRS-2 proposals, NASA made price reasonableness and competitive range determinations. NASA then evaluated remaining proposals using the source evaluation process to determine which proposals provided the best value to the Agency.

- *Price Reasonableness.* According to the FAR, a proposal's price is deemed reasonable if there is adequate competition.[40] Because there were five initial offers, the CRS-2 proposals met the threshold definition of price reasonableness under Federal contracting rules. Additionally, NASA compared the proposals to CRS-1 and COTS prices for past development, integration, and mission prices.
- *Competitive Range Determination.* NASA next determined that proposals from Lockheed Martin and Boeing were not acceptable because they did not meet technical requirements. As a result, the companies were removed from the competition, leaving Orbital ATK, Sierra Nevada, and SpaceX to submit final CRS-2 proposals.[41]

[40] FAR 15.404.1(b)(2).

[41] Agencies shall evaluate all proposals in accordance with 15.305(a), and, if discussions are to be conducted, establish the competitive range. FAR 15.306(c)(1). After evaluating all proposals in accordance with 15.305(a) and paragraph (c)(1) of this section, the contracting officer may determine that the number of most highly rated proposals that might otherwise be included in the competitive range exceeds the number at which an efficient competition can be conducted. Provided the solicitation notifies offerors that the competitive range can be limited for purposes of efficiency (see 52.215-1(f)(4)), the contracting officer may limit the number of proposals in the competitive range to the greatest number that will permit an efficient competition among the most highly rated proposals (10 U.S.C. 2305(b)(4) and 41 U.S.C. 3703). FAR 15.306(c)(2).

- *Source Evaluation Process.* The objective of source selection in Federal contracting is to choose the proposal or proposals that represent the best value to the Federal Government.[42] Each CRS-2 proposal was evaluated using three factors: price, mission suitability, and past performance on recent relevant contracts. Price was the most important factor, reflecting approximately 50 percent of the criteria used to make a determination. Mission suitability and past performance combined accounted for the other criteria used, with mission suitability more important than past performance. NASA used a trade-off process to select contract awards not based on the lowest price or the highest technical score, but instead representing the best overall value to the Agency.[43] Using this trade-off process, NASA evaluated and ranked each proposal as shown in Table 2.

Table 2: Final Proposal Evaluation Offers

CRS-2 Offerors	50 Percent of Criteria: Evaluated Price[a]	50 Percent of Criteria: (Mission Suitability > Past Performance)	
		Mission Suitability[b]	Past Performance[c]
Orbital ATK	Lowest price	880	High
Sierra Nevada	Mid-price	879	High
SpaceX	Highest Price	922	High
Boeing	Excluded from the competitive range		
Lockheed Martin	Excluded from the competitive range		

Source: ISS CRS-2 Source Selection Statement.

[a] 50 percent is an approximation. Evaluated prices for proposals were calculated for each mission type using the following formula: integration costs plus the number of missions to reach 7,500 kg or half of the ISS annual upmass needs for 6 years.
[b] Total possible mission suitability score is 1,000 points.
[c] NASA reviewed each contractor's past performance on recent relevant contracts to determine a confidence level of very high, high, moderate, low, very low, or neutral.

Using the criteria, NASA selected final offers from Orbital ATK, Sierra Nevada, and SpaceX in January 2016, determining the proposals were reasonable according to the FAR, were within the competitive range, and represented the best value to the Agency.

CRS-2 Increases Mission Capabilities and Flexibility

NASA's procurement approach to the CRS-2 contract incorporated improvements based on lessons learned during the CRS-1 contract. The improvements will provide better cargo capabilities with greater upmass requirements and a density requirement to maximize each vehicle's upmass capability, transport flexibility using three different spacecraft launching on at least three different launch vehicles, insurance coverage for NASA payload losses, clearer Government insight into contractor (or subcontractor) activities, and additional cargo capabilities for time-sensitive research experiments.

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[42] FAR 2.101 explains that best value means "the expected outcome of an acquisition that, in the Government's estimation, provides the greatest overall benefit in response to the requirement."

[43] As part of the process, NASA determined the overall value of each of the final three proposals by reviewing evaluated prices, mission suitability scores, and past performance confidence levels. The CRS-2 Request for Proposal VII.A.1 applied the trade-off process as described in FAR 15.101-1 for the source selection. The trade-off process allows the selection of a proposal even if it is not the lowest-priced offeror or the highest technically rated offeror "when it may be in the best interest of the Government." FAR 15.101-1.

The CRS-2 contract set new per-mission pressurized upmass requirements in an effort to decrease the number of required cargo missions to resupply the ISS, thereby reducing the burden on the crew and allowing more time for research. With Orbital ATK averaging 2,723 kg and SpaceX averaging 1,569 kg of pressurized upmass for past CRS-1 missions through 2017, NASA required more frequent missions to maintain necessary supplies and equipment on the Station. In addition, berthing spacecraft, unloading cargo, and unberthing spacecraft consumed a significant amount of crew time.[44] Therefore, CRS-2 contracts require spacecraft capable of delivering 2,500 kg to 5,000 kg of pressurized cargo to reduce the number of cargo flights, which in turn reduces the time required by Station crew to load and unload cargo resupply spacecraft. Current projections assume an average of 3,754 kg of pressurized upmass per mission, almost double the amounts actually delivered on CRS-1. As a result, NASA plans to fly fewer cargo missions to meet ISS needs.

In response to spacecraft volume limitations encountered during CRS-1 missions, NASA added a density requirement to the CRS-2 contract to help the Agency maximize the use of contractor capabilities. According to Agency officials, this requirement was based on NASA's historical cargo packing densities. For CRS-2, each of the contractor's vehicles must be certified to provide 3.44 cubic meters of useable volume for every 1,000 kg of pressurized upmass.[45] Once the contractors demonstrate adherence to this requirement, NASA is responsible for managing the cargo manifest in accordance with each vehicle's capabilities and the contractors are responsible for efficiently packing the vehicle to fully utilize its capabilities. Throughout CRS-1, cargo vehicles usually reached volume limits before they reached the limits of the mass they could carry. For example, despite a total upmass capability of 3,310 kg, the SpaceX Dragon 1 averaged only 1,569 kg of pressurized upmass in its first 6 years of cargo flights and, if only missions after the second are included, this average increases to 1,755 kg of pressurized upmass.[46]

NASA also added insurance requirements for CRS-2 missions to mitigate potential losses from launch failures. As a result of CRS-1 mission failures, NASA lost cargo worth $51 million on Orbital ATK's third cargo flight and $118 million on SpaceX's seventh mission. Contractors are now required to purchase up to $100 million in insurance to cover damage to Government property and cargo incurred during the operation of the contractor's vehicles.

In addition, NASA clarified its insight requirements into subcontractor activities. After Orbital ATK's Orb-3 failure, NASA's independent investigation found the ISS Program had limited insight into the AJ-26 engine's turbopump design provided by an Orbital ATK subcontractor because of proprietary restrictions.[47] We identified similar concerns about the limited insight in AJ-26 engines in our past reports.[48] The clarification of NASA's right to review subcontractor design, operation, and hardware information will increase NASA's insight into contractors' activities to reduce technical risks.

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[44] To berth a vehicle, an ISS crew member must attach the ISS robotic arm to the spacecraft, guide it to a berthing hatch, and screw multiple bolts around the hatch to seal the connection between the spacecraft and the ISS.

[45] With the density requirement, each spacecraft must be able to use at least 65 Cargo Transfer Bag Equivalents (CTBE) per 1,000 kg of pressurized cargo. One CTBE holds 0.053 cubic meters. NASA uses CTBEs as a unit of measurement for different types of cargo to standardize spacecraft packing. For example, SpaceX's Dragon 2 must be capable of fitting at least 163 CTBEs or similar cargo to hold 2,507 kg of pressurized upmass.

[46] The average total upmass for Dragon 1 was 2,189 kg for all past flights and 2,467 kg for all missions after the second flight, which include both pressurized and unpressurized cargo. Program officials asserted CRS-1 upmass averages continue to increase due to packing efficiencies and other cargo integration improvements.

[47] Orb-3 Accident Investigation Report.

[48] IG-15-023 and IG-16-025.

Further, NASA modified cargo loading and unloading requirements to increase both cargo manifest flexibility and the number of science research payloads. For all CRS-2 launches, contractors must provide a late load capability for a small portion of cargo within 24 hours of launch and, if the launch is delayed, contractors must be able to easily access, remove, and reload (known as refresh) any sensitive cargo and launch as soon as 24 hours after the previous launch attempt. While the CRS-1 contract did not originally have a requirement to refresh time-sensitive cargo and science payloads within 24 hours, post-award negotiations resulted in incorporation of this capability into both CRS-1 contracts at 24 to 48 hours. For returned downmass capabilities, NASA requires cargo be accessible within 3 to 6 hours of landing to unload time-sensitive science experiments. Similar to late load capabilities, returned downmass capabilities were not initially required for CRS-1, but later contract modifications required time-sensitive cargo be accessible within 48 hours of landing rather than the 3 to 6 hours required by CRS-2.

Besides these features, the CRS-2 contract also increases the number and type of commercial transportation capabilities available to NASA. For example, with the addition of Sierra Nevada, NASA will have three different spacecraft launching on at least three different launch vehicles to provide flexibility in the event of a failure or delay. NASA is also gaining increased cargo capabilities from each contractor with the average total upmass capability per mission increasing more than 1,000 kg as a result of increased upmass capabilities from Orbital ATK and Sierra Nevada. SpaceX's total upmass capability from Dragon 1 to Dragon 2 did not change but design modifications increased the useable pressurized cargo volume by roughly 30 percent. Moreover, returned downmass capabilities from SpaceX and Sierra Nevada provide multiple options to transport important science research back to Earth. Orbital ATK's Cygnus spacecraft does not have this return capability but an external payload disposal capability was added for CRS-2.

Potential Savings Available Under CRS-2 Contracts

While CRS-2 provides improved cargo capabilities and greater flexibility compared to CRS-1, we found that once the contractor meets the minimum six flights, NASA could potentially save money by competing future missions. Both CRS-1 and CRS-2 contracts require NASA to provide fair opportunity to compete for task orders among all contractors unless the Agency can justify awarding the mission to a specific contractor.[49]

Despite this competition requirement, as of December 2017, NASA has approved sole-source awards for all CRS-1 and CRS-2 task orders using two of the four allowable exceptions – the necessity to meet minimum purchase guarantees set by CRS contracts and the unique capabilities of a contractor's vehicle – and therefore, has not competed any of the 31 CRS-1 cargo missions or the first 8 CRS-2 missions.[50] Using exceptions to the competition requirement in order to meet minimum purchase guarantees appears reasonable; however, with the addition of a third contractor under CRS-2, NASA has more flexibility to compete task orders and should be better positioned to avoid consistently using sole-source

[49] CRS-1 and CRS-2 are IDIQ commercial services contracts and Federal procurement law generally requires all task orders be competed between pre-selected IDIQ contractors. Further, NASA must justify awarding a task order as a sole-source award not subject to competition.

[50] Both CRS-1 and CRS-2 contracts require NASA provide each selected contractor fair opportunity to compete for each task order unless (1) time is of the essence and competition would result in unacceptable delays, (2) only one contractor is capable of providing a unique service such as returned or disposed downmass, (3) sole-source awards are issued in the interest of efficiency and economy, or (4) it is necessary to meet minimum purchase guarantees.

awards. In comparison, LSP competes its launch opportunities for science missions among pre-qualified IDIQ contractors to maximize value to the Agency. This approach enabled LSP to obtain substantial savings beginning in 2013 when SpaceX's Falcon 9 was qualified to compete against ULA's Atlas V for launch services.[51] See Appendix C for more information on Agency savings as a result of LSP task order competition.

Separate from the competition requirement among existing contractors, the CRS-2 contract has an On-Ramp clause that allows NASA to recompete contracts with its current contractors and potential new contractors for any missions beyond the six guaranteed missions for its three contractors.[52] If the pricing or capability proposals from current or new contractors are no better than the existing CRS-2 options, the Agency can continue ordering missions from its existing contracts.

As of December 2017, NASA has purchased initial integration services for four vehicle configurations and eight CRS-2 missions worth $2.6 billion, or 19 percent of the contracts' total potential value of $14 billion. Using current flight cadence projections, at least three missions could be competed through the CRS-2 contract's existing competition requirements or the On-Ramp clause prior to the Station's potential retirement in 2024. However, if the ISS is extended through 2028, NASA will have the opportunity to compete up to 19 additional cargo missions if four missions per year are assumed.

We believe NASA also has the potential to obtain substantial savings under CRS-2 if Sierra Nevada uses a commercial launch vehicle other than the Atlas V. Specifically, Sierra Nevada has committed to using Atlas V launch vehicles for its first two cargo resupply missions but the company is considering alternative launch vehicles currently under development to lower their costs for future NASA missions. Public statements from launch vehicle providers have proposed prices ranging from roughly $90 million to $120 million per launch. While the Atlas V is highly reliable with a 100 percent success rate after more than 70 launches, it has a list price of $175 million for the configuration needed for Sierra Nevada's missions.[53] Because Sierra Nevada's cargo flights are procured under a fixed-price contract, any reduction in its launch costs accrue to Sierra Nevada's benefit. However, the CRS-2 contract allows NASA to renegotiate mission pricing if a contractor uses an alternative vehicle. Any renegotiation would need to be finalized by early 2019 should Sierra Nevada plan to use an alternative launch vehicle for its third CRS-2 mission, which could occur as early as 2022. NASA's CRS-2 contract with Orbital ATK has similar contract language to negotiate lower per-mission prices to reflect cheaper launch costs if the company uses ULA's Vulcan launch vehicle instead of the Atlas V.[54]

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[51] Agency officials asserted that LSP was able to obtain substantial savings through task order competition due to the ISS Program's approach to commercial crew and cargo transportation capabilities. Absent the COTS and CRS awards, the Falcon 9 would likely not be qualified to compete against the Atlas V.

[52] Clause A.II.6 for all three contracts. CRS-1 had a similar On-Ramp provision that NASA never implemented.

[53] The ULA website, rocketbuilder.com (last accessed October 2, 2017), provides general pricing information for the Atlas V through Fall 2019. However, Sierra Nevada and other companies may negotiate Atlas V launch services at rates different than those advertised.

[54] As part of the CRS-2 contract, Orbital ATK proposed using the Atlas V launch vehicle to transport a stretched Cygnus spacecraft capable of carrying almost 5,000 kg to the ISS. NASA has not initiated a task order for development or ISS certification of this option, but the Agency could instead seek to negotiate discounts if Orbital ATK sought to use a Vulcan launch vehicle.

NASA IS TAKING STEPS TO REDUCE HIGHER CARGO RESUPPLY COSTS UNDER CRS-2

While CRS-2 provides NASA with additional capabilities, budget estimates show the contract may deliver less cargo overall than CRS-1 at greater costs. Specifically, 2016 budget estimates made after the contract award but before any task orders were issued showed CRS-2 would be roughly $400 million more expensive than CRS-1 and deliver about 6,000 kg less upmass.[55] Based on the assumptions at that time, the CRS-2 contract would cost at least $6.3 billion for 21 missions through 2024.[56] In addition, per-kilogram pricing of upmass capability for CRS-2 is estimated to increase by 14 percent compared to CRS-1. Further, when compared to the cost of each contractor's final CRS-1 mission, SpaceX's average pricing per kilogram will increase approximately 50 percent under CRS-2 while Orbital ATK's average per-kilogram pricing will decrease by roughly 15 percent. By December 2017, 8 of the 21 planned CRS-2 missions had been awarded, and while actual task order prices are approximately $50 million less than the original 2016 projections due to flight cadence adjustments, overall CRS-2 costs are still projected to be roughly $350 million higher than CRS-1. Table 3 compares CRS-1 contract values based on currently awarded task orders and CRS-2 projected budget estimates based on 2016 ISS Program budget assumptions.

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[55] Budget estimates are impacted by changes to NASA's assumed flight cadence, ISS upmass and downmass needs, and the number of missions per year for each contractor. To determine initial CRS-2 estimated costs, we took NASA's projected flight cadence for each contractor, applied per-mission pricing based on the number of missions each year, and added integration costs already awarded. Because task orders were not awarded at the time of the flight cadence assumptions in 2016, the cost projections are likely to change in the future as more missions are ordered.

[56] According to Program officials, CRS-2 will save the ISS Program operational resources by reducing the number of flights to the Station from 31 to 21, or 32 percent, while providing similar amounts of pressurized upmass.

Table 3: CRS-1 Costs Compared to Initial CRS-2 Budget Estimates in 2016

Key Contract Metrics	CRS-1 Costs (All Task Orders Awarded)	Initial CRS-2 Cost Estimates in 2016 (Prior to Task Order Awards)
Years of Missions	5–7 years	5–6 years
Total Contract Costs	$5.93 billion (Awarded)	$6.31 billion (Projected)
Launches	31 (Awarded)	21 (Projected)
Average Cost Per Flight	$191.3 million (Awarded)	$300.6 million (Projected)
Per-Mission Average Upmass Capability	3,025 kg (Estimated)	4,178 kg (Projected)
Total Pressurized Upmass Capability	79,200 kg[a] (Capability, Not Delivered)	78,800 kg (Projected)
Total Upmass Capability	93,800 kg (Estimated)	87,900 kg (Projected)
Cost Per Kilogram	$63,200 (Estimated)	$71,800 (Projected)
Cost Per Kilogram Increase from CRS-1	-	+14% (Projected)

Source: NASA OIG analysis based on CRS-1 task orders; ISS Program information; and fiscal year 2018 Planning, Programming, Budgeting, and Execution assumptions with flight cadences.

Note: Awarded numbers are already contracted through task orders. Estimated values are based on awarded task orders. Projected values are OIG projections based on initial budget assumptions prior to any task order awards.

[a] No past SpaceX mission has exceeded 2,100 kg of pressurized upmass. Accordingly, we set the Dragon 1 pressurized upmass capability to 2,500 kg to conservatively match the contractual limit for downmass returning to Earth.

In light of these cost projections, the ISS Program is currently studying ways to reduce CRS-2 costs without reducing the number of total missions flown. In October 2017, the ISS Program Planning and Control Office (the group that conducts budget analysis) shared proposed changes to the Program's cargo resupply mission cadence to potentially reduce total costs by about $300 million by taking advantage of additional discounts for flying multiple missions in a year with individual contractors. If adopted, such revisions could reduce the average price per mission by $12 million and the average price per kilogram from $71,800 to $68,800. However, this is still 9 percent higher than the CRS-1 per-kilogram price and roughly 50 percent higher per mission. At the time of our review, Program officials explained the proposal is not yet part of the Agency's formal flight plans and will only be formalized when task orders are awarded to each contractor. Nonetheless, by the end of 2017, NASA had ordered eight CRS-2 missions that matched this proposal and, if the ISS Program continues to follow the proposed flight cadence, total CRS-2 costs could be reduced from $6.31 billion to $6.05 billion. It remains to be seen if the proposal from the ISS Program's budget office will be followed on the remaining 13 CRS-2 missions.

Cost Drivers for Increased CRS-2 Prices

Higher costs for CRS-2 missions are primarily driven by three factors: (1) increased prices from SpaceX, (2) the selection of three contractors instead of two, and (3) integration costs of at least $700 million.

Increased SpaceX Prices

Using current flight projections for CRS-2, SpaceX's average price per kilogram increased by 50 percent compared to its final CRS-1 mission price. In comparison, Orbital ATK's average per-kilogram pricing decreased by roughly 15 percent from its last CRS-1 mission. SpaceX officials said its increased prices are due to new CRS-2 contract terms that required a redesign of the spacecraft's interior to increase the useable cargo volume by 30 percent, longer duration missions, accelerated cargo loading and unloading timeframes, and quicker access to time-critical research cargo after the Dragon 2 returns to Earth. They also indicated that their CRS-2 pricing reflected a better understanding of the costs involved after several years of experience with cargo resupply missions. Further, they said their proposed prices took into account the uncertainty at the time of providing fixed per-mission pricing without knowing whether NASA wanted them to fly the Dragon 1 or Dragon 2, which would require keeping open two production lines. Other factors, such as the new requirement for contractors to carry up to $100 million worth of insurance per flight and reduced discounts due to fewer missions flown contributed to SpaceX's increased CRS-2 pricing.

Selection of Three Contractors

We found NASA – prior to the CRS-2 award – did not determine the total financial impact of selecting three contractors instead of two. Rather, officials conducted a limited budget feasibility analysis outside the Source Evaluation Board (the Board) to determine if the ISS Program could afford to select three contractors.[57] Given the limitations of this analysis to determine the cost impact of choosing three contractors instead of two, we applied the same pricing models the Board used to evaluate CRS-2 contractor pricing proposals.[58] Using this methodology, we independently determined the Program's selection of three contractors was more expensive than most two-contractor options. In particular, half of the evaluated prices for the two-contractor options were several hundred million dollars less costly than selecting the cheapest three-contractor option.

NASA officials readily acknowledge their decision to choose three contractors rather than two for CRS-2 was the more expensive option. However, they told us the overall value of the redundancy provided by a third contractor, coupled with obtaining a second contractor that could return downmass and added spacecraft upmass capabilities, outweighed the potential cost savings of choosing two contractors.

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[57] In this budget analysis, NASA only utilized two scenarios when reviewing the potential annual costs: one in which all three contractors are selected and the other in which only Orbital ATK's Cygnus and SpaceX's Dragon 1 spacecraft are considered. The analysis did not compare the three-contractor options with other two-contractor options like the Cygnus and Dragon 2 or Cygnus and Dream Chaser – both of which were significantly cheaper than the two-contractor option of the Cygnus and Dragon 1 spacecraft.

[58] All of these calculations apply the same price evaluation methodology used by the Board to rank contractor proposals prior to the CRS-2 award except the formula was adjusted for three contractors. The Board's methodology assumed the full upmass requirements for the 6-year contract period (90,000 kg) will be utilized and divided evenly. The calculations do not factor in subsequent cost changes as a result of reduced upmass assumptions or shifts in flight cadence to optimize discounting.

The primary drivers for the increased overall costs when using three contractors are reductions in discounting for multiple missions a year and extra integration costs. Specifically, the selection of three contractors reduced the number of cargo resupply missions available for each contractor, thereby minimizing the potential benefit to NASA of price discounting for multiple missions in a year contained in the CRS-2 contracts. For example, based on our analysis of the contracts, we believe Sierra Nevada proposed a substantial discount for multiple missions a year but the selection of three contractors reduced the need for NASA to rely on individual contractors for multiple cargo resupply flights in the same year.[59] Orbital ATK and SpaceX also provided discounts for multiple missions in their proposals and are similarly impacted by NASA's decision to apportion cargo missions to three rather than two contractors. To offset these increased costs, NASA officials plan to purchase multiple missions per year from the same contractor whenever technically feasible to take advantage of the discounted pricing to save on total CRS-2 costs.

For the fixed-price CRS-2 contract award, NASA was not required to select the cheapest bidders (even though pricing was approximately 50 percent of selection criteria) but rather the proposals that provided the best value to the Agency. We believe a more comprehensive analysis to weigh the additional capabilities of three contractors against potential savings of selecting two contractors due to multiple mission discounting and less integration costs could have better informed the Agency's decision-making process for the CRS-2 contract.

Integration Costs

As of December 2017, NASA has awarded approximately $700 million for CRS-2 integration costs for Orbital ATK's berthing Cygnus, Sierra Nevada's berthing and docking Dream Chaser, and SpaceX's docking Dragon 2 configurations.[60] While similar to the amount of money spent on COTS, NASA's integration payments for CRS-2 include only spacecraft development and not launch vehicle development or demonstration flights as was the case during COTS.

In our judgment, NASA prematurely awarded certain integration costs to Sierra Nevada. We found that even though NASA plans to initially use a berthing option with the Dream Chaser, Sierra Nevada has received $4.4 million for the first three integration milestones to develop a docking configuration for its spacecraft to meet ISS certification requirements.[61] ISS Program officials told us that in an effort to reduce potential delays, NASA approved this additional work to ensure the basic spacecraft design could accommodate docking missions if they are purchased in the future. However, with awards to Sierra Nevada for base integration and development of the berthing configuration, we question NASA's decision to fund both the docking and berthing options simultaneously when the Agency only plans initially to use the vehicle's berthing version. Given the inherent risk of an unproven spacecraft and lack of demonstration flight, we believe NASA should have deferred Sierra Nevada's docking integration costs until after its first successful CRS-2 mission. See Appendix D for more details on our questioned cost calculation.

[59] See Table 6 for more information on how the assumption of two contractors during the RFP instead of three impacted the evaluated pricing due to changes in discount rates.

[60] While there are no current plans to do so, NASA may issue additional task orders to complete ISS certification for other configurations: Orbital ATK's extended Cygnus with an Atlas V launch vehicle, Orbital ATK's unpressurized cargo Cygnus variant, SpaceX's Dragon 1, and a fully complete Sierra Nevada docking version of the Dream Chaser.

[61] The ISS Program awarded funds to cover only the first three integration milestones for the docking option. Integration milestones 4 through 7 may be ordered at a later, mutually agreed upon date.

We also found the Board was unable to perform a complete comparative analysis of the overlap of shared ISS certification requirements paid separately to SpaceX through CCtCap and CRS-2 integration milestone payments. At the Board's request, SpaceX provided detailed itemized pricing for CRS-2 integration activities during the proposal process, but the CCtCap contract did not have this level of detail which limited the Agency's ability to detect potential overlaps and duplicative work. Despite this limitation, the Board reviewed SpaceX's proposed CRS-2 integration activities and deemed the proposed prices and actions generally reasonable. By its first CRS-2 mission scheduled in August 2020, SpaceX will have received $1.85 billion towards development and certification of both the crewed Dragon 2 spacecraft and modifications for the cargo version.[62] Of the CRS-2 integration activities required to certify the Dragon 2 cargo configuration, approximately 30 percent will be provided through documentation already completed to certify the crewed Dragon 2 configuration. In our judgment, CRS-2 integration costs and contractor reporting burdens could have been reduced had NASA taken advantage of overlaps between its commercial crew and cargo certifications and designs. Figure 5 summarizes modifications to the crewed Dragon 2 design to certify the spacecraft to carry cargo.

Figure 5: Crewed Dragon 2 Design Modifications to Carry Cargo for CRS-2 Missions

No Modifications

Subsystems:

- Communications
- Guidance, Navigation, and Control
- Propulsion
- Structure

Modifications

Subsystems:

- Avionics
- Cargo Capability
- External Trunk Design
- Life Support
- Power
- Software
- Thermal Control

Modifications:

- Remove some avionics, life support, and thermal control to free volume for cargo
- Modify power levels for cargo
- Upgrade software to support design
- Add unpressurized cargo rack
- Develop new pressurized cargo packing design

Source: NASA OIG presentation of SpaceX documentation.

[62] For the Dragon 2 cargo version, SpaceX will modify internal configurations, life support systems, cargo accommodations, crew displays, flight software, internal thermal and electrical power systems, and external trunk capabilities. If all COTS funding is included, NASA will pay SpaceX $2.2 billion for development and certification of Dragon 1 and Dragon 2.

NEW AND EMERGING CARGO RESUPPLY CAPABILITIES FACE TECHNICAL AND SCHEDULE RISKS

While less risky than the initial COTS and CRS-1 missions, all three contractors face technical and schedule challenges and each must meet ISS certification requirements prior to their first CRS-2 missions. The development and launch of Sierra Nevada's Dream Chaser spacecraft poses the greatest technical and schedule risk to NASA given its lack of flight history. In addition, SpaceX must certify the unproven Dragon 2 cargo configuration while also resolving concerns about software traceability and systems engineering. Finally, while Orbital ATK will use the proven Cygnus spacecraft, it will rely on the relatively new Antares 230 launch vehicle that could be affected by Congressional bans on Russian engines.

Prior to any CRS-2 mission, the contractors must complete seven ISS integration milestones and the ISS Program must confirm the spacecraft meets certification requirements to safely visit the Station. Through these milestones, the company submits documentation to certify its spacecraft meets these requirements, periodically reporting its status through preliminary and critical design reviews.[63] In addition to these integration milestones, the ISS Program tracks risks related to contractors meeting certification requirements for time-sensitive payloads.[64] Program officials said they are also improving their analysis for Station upmass needs and measuring the impacts of cargo mission schedule delays and failures to better utilize each flight's full upmass capabilities. Table 4 shows the status of ISS integration milestones and the number of missions currently awarded to each contractor.

[63] The third milestone is similar to NASA's preliminary design review process and examines whether the design meets all requirements with acceptable risk, is within cost and schedule constraints, and establishes the basis for proceeding with the detailed design. The fourth milestone is similar to the Agency's critical design review process, which demonstrates the maturity of the program's design to support full-scale fabrication, assembly, integration, and testing, and that the activity is on track to meet overall performance requirements within the identified cost and schedule constraints.

[64] In particular, contractors must certify the ability to (1) access and replace time-sensitive cargo to attempt a launch within 24 hours of a launch delay, (2) transfer cargo to the ISS within 96 hours of launch, (3) meet certain power levels and data transfers during flight, and (4) provide extended science laboratory capabilities inside the spacecraft while connected to the ISS.

Table 4: Status of ISS Integration Milestones and Missions for CRS-2 Contractors as of December 2017

Contractor	Mission Configuration	ISS Integration Milestones: Current Status	ISS Integration Milestones: Integration Completion Date	CRS-2 Missions Awarded	First CRS-2 Mission
Orbital ATK	Antares 230 and Cygnus (Berthing)	Milestone 5 of 7 (Cargo Loading and Telemetry Plans)	October 2018	3	October 2019
Sierra Nevada	Dream Chaser Cargo System (Berthing)	Milestone 3 of 7 (Preliminary Design Review)	February 2020	1	September 2020
	Dream Chaser Cargo System (Docking)	Milestone 3 of 7 (Preliminary Design Review)	Paused	None	Unknown
SpaceX	Dragon 2 (Docking)	Milestone 4 of 7 (Critical Design Review)	November 2018	4	August 2020

Source: NASA OIG presentation of ISS Program information.

Sierra Nevada Development and Production Risks

The development, first launch, and safe return of the Dream Chaser are the greatest technical and schedule risks under the CRS-2 contract. Additionally, Sierra Nevada's plans to build only one Dream Chaser could result in lengthy schedule delays if there are anomalies or failures over the course of the contract.[65] In March 2017, Sierra Nevada completed its third milestone – preliminary design review – and plans to complete initial ISS integration and certifications for berthing by February 2020 for its first CRS-2 mission scheduled in September 2020.

Sierra Nevada has about 2 years to finish developing, building, and testing the Dream Chaser Cargo System before its first mission, leaving 4 years to complete at least five additional missions through 2024, a time period that includes a 1-year review period after the first launch.[66] Although SpaceX and Orbital ATK needed roughly 6 years to launch their first CRS-1 missions after receiving COTS funding, Sierra Nevada will only have about 4 years from initial CRS-2 funding to complete its first mission.[67] Additionally, Sierra Nevada does not plan to conduct a demonstration flight which, while not required by

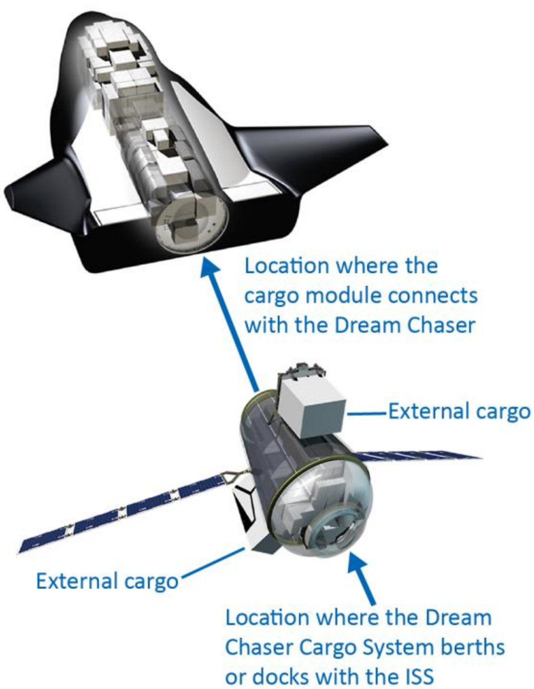
[65] For example, even though Orbital ATK and SpaceX already had additional spacecraft in production, about a year passed before the companies resumed cargo missions after their respective failures.

[66] Sierra Nevada officials are scheduling 10 to 12 months after the first Dream Chaser mission for extensive analysis of the flight data and detailed examination, inspection, and processing in excess of normal ground turnaround activities in preparation for Dream Chaser's second mission.

[67] While initial payments to develop the Dream Chaser Cargo System started in June 2016, Sierra Nevada has received $363 million for the development of the crewed configuration of the Dream Chaser since 2010 and the company is building upon years of design and analysis work through the Commercial Crew Program development agreements.

the CRS-2 contract, introduces additional risk for the first flight.[68] The ISS Program is tracking Sierra Nevada's mission readiness through design reviews and technical meetings and is relying on the completion of technical production milestones to ensure the September 2020 launch date is met. In the event there are delays, NASA plans to utilize other contractors to mitigate any cargo resupply gaps. See Figure 6 for an illustration of the Dream Chaser Cargo System that includes the Dream Chaser spacecraft and cargo module.

Figure 6: Dream Chaser Cargo System for CRS-2 Missions



Dream Chaser

- Reusable spacecraft that lands on airport runways
- No demonstration flights
- Reusable up to 15 flights
- One or two spacecraft for all CRS-2 missions (second spacecraft pending decision by Sierra Nevada)

Cargo Module

- Attaches to Dream Chaser and connects to the ISS
- Disposed and does not return with the Dream Chaser
- New cargo module is built for each mission
- Cargo module can be customized between docking or berthing for each mission
- Up to 3 locations for unpressurized cargo

Source: NASA OIG presentation of ISS Program information.

Using current flight rate assumptions, we estimate NASA will pay Sierra Nevada more than $1.1 billion for integration and milestone payments for four upcoming missions prior to the Dream Chaser's first mission in September 2020. In contrast, COTS development agreements paid for three demonstration flights for the other cargo contractors – two for SpaceX and one for Orbital ATK – prior to their first CRS-1 missions.

Sierra Nevada's plan to build a single Dream Chaser spacecraft for CRS-2 missions is a single point-of-failure that represents substantial technical and schedule risks for the ISS Program.[69] During a visit to Sierra Nevada in June 2017, company officials told us they had no plans to build a second Dream Chaser. In August 2017, ISS Program officials said Sierra Nevada was considering building a second Dream

[68] For the first CRS-2 mission, the Dream Chaser will be required to demonstrate additional orbital maneuvers before approaching the ISS. Other cargo vehicles such as the Cygnus, European cargo spacecraft, and Japanese cargo spacecraft were allowed to berth with the ISS on their maiden flight after performing similar maneuvers.

[69] In the past, NASA managers stated CRS-1 mission failures and schedule delays were expected given the complexities involved in producing new launch vehicles and spacecraft.

Chaser to be completed by 2021, but no decision had been made as of October 2017. In the event of a failure, Sierra Nevada officials told us in June 2017 that a second spacecraft could be built from spare parts without additional costs to NASA.

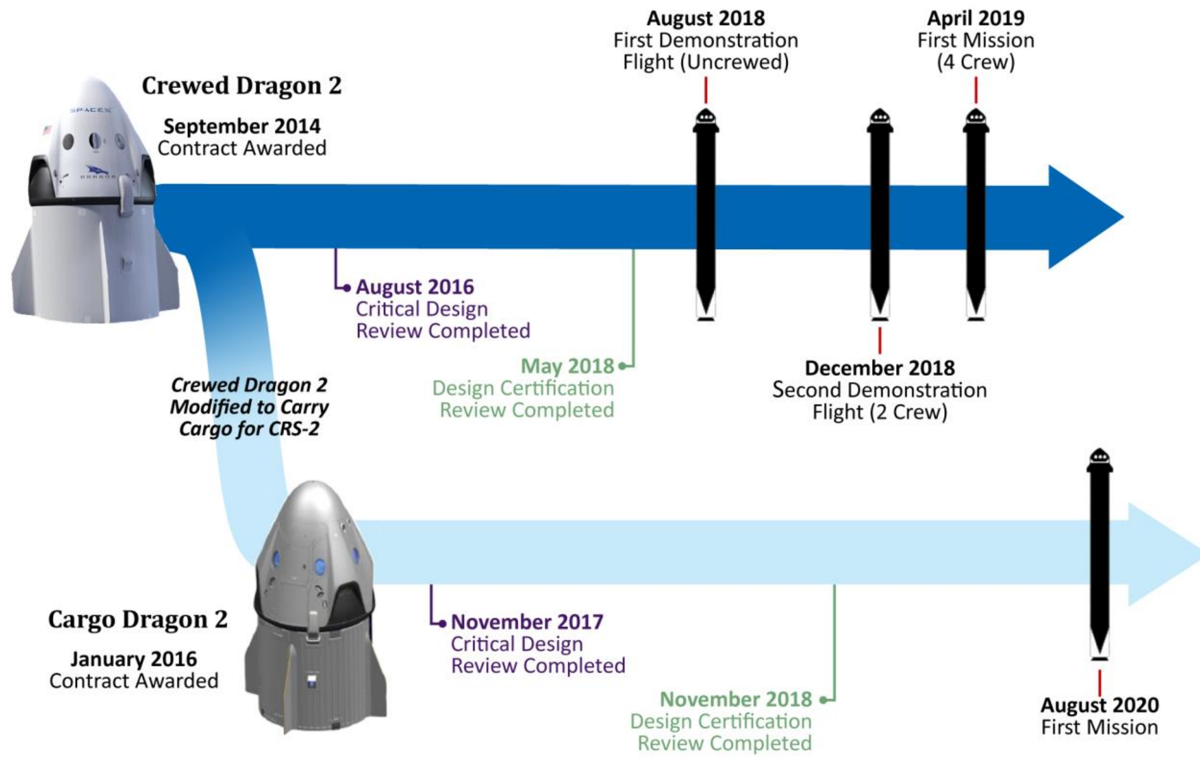
In our judgment, it is highly unlikely Sierra Nevada could build another Dream Chaser after a launch failure in time to meet its CRS-2 cargo delivery requirements of six missions by 2024. Additionally, anomalies during any of the flights could adversely impact future Sierra Nevada cargo missions because the company cannot launch its sole spacecraft until all issues are resolved. If delays occur, NASA may be obligated to continue to make payments for already awarded Sierra Nevada missions even though the Agency may be forced to ask Orbital ATK or SpaceX to fly additional missions to make up ISS upmass shortfalls as a result of Sierra Nevada delays.[70]

SpaceX Dragon 2 Certification, Software Traceability, and Systems Engineering Risks

For CRS-2, SpaceX must certify the Dragon 2 for cargo missions, address software traceability and systems engineering concerns, and mitigate risks for its new CRS-2 capabilities. SpaceX plans to switch from the Dragon 1 spacecraft used during CRS-1 to the unproven Dragon 2, the same spacecraft being developed for the Commercial Crew Program. The company completed its fourth milestone – critical design review – in November 2017 and plans to complete initial integration by November 2018 for a first CRS-2 mission in August 2020. While no CRS-2 demonstration flights are planned, SpaceX will conduct two demonstration flights in 2018 with a substantially similar Dragon 2 spacecraft as part of its commercial crew contract with NASA. To further mitigate technical and schedule risks, substantial portions of ISS certification requirements are the same for the Dragon 2 crew and cargo configurations and have already been reviewed as part of Commercial Crew Program requirements. Figure 7 compares the Cargo and Crew Dragon 2 schedules, certifications, and initial launch dates.

[70] Once NASA issues a task order for a CRS-2 mission, the Agency is required to pay for the service unless it makes a decision to terminate for cause or convenience, both of which represent last resort options in contract management. NASA may receive monetary or in-kind consideration if there are contractor delays but that still may not mitigate the need to procure services from other contractors to make up for delivery shortfalls.

Figure 7: Comparison of Cargo and Crew Dragon 2 Schedules, Certifications, and Initial Launch



Source: NASA OIG analysis based on ISS Program documentation.

Since 2014, NASA has had ongoing concerns about SpaceX software traceability issues related to the Agency's and company's use of different software development processes. To develop software, NASA traditionally sets all requirements, develops discrete parts, creates documentation for clear traceability, and tests the entire system at the end of its development. SpaceX on the other hand uses an iterative approach that focuses on testing throughout all phases of development and emphasizes creating working software versions with progressive updates instead of setting requirements and completing comprehensive documentation. The lack of full documentation under the SpaceX approach increases NASA's difficulty for ensuring SpaceX software changes meet ISS safety certification requirements. In February 2017, an operator error induced by using an uncertified software tool caused SpaceX's 10th CRS-1 mission to abort its planned rendezvous with the ISS before successfully berthing a day later. A subsequent audit conducted by the ISS Program in October 2017 before SpaceX's 13th mission showed the company had made significant progress in improving their software development processes and mitigating NASA's concerns.

Additionally, NASA's concerns about SpaceX systems engineering processes increased after the June 2015 SpX-7 and September 2016 AMOS-6 failures.[71] Because SpaceX continuously makes changes to its launch vehicle and spacecraft, the company has had more difficulty following industry standard systems engineering principles.[72] SpaceX has responded to these concerns by providing NASA more insight into its quality control and systems engineering processes.

Moreover, SpaceX's use of previously flown Falcon 9 first stage boosters for a CRS mission is a deviation from the original contract terms that we believe could introduce new risks to CRS missions. The Agency approved the use of a previously flown booster for the first time on the December 2017 SpX-13 mission.[73] While both CRS-1 and CRS-2 contracts require a new Falcon 9 for all missions, both contracts provide NASA with the option to use a previously flown booster for a specific mission if the Agency determines the launch presents an acceptable level of risk for cargo resupply missions. For SpX-13, the Agency received contractor in-kind contributions – such as accommodations for external payloads and manifest changes – to reconcile the cost difference between a new and previously flown booster.[74] For CRS-2, NASA could receive a marginal discount on per-mission pricing if the Agency opts to use a previously flown booster for a mission. As we reported in 2016 in our audit of the SpX-7 failure, NASA does not conduct a risk rating for each CRS launch or type of launch vehicle.[75] To mitigate the risks associated with using a previously flown booster for CRS missions, NASA officials conducted a review and determined this approach poses an equivalent risk compared to using a new booster. In addition, in 2017, the ISS Program and LSP conducted a study to set technical approval requirements and review SpaceX's reuse qualification testing and vehicle processing. The ISS Program plans to continue to monitor SpaceX's processes for using previously flown boosters.

Orbital ATK Launch Vehicle, Mission Capability, and Subcontractor Risks

Orbital ATK must address risks related to its Antares 230 launch vehicle, reloading cargo within 24 hours of a launch delay, insight into subcontractor activities, and foreign subcontractors. For CRS-2, Orbital ATK plans to use a slightly modified Cygnus spacecraft and Antares 230 configuration to deliver cargo to the ISS. The company successfully completed its critical design review in June 2017 and fifth milestone – which includes cargo loading demonstrations and implementation plans – in December 2017. Orbital ATK plans to complete all initial ISS certification milestones by October 2018 for the first CRS-2 mission in October 2019 in what should be the fifth use of the Antares 230 rocket.

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[71] Systems engineering is the process for setting design requirements, constructing a system to the design, managing configuration changes, and operating a system successfully.

[72] A recent audit by the U.S. Department of Defense OIG also identified concerns with SpaceX's quality management system. Department of Defense OIG, "Evaluation of the Evolved Expendable Launch Vehicle Program Quality Management System" (DODIG-2018-045, December 20, 2017).

[73] SpX-14 also used a previously flown Falcon 9 first stage booster in April 2018. When considering using previously flown boosters for missions, NASA meets regularly with the contractor to evaluate inspection results and refurbishment progress and participates in the contractor's Reuse Readiness Assessment to decide whether the risk to flying cargo on a given mission is acceptable.

[74] In-kind contributions are compensation in the form of goods or services rather than money. Prior to SpaceX's 13th CRS-1 launch, NASA updated the contract to clarify that the Agency must approve the use of a previously flown booster for any mission and both parties must negotiate potential discounts prior to any such approval.

[75] IG-16-025.

Throughout its CRS-1 missions, Orbital ATK encountered several delays with earlier Antares versions that used older AJ-26 engines. After the Orb-3 failure in October 2014, Antares launches were delayed 2 years while the company replaced the AJ-26 with newer RD-181 rocket engines. With only two launches as of December 2017, the Antares 230 faces risks normally expected with development of a new launch vehicle configuration such as integrating rocket engines with the core stage and testing the integrated systems. These risks are expected to be reduced as the Antares 230 demonstrates reliability through repeated successful launches. Further, Orbital ATK is required under the CRS-2 contract to have the capability to reload cargo and attempt a launch within 24 hours of a launch delay.[76] According to NASA officials, Orbital ATK has yet to fully meet this requirement. Although the December 2017 milestone demonstration partially provided that Cygnus cargo loading and unloading capabilities could be completed within the time allocations necessary to meet this requirement, the company plans to fully demonstrate its ability to meet the 24-hour requirement in June 2018.

In addition, Orbital ATK outsources critical launch vehicle and spacecraft components to foreign contractors, a situation that raises concerns about insight into those subcontractors and potential impacts from congressional bans on dealing with Russian companies.[77] The Antares 230 core stage is built by Yuzhmash in Ukraine, the RD-181 rocket engines by Energomash in Russia, and the pressurized cargo module by Thales Alenia in Italy.[78] All of these components are shipped to Orbital ATK and assembled at NASA's Wallops Flight Facility. To mitigate potential subcontractor insight risks, Orbital ATK has Yuzhmash and Energomash employees working at Wallops to help integrate the Ukrainian core stage and Russian engines into the Antares 230.

With respect to restrictions on commerce with certain Russian companies, Orbital ATK cargo deliveries to the ISS have a waiver until the end of 2020 from Federal sanctions laws prohibiting payments to the Russian Federal Space Agency or affiliated companies like Energomash. Should the waiver not be extended, Orbital ATK may not be able to use the Antares 230 for future CRS-2 missions. To help mitigate this risk, Orbital ATK plans to purchase enough RD-181 engines in 2018 to complete missions through the fourth CRS-2 flight. The company is also considering using the Vulcan launch vehicle or its own Next Generation Launch Vehicle, both in development. Figure 8 illustrates the Cygnus and Antares 230 components and summarizes the subcontractors and manufacturing locations.

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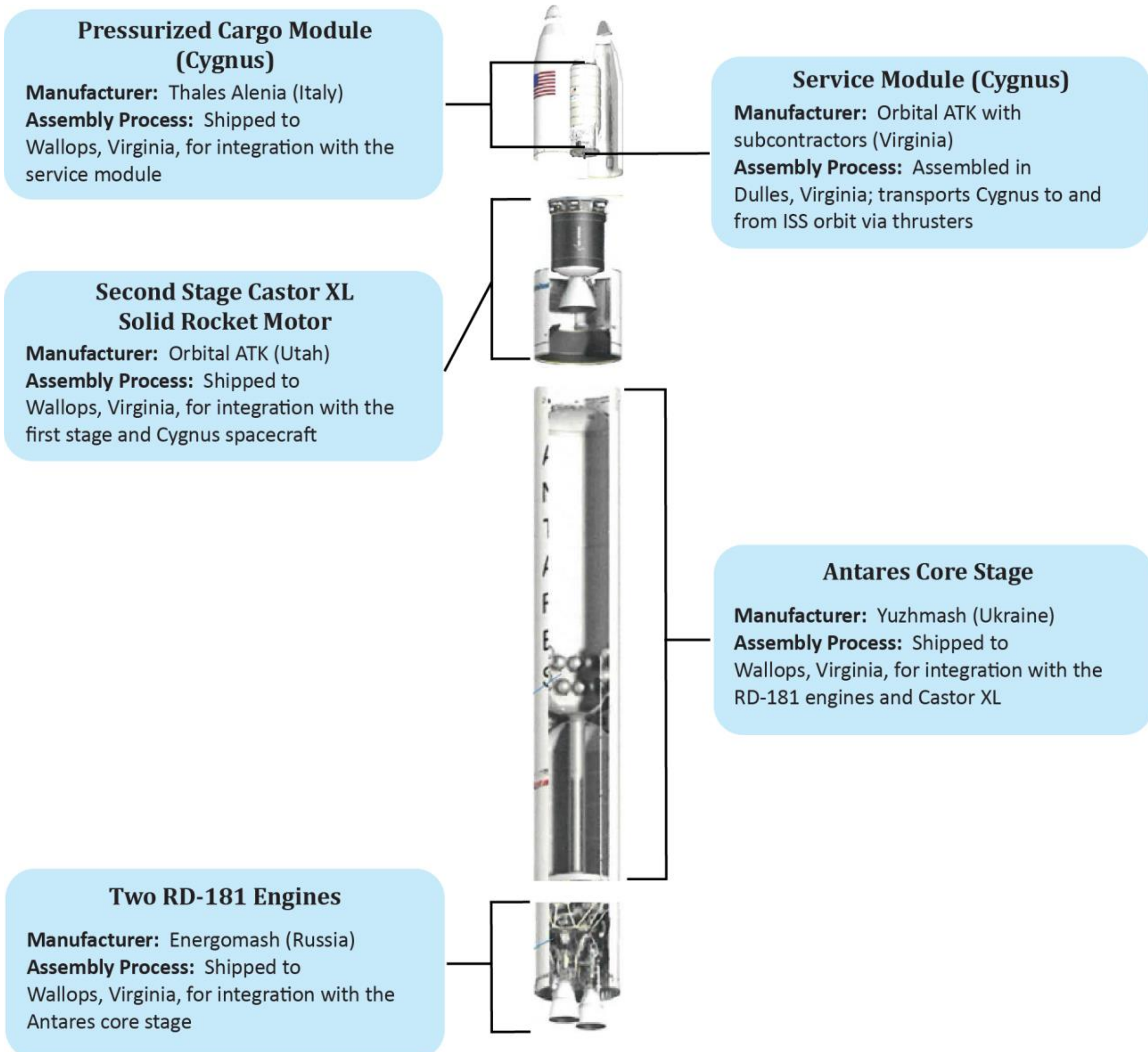
[76] To refresh the cargo, Orbital ATK must conduct a complex process during which the Antares 230 is brought from a vertical to horizontal position with parts of the spacecraft connected to the launch pad while the top of the payload fairing is removed to replace sensitive cargo such as biological science experiments.

[77] A recent round of Russian sanctions exempted activities related to NASA space launches, including Orbital ATK's CRS missions that use Russian engines. Countering America's Adversaries Through Sanction Act, Pub. L. No. 115-44 (2017). Additionally, NASA has an exemption from broader sanctions for activities related to the ISS until December 31, 2020. Iran, North Korea, and Syria Nonproliferation Act, 50 U.S.C § 1701 note (2013).

[78] For the Cygnus spacecraft, the service module that attaches to the Italian cargo module is assembled in Dulles, Virginia.

Figure 8: Cygnus and Antares 230 Components, Subcontractors, and Assembly Process



Source: NASA OIG analysis based on ISS Program documentation.

CONCLUSION

Reliable cargo transportation using commercial companies is key to the sustainment and successful utilization of the ISS. In general, we believe CRS-1 and its successor contracts under CRS-2 are positive steps in ensuring such reliable cargo transportation. NASA's continued commitment to the commercial space industry also helps spur innovations in the commercial launch vehicle market by creating additional competition, spurring development of new domestic capabilities, and helping enable cheaper access to space for commercial activities.

For CRS-2, NASA followed Federal procurement rules to review price reasonableness and make competitive range determinations for the five proposals submitted by contractors. Moreover, NASA applied lessons learned from the CRS-1 contract to provide the ISS Program with better cargo capabilities, more transport flexibility, added insurance coverage for NASA payload losses, and clearer contractor insight authority. Looking forward, we believe NASA could apply existing CRS-2 contract options beyond the six missions guaranteed for each company and compete subsequent task orders to obtain the best value to the Government and improve its pricing for future commercial missions.

While less risky than the initial COTS and CRS-1 missions, all three contractors face technical and schedule risks before their first CRS-2 missions. Most pointedly, successful development and launch of Sierra Nevada's Dream Chaser spacecraft poses NASA's greatest CRS-2 technical and schedule risk.

OTHER MATTERS OF INTEREST: IMPROVEMENTS FOR FUTURE COMMERCIAL CONTRACTS

During this review, we identified areas related to the contract selection process that could be improved for future commercial space transportation contracts. These issues did not materially impact the awards of the CRS-2 contract but could impact the results of future Agency procurements.

Downmass Capabilities Were Not Included in Pricing Analysis

Although NASA officials stated both return and disposal downmass capabilities are critical to ISS operations – a point discussed extensively during development of the RFP – they were not included in the CRS-2 pricing criteria. Since the companies could propose multiple mission approaches to meet RFP requirements and were not required to provide return capabilities, ISS Program officials decided that downmass would instead be considered as part of mission suitability criteria. However, by not including a downmass pricing analysis, Orbital ATK's disposal capability was not differentiated from the more robust return downmass capabilities of Sierra Nevada and SpaceX. In contrast, during the CRS-1 contract selection process, the pricing criteria differentiated between disposal and returned downmass which allowed NASA to conduct a more detailed evaluation of each contractor's submission.

Areas for Potential Improvement in RFP Pricing Methodologies

We also believe NASA can improve its pricing evaluations. We found the RFP pricing methodology applied discounted prices for fractional missions per year and did not include the impact of selecting three contractors in the RFP's evaluation. Both of these issues influenced the overall evaluated prices for each contractor's CRS-2 proposal by changing the discounts assumed for multiple missions a year.[79] While the pricing methodology was consistently applied to all three contractor proposals, the Agency's approach influenced NASA's evaluated prices for Sierra Nevada more significantly than SpaceX and Orbital ATK.

[79] For each CRS-2 proposal, the companies provided per-mission pricing based on the year of launch and the number of missions per year. In most cases, NASA receives a discount on per-mission pricing as the number of missions in a year increases. For example, if NASA purchases two missions in a year from a contractor, the total costs are generally lower than if the Agency were to buy two missions over a two-year period.

Using Fractional Missions to Determine Per-Mission Pricing Discounts

We found the pricing methodology NASA used to calculate the total evaluated price for CRS-2 proposals could be improved for future procurements. The methodology set total pressurized upmass needs for the ISS at 15,000 kg a year. The RFP criteria assumed only two contractors would be selected and divided the annual pressurized upmass by two to set each company's assumed upmass delivery requirement at 7,500 kg a year. The upmass delivery rate was divided by each spacecraft's upmass capability to yield the number of missions per year for each contractor, a calculation that created fractional missions per year. For example, using this approach Sierra Nevada would need to fly 1.5 missions a year (9 missions over 6 years) to meet its annual upmass requirement of 7,500 kg. Agency officials determined per-mission pricing by rounding up fractional missions per year to the next highest whole number and applying discounts for that number of missions per year. While Sierra Nevada could meet its upmass requirements with 1.5 missions per year, NASA applied discounted prices for 2 missions per year. To determine the annual costs for each contractor, NASA multiplied the fractional missions per year by the assumed price per mission. The Agency then added the annual costs for each of the 6 years with one-time integration costs to determine each company's total evaluated price. Table 5 shows how NASA's pricing methodology was applied to each contractor's proposal.

Table 5: RFP Pricing Methodology to Calculate Evaluated Proposal Prices Assuming Two Contractors

Pricing Criteria	Orbital ATK	Sierra Nevada	SpaceX
Assumed Delivery Rate (Assuming 2 contractors)	7,500 kg per year	7,500 kg per year	7,500 kg per year
Pressurized Upmass Capability	3,754 kg	5,000 kg	2,507 kg
Fractional Missions (Delivery Rate/Capability)	2 missions per year	1.5 missions per year	2.99 missions per year
Pricing Based on Missions Per Year	2 missions-per-year pricing	2 missions-per-year pricing	3 missions-per-year pricing
RFP Methodology to Calculate Evaluated Prices for All 6 Years			
(Each Year's Fractional Missions x Each Year's Per-Mission Price) + One-time Integration Costs = Total Evaluated Proposal Price			

Source: NASA OIG analysis based on NASA CRS-2 RFP documentation and the Source Selection Statement.

For Sierra Nevada, this RFP pricing methodology resulted in a total evaluated proposal price that was cheaper than technically possible because NASA applied discounts for 2 missions per year when only 1.5 missions per year were needed. Had NASA instead used whole missions for the flight cadence by alternating the flight rate between 1 and 2 missions over the 6-year period, the contractor would have received 2-per-year pricing for just 3 of the 6 years, and the total evaluated price would have risen by 10 percent. NASA used the same bulk discounting methodology for Orbital ATK and SpaceX; however, the rounding methodology had less of an impact because the fractional shares (2 and 2.99, respectively) were closer to the whole numbers actually used.

Pricing Analysis Did Not Include Impact of Three Contractors

We also found that NASA's CRS-2 RFP pricing methodology assumed there would be two contractors even though NASA eventually selected three. As a result, the RFP set each contractor's annual pressurized upmass requirements at 7,500 kg or half of the total ISS annual cargo needs. If the RFP pricing criteria had assumed three contractors instead of two, each contractor's pressurized upmass requirements would be reduced to 5,000 kg per year. A reduction in the annual requirement reduces the number of missions a year for each contractor, which in turn reduces discounts for flying multiple missions in a year. Compared to Table 5, Orbital ATK's missions per year would be reduced from 2 to 1.33, Sierra Nevada's from 1.5 to 1, and SpaceX's from 2.99 to 1.99. Table 6 shows how adjusting the RFP pricing methodology to calculate fractional missions per year assuming three contractors would have reduced multi-mission discounts.

Table 6: RFP Pricing Methodology to Calculate Evaluated Prices Assuming Three Contractors

Pricing Criteria	Orbital ATK	Sierra Nevada	SpaceX
Assumed Delivery Rate (Assuming 3 contractors)	5,000 kg per year	5,000 kg per year	5,000 kg per year
Pressurized Upmass Capability	3,754 kg	5,000 kg	2,507 kg
Fractional Missions (Requirement/Capability)	1.33 missions per year	1 mission per year	1.99 missions per year
Impact of Adjusting RFP for Three Contractors			
Fewer Missions a Year = Fewer Discounts on Contractor Pricing			

Source: NASA OIG analysis based on NASA CRS-2 RFP documentation and the Source Selection Statement.

The assumption of only two contractors in the RFP criteria could have influenced the total evaluated proposal prices, which were approximately 50 percent of the selection criteria for the CRS-2 awards. For example, using the original RFP pricing criteria that assumes two contractors, the Source Evaluation Board (the Board) found SpaceX's proposed prices were more expensive than Sierra Nevada and Orbital ATK as illustrated in Table 2. However, when three contractors are considered, Sierra Nevada's total evaluated price becomes roughly the same as SpaceX because an adjusted flight rate of one mission per year for Sierra Nevada as shown in Table 6 does not result in discounts on per-mission pricing.[80] Nevertheless, when assuming only two contractors, as was done in the RFP, Sierra Nevada's evaluated pricing was significantly cheaper than SpaceX's evaluated pricing.

[80] An evaluated price is used during the source selection process and does not necessarily reflect the actual cost estimate for each contractor because many factors can change after the award such as flight cadence assumptions, upmass needs, and the number of discounts for flying multiple missions a year.

We acknowledge the difficulty of including all relevant factors into an RFP, particularly considering CRS-1 used two rather than three contractors. Also, while we noted weaknesses related to the use of fractional missions a year for discounting and the assumption of two contractors in the price evaluation criteria, the impact on the CRS-2 selection was limited because all three final proposals were selected. NASA officials explained the Agency had to make some assumptions for the RFP criteria and using pricing methodologies for two contractors was consistent with the CRS-1 contract. They also told us that changes to the pricing methodology to account for three contractors after the publication of the RFP could have resulted in additional delays to the procurement. Nonetheless, as NASA continues to use commercial space transportation services for both cargo and crew, we believe the Agency can improve its procedures to ensure more realistic and flexible pricing methodologies to inform contract awards.

Recommendations, Management's Response, and Our Evaluation

For NASA to obtain the best value for cargo resupply missions and to mitigate technical risks, we recommended the Associate Administrator for Human Exploration and Operations Mission Directorate ensure the ISS Program:

1. Incorporates, to the extent practicable, the ISS Program Planning and Control Office's proposed mission cadences into the Planning, Programming, Budgeting, and Execution process for fiscal year 2020 to take advantage of contractor discounts for multiple missions through 2024.

2. Ensures appropriate pacing of expenditures for integration costs to avoid paying for configurations too far in advance of when they may be used.

3. Clarifies whether Sierra Nevada will deliver a second Dream Chaser spacecraft for CRS-2 missions and, if not, incorporates the risk of having only a single vehicle into the ISS Program risk management database.

4. Ensures that the Agency negotiates monetary discounts, as required by the CRS contracts, in the event contractors use an alternate launch vehicle or a previously flown vehicle.

5. Decides by January 2020 whether to compete task orders beyond the minimum guarantee of six for each contractor through the existing IDIQ contract or through the On-Ramp clause.

We provided a draft of this report to NASA management who concurred with our recommendations and described planned corrective actions. We consider the proposed actions responsive for four of the five recommendations and will close them upon verification and completion of those actions. With regard to Recommendation 3, the ISS Program updated the risk to Sierra Nevada mission readiness for its first CRS-2 mission to include the significant schedule risk of only having a single Dream Chaser spacecraft. However, in their response NASA officials did not specifically address whether Sierra Nevada plans to develop a second Dream Chaser spacecraft to meet its CRS-2 mission obligations. In addition, in our review of the ISS Program's risk database we found that the estimated completion date for the tracked risk coincides with the date of Sierra Nevada's first CRS-2 mission, September 2020, while the risk of not having a second Dream Chaser may persist for the length of the contract. Given these issues, we consider this recommendation unresolved pending further discussion with the Agency.

Management's comments are reproduced in Appendix E. Technical comments provided by management have also been incorporated, as appropriate.

Major contributors to this report include Ridge Bowman, Space Operations Director; Letisha Antone, Project Manager; Robert Proudfoot; Gina Davenport-Bartholomew; and Thomas Dodd. Lauren Suls and Sarah McGrath provided editorial and graphic assistance.

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 April 2017 through March 2018 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.

In April 2017, we initiated our audit to examine whether NASA's contract administration and oversight processes are sufficient to mitigate significant cost, schedule, and technical risks related to the CRS-2 activities upon award and during the administration of major Commercial Resupply Services contracts. The primary audit locations were at NASA Headquarters, Wallops Flight Facility, Johnson Space Center, Orbital ATK, Sierra Nevada, and SpaceX.

Given the importance of commercial cargo transportation coupled with its substantial costs and ongoing challenges, we examined NASA's CRS contracts for resupplying the ISS through 2024 with a special emphasis on the CRS-2 contracts. Specifically, the audit examined (1) the extent to which CRS-2 contracts provide best value to NASA, (2) CRS-2 costs, and (3) technical and schedule risks to CRS-2 contractors. Overall, we reviewed CRS contract documentation and interviewed ISS Program officials and Launch Services Program personnel, as well as Orbital ATK, Sierra Nevada, and SpaceX officials. In addition, we reviewed ISS Program documentation, including the Board's documentation from the CRS-2 RFP.

To determine the extent to which CRS-2 contracts provided the best value to NASA we reviewed Federal law, the FAR, the NASA FAR supplement, the CRS-2 Source Selection Statement, and Board documentation, including the competitive range determination. We interviewed the Source Selection Authority, the Cost/Price Analyst from the Board, the Contracting Officer from the Board, and ISS Program procurement officials.

To assess CRS-2 costs, we reviewed documentation from the CRS-1 contracts, CRS-2 contracts, past and current ISS Program budget estimates, and issued CRS-2 task orders. Further, we interviewed ISS Program officials from the Program Planning and Control Office, Mission Integration and Operations Office, and ISS Transportation Integration Office. We also interviewed Board officials, including the Cost/Price Analyst, and officials from Orbital ATK, Sierra Nevada, and SpaceX.

Finally, to assess the CRS-2 technical and schedule risks, we reviewed contractor status briefings and Space Station Program (SSP) criteria, including the "International Space Station (ISS) to Commercial Orbital Transportation Services (COTS) Interface Requirements Document (IRD)" (SSP 50808), September 2014, and "ISS Cargo Transport Requirements Document" (SSP 50833), February 2015. Further, we reviewed the ISS Integrated Risk Management Application for program-identified risks.

Use of Computer-Processed Data

We relied on computer-processed data such as cost data obtained from Business Objects and data queries from the Integrated Risk Management Application and Electronic Document Management System to access ISS Program documents to perform this audit. The team corroborated information with other sources where possible and performed audit steps to validate the accuracy of a limited amount of data contained in these databases; however, the data is only as accurate as that entered by the database personnel. The accuracy of the data did not affect our conclusions.

Review of Internal Controls

We reviewed and evaluated the internal controls associated with NASA management of the ISS, specifically the commercial resupply missions. We reviewed appropriate policies, procedures, plans, regulations, and Statements of Assurance relating to internal controls and conducted interviews with responsible personnel. We concluded that the internal controls were adequate.

Prior Coverage

During the last 8 years, the NASA Office of Inspector General (OIG) and the Government Accountability Office have issued eight reports of significant relevance to the subject of this report. Unrestricted reports can be accessed at http://oig.nasa.gov/audits/reports/FY18 and http://www.gao.gov, respectively.

NASA Office of Inspector General

NASA's Commercial Crew Program: Update on Development and Certification Efforts (IG-16-028, September 1, 2016)

NASA’s Response to SpaceX’s June 2015 Launch Failure: Impacts on Commercial Resupply of the International Space Station (IG-16-025, June 28, 2016)

NASA's Response to Orbital's October 2014 Launch Failure: Impacts on Commercial Resupply of the International Space Station (IG-15-023, September 17, 2015)

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

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

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

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

Government Accountability Office

Commercial Space Launch Insurance: Weakness in FAA’s Insurance Calculation May Expose the Federal Government to Excess Risk (GAO-17-366, March 2017)

APPENDIX B: SUMMARY OF NASA'S COMMERCIAL CARGO AND CREW CONTRACT AWARDS

Table 7 summarizes the $17.8 billion in contract awards to deliver cargo and crew to the ISS. NASA completed payments for COTS in 2013 and does not expect to award any additional missions through the CRS-1 contracts. CRS-2 funding includes integration costs and 8 cargo missions but does not include the additional 10 missions required to be purchased through the CRS-2 contract. Commercial crew activities include all Space Act Agreement payments and the total awarded contract value for the Boeing and SpaceX Commercial Crew Transportation Capability contracts. Current spending is through calendar year 2017.

Table 7: NASA's Awards for Commercial Cargo and Crew Activities Occurring Through 2024 (Dollars in Millions)

Contractor	COTS	CRS-1	CRS-2 (Current)	Commercial Crew Activities	Total Spent Through 2017	Total Awards Through 2017
Orbital ATK	$288.0	$2,888.8	$638.9	$0.0	$3,134.7	$3,815.8
Sierra Nevada	0.0	0.0	893.3	363.1	499.6	1,256.4
SpaceX	396.0	3,042.1	1,073.8	3,191.1	4,462.4	7,702.9[c]
Boeing	0.0	0.0	0.0	4,942.8	2,092.8	4,942.8
Others	32.1[a]	0.0	0.0	33.8[b]	65.9	65.9
Total NASA Funding	**$716.1**	**$5,930.9**	**$2,606.0**	**$8,530.8**	**$10,255.4**	**$17,783.8**

Source: NASA OIG analysis of commercial cargo and crew Space Act Agreements and contracts.

Note: These amounts represent total awards through December 2017 for activities that will take place through 2024.

[a] In 2006, NASA awarded Rocketplane Kistler $207 million in COTS funding but the agreement was terminated in 2007 after the Agency paid $32.1 million.

[b] Throughout the Commercial Crew Program, NASA awarded funded and unfunded development activities to eight companies: Alliant Techsystems; Blue Origin; Boeing; Excalibur Almaz, Inc.; Paragon Space Development Corporation; Sierra Nevada; SpaceX; and United Launch Alliance.

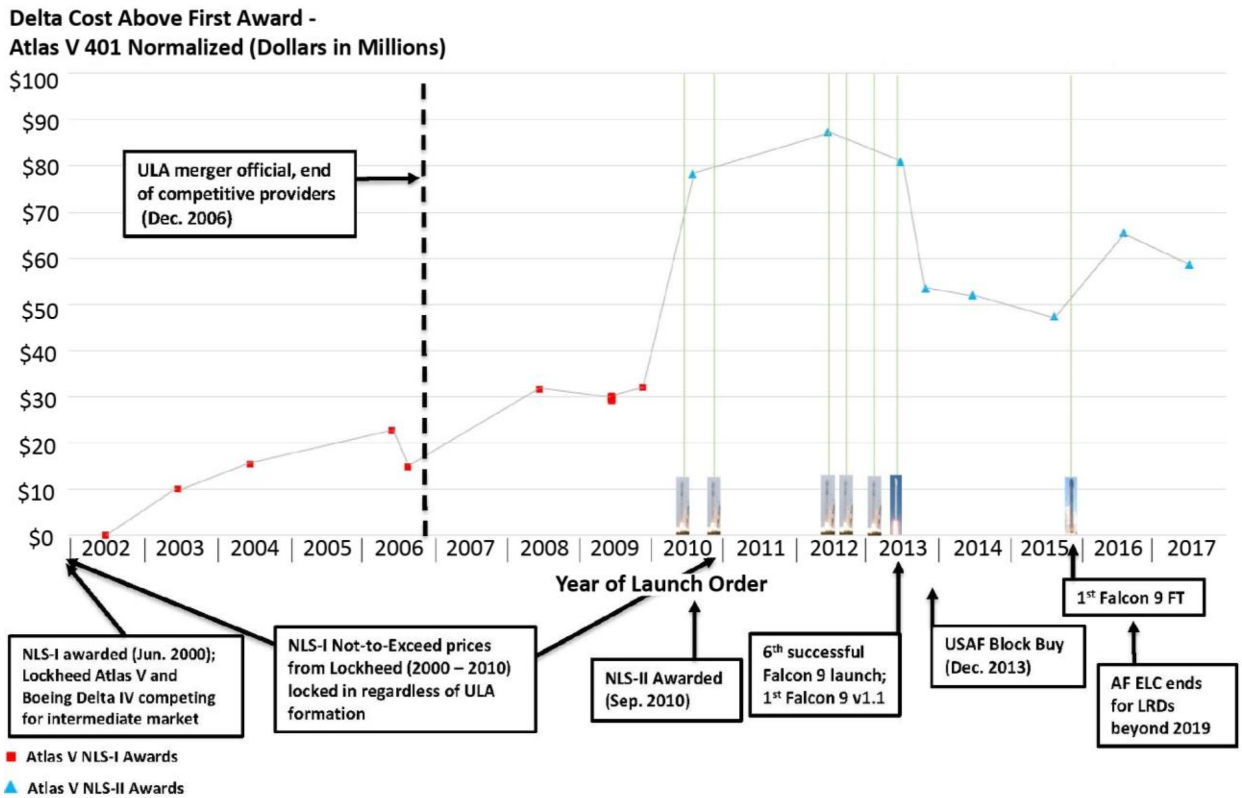
[c] In addition to the total awards listed above, SpaceX has been awarded four LSP contracts worth a combined $378 million for commercial launches of NASA science payloads. Total launch costs include launch services, payload processing, launch vehicle integration, and mission unique ground support and can be different than the actual price paid to the launch service contractor.

APPENDIX C: IMPACT OF COMPETITION ON ATLAS V PRICING

During the course of our audit, we obtained NASA's analysis of the impact that new commercial launch capabilities, such as the Falcon 9, had on the commercial launch market. Through this analysis, NASA officials found the development of new launch vehicles during COTS and CRS-1 directly reduced the LSP commercial launch prices through competition. LSP openly competes science missions between IDIQ contractors that have qualifying launch vehicles to provide the best value to the Agency. Since Lockheed Martin introduced the Atlas V launch vehicle in 2002, LSP has purchased 20 launches of the rocket with varied booster and payload fairing configurations for an average total launch cost of $160 million.[81] After removing additional costs to compare the baseline launch service configuration for each mission, NASA experts conducted a review of past pricing and determined Atlas V pricing significantly decreased by roughly $20 million per launch after the Falcon 9 was eligible to compete for LSP contracts in 2013. Additionally, LSP has received the benefits of a cheaper launch vehicle by selecting a SpaceX Falcon 9 for four missions at an average launch cost of $95 million. Figure 9 is a summary of NASA's analysis showing the impact of competition on Atlas V pricing.

[81] For LSP missions, total launch costs include launch services, payload processing, launch vehicle integration, and mission unique ground support and can be different than the actual price paid to launch service contractors such as United Launch Alliance or SpaceX.

Figure 9: NASA Analysis Showing the Impact of Competition on Atlas V Pricing



Source: NASA OIG presentation of the Agency's analysis of Atlas V pricing.

Note on acronyms: NASA Launch Services 1 (NLS-I) contract, NASA Launch Services 2 (NLS-II) contract, U.S. Air Force (USAF and AF), Full Thrust (FT), Evolved Expendable Launch Vehicle (EELV), EELV Launch Capability (ELC) contract, Launch Readiness Date (LRD).

Note on NASA analysis: This chart includes NASA LSP launch service procurements through March 2017. This cost trend is derived by comparing "normalized" launch service prices paid at award. The launch service prices have been normalized to an Atlas V-401 configuration, which for all missions except the Mars Reconnaissance Orbiter, means taking the awarded basic launch service cost (e.g., no mission uniques, no payload processing costs, no telemetry, no nuclear costs, and no actual costs such as delay penalties) and subtracting the applicable costs for a larger fairing and strap-on solids. The Mars Reconnaissance Orbiter mission was awarded in 2002 on an Atlas IIIB and converted at no cost in 2003 to an Atlas V-401; so for the purposes of this chart, the comparable price is as awarded.

Appendix D: Summary of Questioned Costs

We question NASA's decision to fund the Sierra Nevada Dream Chaser vehicle docking and berthing options simultaneously when NASA only plans to initially use the berthing version. NASA awarded the berthing mission milestones to Sierra Nevada on June 3, 2016, and the docking mission delta integration milestones 1 through 3 to Sierra Nevada on July 25, 2016.

In total, NASA has spent $4,384,395 on the delta integration milestones for the Sierra Nevada Dream Chaser vehicle docking option. Given the inherent risk of an unproven spacecraft and lack of a demonstration flight, we believe NASA should have deferred the docking integration costs until Sierra Nevada has successfully completed their first Dream Chaser mission for the CRS-2 contract.

Appendix E: Management's Comments

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

APR 24 2018

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: Agency Response to OIG Draft Report, "Audit of Commercial Resupply Services to the International Space Station" (A-17-013-00)

NASA appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled, "Audit of Commercial Resupply Services to the International Space Station" (A-17-013-00), dated March 22, 2018.

In the draft report, the OIG makes five recommendations addressed to the Associate Administrator for the Human Exploration and Operations Mission Directorate (HEOMD) intended to obtain the best value for cargo resupply missions and to mitigate technical risks of the Commercial Resupply (CRS) contracts for the International Space Station (ISS).

Specifically, the OIG recommends the Associate Administrator for HEOMD ensure the ISS Program:

Recommendation 1: Incorporates, to the extent practicable, the ISS Program Planning and Control Office's proposed mission cadences into the Planning, Programming, Budgeting, and Execution (PPBE) process for fiscal year 2020 to take advantage of contractor discounts for multiple missions through 2024.

Management's Response: NASA concurs. This is currently being done as a standard process in ISS. The Flight Program Integration Plan is an attachment incorporated into the ISS PPBE guidelines sent out to the Program as they provide budget planning input to the Program Manager (PM). The ISS Program reviews on-orbit demand, flight cadence, and multi-mission discount contract options to determine the best value for the Government.

Estimated Completion Date: Annually with the next update as part of the PPBE Program Manager submit, May 31, 2018.

Recommendation 2: Ensures appropriate pacing of expenditures for integration costs to avoid paying for configurations too far in advance of when they may be used.

Management's Response: NASA concurs. As a standard process, the ISS Program continuously weighs the options and risks associated with vehicle configuration needs, budget constraints and on-orbit requirements. Long lead development is a major factor in making decisions in advance of the on-orbit need as well as balancing the risk of the ISS program operations in case of major delays or failure of a provider. Sometimes, activities are started earlier than would appear necessary. These early starts are required to provide margin for delivery of critical capability. Delaying start of activities will guarantee reduced margin to obtaining a critical capability. We believe integration activities were started at an appropriate time to provide margin to a critical capability. The additional cost associated with an early start would be small compared to the loss of ISS functionality if the capability is not available at the required time.

Estimated Completion Date: Action Completed.

Recommendation 3: Clarifies whether Sierra Nevada will deliver a second Dream Chaser spacecraft for CRS-2 missions and, if not, incorporates the risk of having only a single vehicle for CRS-2 missions into the ISS Program risk management database.

Management's Response: NASA concurs. There is a critical programmatic benefit for receiving logistics capability through the CRS-2 providers so that one anomaly or event does not preclude availability of cargo transportation services. The CRS-2 contracts were awarded to three viable offerors to offset the risk of awarding to only one or two contractors who could potentially fail, leaving NASA without adequate cargo capabilities. The CRS contracts are structured like industry-to-industry contracts where more risk (financial, schedule, and technical) is shifted from the Government to industry. These contracts also are intended to create the most advantageous contract operations environment to promote U.S. industry success by lowering barriers to contracting with the Federal Government. Based on this recommendation, the ISS Program has updated the program risk system to track Top Organization Risk (TOR) 6647 on Sierra Nevada Corporation's mission readiness.

Estimated Completion Date: Action Completed.

Recommendation 4: Ensures that the Agency negotiates monetary discounts, as required by the CRS contracts, in the event contractors use an alternate launch vehicle or a previously flown vehicle.

Management's Response: NASA concurs. The Contracting Officer will negotiate discounts or in-kind considerations within the bounds of the firm fixed price contract in the event contractors use an alternate launch vehicle or previously flown vehicle. This is a standard process at the mission Vehicle Baseline Review (VBR). A memorandum for the record will be used to document this in the contract file.

Estimated Completion Date: May 31, 2018

Recommendation 5: Decides by January 2020 whether to compete task orders beyond the minimum guarantee of six for each contractor through the existing indefinite delivery/indefinite quantity (IDIQ) contract or through the On-Ramp clause.

Management's Response: NASA concurs. The ISS Program will assess viability and determine future competition beyond the minimum guarantee through the existing contract or through the On-Ramp clause.

Estimated Completion Date: January 31, 2020

We have reviewed the draft report for information that should not be publicly released. As a result of this review, we have identified information that should not be publicly released and have communicated our concerns to the OIG in our Technical Comments document.

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

William H Gerstenmaier

William H. Gerstenmaier

APPENDIX F: REPORT DISTRIBUTION

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Congressional Committees and Subcommittees, Chairman and Ranking Member

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

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

Senate Committee on Homeland Security and Governmental Affairs

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

House Committee on Oversight and Government Reform
    Subcommittee on Government Operations

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

(Assignment No. A-17-013-00)