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OFFICE OF INSPECTOR GENERAL

Extending the Operational Life of the International Space Station Until 2024

OFFICE OF AUDITS

AUDIT REPORT

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Acronyms

ATV	Automated Transfer Vehicle
CASIS	Center for the Advancement of Science in Space
CRS2	Commercial Resupply Services round 2
CSA	Canadian Space Agency
ESA	European Space Agency
EVA	Extra-vehicular Activity
FAR	Federal Acquisition Regulation
FDO	Fee Determination Official
FY	Fiscal Year
GAO	Government Accountability Office
HTV	H-II Transfer Vehicle
IEA	Integrated Equipment Assembly
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
kg	Kilogram
kW	Kilowatt
Ni-H2	Nickel-Hydrogen
OIG	Office of Inspector General
ORU	Orbital Replacement Units
ROS	Russian Orbital Segment
SAW	Solar Array Wings
SSP	Space Station Program
USOS	U.S. Orbital Segment

OVERVIEW

EXTENDING THE OPERATIONAL LIFE OF THE INTERNATIONAL SPACE STATION UNTIL 2024

The Issue

In November 2013, the International Space Station (ISS or Station) completed 15 years of continuous operation in low Earth orbit, marking a significant achievement in the history of human spaceflight. Two months later, the Administration announced its intent to extend Station operations until 2024. Originally designed and tested for a 15-year life span, the ISS may now operate for 26 years.

The United States has invested almost $75 billion in the ISS – including construction, operating costs, and transportation – and NASA will continue to spend between $3 and $4 billion per year to maintain and operate the Station going forward.[1] Historically, the Agency's international partners have contributed to ISS operations and helped share associated expenses by providing astronauts, ground facilities, launch vehicles, and other items and services; however, the level of partner participation beyond 2020 is uncertain. A decision by one or more partners to end its participation would increase costs for NASA and any remaining partners.

NASA continues to utilize the ISS as a research platform to study and mitigate a variety of human health risks that will facilitate long-term exploration missions. However, a major portion of the Station's future success as a research platform hinges on the ability of the Center for the Advancement of Science in Space (CASIS) – the group that manages non-NASA research on the portion of the ISS known as the ISS National Laboratory – to attract sufficient interest and funding from private users and investors.

[1] This investment includes $43.7 billion for construction and program costs through 2013, plus $30.7 billion for 37 supporting Space Shuttle flights, the last of which took place in July 2011. We validated construction and development, operations, and research costs; however, the actual cost of Shuttle flights is less certain. For example, Section 202 of the NASA Authorization Act for fiscal year (FY) 2000 (Pub. L. No. 106-391) established general cost limitations on the ISS and Space Shuttle programs and capped Shuttle costs at $380 million per launch. However, in August 2001 the Government Accountability Office (GAO) determined actual costs were closer to $759 million per launch. GAO, "NASA: International Space Station and Shuttle Support Cost Limits" (GAO-01-1000R, August 31, 2001). We used the GAO estimate (adjusted for inflation) in our cost calculation.

In this audit, we examined the challenges facing NASA in extending ISS operations until 2024. Specifically, we assessed NASA's (1) progress in certifying the Station's structure and hardware for a longer lifespan, (2) cost and schedule estimates associated with the extension, and (3) efforts to increase utilization of the Station for exploration and other scientific research. We also examined several of the contracts associated with the Station, including the largest contract – the Boeing ISS Vehicle Sustaining Engineering Contract (Boeing Contract).

Results

We found that while NASA has identified no major obstacles to extending ISS operations to 2024, it must address several areas of risk to ensure continued safe operations. In addition, NASA projects its annual budget for the ISS Program to grow from $3 billion in FY 2014 to nearly $4 billion by FY 2020. However, with a 26 percent cost increase between FYs 2011 and 2013 and an average increase of 8 percent annually over the life of the Program, we believe the assumptions underlying NASA's cost projections are overly optimistic and result in an understated projection of out-year expenses.[2] Third, while utilization of the ISS for research continues to increase, NASA and CASIS continue to face challenges to maximizing its research capabilities.

NASA Has Not Identified Major Obstacles to Extending ISS Operations to 2024 But Several Risks Require Mitigation. NASA continues to assess the long-term viability of the ISS and to date has identified no major obstacles to extending operations to 2024. Nevertheless, the Agency must address several risks. First, the ISS faces a risk of insufficient power generation due in part to faster than expected degradation of its solar arrays. Second, although most replacement parts have proven more reliable than expected, sudden failures of key hardware have occurred requiring unplanned space walks to repair or replace hardware. Third, although NASA has a robust cargo transportation system, it has a limited capacity to transport large replacement parts – such as solar arrays and radiators – to the Station. While the ISS Program is actively working to mitigate these risks, anticipating the correct number and type of replacement parts and transporting them to the ISS present major challenges to extending operations 10 or more years beyond the Station's original expected service life. Additionally, the Program may have to augment the Station's power generating capability due to continued degradation of the solar arrays.

[2] ISS Program officials stated that these costs increases resulted from a number of unique factors they do not expect to reoccur, including acquisition of new hardware to accommodate commercial crew flights by commercial suppliers. However, our analysis shows costs have grown an average of 8 percent per year since inception of the Program in 1994.

NASA's Cost Projections for Future ISS Operations Appear Overly Optimistic. NASA officials have indicated they intend to maintain the ISS annual budget between $3 billion and $4 billion per year through 2024. In our judgment, this estimate is based on overly optimistic assumptions and the cost to NASA will likely be higher. First, much of the projected cost increase is attributable to higher transportation costs, and we found NASA's estimate for transportation costs unrealistic. For example, NASA's estimates for the cost of the commercial crew transportation services they expect to replace for the Russian Soyuz are based on the cost of a Soyuz seat in FY 2016 – $70.7 million per seat for a total cost of $283 million per mission for four astronauts. However, the Program's independent government cost estimates project significantly higher costs when the Agency transitions to purchasing these seats from commercial companies. Second, the Agency's international partners have yet to commit to participating in Station operations beyond 2020. Should they decide not to participate NASA and any remaining partners will likely face higher costs. While ISS Program officials have been seeking ways to reduce costs and consolidate resources, it is unclear whether these efforts will be sufficient to address anticipated cost increases, particularly because the Program does not expect to maintain any funding reserves over the next several years.

Increased Utilization Not Expected to Fully Mitigate Human Health Risks While CASIS Continues to Face Challenges in Encouraging Research by Commercial Industry. While utilization of the ISS for research has increased, NASA and CASIS continue to face challenges. A significant amount of NASA research aboard the ISS involves mitigating risks associated with long-term human presence in space. However, the Agency will not be able to address all of these risks through ISS research even if Station operations continue through 2024. Accordingly, NASA needs to prioritize its research aboard Station to address the most important risks in the time available.

With regard to CASIS, issues relating to funding and patent licenses and data rights continue to pose challenges to the organization's efforts to attract private entities to ISS research. To date, CASIS has raised just $14,550 in cash and received pledges of $8.2 million to supplement NASA's $15 million annual contribution. Moreover, CASIS officials reported provisions in its agreement with NASA that require researchers to assign certain patent licenses and data rights to the Government are deterring commercial stakeholders from conducting research on the ISS. To address this issue, NASA submitted proposed legislation in June 2013 to the Congress that would allow researchers to retain "all rights in inventions made … during the conduct of [Station] activities." However, as of July 2014, the proposal has not been included in any legislation introduced in Congress.

Other Matters of Interest. The Boeing Contract, a cost-plus-award-fee instrument with a period of performance from 1995 through 2015, provides sustaining engineering to the U.S. segment of the ISS. The value of the contract is $17.3 billion. As part of this review, we analyzed NASA's award-fee evaluation scores for the Boeing Contract and found discrepancies between the established guidance in the contract's Award-Fee Plan and the fees awarded to Boeing. Specifically, the Award-Fee Plan provides for evaluations to be conducted using weighted scores with grades in each of four categories. However, NASA performed this evaluation for only two of the four categories. We found that by taking this approach NASA paid Boeing between $6.7 and $13.2 million in award fees we could not validate using the established criteria for the weighted evaluation scoring system.

Management Action

To reduce potential cost growth in the ISS Program, we recommended the Associate Administrator for the Human Exploration and Operations Mission Directorate continue to solicit commitments from international partners to improve ISS cost sharing. To ensure maximum use of the Station for scientific research, we recommended the Associate Administrator prioritize the human health risks to long-term exploration that must be mitigated prior to ISS decommissioning and that the Agency continue to pursue a legislative remedy to the patent license and data rights issue.

In response to a draft of this report, the Associate Administrator concurred with each of our recommendations and proposed corrective action. We consider the proposed corrective action responsive to the recommendations to improve cost sharing and pursue a legislative remedy to the patent and data rights issues and will close those recommendations after verification of the proposed actions. However, with respect to our recommendation to prioritize human health risks, NASA has not yet completed a prioritized and integrated list of risks. Accordingly, we do not consider management's proposed actions fully responsive and therefore the recommendation remains unresolved.

In addition, NASA disagreed with our analysis of the Boeing award-fee process, and stated that we misinterpreted the facts and misconstrued the applicable regulations and program requirements. Specifically, the Associate Administrator stated that our analysis is premised on the inaccurate assumption that the Award-Fee Evaluation Plan "*requires*" the Agency to assign scores and points at the factor level, from which the final score "*must*" be arithmetically computed. The Associate Administrator said no such requirement exists in the Evaluation Plan or any other regulation or directive. He added that NASA officials based the award fees on a "qualitative assessment" of Boeing's performance and that this was the most appropriate way to incentivize the company to perform well.

We disagree with the Associate Administrator's characterization of our report. We did not state that NASA was required to use a weighted scoring system. Rather, because the Evaluation Plan established a system of weighted scores, we attempted to validate the award fees Boeing received using that system and found we could not do so. Indeed, as explained in this report, even though we assumed Boeing received a 100 percent score on two of the major performance factors – management and technical performance and safety and mission assurance – we still could not replicate Boeing's award fee. We acknowledged in the report that NASA's Fee Determination Official (FDO) could have increased Boeing's award fee even if the Performance Evaluation Board had calculated weighted scores for all four factors instead of just two. However, we believe the Board's failure to provide the FDO with this information made NASA's award-fee process less transparent and perhaps less reflective of the company's actual performance.

This is not the first time we have questioned NASA's award-fee practices. In a November 2013 report, we found that overly complex award formulas and a contract clause designed to hold contractors accountable for the quality of the final product that disregards interim performance evaluations have diminished the effectiveness of NASA's award-fee contracts.[3] We also found NASA failed to collect required data on award-fee contracts, thereby reducing its ability to measure their effectiveness. Two recommendations from that audit have yet to be resolved. Most significantly, NASA continues to disagree with the our position that the Agency's practice of making unearned funds from interim award periods available in the final award pool circumvents a provision in the Federal Acquisition Regulation that prohibits Federal agencies from "rolling over" unearned fees to subsequent performance periods. In our view, NASA's policy promotes a philosophy that as long as a mission ultimately provides good science data the Agency will overlook cost and schedule overages that occur during project performance.

We incorporated management's technical comments on our draft into the final report as appropriate. Management's full response to our report is reprinted in Appendix C.

[3] NASA OIG, "NASA's Use of Award-Fee Contracts" (IG-14-003, November 19, 2013).

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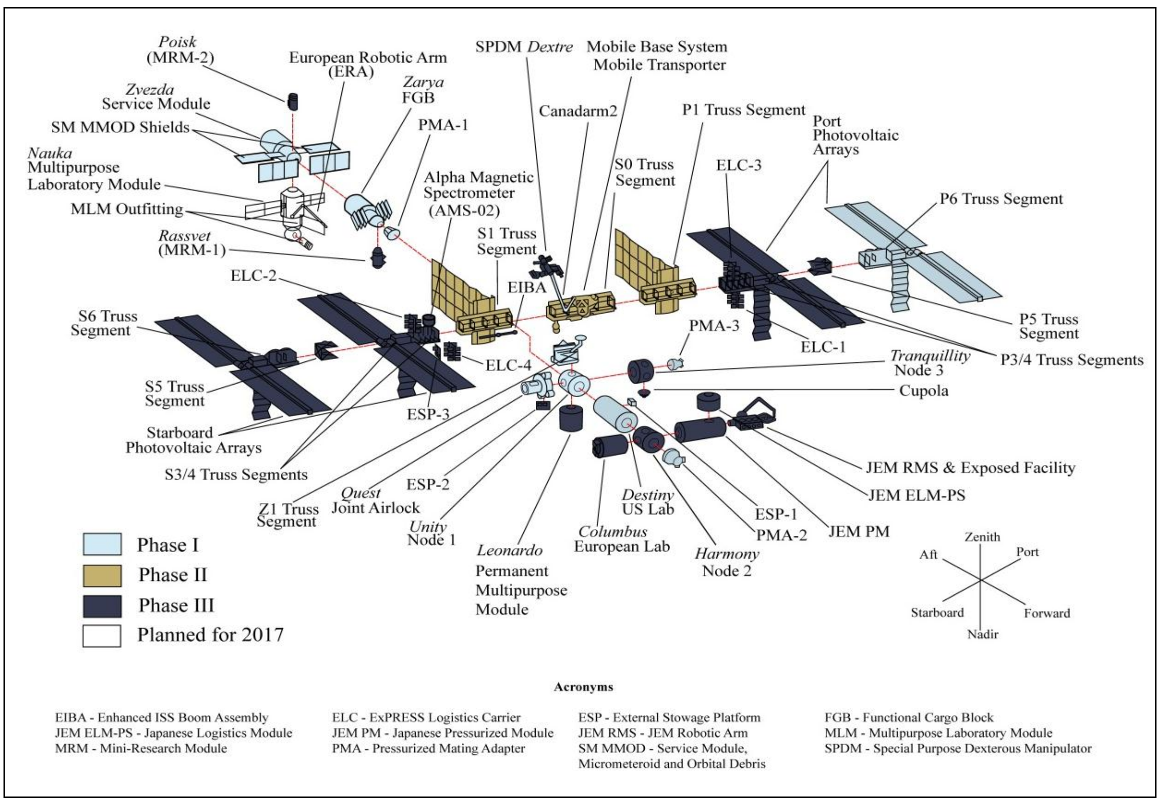
INTRODUCTION

Background

In November 2013, the International Space Station (ISS or Station) completed 15 years of continuous operation in low Earth orbit, marking a significant achievement in the history of human spaceflight. Efforts to inhabit outposts in space began in 1971 when the Soviet Union launched the world's first space station, Salyut 1. NASA followed with Skylab in 1973. Both Salyut 1 and Skylab housed crews for relatively short visits and were not capable of supporting long duration habitation. In 1986, the Russians launched the first module of Mir, the next-generation space outpost. Between 1989 and 1999, Mir hosted astronauts and cosmonauts from the United States, Russia, and other countries, and the Space Shuttle visited nine times. In the mid-1980s, the United States began negotiating with the Canadian, Japanese, and European space agencies to jointly build and operate a space station in low Earth orbit. Russia joined the partnership in 1993, and assembly of the ISS began in 1998. Constructed on-orbit between 1998 and 2011, ISS components were delivered and assembled in three phases. (See Figure 1.)

Figure 1. ISS Assembly by Phase



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

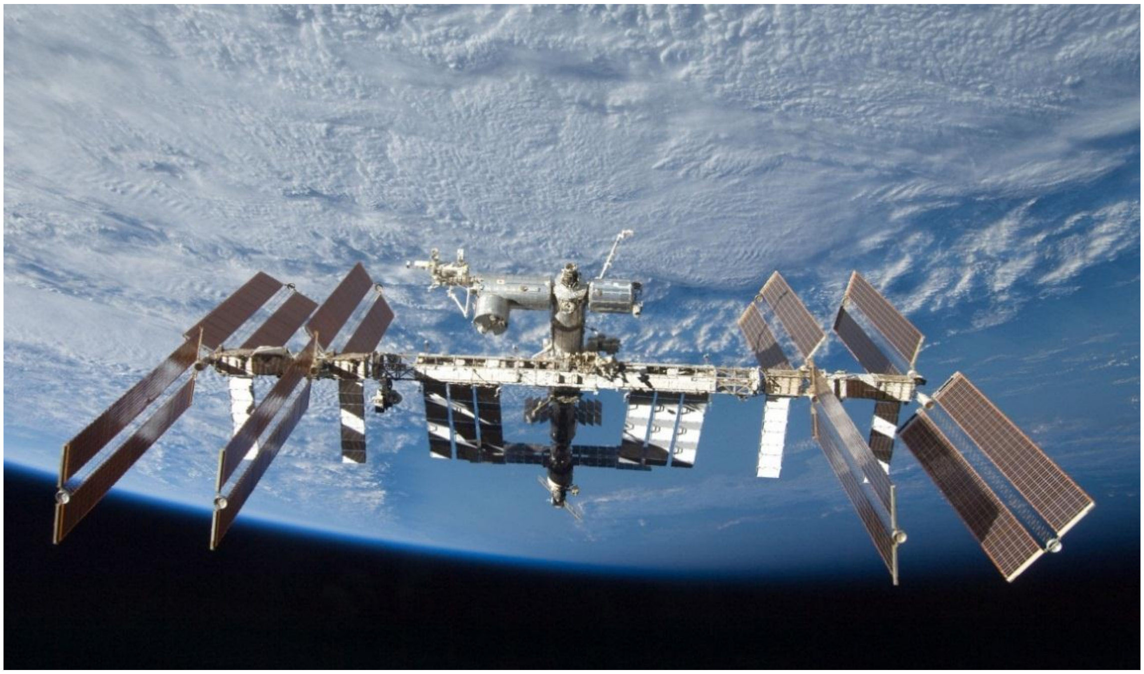
The first module – the Russian-built, U.S.-funded Zarya – launched on a Russian Proton rocket in November 1998 and provided electrical power, storage, propulsion, and guidance for the Station. The following month a Space Shuttle delivered the U.S. module, Unity, which connected environmental control, life support, and electrical and data systems to the Station and provided six docking locations for connecting other modules. In July 2000, Russia launched the Zvezda Service Module, which provided the main living quarters for the crew as well as environmental systems, electronic controls, and additional docking locations. In November 2000, two Russian cosmonauts and one American astronaut became the first crew to live and work on the ISS. Almost 9 years later in May 2009, with the addition of the fourth and final power-generating section, the ISS became capable of supporting a crew of seven.[4] Final assembly of the Station was completed in July 2011, with installation of platforms to support external payloads and the Alpha Magnetic Spectrometer.[5] (See Figure 2.)

The ISS is divided into two segments – the Russian Orbital Segment (ROS) and the U.S. Orbital Segment (USOS). The USOS segment is comprised of hardware from NASA, the European Space Agency (ESA), the Canadian Space Agency (CSA), and the Japan Aerospace Exploration Agency (JAXA).

[4] Although the ISS can support a crew of seven, currently only six individuals can be on Station at one time to accommodate evacuation in case of an emergency. The Russian Soyuz capsule, which is currently the only vehicle transporting astronauts to the Station, has a three-person capacity and only two Soyuz capsules are attached to the Station simultaneously. Higher-capacity transport vehicles under development by private companies will enable NASA to increase the Station's capacity to a full crew complement of seven.

[5] The Alpha Magnetic Spectrometer collects protons, electrons, and other charged particles, for analysis by recording the number and type of particles that pass through its collectors, as well as information about their charge, mass, and velocity.

Figure 2. Completed ISS



Source: NASA.

Value of the ISS. The ISS provides a platform to perform a wide variety of experiments focused on life and physical sciences, human research, exploration research, and technology development. According to NASA officials, the ISS serves an essential role in helping the Agency develop ways to mitigate human health risks associated with space travel, test new technology in anticipation of future long-term exploration missions, and serve as a research platform to improve life on Earth. Federal law directs NASA to pursue commercialization of low Earth orbit, and the ISS is the only existing micro-gravity platform upon which to perform research and determine commercially viable uses of low Earth orbit. NASA officials also point to other less tangible benefits of the Station, including maintaining U.S. leadership in space, supporting cooperation with international partners, and inspiring current and future engineers and scientists.

ISS Costs. The final configuration of the ISS cost more, took longer to complete, and is less capable than NASA and its partners envisioned. NASA originally estimated assembly of the Station would be complete by 2002 at a total cost to the Agency of $17.4 billion. However, construction was not completed until 2011, and through fiscal year (FY) 2013 the Agency has spent approximately $74.4 billion for ISS development, operations, research, and associated Space Shuttle flights.[6] Cost projections estimate NASA will spend an additional $20.6 billion between FYs 2014 and 2019.[7]

Initial plans called for a space outpost that would serve more functions than the current Station, including as a manufacturing and a staging facility for other exploration missions.[8] Further, the length of the ISS decreased from 493 to 357 feet, a 27.6 percent reduction compared to early plans, and crew capacity dropped from eight to seven. The cost growth, schedule delays, and functional changes resulted primarily from underestimation of the technical complexity of building the Station; changes in Federal Government funding priorities; and the Challenger and Columbia Space Shuttle accidents, which delayed and reduced the number of flights devoted to ISS assembly.[9]

In FY 2013, NASA devoted $2.9 billion, or approximately 17.2 percent of its $16.9 billion budget, to the ISS Program.[10] In comparison, funding for development of NASA's heavy-lift rocket – the Space Launch System – was $1.4 billion and the accompanying space capsule (Orion) $1.1 billion. As shown in Figure 3, most ISS funding is devoted to system operations and maintenance (43 percent) and crew and cargo transportation (34 percent).

[6] The $74.4 billion amount includes $30.7 billion for Shuttle flights. Section 202 of the NASA Authorization Act for FY 2000 (Pub. L. No. 106-391) established general cost limitations on the ISS and Space Shuttle programs, capping Shuttle launch costs at $380 million per launch. However, in August 2001, the Government Accountability Office (GAO) found actual costs were closer to $759 million per launch. GAO, "NASA: International Space Station and Shuttle Support Cost Limits" (GAO-01-1000R, August 31, 2001). We used the GAO estimate in our cost calculation adjusted for inflation.

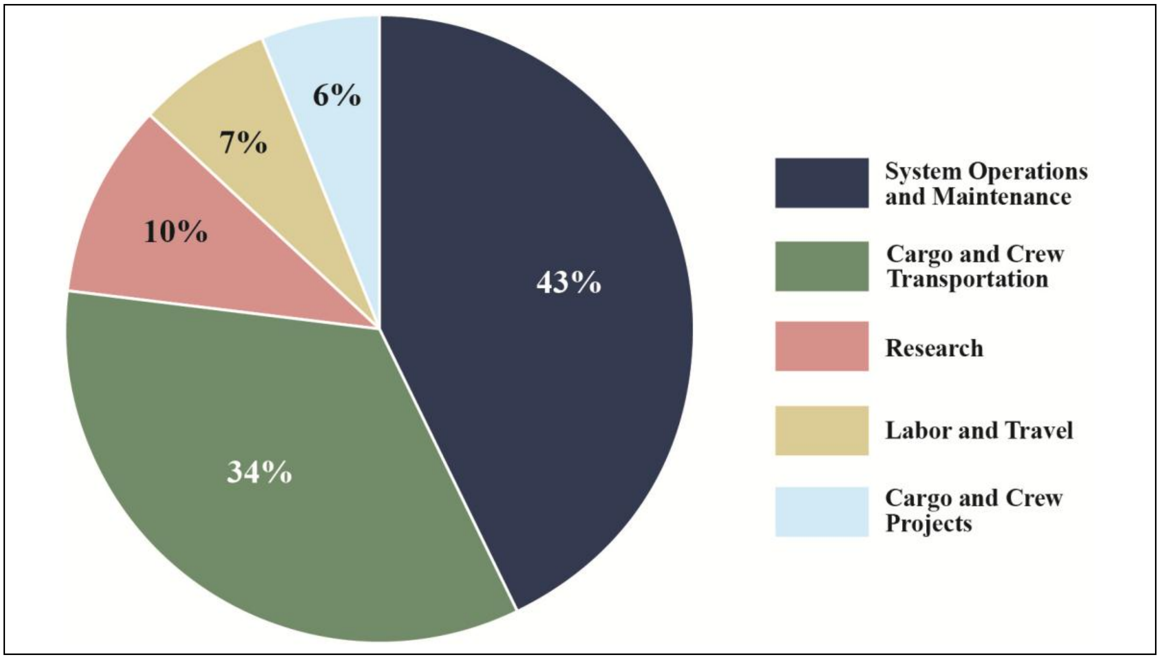
[7] This totals almost $100 billion through 2019 – a figure often cited as the amount NASA spent to build and operate the ISS. However, the actual cost to date is closer to $75 billion. Differences in cost figures are partially due to variations in the cost-per-flight assumptions for the Space Shuttle, which has been estimated as high as $1.5 billion per launch including all direct and indirect costs. The Shuttle made 37 flights to support ISS construction and operation.

[8] Other planned functions included a transportation hub to process vehicles and payloads, a servicing facility, an assembly facility, and a storage depot.

[9] Loss of the Challenger Space Shuttle in 1986 led to a significant reduction in the number of planned flights and missions. Further, after the loss of the Columbia Space Shuttle in 2003, NASA suspended flights to the Space Station for over 2 years.

[10] Although the ISS Program spent $2.9 billion in FY 2013, its budget allocation was approximately $2.8 billion. The additional funds (about $91 million) rolled forward from previous years in accordance with NASA's 2-year appropriation.

Figure 3. Allocation of FY 2013 ISS Operating Costs



Source: NASA OIG analysis of ISS Program information.

System operations and maintenance costs ($1.23 billion/43 percent) encompass expenses related to mission operations; hardware, including Orbital Replacement Units (ORU); and extra-vehicular activities (EVA) commonly known as space walks.[11] In FY 2013, the ISS Program spent $90 million on ORUs and plans to spend $422 million more on these items between FYs 2014 and 2020. As of January 2014, NASA's ORU inventory was valued at $1.1 billion, with half the inventory located on-orbit and half in storage on Earth.

Crew and cargo transportation costs ($970 million/34 percent) include all transportation expenses to the Station. Crew transportation costs (13 percent) primarily reflect NASA's payments to Russia for seats on the Soyuz capsule. Since retirement of the Space Shuttle in 2011, Soyuz is the sole means of transporting humans to the ISS. For the past several years, NASA has been working with several domestic companies to develop commercial crew transportation systems and hopes to procure crew transportation to the ISS from at least one commercial company by 2017.[12] Once this occurs, NASA plans to purchase a

[11] ORUs are ISS hardware items such as fluid pumps, electrical switches, and motors replaced upon failure or as part of routine maintenance.

[12] Commercial Crew Program development funding is a separate budget line not included in this category. For more information about NASA's Commercial Crew Program, see NASA OIG, "NASA's Management of the Commercial Crew Program" (IG-14-001, November 13, 2013).

limited number of seats aboard the Soyuz as a backup. Cargo transportation costs (21 percent) consist of the money NASA pays to Space Exploration Technologies (SpaceX) and Orbital Sciences Corporation (Orbital) under its Cargo Resupply Services contracts with those companies to deliver supplies to the ISS.[13]

Research costs ($273 million/10 percent) include expenses NASA incurs conducting exploration-related research aboard the ISS, as well as the $15 million annual award the Agency makes to the Center for the Advancement of Science in Space (CASIS). CASIS manages non-NASA research on the portion of the ISS known as the ISS National Laboratory (National Lab) pursuant to a cooperative agreement with the Agency.[14]

Labor and travel costs ($223 million/7 percent) fund the salaries, travel, and other personnel expenses for the civil servants assigned to the ISS Program.

Cargo and crew projects costs ($167 million/6 percent) include Station development projects such as the International Docking Adapter and a common communications box, which will provide a standard docking and communications interface for commercial crew and international partner vehicles.

NASA funds these activities through 29 major contracts with a current value of $32 billion and an additional $4.6 billion in contract options.[15]

ISS Supporting Contracts. Seventeen of NASA's 29 major ISS contracts are cost-reimbursement vehicles pursuant to which the Agency agrees to pay all allowable costs incurred by the contractor as a function of delivering the covered services or products. Most of these contracts also include an "award fee" – an additional pool of money the contractor may earn depending upon its performance. Of the 17 cost-reimbursement contracts, 15 include award-fee provisions. Properly structured award-fee contracts can reduce the risk of cost overruns, delays, and performance failures by providing a well-performing contractor the opportunity to earn additional money. The largest ISS contract, known as the Boeing Vehicle Sustaining Engineering Contract (Boeing Contract), is a cost-plus-award-fee contract. With a period of performance from 1995 through 2015, the $17.3 billion Boeing Contract provides sustaining engineering to the U.S. segment of the ISS.

[13] In addition to SpaceX and Orbital, ESA and JAXA also provide cargo transportation to the ISS. For more information about NASA's commercial cargo transportation efforts, see NASA OIG, "Commercial Cargo: NASA's Management of Commercial Orbital Transportation Services and ISS Commercial Resupply Contracts" (IG-13-016, June 13, 2013).

[14] The NASA Authorization Act of 2005 (Pub. L. No. 109-155) designated the U.S. segment of the ISS as a national laboratory and directed NASA to work to increase utilization of the Station's research capabilities by other Federal entities and the private sector. The NASA Authorization Act of 2010 (Pub. L. No. 111-267) required NASA to enter into a cooperative agreement with a nonprofit organization to manage at least 50 percent of the Agency's available research resources on the ISS.

[15] NASA disbursed an additional $46.7 million for research through other contracts, grants, and cooperative agreements.

Utilization and Research. Given the resources and effort expended to build the ISS, national leaders have emphasized the importance of maximizing the Station's scientific research capabilities to benefit NASA's human exploration efforts and the nation generally. Pursuant to Federal law, 50 percent of the U.S. research capability of the Station is to be dedicated to commercial and private entities and other Government agencies, and the other half to NASA research that, among other things, seeks to reduce risks associated with human space exploration.

In 2011, NASA awarded CASIS a cooperative agreement to facilitate utilization of the National Lab. CASIS promotes scientific research in the Lab by directly soliciting potential users; educating them on the ISS's research capabilities; and utilizing professional, academic, and personal contacts to match potential investors and researchers. CASIS stimulates research activity by funding proposals directly, matching outside investors with researchers, and encouraging self-funded research. NASA provides CASIS $15 million annually, at least $3 million of which the organization must use to fund research grants. In FY 2013, CASIS distributed $4.9 million in research grants.

NASA measures utilization of the ISS in several ways, including crew time spent on research, number of scientific investigations, and occupancy rate of allocated research space.

Crew Time. Crew time refers to the hours the crew devotes to research activities as opposed to other tasks, such as sleeping, exercising, eating, and personal time. NASA divides each 24-hour period into 11 hours for work activities and 13 hours for other activities. Of the 11 work hours, 2.5 are set aside for exercise and 2 for planning and work preparation. NASA allocates the remaining 6.5 hours as follows:

- <u>Utilization and research (41 percent)</u> – includes set-up, completion of scientific investigations, and removal of the items for return to Earth.
- <u>Visiting vehicle traffic operations (27 percent)</u> – includes time for preparing for vehicle arrival and departure. For cargo vehicles, the time to unpack, stow, and document the location of supplies and repack the vehicle with trash or other items for return to Earth is included in this category. For a crew vehicle, this category includes time for crew exchange and information handover.
- <u>Maintenance (14 percent)</u> – includes corrective and preventive maintenance activities.
- <u>EVA operations (6 percent)</u> – includes planning for spacewalk activities outside the ISS.
- <u>Training (4 percent)</u> – includes emergency egress training, depressurization response, Soyuz evacuation, simulated fire drills, emergency response, procedures review, and robotics proficiency.

- Routine operations (4 percent) – refers to crew meetings, stowage management, auditing of supplies, and public affairs events.

- Medical operations (3 percent) – includes maintenance of exercise and health monitoring equipment and other activities associated with monitoring the effects on the human body due to traveling and living in space.

- Resupply and outfitting (1 percent) – includes hardware and software upgrades and vehicle configuration changes.

Occupancy of Allocated Space. NASA has 19 laboratory bays and 15 external sites that house research experiments on the ISS. The laboratory bays, which contain racks, freezers, and other infrastructure that support biological, life science, and other types of experiments, are located in the U.S., European, and Japanese labs. The external sites, located outside the ISS, are used primarily for astronomical studies, Earth observation, and technology development and demonstrations for robotics, materials, and space systems.

Hardware Assessment and Certification. NASA and its international partners designed and tested the ISS for a 15-year life span – a benchmark the oldest segments of the Station surpassed in November 2013. The NASA Authorization Act of 2010 extended the life of the Station until 2020, and NASA and its Canadian, Japanese, and European partners have certified that the ISS structure and hardware are sufficient to continue operations until that date.[16] In January 2014, the President announced his support for extending Station operations until at least 2024.[17] Prior to this announcement, NASA had initiated a feasibility assessment for continuing operations until 2028.[18]

In order to predict the reliability of equipment aboard the ISS, NASA calculates a "mean time between failures" for each component and uses these figures to predict component life span, determine the need for ORUs, and manage procurement of new ORUs and repairs of existing units. The ISS Program performs an analytical assessment of its ORU inventory annually and uses a 90 percent functional availability target.[19]

[16] Certification is the formal written act whereby a responsible official attests to the satisfactory accomplishment of specified activities and authorizes the specified hardware or software, procedures, facilities, or personnel for Program usage. Russian officials reportedly are nearing completion of certification of their portion of the ISS through 2020 but have not yet provided NASA with a written analysis.

[17] As of July 2014, the House of Representatives had passed a NASA Authorization Act and the Senate was considering its version. Both bills include reporting requirements related to the Station's technical/operational feasibility, financial, and international partnerships.

[18] NASA defines an assessment as the method for performing verification or certification. For ISS certification, the focus is primarily on analytical assessments using the performance data from the 15 years of ISS operation. NASA expects to complete its 2028 assessment in 2018.

[19] Functional availability measures the overall performance of ISS logistics and maintenance capability to sustain the ISS on-orbit system operations and the achieved operating time for a system over a possible operating time.

In the first several years of the ISS Program, NASA officials had difficulty predicting when failures would occur given that many parts were new, one-of-a-kind components. Over the past 15 years, as the Agency has received actual performance data, its ability to predict the "mean time between failures" has improved.[20]

In order to prepare for unexpected component failures on the ISS, astronauts undergo extensive training, including preparations for EVAs to repair Station hardware and for an emergency return to Earth. Although the Station has experienced significant component failures over the years, no critical life support system has ever failed, mainly due to the levels of redundancy in the Station's structural and operational systems. (See Table 1.)

Table 1. Significant Station Events That Caused Operational Uncertainty

Issue	Date	Description	Corrective Action
Air leak	January 2, 2004	Minor air leak of up to five pounds per day; no immediate risk to crew	Leak found in vacuum jumper hose installed onto window of U.S. segment; leak fixed
Potassium hydroxide leak	September 18, 2006	Russian-built oxygen generator leaked potassium hydroxide; unit shut down	Spare parts delivered to repair the oxygen generator; unit reactivated
Computer malfunction	June 14, 2007	Three Russian computers shut down, resulting in the loss of capability to control Russian segment systems	Failure caused by excessive condensation on the units; computer network was rebuilt using new hardware; steps taken to prevent future condensation issues
Solar panel tear	October 30, 2007	Solar panel tore during deployment	Improvised cuff links installed to strengthen the area near the tear
Solar Alpha Rotary Joint (Solar Joint) not working correctly	November 2007	Unusual vibration noticed when repositioning right-side solar arrays; EVA conducted in November 2007 found damage to Solar Joint	Problem believed to have been caused by inadequate lubrication; four EVAs conducted to replace 11 trundle bearings in Solar Joint
Coolant pump A malfunction	July 31, 2010	Coolant pump module used to circulate ammonia cooling fluid malfunctioned, causing ISS cooling capability to drop to 50 percent	Three EVAs conducted to replace pump module
Orbital debris close call	June 28, 2011	Orbital debris passed within 1,100 feet of the ISS	Crew entered Soyuz escape vehicles in preparation for possible strike from orbital debris

[20] In a 2011 report, GAO found NASA was utilizing a reasonable method for predicting the "mean time between failures" of ORUs. GAO recommended NASA continually update its data based on actual performance in order to ensure increasingly accurate estimates. NASA concurred with the recommendation. See: GAO, "International Space Station: Approaches for Ensuring Utilization through 2020 Are Reasonable but Should Be Revisited as NASA Gains More Knowledge of On-Orbit Performance" (GAO-12-162, December 2011).

Issue	Date	Description	Corrective Action
Main Bus Switching Units (MBSU) malfunction	Late 2011-September 2012	MBSU malfunctioned causing ISS power capability to drop to 75 percent available	Two EVAs conducted to replace component with spare
Ammonia leak	May 9, 2013	Astronauts observed ammonia leaking from coolant loop	EVA conducted to replace faulty pump controller box
EVA Terminated Early – Spacesuit Malfunction	July 16, 2013	Hardware failure caused water to enter into astronaut's helmet causing impaired breathing, vision, and communication	Mishap accident board developed 49 recommendations. Suits were inspected, blockage was cleared, and astronauts resumed use.
Coolant pump A malfunction[a]	December 11, 2013	Coolant pump module that circulates ammonia cooling fluid malfunctioned and caused half the ISS to lose cooling power	Two EVAs conducted to replace pump module
External Computer Malfunction	April 2014	Back-up Computer used to relay commands between computers and systems outside the ISS failed	EVA conducted to replace the faulty computer with a spare

[a] We discuss coolant pump A in more detail later in the report.

Source: NASA OIG review of ISS Program data.

Inherent Risks of Human Spaceflight. Although NASA and its partners have enjoyed more than 15 years of successful flights to and from the ISS, space exploration remains an inherently risky endeavor.[21] For example, NASA officials estimate a 1-in-42 chance in any given 6-month period that orbital debris will puncture the Station and cause a loss of pressurization. Applying this estimate over the life of the ISS equates to a 1-in-4 chance of such a puncture. NASA has put in place a variety of contingency plans to avoid loss of mission or crew should a puncture or other emergency occur. For example, astronauts routinely train for an emergency evacuation using the docked Soyuz capsules. Although the risks involved in space exploration are apparent and subject to mitigation, NASA cannot fully eliminate them.

Objectives

In this audit, we examined the challenges facing NASA in extending the ISS until 2024. Specifically, we assessed NASA's (1) progress in certifying the Station's structure and hardware for a longer lifespan, (2) cost and schedule estimates associated with the extension, and (3) efforts to increase utilization of the Station for exploration and other scientific research. See Appendix A for details of the audit's scope and methodology, our review of internal controls, and a list of prior coverage.

[21] Shuttle Columbia and its seven astronauts who were lost during reentry in February 2003 did not visit the Station.

NASA HAS NOT IDENTIFIED MAJOR OBSTACLES TO EXTENDING ISS OPERATIONS TO 2024 BUT SEVERAL RISKS REQUIRE MITIGATION

NASA continues to assess the long-term viability of the ISS and to date has identified no major obstacles to extending operations to 2024. Nevertheless, the Agency must address several areas of risk. First, the ISS faces a risk of insufficient power generation due in part to faster-than-expected degradation of its solar arrays. Second, although most replacement parts have proven more reliable than expected, sudden failures of key hardware have occurred requiring unplanned space walks to repair or replace the hardware. Third, although NASA has a robust cargo transportation system for many supplies, the Agency has a limited capacity to transport large replacement parts such as solar arrays and radiators to the Station. While the ISS Program is actively working to mitigate these risks, anticipating the correct amount of replacements parts and transporting them to the ISS present major challenges to extending Station operations 10 or more years beyond its expected 15-year service life. Additionally, the Program may need to augment the Station's power generating capability due to continued degradation of the solar arrays.

NASA and its International Partners are Actively Assessing the Long-term Viability of ISS Structure and Hardware

NASA has certified the U.S. segment of the Station and the Zarya module for operation through 2020, and to date has not identified any major structural, hardware, or software deficiencies that would prevent continued use of the ISS until 2024.[22] As discussed earlier, the President recently proposed extending Station operations until 2024, and NASA is conducting a formal assessment of the possibility of extending operations four years beyond that date to 2028. At the same time, NASA's international partners are assessing the viability of extending the service life of the portions of the Station for which they are responsible. Table 2 shows the status of assessments for extending the ISS until 2020 and 2028 for the United States and its partners.

[22] As noted previously, although part of the ROS, NASA funded the Zarya module.

Table 2. Status of ISS Structure and Hardware Assessments

Partner	2020	2028	Status
United States			2028 extension analysis not expected until 2018; results heavily dependent on sufficient ORUs
Russia			Russians have not identified any major issues in verbal discussions, but NASA has not received any written studies or reports
Japan			All work is complete to certify JAXA hardware through 2028; adequate number of spare parts through 2020
European Space Agency			Cleared both module and payload facilities and spares for 2028 life span
Canada			Extension until 2020 has no major issues; limited spares for Mobile Servicing System

Legend

Cleared with supportable plan in place to correct future deficiencies

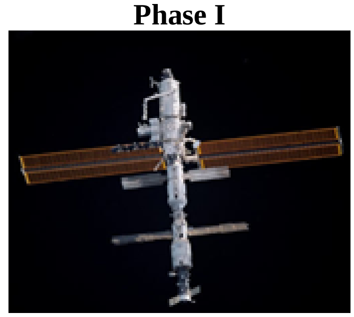
Only minor issues identified so far that require mitigation

Source: NASA OIG presentation of ISS Program data.

NASA is analyzing the primary U.S. structural hardware components using a three-phased approach based on the parts' delivery date to the ISS. The Agency has completed its assessment of almost all hardware included in the first two phases.

- *Phase I* – assessment of hardware installed through summer 2001, including the oldest U.S. segments such as the Unity Node, which surpassed its expected life span in December 2013.

Phase I



Source: NASA.

- *Phase II* – assessment of hardware installed between summer 2001 and November 2002. Expected life span for these items expires in 2016-2017.

Phase II

Source: NASA.

- *Phase III* – assessment of hardware installed between November 2002 and February 2011. The expected life span for this hardware expires between 2017 and 2026.

Phase III

Source: NASA.

NASA has certified for operation through 2028 all Phase I and II hardware, except the P6 Integrated Equipment Assembly (IEA), one of the truss segments that forms the backbone of the ISS. Two of the Station's solar arrays and other electrical equipment are attached to the P6 IEA. When the P6 IEA was delivered to the ISS in 2000, it was installed in a temporary location. Because of mission-related delays resulting from the Shuttle Columbia accident in 2003, the P6 IEA remained in the temporary location until October 2007, much longer than anticipated. Accordingly, NASA is taking extra steps to verify that the stresses exerted on the P6 IEA in the temporary location were within acceptable limits to certify the component through 2028. The P6 IEA analysis report is scheduled for release in September 2014, and ISS Program officials expect the truss will be cleared for continued operation.

Analysis of all Phase III hardware is scheduled for completion by June 2018. While NASA does not anticipate any major issues, to further reduce risk the Agency initiated an additional study scheduled for completion by March 2015 of all Phase III hardware considered medium- or high-risk.[23]

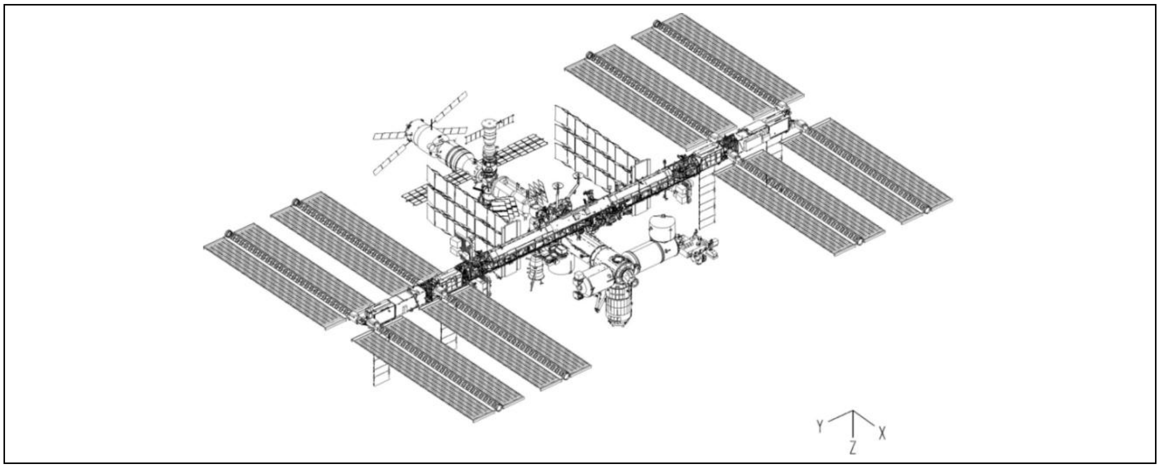
Electrical Power Systems Face Risks Due to Faster-than-Expected Degradation of Key Hardware

The ISS's solar arrays – each of which is almost 240 feet in length when fully deployed – generate electricity for the Station's electrical power system and use bearing motors to position the arrays toward the sun. Both the arrays and the motors have degraded more quickly than expected. NASA attributes the expedited solar array degradation to exposure to more space debris than anticipated. With regard to degradation of the bearing motors, ISS Program officials have identified a root cause and determined that additional lubrication will help alleviate the issue.

[23] The Solar Joints are hardware designated a medium risk while the P3/S3 trusses are high risk.

The USOS is equipped with eight Solar Array Wings (SAW) (see Figure 4). Two Solar Alpha Rotary Joints (Solar Joints) and eight bearing motors continuously position the arrays toward the sun to maximize collection of usable solar energy. Each array has an operational life of 15 years, and the first two units delivered and installed on the ISS will reach the end of their expected life spans in 2015. The remaining units will reach their expected life spans in 2021, 2022, and 2024 (two each year).

Figure 4. The Eight SAWs of the ISS



Source: NASA.

The electricity generated by the solar arrays is distributed to the Station through eight channels. Each channel connects to three pairs of rechargeable Nickel-Hydrogen (Ni-H2) batteries, which provide electricity to the USOS during the eclipse portion of each ISS orbit.[24] These batteries are recharged when the Station is orbiting in the direct path of the sun.

The USOS electrical power system is designed to provide 76.4 kilowatts (kW) of electricity to the USOS segment, of which a maximum of 30 kW is required to support payloads and research. In addition, NASA has agreed to provide up to 12 kW of power to the ROS. Actual power demands have been less as payloads and research have been consuming only 7 to 12 kW per day on average and the USOS is transferring only about 4 kW to the ROS.

[24] The eclipse portion of each orbit around the Earth occurs when the ISS is in the Earth's shadow and has no contact with the sun.

NASA designed each SAW to generate 30.8 kW of power and expected power output to diminish by about 1 percent per year over each unit's operational life due to the harsh space environment, in particular micro-meteor strikes and radiation emitted by protons.[25] However, the SAWs are degrading faster than predicted. As shown in Table 3, the two oldest SAWs, Channels 2B and 4B, are degrading at an average rate of 1.8 percent per year, and the Channel 4A SAW is degrading at an average rate of 2 percent per year.

Table 3. SAW Degradation Rates

SAW	End of Design Life	Degradation Rate
Channel 4A	2021	2.0%
Channel 2B	2015	1.8%
Channel 4B	2015	1.8%
Channel 2A	2021	1.8%
Channel 3A	2022	1.7%
Channel 1B	2024	1.7%
Channel 3B	2024	1.6%
Channel 1A	2022	1.5%

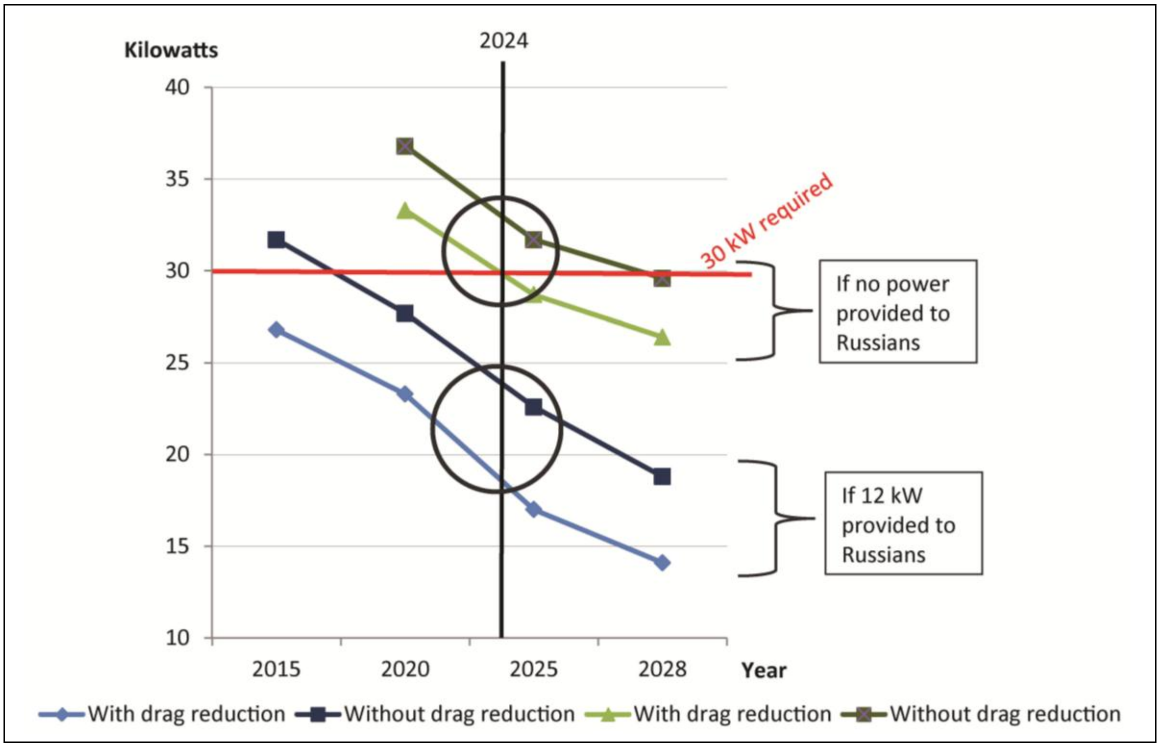
Source: NASA OIG presentation of NASA information.

ISS Program officials are making plans to compensate for the faster-than-expected degradation rates of the solar arrays. First, the Russians plan to deliver a module (the Scientific Power Module) around 2019 that will increase the Station's capability to generate power and eliminate the need for the USOS to provide them with power. Second, the ISS Program has the option to reconfigure the orientation of the solar arrays so they will generate approximately 2 to 3 kW more power (see Figure 5).[26] Program officials believe the Station will be able to meet the 30 kW requirement once the Russians deliver their module and, if needed, the solar arrays are oriented to a position that maximizes exposure to sunlight and power generation.

[25] Protons are charged subatomic particles and the main source of radiation astronauts receive during spaceflights.

[26] To help the ISS maintain orbit, NASA has placed the solar arrays in a position that reduces aerodynamic drag on the ISS. However, this diminishes their capacity to generate electricity. Although repositioning would increase energy production, it would also increase drag and therefore make it more difficult for the Station to maintain orbit. To compensate for this, NASA would use more propellant to boost the Station back into the correct orbit.

Figure 5. Solar Array Degradation Based on 30 kW Power Requirement



Source: NASA OIG presentation of ISS Program data.

Although NASA is confident it can address the accelerated degradation of the SAWs, the Agency also faces issues related to the bearing motors that rotate the SAWs toward the sun. One of the eight bearing motors is currently operating outside of specifications, but analysis has shown the effect on overall power generation is not significant. Although the Program developed contingency plans for replacing four of the eight motors, Program officials have instead decided to procure repair kits and execute a return-and-repair plan only if the motors lose full function.

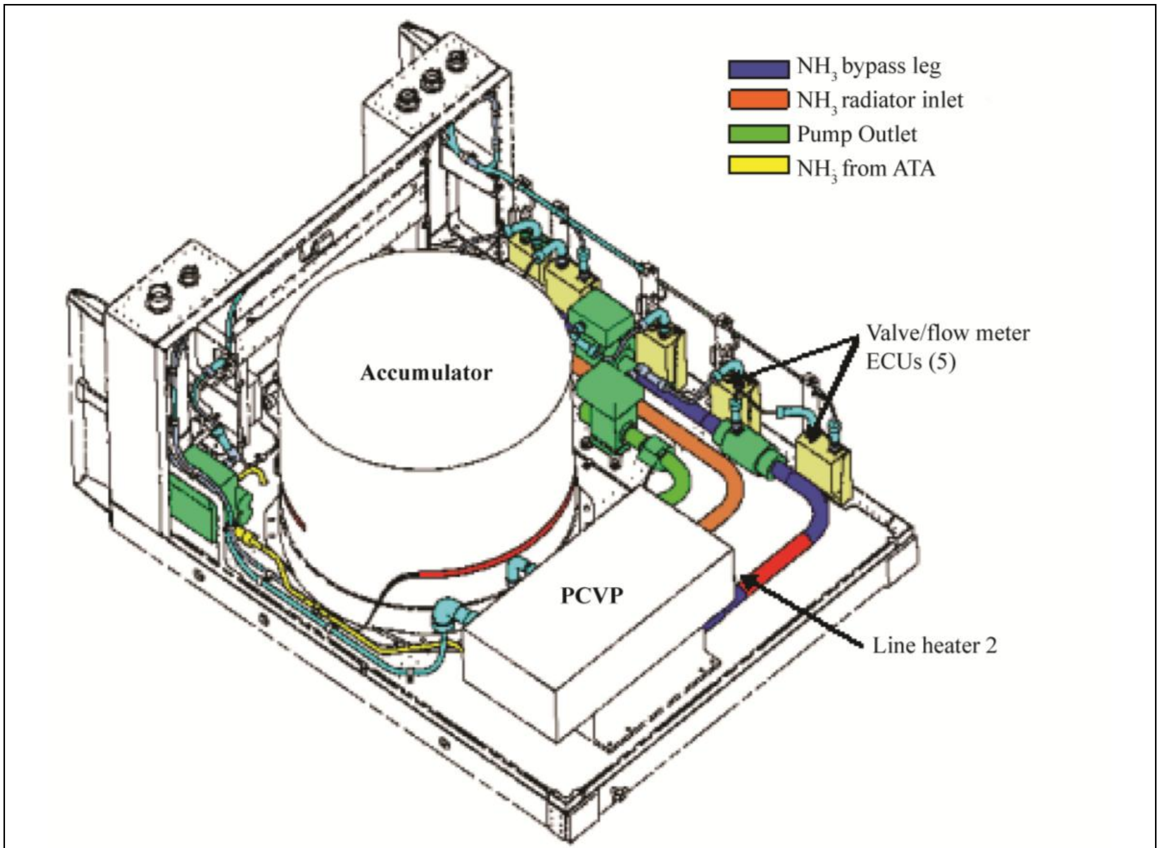
While NASA has plans for managing degradation of the SAWs, its ability to meet the 30 kW power requirement for payloads and research depends on all of these pieces falling into place. If, to the contrary, degradation rates increase, bearing motors fail, or the Russians continue to require power from the USOS beyond 2019, NASA would need to devise a solution for generating additional electricity or begin rationing available power, with the latter option likely resulting in less research on Station. One possibility the Agency is considering is augmenting the existing solar arrays with smaller, redesigned arrays; however, managers have not yet approved a plan to proceed with this option.

ORUs Proven More Reliable than Anticipated but Risks Remain

The ISS Program currently has more than $1.1 billion worth of spare ORUs on-orbit or on Earth, and NASA expects to procure an additional $420 million of ORUs through FY 2020. Nevertheless, NASA may not have sufficient spare ORUs to replace those that fail or exceed their operational lives. In addition, with retirement of the Space Shuttles, NASA has lost the capacity to launch the largest ORUs and therefore runs the risk it will not be able to replace this hardware should it fail.

Lack of Spare ORUs Creates Risk. Beyond what is already being built or repaired, the ISS Program determined that only a small number of additional ORUs are needed in the near term – from 2014 through 2018 – to supplement those on-orbit or in a ready-to-fly status. However, continuing to operate beyond that date creates additional ORU-related risks NASA must manage. For example, the Agency's most recent assessment shows that although the two Pump Module Assemblies (Pump Modules) currently on-orbit should be sufficient to sustain operation to 2018, six more would be needed to extend operations to 2028. The Pump Modules are part of the External Active Thermal Control System that reduces heat inside the USOS pressurized cabins (see Figure 6). The system consists of two independent loops – A and B – which collect heat from inside the Station and transfer it to radiators that expel the heat into space. The loops are redundant and each provides adequate heat dissipation should the other fail. The Pump Modules provide the flow and temperature control for the ammonia that runs through both loops.

Figure 6. Diagram of Thermal System Pump Unit



Source: NASA's ISS Program.

The loop A Pump Module failed twice in the past 3 years, most recently in December 2013. Although loop B continued to operate, loss of the loop A Pump resulted in no back-up capability.[27] Although not classified as an emergency, NASA recognized the urgency of the situation and immediately scheduled two unplanned spacewalks during which astronauts replaced the failed unit. To accommodate the spacewalks, a cargo resupply mission was delayed until the following month. The ISS now has two fully functional spare Pump Modules on-orbit. ISS Program managers believe the current spares will be adequate until 2017 when a repaired Module will become available.

A similar situation exists with the six External Active Thermal Control System radiators that transfer the heat absorbed by the system into space. NASA currently has one radiator ORU stored on-orbit and managers believe this will be sufficient to continue operation until 2018. However, two additional radiator ORUs would be required on-orbit to extend the Station to 2023, and one more to sustain operations until 2028.

[27] Loop B has been operating for over 7 years without issue.

Limited Capacity to Transport Large ORUs. Most of the spare ORUs currently on-orbit were flown and positioned on the ISS using the Space Shuttle, which was capable of transporting large ORUs. However, since retirement of the Shuttles, NASA does not have a vehicle capable of carrying a replacement SAW or Heat Rejection Subsystem radiator to the Station. Although Orbital has a design that could carry large ORUs and SpaceX is developing a heavy lift version of its Falcon launch vehicle, neither vehicle is expected to be available until 2015 at the earliest. Moreover, although NASA has other options to transport SAW or Heat Rejection Subsystem radiator replacements– for example, sending smaller, redesigned arrays on the current fleet of cargo spacecraft to augment the existing solar arrays – the Program believes the arrays will last until 2024 and therefore has not approved such alternatives.

Battery Replacement Dependent on Japanese Vehicle. Another large set of ORUs that will need replacing to extend ISS operations are the Ni-H2 batteries that provide electricity when the Station is in the eclipse portion of its orbit. The batteries had an expected operational life of 6.5 years, which has been extended to 10 years by reconditioning and lower-than-expected drainage rates. The oldest batteries on Station have been operating since 2006 and the newest since 2010. Accordingly, replacements will be needed to extend ISS operations beyond 2020.

NASA plans to replace the Ni-H2 batteries with newly designed Lithium-Ion batteries, which have a greater capacity to store energy. One of the new batteries will replace two Ni-H2 models. NASA plans to deliver 24 of the new batteries in a series of four launches between 2017 and 2020 using Japan's H-II Transfer Vehicle (HTV). The Japanese provide the HTV to NASA as part of a barter arrangement to offset their portion of ISS operational costs. During the course of this audit, the Japanese verbally agreed to delay two previously scheduled HTV launches to accommodate battery delivery missions in 2016 and 2017 and to fly two additional missions in 2019 and 2020 to transport the remaining batteries. However, NASA officials told us the Japanese are reluctant to continue production of the HTV beyond 2020 because of the high cost of producing and operating the vehicle. With no HTV missions scheduled after 2020, NASA will lose the largest cargo vehicle currently available. Accordingly, if additional radiators and solar arrays are needed, NASA will have to either reduce the size of the ORUs or hope that commercial cargo vessels capable of transporting larger equipment are available.

NASA's Cost Projections for Future ISS Operations Appear Overly Optimistic

NASA projects its annual budget for the ISS Program to grow from $3 billion in FY 2014 to nearly $4 billion by FY 2020. However, with a 26 percent rise in Station costs between FYs 2011 and 2013 and an average increase of 8 percent annually over the life of the Program, we believe the assumptions underlying NASA's cost estimates are overly optimistic and result in understated budget projections.[28] Moreover, we found that the President's FY 2015 budget request for the ISS is cumulatively $614 million less than projected life cycle costs for the next 5 years and underestimates the cost to the ISS Program of a new commercial cargo contract and the start of commercial crew missions.[29] While ISS Program officials are seeking ways to reduce costs and consolidate resources, it is unclear whether these efforts will be sufficient to address anticipated cost increases, particularly since the Program does not expect to maintain funding reserves over the next several years.

NASA's Transportation Cost Estimates are Understated

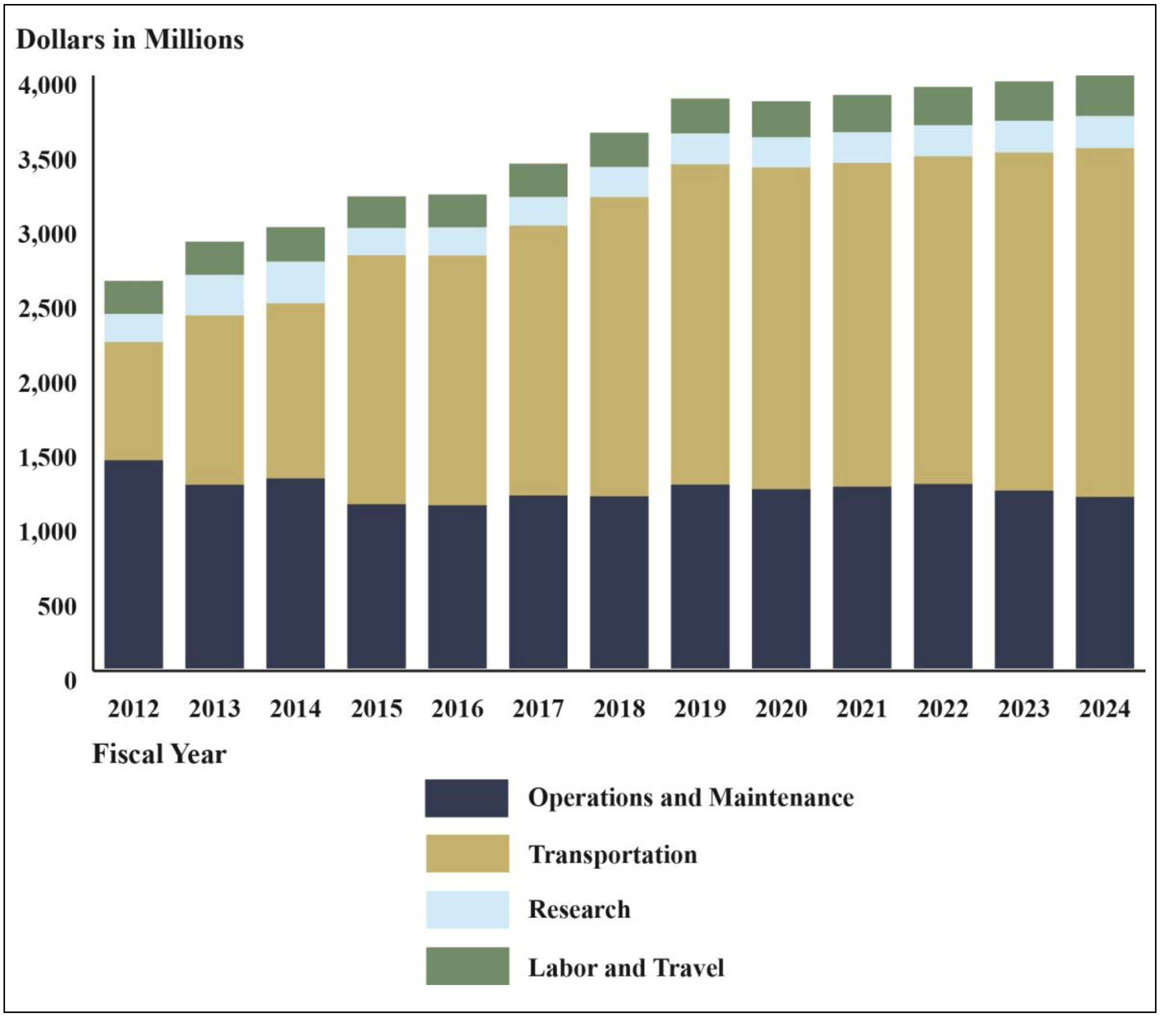
NASA officials expect higher crew and cargo transportation costs to be the main driver of future increases in the cost of the ISS Program (see Figure 7). For example, by 2024 transportation costs are expected to account for 59 percent of the Program's total operating budget compared to 34 percent in FY 2013. The expected cost growth is mainly a result of two factors: the shift from purchasing seats on the Soyuz to entering into contracts with commercial crew companies and the shift from reliance on Japanese and European cargo vehicles to additional contracts with commercial cargo providers.[30]

[28] Program officials stated that these cost increases resulted from a number of unique factors they do not expect to reoccur, including acquisition of new hardware to accommodate commercial crew flights by commercial suppliers. However, our analysis shows costs have grown an average of 8 percent per year since inception of the Program in 1994.

[29] The FY 2015 President's Budget Request includes projections through 2019.

[30] NASA also expects commercial cargo providers to fly more often than in previous years (six flights per year in FY 2015 versus two in FY 2013 and four to five flights in FY 2014). In addition, increased utilization demand between FYs 2016 and 2020 will drive cost increases as the ISS Program supports NASA and commercial research needs.

Figure 7. Life Cycle Cost Estimates from FY 2012 to FY 2024



Note: Data for FYs 2012 and 2013 is actual data. FY 2014 data is projected based on current budget. FYs 2015 through 2024 values are taken from the current ISS Program life cycle cost estimates based on the President's 2014 Budget Request.

Source: NASA OIG analysis of ISS Program information.

We found the assumptions underlying NASA's future life cycle estimates for transportation costs unrealistic. For example, NASA estimates for commercial crew transportation are based on the cost of a Soyuz seat in FY 2016 – $70.7 million per seat for a total cost of $283 million per mission for four seats. However, the Program's independent government cost estimates project significantly higher crew transportation costs when using commercial crew companies.[31] ISS Program officials explained they used the price of a Soyuz seat as a planning tool and are tracking the cost of commercial crew missions as a program risk, in essence acknowledging that the price for commercial crew missions is expected to be more than the current Soyuz prices paid by the Program.[32]

Continued Involvement of International Partners Needed to Maintain Costs

NASA's primary international partners on the ISS – the Russian Space Agency, JAXA, ESA, and CSA – have yet to commit to continued operation of the ISS beyond 2020. Russian support of the extension is particularly significant because the country provides three primary ISS capabilities: crew transportation via the Soyuz, the propulsion system to maintain proper altitude, and resupplies of fuel and water. Without continued Russian involvement, NASA would need to acquire these capabilities elsewhere.

NASA expects to secure transportation for its astronauts from two commercial companies beginning in 2017.[33] Assuming this comes to fruition, loss of the Soyuz would not be fatal to the Program. However, replacing the propulsion system used to boost the Station is more problematic. First, the Russian Progress vehicle routinely conducts reboosts to achieve altitude adjustments.[34] Previously, ESA's Automated Transfer Vehicle (ATV) also fulfilled this function (see Figure 8) but the ATV conducted its final mission on July 29, 2014. Second, the on-board system that adjusts and controls ISS altitude is located in the ROS service module. The U.S.-owned Functional Cargo Block, or Zarya Module, has an on board propulsion system as well, but testing has shown its engines are no longer usable.

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[31] The ISS Program's independent government cost estimate takes into account the recurring cost of all flight hardware to support two flights per year, plus the cost of sustaining engineering; crew training and processing; mission, launch site, and return operations; insurance (contractor procured); and the ISS docking system.

[32] Appendix B chronicles the top risks to the ISS program. Two of the three top risks – "Lack of Assured Access" and "ISS Operations Budget Reduction" – relate to concerns over the cost of commercial crew missions.

[33] In September 2014, NASA awarded two fixed-price contracts worth a combined $6.8 billion to Boeing ($4.2 billion) and SpaceX ($2.6 billion) to complete development and certification of their respective spaceflight systems. Each contract also includes at least one test flight and between two and six operational flights to the ISS.

[34] The ISS orbits Earth at an altitude that ranges from 370 to 460 kilometers (230 to 286 miles) and at a speed of 28,000 kilometers per hour (17,500 miles per hour). As a result of atmospheric drag, the Station is constantly slowed and must be boosted periodically in order to maintain its altitude.

Figure 8. ESA Depiction of ATV Conducting Reboost of the ISS

Source: Image courtesy of ESA.

In addition, the Russians have been making four cargo flights a year to the ISS. A decision by the Russians not to participate would increase costs for the United States and any remaining partners since a portion of the upmass currently carried by Russian cargo vehicles would need to be delivered by the United States or remaining partner vehicles. For example, in the absence of the ATV and the possible discontinuation of the HTV, U.S. cargo carriers may need to redesign their vehicles to accommodate additional propellant storage tanks and other spare parts for continued support of Russian Segment functions necessary to operate the ISS.

NASA also splits operations costs of common systems with JAXA, ESA, and CSA and has barter agreements for cargo transportation and other provisions with these agencies. If these arrangements are not updated to cover ISS operations beyond 2020, NASA would have to absorb additional expenses not accounted for in the Agency's current life cycle cost estimates. For example, under the original Memorandums of Understanding between NASA and the international partners, NASA pays 76.6 percent, JAXA 12.8 percent, ESA 8.3 percent, and CSA 2.3 percent. However, in the past, NASA and international partners have negotiated bi-lateral arrangements for NASA to cover a portion of the partner's share of common systems operations costs in order to save money. For example, one partner reached an arrangement with NASA in which they ceded a percentage of their crew utilization time, upmass, and crew flight opportunities in exchange for reducing their portion of shared costs. While in this case ISS Program officials stated the arrangement was beneficial to NASA, if one or more international partners chooses to discontinue or reduce involvement with the Station, NASA and possibly the remaining partners would have to cover those costs.

In addition, ISS Program officials are in ongoing discussion with JAXA officials regarding the future of the HTV, which may not be available after 2020. NASA officials have stressed the importance of the upmass provided by the HTV. However, if Japan chooses not to continue involvement with ISS past 2020, NASA will have to address both an upmass and funding shortfall.

Moreover, NASA may choose to make new barter arrangements with international partners that fulfill other Agency priorities at the expense of the ISS Program. For example, NASA and ESA officials reached an understanding in 2007 that ESA's provision of five ATVs would meet its obligation for common systems operations costs and other costs projected through 2015.[35] Later, NASA and ESA agreed to an arrangement under which ESA will supply the service module for the Orion test flight Exploration Mission-1 and various hardware components for Exploration Mission-2, but no additional ATVs after 2014. ISS Program officials noted that although this arrangement benefits the Orion Program and the overall Human Exploration and Operations Mission Directorate (of which ISS is a part), there is no plan for the ISS Program to recoup the value of the forgone ATVs from the Orion Program or other parts of NASA's budget.[36]

Capabilities of U.S. Commercial Partners. While purchasing additional cargo missions from SpaceX and Orbital to replace lost capacity from the ATV flights may be an option, NASA's expectations for these companies and the price it expects to pay for these missions may prove unrealistic.[37] In February 2014, NASA issued a request for information for CRS2, a follow-on to its current cargo resupply contract. Requirements in the request include:

- delivery of 14,250 to 16,750 kilograms (kg) per year of pressurized cargo,[38]
- delivery of 1,500 to 4,000 kg per year of unpressurized cargo,

[35] The final ATV under this arrangement launched on July 29, 2014.

[36] At the time the agreement was signed, NASA planned to use the Orion vehicle as an alternative means of delivering crew to the ISS.

[37] Although SpaceX and Orbital are the only two companies currently providing cargo services to the ISS, other companies may respond to the solicitation for Commercial Resupply Services round 2 (CRS2). For the purposes of this discussion, we used specifications for the existing SpaceX and Orbital vehicles.

[38] Pressurized cargo is transported under Earth-like atmospheric pressure.

- return and disposal of up to 14,250 to 16,750 kg per year of pressurized cargo,
- disposal of 1,500 to 4,000 kg per year of unpressurized cargo,
- services are required to be provided in 4 to 5 missions per year, and
- a NASA budget to procure this service is anticipated between $1 billion and $1.4 billion per year.[39]

The requirements reflect increased reliance on domestic companies due to the retirement of the ATV and may also represent the uncertain future of Japanese upmass responsibilities.

In comparison to cargo missions completed under the original CRS contract, the new requirements reflect increased expectations for the commerical providers. Assuming the minimum pressurized requirement of 14,250 kg spread over the maximum of five missions per year at an annual cost of $1.4 billion, of the two commercial companies that currently transport cargo to the ISS – SpaceX and Orbital – only the SpaceX vehicle meets the requirements as written. However, even that vehicle is often limited by space available (volume) before the maximum weight is reached. Therefore, even SpaceX may not be able to deliver 14,250 kg in a given year in only five missions, depending on the density and volume of cargo and how it is packed. Table 4 compares CRS2 requirements with the current capabilities of SpaceX and Orbital.

[39] In comparison, the 2008 CRS contracts required each partner deliver a minimum of 20,000 kg to the ISS over several flights – 12 for SpaceX and 8 flights for Orbital.

Table 4. Current Commercial Cargo Transportation Capability versus CRS2 Requirements

	Average Price Per Mission ($ in millions)	Potential Pressurized Payload Delivered to ISS Per Mission	Payload Returned From ISS or Disposed Per Mission	Available from 2017 through 2024
CRS2 Requirement[a]	$280	2,850 kg	2,850 kg	Required
Current Capabilities				
SpaceX	$133.3	3,310 kg	2,500 kg pressurized (returned) 3,310 kg pressurized + unpressurized[c]	Yes
Orbital	$237.5	2,700 kg	2,000 kg (disposed)[b]	Yes

Legend

Green: Current capability meets CRS2 requirements

Red: Current capability does not meet CRS2 requirements

[a] CRS2 figures based on minimum required pressurized delivery of 14,250 kg per year, for $1.4 billion per year, delivered over 5 missions.

[b] Orbital's return capability consists of waste disposal only.

[c] SpaceX has the ability to return cargo to Earth.

Source: NASA OIG analysis of NASA and open source data.

In our judgment, it is unlikely NASA will obtain the increased capacity sought in the CRS2 request for a price similar to what it paid under the original CRS contract. Orbital's cargo vessel does not meet the payload weight requirement and therefore would require additional development work. Moreover, given the tendency to exhaust available space on past cargo missions before reaching the maximum weight capacity of the vehicles, even SpaceX would likely have to redesign its vehicle to meet these requirements. Unless a new commercial cargo transportation company emerges to satisfy the requirements of the CRS2 request or SpaceX and Orbital redesign their capsules, NASA will need to procure more than the four to five missions contemplated in the request, which would increase costs to the Agency.

Efforts to Reduce Operations and Maintenance Costs

Given the expected increase in transportation costs and NASA's desire to maintain a steady budget for the Program, ISS Program officials have made some progress in reducing operations and maintenance costs. For example, the Mission Operations Directorate expects to decrease costs by $445 million between FYs 2015 and 2020 through workforce reductions and increased use of commercial off-the-shelf hardware. A large portion of these expected reductions are tied to the directorate finding a new, more cost-effective way to run the Mission Control and training facilities. While it is possible that the 16 other offices and directorates supporting ISS could achieve efficiencies with the use of commercial off-the-shelf hardware, it is unclear they could achieve a similar amount of savings.[40] Furthermore, the Defense Contract Management Agency, which provides contract management assistance for many ISS Program contracts, estimates operations costs will grow an average of 1 to 4 percent per year due to inflation and other factors.[41]

In order to reduce costs, NASA continues to streamline operations. For example, ISS officials have reduced Mission Evaluation Room activities to significant on-orbit events only.[42] Officials have also reduced software releases, EVA training runs, facility requirements, and program change requests. In addition, ISS Program officials are seeking ways to consolidate procurement activities and contracts.

Moreover, ISS Program management said they plan to hold steady or further reduce costs by managing operations and the development, design, and construction of ORUs more efficiently. Because SpaceX can return ORUs from the Station, ISS officials plan to maximize opportunities to repair and refurbish ORUs rather than procure new equipment, which can result in substantial cost savings. For example, the cost to procure a new Remote Power Controller Module is $2.2 million per unit compared to an average of $267,000 to repair the unit.[43]

However, this "repair rather than replace" strategy will not address all ORU issues for several reasons. First, some ORUs are simply too large to return to Earth or contain

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[40] The ISS Program consists of eleven separate offices that support the ISS directorate: Vehicle, Mission Integration and Operations, Avionics and Software, Safety and Mission Assurance/Program Risk, Development Projects, Program Planning and Control, Systems Engineering Integration, ISS Transportation Integration, Research Integration, Program Scientist, and External Integration. In addition, the ISS Program is supported by six Johnson Space Center (Johnson) directorates: EVA, Mission Operations Support, ISS Ground Processing and Research Projects, Flight Programs and Partnerships, Engineering Support, and Safety and Mission Assurance.

[41] The average increase of 1 to 4 percent per year is based on direct labor rates and does not include adjustments for indirect expenses, medical insurance, and other items.

[42] The Mission Evaluation Room is part of the Mission Control Center building at Johnson and is where the Station operators from multiple disciplines work to support certain ISS operations. Program officials at Johnson have worked to streamline and modernize these activities so that personnel can support operations remotely when required rather than being physically in the room on standby.

[43] Remote Power Controller Modules are circuit breakers mounted on top of the Station's central truss segment above the U.S. Laboratory Destiny.

chemicals such as ammonia that cannot be safely transported. Second, repairs performed on the Station may require specialized training and equipment for the astronauts, which may not be feasible in many cases. In a situation where repair on the ground or on Station is not possible and a new ORU is needed, the Program may encounter obsolescence of parts or vendor resistance to undertake small production runs on specialty parts.

Given these challenges, officials concede they are unlikely to identify further savings in operations and maintenance costs sufficient to offset increased transportation costs. To this end, Program officials believe any substantial budget savings are more likely to come from flying fewer missions than currently planned. However, flying fewer missions would negatively affect ISS support operations, such as getting supplies and ORUs to the Station and potentially mean less opportunity for research on Station. Furthermore, as noted earlier, projected tranportation costs may already be understated. Therefore, in our judgment it is unlikely that NASA will be able to maintain annual ISS operating costs between $3 and $4 billion through FY 2024.

Lack of Reserves Reduces Flexibility. As of March 2014, the ISS Program projected an overall shortfall of $663 million in Cost Management Reserves between FYs 2015 and 2018.[44] This shortfall is based on the Program's analysis of reserves needed to address potential but unidentified cost increases in systems operations and maintenance (FYs 2015 and 2016) and commercial crew and cargo services between FYs 2015 and 2018 (see Table 5).

Table 5. ISS Cost Management Reserves as of March 2014

	Fiscal Year						
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
System Operations and Maintenance	$49	($29)	($43)	$93	$77	$79	$75
Research Operations	$11	$9	$18	$19	$17	$15	$13
Cargo and Crew	$261	($3)	($93)	($283)	($447)	$84	($54)
Total	**$321**	**($23)**	**($117)**	**($171)**	**($352)**	**$178**	**$35**

Note: Numbers are rounded and dollars in millions.

Source: ISS Program Office.

[44] Cost Management Reserves are funds held in reserve to cover potential but unidentified costs that may require additional funding. Reserves are projected based upon a Quantitative Risk Assessment of the Program to determine where additional funding may be needed and thus set-aside. Programs in development typically have a base percentage requirement for reserves but because the ISS Program is in its operations and sustainment phase, it has no minimum requirement.

The lack of adequate reserves reduces the ISS Program's flexibility to cover unexpected costs. FYs 2016 through 2018 are especially critical as NASA begins paying for both new cargo contracts under CRS2 and commercial crew transportation contracts. The Program is responsible for any system upgrades due to Agency-directed increases in cargo capabilities and for the costs of the cargo and crew service contracts.[45] Furthermore, with regard to ORUs – reflected in System Operations and Maintenance in Figure 3 – Program officials told us that independent government cost estimators calculate expected costs at a 70 percent confidence level but actual costs can be higher.[46] If the actual cost to build ORUs exceeds the estimate, the extra funds come from reserves. Consequently, as the ISS ages and ORUs are replaced or repaired the need for these reserves may increase.

[45] NASA developed commercial cargo and crew vehicles under separate programs. Cargo vehicles were developed under the Commercial Orbital Transportation Services Program and crew vehicles under the Commercial Crew Program. Once NASA contracts for cargo or crew services, the costs associated with the contracts and any system upgrades become the responsibility of the ISS Program rather than the development programs.

[46] Actual cost for spare purchases currently underrun the independent government estimate by an average of 4 percent.

INCREASED UTILIZATION NOT EXPECTED TO FULLY MITIGATE HUMAN HEALTH RISKS WHILE CASIS CONTINUES TO FACE CHALLENGES IN ENCOURAGING RESEARCH BY COMMERCIAL INDUSTRY

While utilization of the ISS for research has increased, NASA and CASIS continue to face challenges. Although NASA performs a variety of research on the ISS, a major part of its research efforts involve mitigating risks associated with long-term human presence in space.[47] However, some of these risks cannot be adequately addressed through ISS research, and the Agency projects that even if ISS operations are extended through 2024 it will be unable to mitigate several known risks. Accordingly, NASA needs to prioritize its research to address the most important risks in the time available. With regard to CASIS, issues relating to patent licenses and data rights and funding continue to pose challenges.

ISS Utilization Increasing

As we reported in July 2013, no single measure provides a complete picture of ISS utilization status. NASA uses three primary data points to assess utilization of the Station – average weekly crew time, number of investigations, and use of allocated space.[48] Since the release of our 2013 report, each of these measures has continued to grow.

Average Weekly Crew Time. Until commercial suppliers begin providing crew transportation in 2017, the ISS will remain limited to a six-person crew. As of October 2013, NASA's goal is to allocate an average of 35 hours per week to research-related activities. As shown in Table 6, average crew time dedicated to scientific research has increased steadily since the first ISS expedition not devoted to construction in September 2011. For example, the average amount of time dedicated to research between September 2011 and March 2014 grew from 24.1 hours to 44.3 hours, an increase of 84 percent and 127 percent, respectively, over NASA's 35-hours-per-week goal. NASA is projecting average research time to decrease slightly to approximately 39.4 hours per week in mid-2014 when the crews begin reconfiguring the Station to prepare for commercial crew systems.

[47] The NASA OIG is currently conducting a review on NASA's efforts to mitigate astronaut health risks.

[48] NASA OIG, "NASA's Efforts to Maximize Research on the International Space Station" (IG-13-019, July 8, 2013). In addition to average weekly crew time, number of investigations, and use of allocated space, NASA also tracks upmass, downmass, and power, thermal, and data usage, but does not consider these measures primary indicators of research utilization.

Table 6. Average Crew Time for Scientific Research

Expedition	Date	Hours (weekly average)
21/22	10/2009 to 3/2010	28.9
23/24	3/2010 to 9/2010	23.4
25/26	9/2010 to 3/2011	23.7
27/28	3/2011 to 9/2011	24.1
29/30	9/2011 to 4/2012	35.8
31/32	4/2012 to 9/2012	36.3
33/34	9/2012 to 4/2013	38.2
35/36	4/2013 to 9/2013	41.3
37/38	9/2013 to 3/2014	44.3
39/40	3/2014 to 9/2014	39.4[a]

[a] Expedition 39/40 is projected. Data is through May 31, 2014.

Source: NASA OIG analysis of NASA data.

Number of Investigations. NASA has shown an upward trend in the number of active research investigations conducted over time. Between December 1998 and March 2014, 539 investigations were performed aboard the ISS, with an additional 60 experiments scheduled to take place during Expedition 39/40, which ended in early September 2014.[49] Moreover, during expeditions 33/34 NASA conducted 114 experiments, compared to 168 experiments planned for Expedition 39/40, a 47 percent increase.

Use of Allocated Space. As shown in Table 7, the internal space allocated for research in the U.S. portion of the ISS was about 70 percent occupied as of the first nonconstruction related period of September 2011 to April 2012. This rate increased to 80.7 percent in March 2014 – a 15 percent increase – with an additional increase to 86.3 percent occupancy planned during Expedition 39/40. NASA management told us their goal is to accommodate all research needs, not necessarily achieve full occupancy. They noted that 100 percent occupancy may not be feasible or desirable given the power, thermal, and data usage constraints it would place on the ISS.

[49] In July 2013, we reported NASA had performed 527 total investigations aboard the ISS between December 1998 and September 2012. However, thereafter NASA recategorized certain educational activities and excluded them from the count of total investigations.

Table 7. Internal Occupancy Rates

Expedition	Date	Percentage occupied
21/22	10/2009 to 3/2010	Not tracked
23/24	3/2010 to 9/2010	Not tracked
25/26	9/2010 to 3/2011	Not tracked
27/28	3/2011 to 9/2011	Not tracked
29/30	9/2011 to 4/2012	70%
31/32	4/2012 to 9/2012	70%
33/34	9/2012 to 4/2013	71%
35/36	4/2013 to 9/2013	81%
37/38	9/2013 to 3/2014	80.7%
39/40	3/2014 to 9/2014	86.3%[a]

[a] Expedition 39/40 is planned data as of May 31, 2014.

Source: NASA OIG analysis of NASA data.

As shown in Table 8, NASA's external sites were about 31 percent occupied during the first nonconstruction period from September 2011 to April 2012. ISS Program officials expect this rate will increase to 55 percent during Expedition 39/40 – a 77 percent increase.

Table 8. External Occupancy Rates

Expedition	Date	Percentage occupied
21/22	10/2009 to 3/2010	Not tracked
23/24	3/2010 to 9/2010	13%
25/26	9/2010 to 3/2011	13%
27/28	3/2011 to 9/2011	31%
29/30	9/2011 to 4/2012	31%
31/32	4/2012 to 9/2012	37%
33/34	9/2012 to 4/2013	37%
35/36	4/2013 to 9/2013	37%
37/38	9/2013 to 3/2014	37.5%
39/40	3/2014 to 9/2014	55%[a]

[a] Expedition 39/40 occupancy rate is planned data as of May 31, 2014.

Source: NASA OIG analysis of NASA data.

Although Extension of the ISS to 2024 Provides Greater Opportunities to Mitigate Human Health and Performance Risks, Some Risks Will Remain Unresolved

NASA has identified 23 types of human health and performance risks associated with long-term space exploration that can be mitigated aboard the ISS.[50] According to NASA officials, the ISS provides an optimal microgravity environment to conduct experiments that enable the Agency to develop measures to mitigate many of these risks. Extending ISS operations until 2024 would put the Agency in a better position to address 12 of these 23 risks, including decompression sickness, reduced muscle mass, fatigue-induced errors, and cardiac rhythm problems. In comparison, NASA would have time to address only 5 of the 23 risks should ISS operations end in 2020.

Extension to 2024 Not Enough Time to Mitigate Some Risks. While continued operation of the ISS until 2024 will allow for the mitigation of additional risks, NASA will be unable to address 11 types of risk on the ISS until sometime after that date:

- *Human-computer interaction* (planned mitigation for December 2025) – risk of inadequate human-computer interaction.
- *Inadequate food system* (planned mitigation for December 2026) – risk of performance decrement and crew illness due to an inadequate food system.
- *Errors due to training deficiencies* (planned mitigation for December 2027) – risk of performance errors due to inadequate training.
- *Occupant protection* (planned mitigation beyond 2028) – risk of injury during launch and landing.
- *Early onset osteoporosis* (planned mitigation beyond 2028) – risk of early onset of osteoporosis due to spaceflight.
- *Altered immune response* (planned mitigation beyond 2028) – risk of crew adverse health event due to altered immune response.
- *Bone fracture* (planned mitigation beyond 2028) – risk of bone fracture during mission.
- *Unpredicted effects of medication* (planned mitigation beyond 2028) – risk of clinically relevant unpredicted effects of medication during mission.

[50] Long-term space exploration refers to the duration of the mission and/or the distance traveled. While a mission of 6 months or more on the ISS qualifies as a long-term mission, we are referring to planetary and asteroid retrieval missions that require a longer duration to travel beyond the ISS and low Earth orbit. NASA's Human Research Program has identified a total of 32 human health risks in long duration space travel, 9 of which cannot be mitigated aboard the ISS.

- *Vestibular/sensorimotor impacts* (planned mitigation beyond 2028) – risk of impaired control of spacecraft, associated systems, and immediate vehicle escape due to coordination issues.

- *Behavioral conditions* (planned mitigation beyond 2028) – risk of adverse behavioral conditions and psychiatric disorders.

- *In-flight medical capabilities* (planned mitigation beyond 2028) – risk of unacceptable health and mission outcomes due to limitations of in-flight medical capabilities.

Failure to alleviate these risks would hinder NASA's ability to ensure crew health and wellness and to maintain spaceflight capabilities and functionality during long duration exploration missions. In lieu of ISS-based efforts, officials plan to develop less optimal ground-based methods to develop mitigation strategies. For example, NASA officials said they can develop solutions to address muscle-related issues by conducting ground-based experiments. In addition, while astronauts regularly spend 6 months aboard the ISS, NASA assigned astronaut Scott Kelly to a 12-month mission beginning in 2015. Program officials hope to address a variety of human health risks during this mission while also conducting examinations on his twin brother, Mark Kelly, as an on-Earth control. According to officials, if NASA is not able to fully mitigate these risks – either on the ISS or in ground labs – long duration missions will require the Agency to accept the risks in order to move forward.

Some Risks Cannot Be Fully Mitigated on the ISS. NASA is working to address two additional health and performance risks the Agency cannot mitigate with current Station capabilities and within the current ISS life span:

- *Human and automation/robotic* (planned mitigation for December 2027) – risk of inadequate design of human and automation/robotic integration.

- *Radiation exposure on human health* (planned mitigation beyond 2028) – risk of space radiation exposure to human health during mission.

NASA officials said risks involving human and robotic integration are not yet fully understood and a framework for examining them is being developed. Moreover, the tools and metrics for doing so will not be available until 2024. The effects of radiation exposure on human health cannot be addressed aboard the ISS because of the Station's relatively close proximity to the Earth's radiation belts and the protection those belts provide from space-based radiation.

CASIS Continues to Make Progress But Faces Challenges in Encouraging Participation by Commercial Industry

CASIS continues to make progress in facilitating private research aboard the ISS. Although NASA is required to allocate ISS resources equally between its own research and research managed by CASIS, CASIS receives relatively little direct funding from the Agency – only $15 million a year.[51] In contrast, NASA spent approximately $273 million in FY 2013 to conduct and support other research.

Given the limited funding it receives from NASA, attracting private funding is essential for CASIS to succeed in its mission. However, outreach to and participation by commercial industry remains a challenge. Moreover, CASIS officials believe provisions in the cooperative agreement relating to patent licenses and data rights are inhibiting commercial participation.

CASIS's Recent Progress. In January 2014, the first CASIS-sponsored payloads were delivered to the ISS. These payloads included five experiments and investigations ranging from an examination of spaceflight-induced effects on antibiotics to the production of an audio-video book of astronauts conducting simple science experiments for children. A second round of CASIS payloads launched in April 2014 included experiments on protein crystallization and plant development.

Additionally, CASIS developed annual performance metrics to measure its progress in fostering private research aboard the ISS. In our July 2013 report, we found CASIS's FY 2012 performance metrics were focused on achieving organizational milestones rather than measuring how successful the organization has been in encouraging research on the ISS. To address this shortcoming, CASIS developed eight annual performance metrics for FY 2014:

- Description of the Board of Directors plan to proactively generate interest and market opportunities as well as stimulate unsolicited proposals.
- Number and description of research pathways identified by CASIS that will be targeted via grants and the Board of Directors.
- Number of publications from projects related to CASIS activities.
- Number of patents from projects related to CASIS activities.
- Number and market value (if available) of products brought to market related to CASIS activities.

[51] The NASA Authorization Act of 2010 provides "ISS national laboratory managed experiments shall be guaranteed access to, and utilization of, not less than 50 percent of the United States research capacity allocation." This includes sharing data, electrical, crew time, and occupancy resources.

- Economic impacts from use of the ISS National Lab, if available.
- Changes in awareness among key stakeholder groups.
- Changes in requests for information from CASIS on behalf of outside parties.

CASIS plans to report its progress against these metrics to NASA in October 2014.

Attracting Private Funding Continues to Prove Difficult. As of July 2014, CASIS had collected only $14,550 in cash donations, although donors have pledged an additional $8.2 million, $25,000 of which will be in-kind transfers. In our July 2013 report, we highlighted several factors that make attracting private funding to the ISS a challenge. First, NASA historically has received little interest from private entities for ISS research absent a substantial infusion of government funds. Second, in some cases ground-based research provides similar results at significantly less expense than conducting research on the ISS.[52] Third, the majority of the research activities conducted aboard the ISS have related to basic research as opposed to applied research.[53] Finally, potential ISS partners noted that without sufficient funding to produce a proof-of-concept result aboard the ISS, it will be difficult to persuade additional partners to self-fund research.

CASIS continues to refine its efforts to reach potential donors through a variety of means, including conferences, networking, and solicitations. In addition, CASIS officials told us they continue to pursue cost-sharing options with partners as a means to fund experiments. For example, CASIS partners provide their own funds to support on-Earth monitoring and post-experiment analysis of projects. However, it is too early to tell whether these efforts will result in significant additional private funding for research aboard the ISS.

Patent License and Data Rights Obligations and NASA's Annual Allocation. Under the 2011 cooperative agreement with NASA, CASIS and its partners must transfer patent licenses and data rights related to federally supported research conducted on Station to the Government. Federally supported research includes experiments conducted aboard the ISS as well as pre- and post-experiment analysis and discoveries funded by the Federal government via NASA's annual $15 million award. CASIS officials reported this provision was deterring commercial stakeholders from conducting research on the ISS. For example, according to CASIS officials, pharmaceutical and consumer products companies have indicated they will not design commercially significant experiments for the ISS if they must transfer associated patent licenses and data rights to the United States. In 2012, CASIS and NASA amended the patent license and data rights provision

[52] For example, researchers conducted experiments on protein crystallization in space for several years because microgravity afforded researchers the optimal environment in which to crystalize proteins. However, techniques to conduct such research have improved to the point that some protein crystallizations can be performed in ground-based labs.

[53] Basic research increases the understanding of fundamental science, such as physics and biology. Applied research facilitates the practical application of science in a product, such as developing more efficient materials.

in the cooperative agreement to limit the Government's right to data generated aboard the ISS. Under the revised provisions, although NASA still maintains rights to data developed on the ISS, the research entity has more control over the data. According to CASIS officials, the changes have not fully alleviated commercial stakeholders' concerns.

If intellectual property rights remain an issue for commercial stakeholders, it may be difficult for CASIS to solicit significant commercial participation to conduct research aboard the ISS. CASIS officials reported that although some commercial partners have continued utilizing the ISS, they have limited their participation to fundamental research not likely to generate significant intellectual property. The officials assert that that without additional adjustments to the intellectual property aspects of the cooperative agreement – through legislative changes – commercial stakeholders may refrain from conducting research that has the potential to lead to breakthroughs in a variety of fields.

To address this issue, in June 2013 NASA submitted a proposed legislative amendment to the National Aeronautics and Space Act of 1958 to Congress that includes revised provisions related to the retention of patent licenses and data rights on behalf of ISS National Lab users. The proposed legislation allows a National Lab user to retain "all rights in inventions made … during the conduct of [National Lab] activities." However, as of July 2014 the proposal had not been included in any congressional legislation. In our judgment, these revisions would help to alleviate commercial stakeholders' concerns over data rights, which in turn may increase commercial utilization of the ISS.

Conclusion

NASA has not identified any major technical issues in extending the ISS's service life to 2024, but the Program's detailed assessment of the overall structure is still ongoing. Moreover, several identified risks will require continuing mitigation such as potential shortages in electrical power, unexpected ORU failures, and the limited capacity to transport large ORUs to the ISS. Furthermore, the harsh space environment contains unexpected challenges for which Program officials constantly prepare.

Additionally, NASA's intent to maintain the ISS's budget between $3 and 4 billion through 2024 will be extremely challenging given projected cost increases costs for cargo and crew transportation services. With cost increases of 26 percent between FYs 2011 and 2013, NASA will find it difficult to reduce such growth in future years while avoiding negative impacts on other high-priority programs like the Space Launch System and Orion. Moreover, absent any funding reserves, the ISS Program may need to borrow from other Agency programs to meet cost growth.

While current metrics show research on the ISS continues to increase, obstacles remain for NASA and CASIS to ensure full utilization of the platform's research capabilities. In addition, while the Station's extension until 2024 will allow NASA to develop measures to mitigate more of the identified risks posed by long-term space travel, the Agency will be unable to address all risks. As for the National Lab, three CASIS-sponsored payloads were successfully delivered to the ISS and the organization continues to conduct outreach activities and solicit experiments. However, in order to attract significant interest and funding from the commercial sector, NASA and Congress must address issues involving patent licenses and data rights agreements.

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

In order to reduce potential cost growth in the ISS Program, we recommended the NASA Associate Administrator for the Human Exploration and Operations Mission Directorate do the following:

Recommendation 1. Continue to solicit commitments from international partners to improve cost sharing.

Management's Response. The Associate Administrator concurred with our recommendation, noting that all ISS partners seek efficiencies to reduce costs. NASA did not provide a completion date as this proposed action is ongoing.

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

To ensure maximum use of the ISS for scientific research, we recommended the following:

Recommendation 2. The NASA Associate Administrator for Human Exploration and Operations Mission Directorate continue to track, manage, and mitigate human health risks to long-term exploration and identify and prioritize those risks that must be mitigated prior to decommissioning of the ISS.

Management's Response. The Associate Administrator concurred with our recommendation, and explained that the Human Research Program, Flight Medicine Group, and the ISS Program jointly review the Human Research Program's health risk mitigation list to ensure all efforts conducted on the ISS are as efficient and effective as possible. NASA did not provide a completion date as this proposed action is ongoing.

Evaluation of Management's Response. Despite the Associate Administrator's concurrence and explanation that processes are in place for an integrated review of health risks, NASA has not completed a prioritized and integrated list of these risks. Accordingly, we do not consider management's actions fully responsive and the recommendation remains unresolved.

Recommendation 3. The Agency continue to pursue legislative options that will address patent license and data rights.

Management's Response. The Associate Administrator concurred with our recommendation, noting that in June 2013 NASA submitted to Congress a legislative proposal titled "Retention of Intellectual Property Rights by Users of the International Space Station National Laboratory," that would authorize users to retain intellectual property rights arising from ISS National Laboratory activities. NASA said it will continue to work with the Administration to press Congress to act on the proposed legislation.

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

OTHER MATTERS

Award-Fees for the Boeing Company

As noted previously, the ISS Program has entered into 29 major contracts with a current value of $32 billion, 15 of which are cost-plus-award-fee contracts with a current combined total value of $22.4 billion. This category includes the Boeing Contract, valued at $17.3 billion.[54]

The GAO, NASA OIG, and others have reviewed NASA's use of award-fee contracts. In January 2007, GAO issued a report finding that NASA does not consistently follow its award-fee guidance and that award fees paid by the Agency did not consistently correlate with contractor performance.[55] In our November 2013 report, we found a number of questionable practices, including overly complex formulas and a contract clause designed to hold contractors accountable for the quality of the final product that disregards interim performance evaluations, have diminished the effectiveness of award-fee contracts at the Agency. We also found NASA failed to collect required data on award-fee contracts, reducing its ability to measure their effectiveness. We identified incorrect payments and questioned costs totaling $69.7 million and concluded NASA expended approximately $7.4 million to administer performance evaluations on contracts for which performance objectives were undefined, determinations that an award-fee contract was the most beneficial type of contract were not made, and relevant management information for informed decision-making was not gathered.[56]

Properly administering award-fee scores is the foundation for determining that award fees correlate with contractor performance. As part of this review, we analyzed NASA's award-fee evaluation scores for the Boeing Contract. We found discrepancies between the established criteria in the contract's Award-Fee Plan and the fees awarded to Boeing. Specifically, the Award-Fee Plan provides for evaluations to be conducted using weighted scores with grades in each of four factors. However, NASA performed this evaluation for only two of the four factors. We found that by taking this approach NASA paid Boeing between $6.7 and $13.2 million in award fees we could not validate using the established criteria for the weighted evaluation scoring system.

[54] NASA initially awarded the contract on January 13, 1995, and amended it on August 25, 2010, to extend the period of performance to September 30, 2015.

[55] GAO, "NASA Procurement: Use of Award Fees for Achieving Program Outcomes Should Be Improved" (GAO-07-58, January 17, 2007).

[56] NASA OIG, "NASA's Use of Award-Fee Contracts" (IG-14-003, November 19, 2013).

The Federal Acquisition Regulation (FAR) and NASA FAR Supplement, along with the NASA Award-Fee Contracting Guide establish guidance for conducting contractor performance evaluations.[57] Under the guidance, each evaluation factor is assigned a specific percentage weight with the cumulative weight of all factors totaling 100. During an award-fee evaluation, the Agency scores each factor between 0 and 100 and multiplies by the weighting for that factor to determine the weighted score.[58] For example, if a factor has a weight of 60 percent and the numerical score for that factor is 80, the weighted technical score is 48 (80 x 60 percent). The weighted scores for each evaluation factor are added to determine the total award-fee score. Scores for each evaluation factor are multiplied by the respective weight to determine an overall score. In Figure 9, the contractor's overall evaluation score was 91, entitling it to 91 percent of the total amount of award fee available for that period.

Figure 9. Illustration of Weighted Award-Fee Score Calculation

Weighted Factor	Weight		Performance Score		Total Score
Technical Performance	0.40	×	96	=	38
Project Management	0.35	×	90	=	32
Cost Control	0.25	×	85	=	21
	100%				91

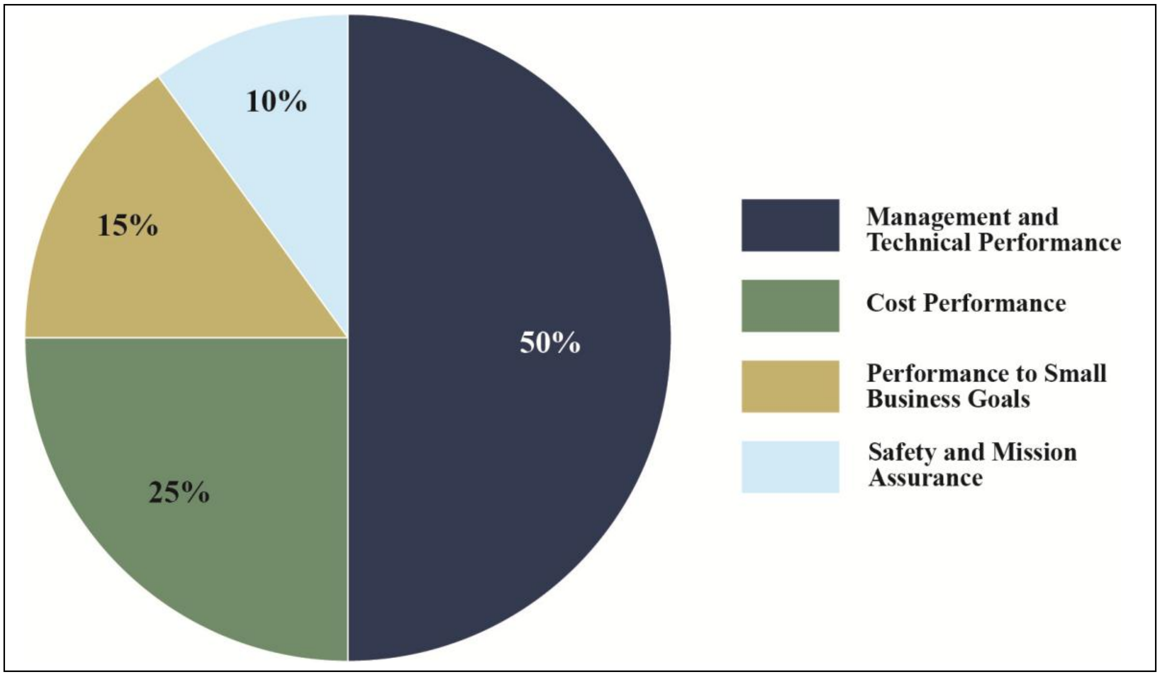
Source: NASA OIG.

[57] FAR 16.401(e)(3), NASA FAR Supplement 1816.405-274, NASA FAR Supplement 1816.405-275, and NASA Award-Fee Contracting Guide, 3.6.1 "Award-Fee Rating Table," and 3.6.4, "Calculating Earned Fee – Example."

[58] Guidance in the NASA FAR Supplement describes how to apply the weighted scoring system: "A weighted scoring system appropriate for the circumstances of the individual contract requirement should be developed. In this system, each evaluation factor (e.g., technical, schedule, cost control) is assigned a specific percentage weighting with the cumulative weightings of all factors totaling 100. During the award-fee evaluation, each factor is scored from 0-100 according to the ratings defined in 1816.405-275(b)."

For the Boeing Contract, the Award-Fee Plan establishes weighted factor percentages, as shown in Figure 10.

Figure 10. Boeing Contract Award-Fee Plan Weights



Source: Boeing Award-Fee Plan.

However, NASA award-fee evaluations assigned scores to only two of these factors – performance to small business goals and cost performance – which together account for 40 percent of the overall score. ISS Program and procurement officials explained that the highly complex factor of management and technical performance, combined with the subjective nature of the award-fee process, often resulted in a wide divergence of opinions among individual monitors making it difficult to arrive at a mathematical score for those areas. Moreover, officials believed assigning a numerical score to that factor would not accurately reflect the overall effectiveness of Boeing's performance and send a negative message regarding the company's true performance. Therefore, they determined actual scores for management and technical performance in terms of "strengths" and "weaknesses." In addition, they also stated that the safety and mission assurance factor was addressed as part of all evaluation factors and therefore found it unnecessary to assign that factor an individual score.

Under the terms of the contract, the management and technical performance and safety and mission assurance factors account for 60 percent of the total award-fee score. Therefore, to verify the accuracy of the scores NASA gave Boeing, we analyzed the feasibility of achieving the approved award fee if NASA followed the established criteria in the Award-Fee Plan and these two categories were assigned a numerical score. We found that even if we assigned a score of 100 percent in these two categories Boeing could not have achieved the final recommended award fee. Rather, that award fee would have been at least $6.7 million less over eight award periods.[59] (Table 9).

Table 9. Analysis of Boeing Award-Fee Scores Assuming Score of 100 Percent

Period of Performance		Maximum Award-Fee Available	Actual Award-Fee Paid	Percent Awarded	Auditor Calculation of weighted evaluations	Auditor Calculation of Weighted Percentages to Available Fee	FDO Award vs. Auditor Score
10/1/2009	3/31/2010	$27,768,240	$26,657,510	96%	95%	$26,379,828	$277,682
4/1/2010	9/30/2010	$33,834,667	$31,127,894	92%	91%	$30,789,547	$338,347
10/1/2010	3/31/2011	$19,307,411	$18,535,115	96%	94%	$18,052,429	$482,685
4/1/2011	9/30/2011	$19,053,433	$17,719,702	93%	89%	$16,948,029	$771,673
10/1/2011	3/31/2012	$30,687,268	$28,846,032	94%	90%	$27,664,572	$1,181,460
4/1/2012	9/30/2012	$28,034,674	$26,913,287	96%	93%	$25,974,125	$939,162
10/1/2012	3/31/2013	$27,998,944	$27,158,976	97%	91%	$25,591,035	$1,567,941
4/1/2013	9/31/2013	$29,261,197	$28,383,361	97%	93%	$27,242,174	$1,141,187
Total		**$215,945,834**	**$205,341,876**			**$198,641,740**	**$6,700,137**

Note: Numbers are rounded.

Source: NASA OIG analysis of ISS Program data.

Moreover, we considered the possibility that Boeing would have been assigned a score of 100 percent for the management and technical performance and safety and mission assurance factors in every award-fee evaluation period unlikely. Therefore, staying within the "excellent" range of 91-100, we assigned a more realistic score of 95 percent to those categories. Using this score the amount of potentially excess award fee was more than $13 million over the eight periods of performance (Table 10).

[59] We recognize the NASA Award-Fee Guide allows the Fee Determination Official (FDO) to award a contractor an amount other than what the Board recommends and that therefore the FDO could have increased Boeing's award fee even if the Board had calculated weighted scores in all categories.

Table 10. Analysis of Boeing Award-Fee Scores Assuming Score of 95 Percent

Period of Performance		Maximum Award-Fee Available	Actual Award-Fee Paid	Percent Awarded	Auditor Calculation of weighted evaluations	Auditor Calculation of Weighted Percentages to Available Fee	FDO Award vs. Auditor Score
10/1/2009	3/31/2010	$27,768,240	$26,657,510	96%	92%	$25,546,781	$1,110,730
4/1/2010	9/30/2010	$33,834,667	$31,127,894	92%	88%	$29,774,507	$1,353,387
10/1/2010	3/31/2011	$19,307,411	$18,535,115	96%	91%	$17,473,207	$1,061,908
4/1/2011	9/30/2011	$19,053,433	$17,719,702	93%	86%	$16,376,426	$1,343,276
10/1/2011	3/31/2012	$30,687,268	$28,846,032	94%	87%	$26,743,954	$2,102,078
4/1/2012	9/30/2012	$28,034,674	$26,913,287	96%	90%	$25,133,085	$1,780,202
10/1/2012	3/31/2013	$27,998,944	$27,158,976	97%	88%	$24,751,066	$2,407,909
4/1/2013	9/31/2013	$29,261,197	$28,383,361	97%	90%	$26,364,338	$2,019,023
Total		**$215,945,834**	**$205,341,876**			**$192,163,365**	**$13,178,512**

Note: Numbers are rounded.

Source: NASA OIG analysis of ISS Program data.

We found that in every instance, the overall score awarded to Boeing could not be supported using the assigned weighted percentages for each evaluation factor established in the Award-Fee Plan. We calculated that based on these scores NASA paid Boeing between $6.7 and $13.2 million over a 4-year period that could not be validated or supported using the established criteria for the weighted evaluation scoring system.

In today's budget constrained environment, NASA needs to ensure its award-fee payment process is transparent and fees are fully justified. In our judgment, NASA would gain a more accurate assessment of contractor performance and provide the FDO with recommended award fees that match actual performance by using weighted and numerical scores in each category.

Management's Response and Evaluation of Management's Response

NASA disagreed with our analysis of the Boeing award-fee process, and stated that we misinterpreted the facts and misconstrued the applicable regulations and program requirements. Specifically, the Associate Administrator stated that our analysis is premised on the inaccurate assumption that the Award-Fee Evaluation Plan "*requires*" the Agency to assign scores and points at the factor level, from which the final score "*must*" be arithmetically computed. The Associate Administrator said no such requirement exists in the Evaluation Plan or any other regulation or directive. He added that NASA officials based the award fees on a "qualitative assessment" of Boeing's performance and that this was the most appropriate way to incentivize the company to perform well.

We disagree with the Associate Administrator's characterization of our report. We did not state that NASA was required to use a weighted scoring system. Rather, because the Evaluation Plan established a system of weighted scores, we attempted to validate the award fees Boeing received using that system and found we could not do so. Indeed, as explained in this report, even though we assumed Boeing received a 100 percent score on two of the major performance factors – management and technical performance and safety and mission assurance – we still could not replicate Boeing's award fee. We acknowledged in the report that NASA's FDO could have increased Boeing's award fee even if the Performance Evaluation Board had calculated weighted scores for all four factors instead of just two. However, we believe the Board's failure to provide the FDO with this information made NASA's award-fee process less transparent and perhaps less reflective of the company's actual performance.

This is not the first time we have questioned NASA's award-fee practices. In a November 2013 report, we found that overly complex award formulas and a contract clause designed to hold contractors accountable for the quality of the final product that disregards interim performance evaluations have diminished the effectiveness of NASA's award-fee contracts.[60] We also found NASA failed to collect required data on award-fee contracts, thereby reducing its ability to measure their effectiveness. Two recommendations from that audit have yet to be resolved. Most significantly, NASA continues to disagree with our position that the Agency's practice of making unearned funds from interim award periods available in the final award pool circumvents a provision in the Federal Acquisition Regulation that prohibits Federal agencies from "rolling over" unearned fees to subsequent performance periods. In our view, NASA's policy promotes a philosophy that as long as a mission ultimately provides good science data the Agency will overlook cost and schedule overages that occur during project performance.

[60] NASA OIG, "NASA's Use of Award-Fee Contracts" (IG-14-003, November 19, 2013).

APPENDIX A

Scope and Methodology

We performed this audit from September 2013 through August 2014 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.

We assessed NASA's progress in certifying the Station's structure and hardware to meet the new lifespan by reviewing past ISS extension studies and interviewing ISS Program personnel. Specifically, we interviewed personnel involved with the electrical, thermal, structural, and life-support systems aboard the Station, as well as individuals who deal with transportation of cargo and crew. We reviewed NASA's Fracture Control Requirements for Spaceflight Hardware document (NASA-STD-5019), and other Space Station Program (SSP) documentation, including the ISS Safety Analysis and Risk Assessment Requirements Document (SSP 30309), Safety Review Process (SSP 30599), Fracture Control Requirements for Space Station (SSP 30558), Certification Baseline Document Volume 4: International Space Station Lifetime Extension (SSP 50699), and the Safety Requirements Document (SSP 50021).

To determine whether cost and schedule estimates associated with the extension were reasonable, we reviewed ISS Program life cycle cost estimates, the President's Budget Requests for FYs 2014 and 2015, and independent government cost estimates for commercial cargo and crew transportation services. Moreover, we reviewed the solicitation for future cargo transportation services, cost estimates for ORUs (spares), and documentation associated with procurement of spares. We also interviewed senior NASA officials within the Human Explorations and Operations Mission Directorate, as well as personnel within the Station's External Integration, Vehicle, Mission Operations and Integration, Program Planning and Control, and Flight Programs and Partnerships offices.

In order to assess the progress made and plans in place to utilize the Station for both NASA and non-NASA users, we reviewed Memorandums of Understanding between NASA and the international partner agencies. We also reviewed NASA's cooperative agreement with CASIS, and CASIS' FY 2014 Annual Program Plan, FY 2013 quarterly reports, and FY 2013 Annual Report. In addition, we interviewed CASIS' external partners, CASIS' Executive Director, NASA's Manager of the National Lab and supporting personnel, and NASA officials from the Human Research Program. Furthermore, we reviewed corresponding project documentation for the Human Research Program, such as risk assessments. To confirm the authorization for Station activities, we reviewed the NASA Authorization Acts of 2005, 2008, and 2010.

Lastly, we reviewed contract award documents, award-fee modifications, Performance Evaluation Board reports, FDO letters, Contracting Officer Technical Representative delegations, cost benefit analyses, Determination and Findings documents, Award-Fee Plans and selected areas of the Boeing Contract (NAS15-10000), and selected areas of the COLSA Corporation Contract (NNM12AA10C), and the Teledyne Brown Engineering, Inc. Contract (NNM13AA29C). We also reviewed Defense Contract Management Agency internal audit reports, and spoke with agency officials about their audit work on the ISS Program. In addition, we interviewed ISS Procurement Office personnel.

All work was performed at NASA Headquarters, Johnson, and Marshall Space Flight Center.

Use of Computer-Processed Data. We used computer-processed data to perform this audit. Specifically, we collected budget, commitment, obligation, disbursement, and total cost data from FY 2009 to early FY 2014. ISS Program officials downloaded the data from NASA's Business Warehouse system and provided the data in Microsoft Excel format. In order to verify the accuracy of this data, we independently ran queries through the Business Warehouse system using bookmarks. We corroborated information with other sources such as prior President's Budget Requests and life cycle cost estimates. We analyzed this data to enable us to evaluate the budgetary/cost information for the Program. The results of these analyses were used in the report. We believe the cost data we received is sufficiently reliable; therefore, we did not rely solely on the computer-processed data to support our findings, conclusions, or recommendations.

Review of Internal Controls

We performed an assessment of the internal controls associated with our audit, including identifying controls that are in place to monitor and assess ISS cost, schedule, and performance. Throughout the audit we reviewed controls associated with the audit objectives and identified that NASA has a comprehensive set of management tools it uses to provide internal controls for the ISS Program. This includes numerous boards and working groups, mission control centers, and procedures identified in the ISS Program Plan.

Further, the ISS Program has complied with NASA's internal control guidance, which requires submitting an annual certification of reasonable assurance. There were no material weaknesses identified. This has been the trend over the past 4 years, but is unusual given the size and scope of the Program and its 29 major contracts. Moreover, the ISS Program is overdue on a NASA plan – approved by the Office of Management and Budget – to conduct an acquisition assessment once every 3 years for contracts with a value over $250 million. NASA's Internal Control Plans do not have a scheduled assessment in FY 2014 – the last acquisition assessment was in 2010.

Prior Coverage

During the last 5 years, the NASA OIG and GAO have issued nine reports of particular relevance to the subject of this report. Unrestricted reports can be accessed over the Internet at http://oig.nasa.gov/audits/reports/FY14 and http://www.gao.gov.

NASA Office of Inspector General

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

"NASA's Efforts to Maximize Research on the International Space Station" (IG-13-019, July 8, 2013)

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

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

Government Accountability Office

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

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

"International Space Station: Approaches for Ensuring Utilization through 2020 are Reasonable but Should Be Revisited as NASA Gains More Knowledge of On-Orbit Performance" (GAO-12-162, December 15, 2011)

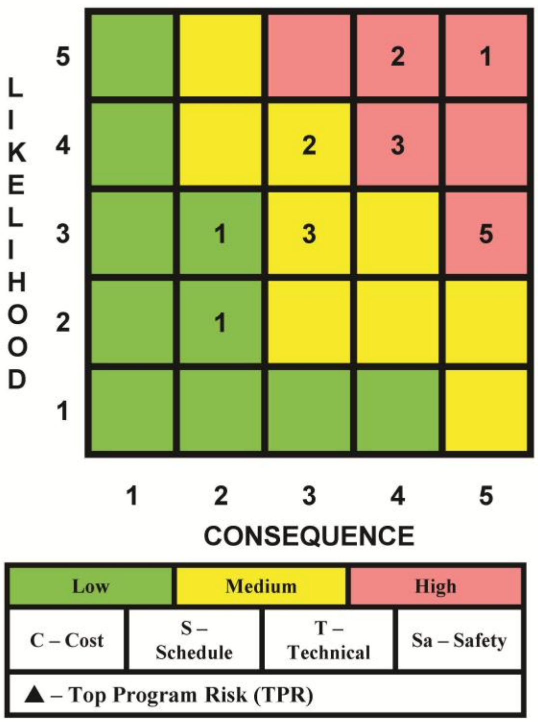
"International Space Station: Ongoing Assessments for Life Extension Appear to be Supported" (GAO-11-519R, April 11, 2011)

"International Space Station: Significant Challenges May Limit Onboard Research" (GAO-10-9, November 25, 2009)

ISS TOP PROGRAM RISK MATRIX

Figure 11 chronicles the top risks to the ISS Program.

Figure 11. ISS Top Program Risk Matrix



Risks (L x C)

Score: 5 x 5
▲ Lack of Assured Access to ISS - (C,S,T,Sa)

Score: 5 x 4
▲ ISS Pension Harmonization - (C)
▲ ISS Operations Budget Reduction - (C)

Score: 4 x 4
▲ Full ISS Utilization at 3 Crew - Level 1 - (C,S)
▲ Visual Impairment / Intracranial Pressure - (C,S,T,Sa)
▲ EPROM Memory Leakage - (C,S,T,Sa)

Score: 3 x 5
▲ Russian Segment (RS) capability to provide adequate MM/OD protection - (C,S,T,Sa)
▲ ISS Solar Array Management Operations Controls and Constraints - (C,S,T,Sa)
▲ ISS Cascading Power Failure - (C,S,T,Sa)
▲ Potential Inability to Support ISS Critical Contingency (& other) EVA Tasks - (C,S,T,Sa)
▲ Structural Integrity of Solar Array Wing (SAW) Masts due to MMOD Strikes - (S,T,Sa)

Score: 4 x 3
▲ The Big 13 Contingency EVA's - (S,T,Sa)
▲ C2V2 Comm Unit Vendor Misinterpreting ISS Requirements - (C,S,T)

Score: 3 x 3
▲ Lack of Sufficient Sparing for the Ku-Band Space to Ground Transmitter Receiver Controller (SGTRC) to reach 2020 - (C,S,T)
▲ NDS Qualification Schedule - (C,S,T)
▲ FGB Sustaining Contract and FGB spares plan post 2016 undefined - (C,S,T,Sa)

Score: 3 x 2
▲ Carbon Dioxide Removal Assembly (CDRA) Function - (C,T,Sa)

Score: 2 x 2
▲ USOS Cargo Resupply Services (CRS) Upmass Shortfall - 2010 through 2016 - (S,T)

Source: NASA.

MANAGEMENT COMMENTS

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

September 12, 2014

Reply to Attn of: Human Exploration and Operations Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Human Exploration and Operations Mission Directorate

SUBJECT: Response to OIG Draft Audit Report, "Extending the Operational Life of the International Space Station Until 2024" Assignment No. A-13-021-00).

The Human Exploration and Operations Mission Directorate (HEOMD) appreciates, the opportunity to review your draft report entitled, "Extending the Operational Life of the International Space Station Until 2024" Assignment No. A-13-021-00).

Extending the life of the ISS until at least 2024 enables NASA and the Nation to accomplish its goals in low earth orbit (LEO), including: developing the knowledge and capabilities necessary to extend human spaceflight beyond LEO; developing a LEO commercial supply and demand market for goods and services; maximizing research in biological, physical, earth and space science to the benefit of humanity on earth; and to provide the basis for international exploration cooperation.

In the report, the Office of Inspector General (OIG) makes three recommendations intended to reduce the potential cost growth in the International Space Station (ISS) Program and to ensure the maximum use of the ISS for scientific research.

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

In order to reduce potential cost growth in the ISS Program, the OIG recommends:

Recommendation 1: The NASA Associate Administrator for the Human Exploration and Operations Mission Directorate continue to solicit commitments from international partners to improve cost sharing.

Management's Response: NASA concurs with this recommendation. It is a matter of regular business for the full ISS partnership to seek efficiencies to reduce costs for all partners. This is formally addressed through ISS control boards and is a key practice that ensures the longest utilization period for the ISS.

Estimated Completion Date: Ongoing.

To ensure maximum use of the ISS for scientific research, the OIG recommends makes the following two recommendations:

Recommendation 2: The NASA Associate Administrator for Human Exploration and Operations Mission Directorate continue to track, manage, and mitigate human health risks to long-term exploration and identify and prioritize those risks that must be mitigated prior to decommissioning of the ISS.

Management's Response: NASA concurs with this recommendation. The Human Research Program (HRP), Flight Medicine Group and the ISS Program jointly review the HRP health risk mitigation list to ensure that all efforts that can be done on ISS are done as efficiently and effectively as possible. Health risks and mitigation activities are regularly reported and assessed through ISS control boards and increment readiness reviews.

Estimated Completion Date: Ongoing.

Recommendation 3: The Agency continues to pursue legislative options that will address patent license and data rights.

Management's Response: NASA concurs with this recommendation. In June 2013, NASA submitted to Congress a number of legislative proposals amending the National Aeronautics and Space Act, which are currently pending resolution as part of NASA authorization legislation. One proposal in the NASA submission, titled "Retention of Intellectual Property Rights by Users of the International Space Station National Laboratory," would amend the Space Act to authorize NASA to enable retention of rights by users in intellectual property arising from the ISS National Laboratory activities. NASA will continue to work with the Administration to press Congress to act on our proposed legislation. NASA also has provided briefings to interested staff members and will continue to do so, as requested. If possible, NASA, in concert with the Administration, will look for an appropriate legislative vehicle on which to include the Administration's proposal regarding retention of intellectual property.

Estimated Completion Date: N/A

In addition to the above recommendations and related findings, the report also discusses the administration and management of NASA's cost-plus-award-fee contract with Boeing. Specifically, the OIG indicates that it could not validate between $6.7 and $13.2 million in award fees paid to Boeing using the established criteria for the weighted evaluation scoring system. NASA does not concur with the OIG's basis for making this determination. NASA believes the OIG has misinterpreted the underlying facts surrounding these awards and misconstrued the applicable regulatory and program requirements under which these awards were properly provided. The factual basis for the OIG's finding and analysis is that the contract's Award Fee Evaluation Plan ***requires*** scores and points at the "factor" level, from which the final score ***must*** be arithmetically computed. The Plan says no such thing, nor does regulation, directives or guidance mandate that the Plan must require such a rigid point system. The Fee Determining Official's (FDO's) final determination was based on his qualitative assessment as documented in regulatory requirements as the most appropriate way to incentivize contractor's performance.

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

William H Gerstenmaier

William H. Gerstenmaier

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SEPTEMBER 18, 2014

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