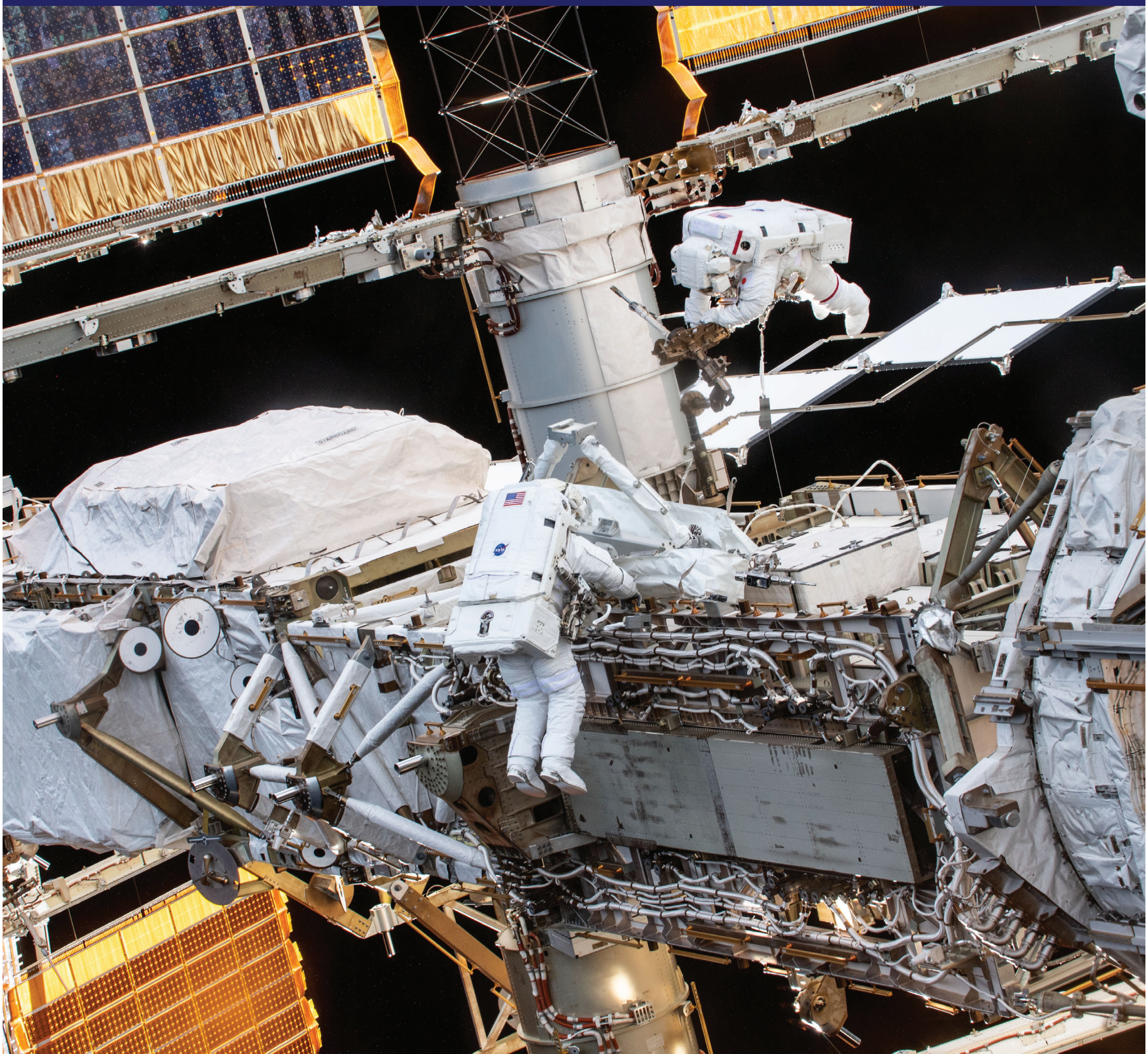
NASA
Office of Inspector General

NASA's Management of Risks to Sustaining ISS Operations through 2030



September 26, 2024

IG-24-020

Office of Inspector General

RESULTS IN BRIEF

NASA's Management of Risks to Sustaining ISS Operations through 2030

September 26, 2024 IG-24-020 (A-23-010-00-HED)

WHY WE PERFORMED THIS AUDIT

For nearly 25 years, astronauts have continuously lived and worked onboard the International Space Station (ISS or Station). Since 1998, when NASA (the United States) and Roscosmos (Russia) placed the foundational elements of the ISS in space, both space agencies—along with the Canadian Space Agency, European Space Agency, and Japan Aerospace Exploration Agency—have added elements that enhanced the Station's capabilities. The ISS is the world's preeminent orbiting, microgravity research and development laboratory. The Station serves as a springboard for NASA's commercialization initiatives in low Earth orbit (LEO) as well as the Agency's long-term deep space exploration goals to the Moon and Mars. The ISS and related operations and research cost approximately $4.1 billion annually, or 16 percent of NASA's fiscal year 2023 and 2024 budgets. As the Station ages, NASA will be challenged to ensure the safety of astronauts aboard and to sustain continuous operations, which includes conducting science and research and maintaining the ISS. At the same time, the Agency will need to develop capabilities to safely deorbit the ISS.

In 2022, the Administration extended the operational life of the ISS through 2030, and in response, NASA's international partners, except Russia, have also committed to that date. NASA committed to replacing the Station with one or more commercially owned and operated space destinations to maintain its presence in LEO. However, the Agency may need to consider other options, including extending ISS operations beyond 2030, if these destinations are not ready for the Station's planned 2031 deorbit. Extending the ISS past 2030 will require significant funding to operate and maintain the Station, acceptance of increased risk stemming from its components and aging structures, and assurances of continued support from NASA's international partners. Further complicating matters is the likelihood that NASA may continue to face a flat or reduced budget, inflation, and supply chain challenges.

In this audit, we examined NASA's management of risks to sustaining ISS operations through 2030, ensuring crew and operational safety, and conducting a safe, controlled deorbit in 2031. We reviewed four subject areas: (1) operations and maintenance, (2) orbital debris, (3) safety plans, and (4) deorbit of the Station. To perform this audit, we examined ISS reports and studies, risk metrics, utilization statistics, procurement documents, plans, processes, and presentations related to the four subject areas. We also interviewed officials involved in the ISS Program as well as officials from the Flight Operations Directorate and Commercial Crew Program.

WHAT WE FOUND

NASA faces increasing risks to sustaining ISS operations through 2030. On-going cracks and air leaks in the Service Module Transfer Tunnel are a top safety risk; and NASA and Roscosmos are collaborating to investigate and mitigate the cracks and leaks, determine the root cause, and monitor the Station for new leaks. However, in April 2024 NASA identified an increase in the leak rate to its highest level to date. Outside of structural risk mitigation, ISS Program officials expect continuing operations of the Station will require further repairs, and upgrades of key replaceable parts may be more difficult to acquire as suppliers decrease or cease production. These supply chain issues may become more persistent should NASA continue operations past 2030. While NASA's strategies and predictive models for parts replacement meet current ISS operational needs, we found the ISS Program faces challenges with future part needs.

Sustaining ISS operations to 2030 will be highly dependent on reliable transportation capabilities for both cargo and crew. The lack of redundancy and limited capabilities increase the risk to NASA's ability to bring supplies, science, and crew to and from the Station. Further heightening this risk is the current reliance on a single launch provider for cargo and crew that may disrupt planned ISS operations. Should the single launch vehicle be grounded or fail, the United States would not have the ability to transport cargo and crew to the Station. Instead, NASA would once again be reliant on its international partners to transport cargo and crew to continue conducting science and research.

NASA considers the threat of micrometeoroids and orbital debris (MMOD) a top risk to crew safety, the ISS structure, visiting vehicles, and sustained ISS operations. Recent events illustrate the impact of MMOD strikes. NASA mitigates the MMOD risk primarily through shielding and tracking. NASA installed shields on the U.S. segment of the ISS to protect it from damage by orbital debris 3 centimeters and smaller and relies on the Space Surveillance Network to provide tracking data on orbital objects in LEO greater than 10 centimeters. However, the Agency accepted some risk from MMOD and does not intend to add further protective exteriors due to the high costs and technical challenges. Recently NASA added emphasis through its Space Sustainability Strategy to increasing its orbital debris tracking capabilities.

While the ISS Program has sufficient plans and procedures in place to ensure crew safety in response to routine or emergency threats to Station operations, these plans continue to evolve. Crew responses typically entail isolating sections of the Station to contain the threat. In instances of more significant threats that cannot be isolated, ISS Program safety procedures require movement to crew vehicles in the event the Station would need to be evacuated. The ISS, Soyuz, Crew Dragon, and Starliner vehicles have specific shelter-in-vehicle and safe haven rules, which includes evacuating the Station. However, due to the high costs and a limited budget, the lack of ready-to-launch vehicles prevent the Agency from having an immediate response capability if crew vehicles encounter significant damage and are no longer safe for crew evacuation.

After more than a decade of effort, NASA and its partners continue to develop a transition and deorbit plan to prevent an operations gap in LEO and ensure a safe and controlled deorbit of the ISS. Russia has not committed to ISS operations through 2030, which includes the deorbit plan and timeline. Without commitment from Russia to the current deorbit plan, the ability to conduct a controlled deorbit is unclear. In June 2024, NASA awarded a contract to SpaceX to develop the U.S. deorbit vehicle to execute the controlled deorbit of the ISS in 2031. Nonetheless, the uncertainty of commercial LEO destination-readiness, limited budget availability, and the potential delay in availability of the U.S. deorbit vehicle adds more schedule challenges and risks to NASA's 2031 deorbit plan.

WHAT WE RECOMMENDED

To further mitigate risks to crew safety, we recommended the Associate Administrator for Space Operations Mission Directorate, in coordination with the Chief, Safety and Mission Assurance and the Chief Engineer (1) report on NASA's progress to reexamine available orbital debris tracking tools and offices to ensure all practicable data sources are leveraged to inform ISS operations and ensure crew safety and (2) document safety contingency plans and vehicle reassignment rules to help ensure the safe return of crew in the event of an emergency—expanding these efforts to include damage to the Crew Dragon and Starliner.

To inform ISS decommissioning and a safe, controlled deorbit, we recommended the Associate Administrator for Space Operations Mission Directorate, in coordination with the ISS Program Manager (3) develop plans that reflect potential cost savings measures and anticipated reductions in operations for ISS decommissioning and (4) update the controlled deorbit plan and ensure the plan includes key commitment, technical, schedule, and cost challenges impacting the 2031 deorbit time frame.

We provided a draft of this report to NASA management who concurred with our recommendations and described planned actions to address them. We consider management's comments responsive; therefore, the recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions.

For more information on the NASA Office of Inspector General and to view this and other reports visit https://oig.nasa.gov/.

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Acronyms

CASIS	Center for the Advancement of Science in Space
CSA	Canadian Space Agency
DOD	Department of Defense
ESA	European Space Agency
FY	fiscal year
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
LEO	low Earth orbit
MMOD	micrometeoroid and orbital debris
OIG	Office of Inspector General

INTRODUCTION

For nearly 25 years, astronauts have continuously lived and worked in low Earth orbit (LEO)—the region in space from about 200 to 270 miles above the Earth's surface—onboard the International Space Station (ISS or Station). During that time, the ISS has provided researchers the unique ability to study the effects of long-term exposure to microgravity and other conditions, including extreme temperatures and space radiation. Among other pursuits, continuing research in LEO is integral to NASA's Artemis lunar missions and future crewed missions to Mars, particularly the research to mitigate human health risks.

The ISS and related operations and research cost approximately $4.1 billion annually, or 16 percent of NASA's fiscal year (FY) 2023 and 2024 budgets, and the Agency expects this expenditure to continue with the Administration extending ISS operations through 2030.[1] As the Station ages, NASA will be challenged to ensure the safety of astronauts aboard and sustain continuous operations, which includes conducting science and research and maintaining the ISS and its systems.[2] At the same time, the Agency will need to develop capabilities to safely deorbit the ISS at the end of its useful life.

In the long-term, NASA has committed to replacing the Station with one or more commercially owned and operated space destinations to maintain its presence and research capabilities in LEO. However, the Agency may need to consider other options, including extending ISS operations beyond 2030, if these destinations are not ready in time for the Station's planned 2031 deorbit. Any extension of the ISS past 2030 will require continued significant funding to operate and maintain the Station, acceptance of increased levels of risk stemming from its replaceable components and aging structures, and assurances of continued support from NASA's international partners with the ISS—Russia in particular. Further complicating matters is the likelihood that NASA—like other federal agencies—may continue to face a flat or reduced budget, inflation, and supply chain challenges.

In this audit, we examined NASA's management of risks to sustaining ISS operations through 2030, ensuring crew and operational safety, and conducting a safe, controlled deorbit in 2031. See Appendix A for details of the audit's scope and methodology.

Background

A large spacecraft that orbits approximately 250 miles above the Earth's surface, the ISS has served as the home and science laboratory for astronauts from several nations and cosmonauts from Russia since 2000. Since 1998, when NASA (the United States) and Roscosmos (Russia) placed the foundational elements of the ISS in space, both space agencies—along with the Canadian Space Agency (CSA), European Space Agency (ESA), and Japan Aerospace Exploration Agency (JAXA)—have added elements that enhanced the Station's capabilities. The Station, weighing over 925,000 pounds, is powered by nearly an acre of solar panels, and its internal pressurized volume is equal to that of a Boeing 747

[1] NASA's FY 2024 budget request totals $27.2 billion, of which $4.5 billion is for space operations and $228 million is for commercial LEO development.

[2] ISS systems include both replaceable components and nonreplaceable structures. NASA manages risk to its replaceable components through hardware analyses and replacement, repair, or upgrade of these components and to its nonreplaceable structures through planned structural assessments to help ensure continued ISS operations.

aircraft. On board, more than 50 computers control the Station's systems, which rely on 1.5 million lines of flight software code.

ISS Utilization

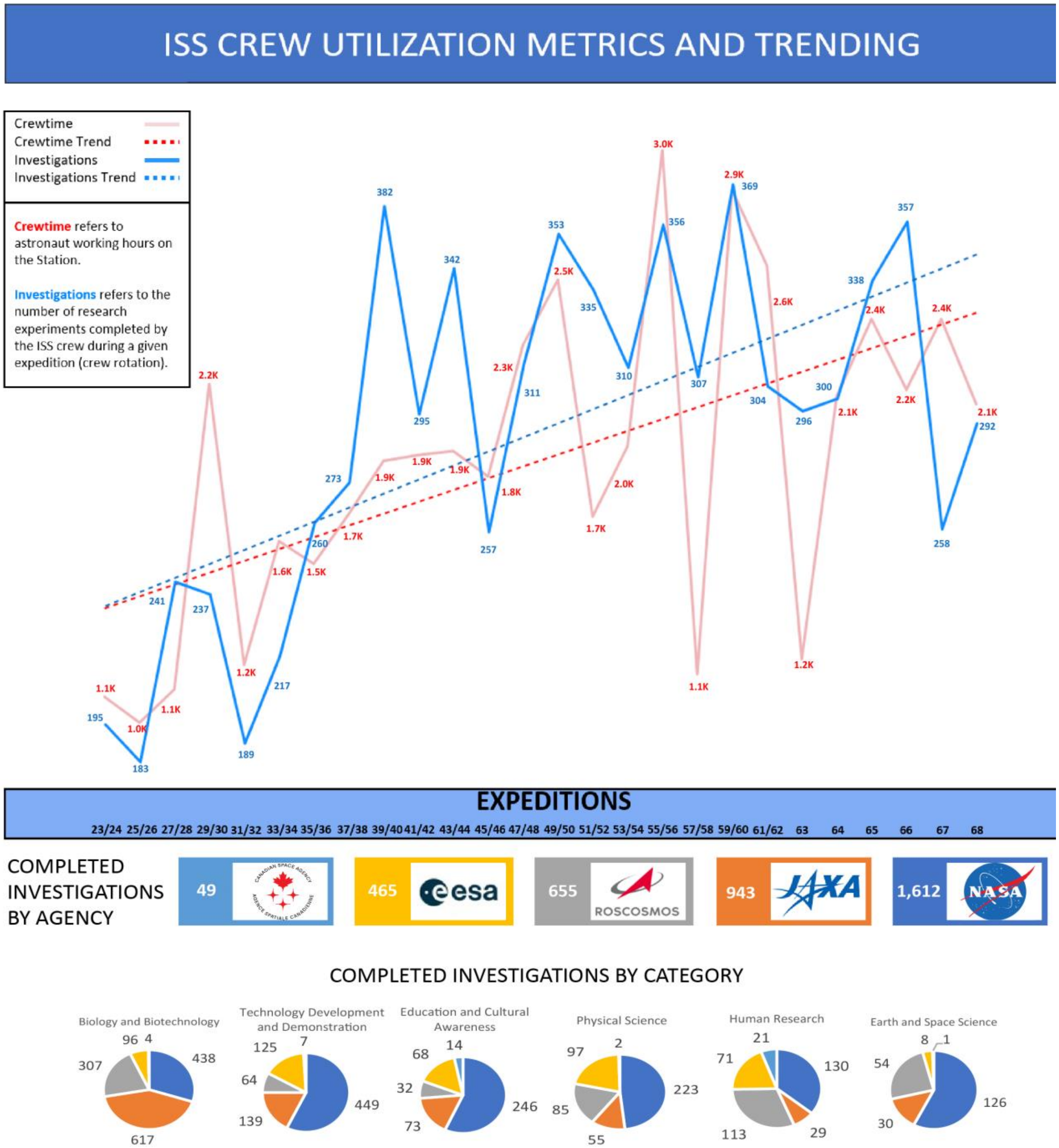
The ISS is the world's preeminent orbiting, microgravity research and development laboratory. Researchers from multiple nations perform multidisciplinary research and technology development activities to benefit deep space exploration, human health, physical and space sciences, Earth observation, and education.[3] The Station serves as a springboard for NASA's commercialization initiatives in LEO as well as the Agency's long-term deep space exploration goals to the Moon and Mars. In NASA's FY 2025 President's budget request, the Agency identified $261 million for research and technology demonstrations on the ISS to prepare for deep space exploration, continue its LEO research and serve as a bridge to commercial LEO destinations, impact life at home through use of the microgravity environment, and sustain and foster partnerships with international partners and within the global science community.

Research performed on the ISS varies, ranging from biology and human research to technology demonstrations and Earth science. Since our 2021 report on the ISS, 684 new investigations were initiated on the ISS and 501 investigations have been completed (see Figure 1).[4]

[3] NASA, *FY 2015 Annual Performance Report and FY 2017 Annual Performance Plan* (2015), Strategic Objective 1.2 states: Conduct research on the International Space Station (ISS) to enable future space exploration, facilitate a commercial space economy, and advance the fundamental biological and physical sciences for the benefit of humanity.

[4] NASA Office of Inspector General (OIG), *NASA's Management of the International Space Station and Efforts to Commercialize Low Earth Orbit* (IG-22-005, November 30, 2021).

Figure 1: Utilization Statistics for the International Space Station (2000 to 2023)



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

Note: NASA typically groups the planning and execution of ISS research investigations into 6-month periods known as expeditions. Expeditions 63 through 68 were 6-month periods. Expeditions 65 through 68 figures are based on preliminary data.

Deep Space Human Exploration Including Artemis. The ISS is a key testing ground for long-duration human deep space exploration research and technology demonstrations. Astronaut health and safety are focal points of the science and research conducted on the Station. Through NASA's Human Research Program, the Agency uses the ISS to study the effects of space on the human body. With future explorations to the Moon and Mars, there is focus on five human space flight hazards: space radiation, isolation and confinement, distance from Earth, gravity fields, and hostile/closed environments.[5] This aligns with NASA's April 2023 Moon to Mars Strategy, which includes leveraging infrastructure in LEO to support Moon to Mars objectives and conducting human research and technology demonstrations.[6] In 2023, NASA budgeted $266 million to support research and technology demonstrations for long-duration human deep space exploration, with $151 million of that going towards research to mitigate long-duration mission risks to astronaut health.

Science and Research. The ISS's scientific research applications extend to life on Earth. The ISS remains a cornerstone for Earth and space science research by NASA's Science Mission Directorate, including projects to improve watering strategies and food crop production on farms, study fire safety, study crystal growth, and understand combustion and fuel efficiency. Scientific research has been conducted onboard the Station since its early years, and today well-established and diverse research serves to test and develop new technologies.[7] Managed by the Center for the Advancement of Science in Space (CASIS), ISS National Laboratory research enables non-NASA entities—such as small companies, research institutions, Fortune 500 companies, and government agencies—to use the ISS and form new public-private partnerships.[8] ISS National Laboratory-sponsored research from academia and commercial entities includes developing new drug therapies, better understanding how cancer forms, creating improved disease models, testing advanced technologies, and manufacturing human tissues in space.

Development of a Low Earth Orbit Economy. The ISS supports development of a commercial ecosystem in LEO. This includes transitioning to commercially provided ISS cargo and crew transportation starting in 2011, supporting non-NASA research through the ISS National Laboratory, and facilitating the transition to commercially owned and operated LEO destinations planned for 2030. Additional efforts include the ISS hosting the Axiom Mission 1 in 2022—NASA's first private astronaut mission focused on science and research. During the 17-day mission, the Axiom crew conducted over 25 scientific experiments and technology demonstrations. In 2023 and 2024, Axiom conducted two additional private astronaut missions with another mission scheduled for late 2024. See Appendix B for further information on ISS utilization activities.

Management of the ISS

The ISS is managed by NASA and four other space agencies—Roscosmos, CSA, ESA, and JAXA. Through a shared vision, a detailed legal framework, and continuing political and budgetary support, this international collaboration has resulted in two decades of continuous ISS operations with 279 individuals from 22 countries having visited the Station. The ISS partners cover their portion of the

[5] NASA, *The Human Body in Space* (February 2, 2021).

[6] NASA, *NASA's Moon to Mars Strategy and Objectives Development* (April 2023).

[7] NASA, *Annual Highlights of Results from the International Space Station 2023* (2023).

[8] In 2005, Congress designated the U.S. segment of the ISS as a National Laboratory, enabling space research and development access to a broad range of commercial, academic, and government users. The ISS National Laboratory is responsible for managing non-NASA research, and all investigations require the capacity to utilize microgravity for the benefit of humanity. In the NASA Authorization Act of 2010, Congress directed the Agency to select an entity to manage the U.S. National Laboratory. In August 2011, NASA entered into a 10-year agreement with CASIS to manage the laboratory, and in 2022, the Agency extended the contract with CASIS through 2027. NASA OIG, *NASA's Management of the Center for the Advancement of Science in Space* (IG-18-010, January 11, 2018).

Station's shared costs based on their contribution to the ISS as a whole. These costs are equivalent to the percentage of the ISS's research resources each of these partners have a right to use. Cost sharing is key to the Station's affordability, given that by 2022 NASA alone had invested approximately $118 billion in the development and operation of the ISS.[9] In addition to Memorandums of Understanding, a variety of bilateral Implementing Arrangements establish guidance and allocate tasks among NASA and its partners.[10]

NASA's ISS Program Office resides within the Agency's Space Operations Mission Directorate. The program office primarily operates out of Johnson Space Center with support from Ames Research Center, Glenn Research Center, Kennedy Space Center, and Marshall Space Flight Center. To manage the systems, programs, projects, and offices that enable the Station to operate, the ISS Program is broken down into 11 offices with different roles and responsibilities to maintain ISS operations. In addition, ISS operations are supported by other NASA offices and federal agencies.

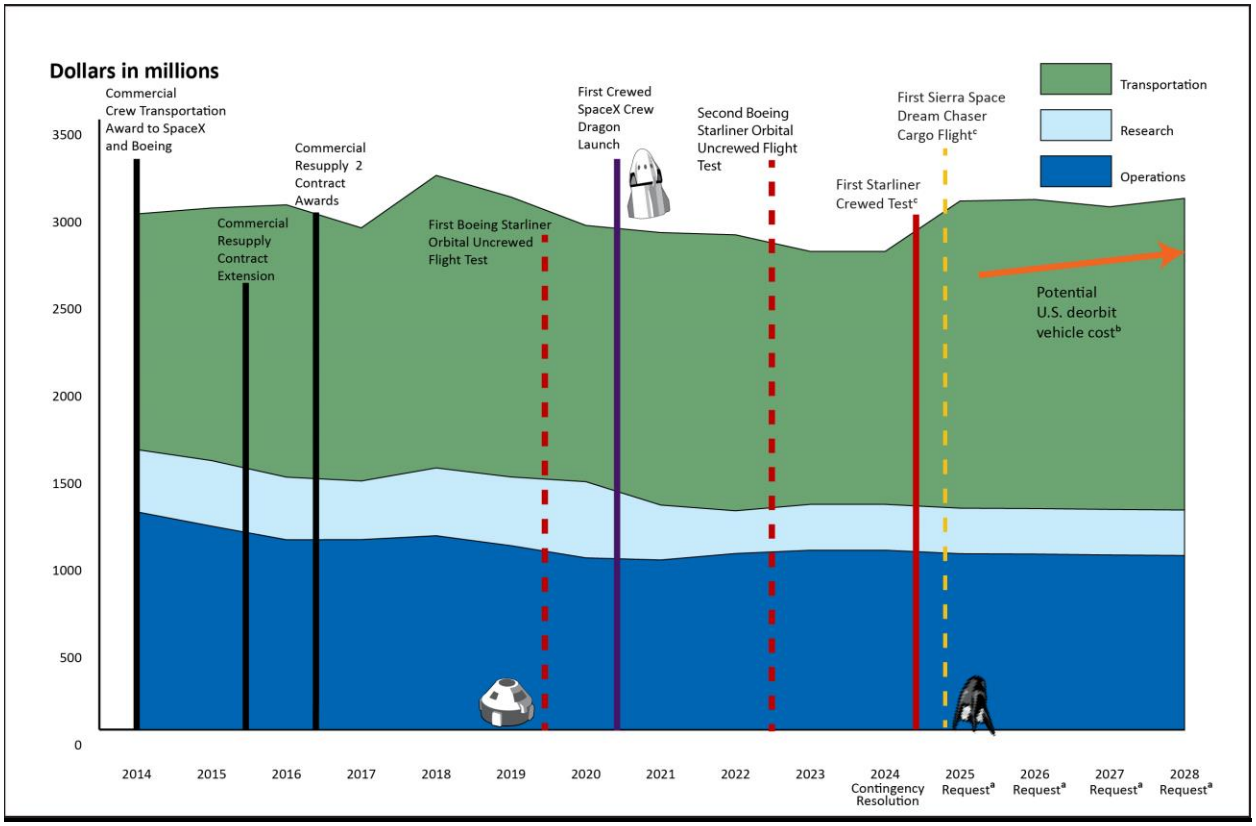
ISS Costs and Budget Outlook

From 2013 to 2023, NASA spent approximately $3 billion annually on ISS operations, maintenance, research, and cargo and crew transportation (see Figure 2). The ISS Program Office expects ISS annual operating costs will remain stable at approximately $3 billion until the Station approaches the end of its lifetime and as NASA begins to spend less on repairs, spare parts, and transportation while transitioning to commercial LEO destinations. In addition, the Agency expends nearly $1 billion annually on other costs that support ISS and other space operations missions, including communications and navigation, human research, flight operations, launch services, and human health and training.

9 The approximately $118 billion investment includes approximately $11 billion for the Space Station Freedom (which although never completed evolved into the ISS); $74 billion for ISS development, operations, research, and associated Space Shuttle flights from FYs 1994 through 2013; and approximately $33 billion spent from FYs 2014 through 2022 to include Commercial Crew Program and development costs. These are actual costs not adjusted for inflation.

10 An Implementing Arrangement, or Implementing Agreement, is a written document that establishes specific cooperation to include concrete guidelines, provisions, and scope between the participating entities.

Figure 2: NASA's ISS Costs from FYs 2014 through 2029 (as of June 2024)



Source: NASA OIG presentation of NASA's annual ISS and commercial transportation funding.

Note: Separate commercial crew and cargo costs not directly tied to ISS resupply missions are excluded.

[a] Financial information for FYs 2025 through 2028 is based on NASA projections in the FY 2025 budget request.
[b] U.S. deorbit vehicle costs are in addition to the current and future ISS budget. For FY 2024, NASA submitted a supplemental budget request for $180 million. In June 2024, the U.S. deorbit vehicle was awarded for $843 million, however this does not include launch vehicle costs.
[c] Both The Boeing Company's Starliner and Sierra Space Corporation's Dream Chaser vehicles have seen significant delays and are not yet certified to carry crew and cargo.

In March 2024, Congress appropriated $2.88 billion for the ISS Program and the Crew and Cargo Program in support of the Station, approximately $50 million less than the FY 2023 enacted level and about $283 million less than the FY 2024 President's budget request. As of June 2024, the Agency is undergoing internal budget reviews to identify potential ISS Program cost savings to account for the reduced funding in FY 2024 and assess the impact on NASA's FY 2025 budget submission.[11] Additionally, the 2024 Appropriations Act expressed support for a U.S. deorbit vehicle—a spacecraft designed to perform the final, safe, deorbit maneuver of the ISS—but did not identify requirements or provide funding for the vehicle.[12]

[11] NASA requested nearly $1.0 billion for ISS operations, $1.9 billion for space transportation, and $1.1 billion for space and flight support in its FY 2025 President's budget request. However, as the Agency is currently reviewing its budget to save or reallocate funding, these amounts are subject to change.

[12] Senate Report 118-62, *Departments of Commerce and Justice, Science, and Related Agencies Appropriations Bill, 2024* (2023).

ISS Operational Life

The ISS was designed and constructed nearly 30 years ago and has been modified throughout the past two decades. The ISS's structure has a finite life and given the Station's age, multiple extensions to its operational life, and strikes and threats from micrometeoroid and orbital debris (MMOD), NASA continuously monitors the ISS's ability to operate safely.[13] This monitoring incorporates a risk-based management approach to operations, including conducting on-orbit maintenance and assessments of the ISS's structure and systems.

The priority of on-orbit maintenance—including preventative, corrective, and contingency—is based on the urgency of the maintenance, time frame for completion, and the location where the maintenance or repair is to be carried out.[14] Beyond routine maintenance, the structural integrity of the Station's U.S. On-Orbit Segment (also known as the U.S. segment) is monitored and certified under a service contract with The Boeing Company (Boeing).[15] Currently, the ISS is structurally certified through 2028. NASA's contract with Boeing for servicing the Station, which includes obtaining and maintaining spare parts, expires at the end of FY 2024. As of July 2024, the Agency and Boeing are negotiating an extension of this contract.

Structural life assessments of the U.S. segment of the ISS have historically looked at operations in 4-year future intervals. In 2026, however, the Agency plans to begin a final certification for the structure's "end of life," or the point in time when the Station's structure is no longer viable for safe operations. Beyond the U.S. segment structural assessments and certifications, the ISS partners assess and certify the structural integrity of their respective segments on a recurring basis.

In 2021, we reported on cracks and air leaks in the Russian Service Module Transfer Tunnel, which connects the Service Module to one of eight docking ports on the Station.[16] Subsequently, the 2022 NASA Authorization Act required the Agency to provide specific briefings to NASA's Aerospace Safety Advisory Panel that address several issues facing the Station and the ISS Program.[17] Since 2022, NASA has been reporting to the Aerospace Safety Advisory Panel on the root causes of the transfer tunnel cracks and air leaks; certification of all U.S. systems and modules to operate through 2030; inventory of

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[13] Millions of naturally occurring micrometeoroids and human-made debris—such as decommissioned satellites and parts of spacecraft—orbit in and around Earth's space environment at speeds averaging 22,000 miles per hour. This "space junk" collides with spacecraft and satellites, potentially causing serious damage or catastrophic failure, and can be a threat to astronauts conducting extravehicular activities in space.

[14] NASA SSP 50520, *International Space Station Logistics and Maintenance Operational Support Concepts and Requirements* (2015) states that preventative maintenance is performed to keep item(s) in a specified condition. This can include periodic checks to verify that the equipment is operating properly and can continue performing as normal. Corrective maintenance is performed to restore system functionality following anomalies or equipment problems encountered during system operations or resulting from conditions discovered during preventive maintenance. Contingency maintenance is performed to restore a function, which is vital to crew safety or vehicle integrity. These are temporary repairs performed in real time with the resources available.

[15] The U.S. On-Orbit Segment of the ISS includes sections of the Station developed and operated by the United States, Canada, Europe, and Japan. The individual modules and their structures are managed by their respective space agencies.

[16] IG-22-005. The ISS Service Module Transfer Tunnel connects the Service Module to one of eight docking ports on the Station (four belong to the United States and the other four to Russia). The Service Module Transfer Tunnel is one of three pressurized compartments of the Service Module, an area in which the crew live and work. A crack is evidenced by a split or break in an item, and a leak occurs when the contents of a container are leaving.

[17] The National Aeronautics and Space Administration Authorization Act of 2022, as enacted by the CHIPS and Science Act, Pub. L. No. 117-167 (2022). The Aerospace Safety Advisory Panel evaluates NASA's safety performance and advises the Agency on ways to improve that performance.

spare or replacement parts for elements, systems, and equipment; and other information relevant to the safe and productive use of the ISS through 2030.

Russian cosmonauts, technology, and transport systems are responsible for a host of key ISS functions. When the ISS launched in 1998, Russia and the United States were each responsible for providing half of the Station. Since then, the United States, Russia, and the other international partners have developed and integrated additional hardware to form and operate the current ISS structure and systems. Operation of the Station's propulsion is reliant on Russian capabilities. NASA continues to negotiate extensions of its agreement with Roscosmos for the joint operation of the ISS, including Russian propulsion to maintain ISS altitude and attitude, structural certifications, and maintenance and repairs of the Russian segments of the Station.[18] Furthermore, the planned deorbit of the Station also requires Russian propulsion capabilities to maintain attitude control and reboost propulsion until final deorbit by the U.S. deorbit vehicle. NASA anticipated that Roscosmos would commit to the Agency's ISS deorbit plan—which requires a continued partnership through 2030—in the summer of 2023. However, as of June 2024, negotiations continue, and no agreement has been finalized.

NASA Plans for ISS Transition to Avoid an Operational Gap in Low Earth Orbit

The ISS was initially scheduled to retire in 2015, but its life was extended twice by Congress, through 2020 and 2024, with a further extension through 2030 by the Biden Administration. These extensions align with the Agency's goal to maintain a presence in LEO. NASA plans to transition operations to at least one commercial LEO destination prior to ISS deorbit, providing an overlap with the ISS that will enable NASA and its international partners to continue conducting science and research in LEO. The Agency has not yet determined the duration of the overlap or when it will occur. NASA's transition from a government-owned to a privately-owned station is estimated to save the Agency between $1.3 billion and $1.8 billion per year, based on current expected capabilities and estimated prices for commercial LEO destination services. To this end, NASA budgeted approximately $204 million in FY 2023 and $228 million in FY 2024 for the development of commercial LEO destinations and has requested increased funding through at least FY 2029 for this effort.

Transition to new LEO destinations will include deorbiting the ISS. When the Station became operational in 1998, the plan was to dispose of the ISS via a controlled deorbit with reentry of the Station's structure into an unpopulated area of the Pacific Ocean, propelled by three Russian Progress cargo spacecraft. NASA is currently working with its international partners to update this plan—developing and executing a coordinated deorbit of the ISS in 2031. In 2018, NASA released its *International Space Station Transition Report* that laid out the Agency's plans for future operational, research, and development plans in LEO.[19] In 2021, we found that the transition plan was still early in development and implementation but showed promise to address many challenges the Agency faces with this effort.[20]

The Agency last updated the report in 2022 to reflect current transition plans in LEO, including its continued ISS international partnerships and reliance on Russian propulsion to complete the planned

[18] Altitude is the vertical elevation of an object above a surface of a planet, such as Earth. Attitude is the position of a spacecraft determined by the relationship between its axes and a reference point such as the horizon or a particular star.

[19] NASA, *International Space Station Transition Report* (March 2018).

[20] IG-22-005.

controlled deorbit of the Station.[21] Since the 2022 report, NASA has committed to deorbiting and replacing the Station with one or more commercial destinations to maintain its presence in LEO. Reflective of these efforts, NASA has issued a Final Request for Proposal for a U.S. deorbit vehicle and awarded contracts to three U.S. industry partners for the development of commercial LEO destinations with operations to begin in the late 2020s for government and private-sector customers.

Prior NASA Office of Inspector General Reports on Ongoing Risks to the ISS

In November 2021, we reported on the various signs of ISS aging—such as cracks and air leaks—within the Russian Service Module Transfer Tunnel, NASA's efforts to manage those issues, and the potential long-term impacts on the Station's structural integrity.[22] In January 2021, we reported on the growing volume of orbital debris that threatens the loss of important space-based applications, and how remediation—the removal of debris in orbit—is needed to stabilize the orbital debris environment.[23] Millions of pieces of orbital debris exist in LEO—at least 26,000 of which are the size of a softball or larger that could destroy a satellite on impact, over 500,000 are the size of a marble big enough to cause damage to spacecraft or satellites, and over 100 million are the size of a grain of salt that could puncture a spacesuit. In November 2019, we reported on NASA's management of its two commercial crew providers efforts to provide U.S.-based transportation capabilities to and from the ISS for U.S. and international partner astronauts.[24] In July 2018, we reported on the utilization of the ISS and early planning for the end of the Station's life and deorbit.[25] The challenges identified in these four reports remain relevant as the Agency continues to evaluate risks to sustaining ISS operations and to the Station and crew, while planning for the eventual deorbit of the Station.

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[21] NASA, *International Space Station Transition Report* (January 2022).

[22] IG-22-005.

[23] NASA OIG, *NASA's Efforts to Mitigate the Risks Posed by Orbital Debris* (IG-21-011, January 27, 2021).

[24] NASA OIG, *NASA's Management of Crew Transportation to the International Space Station* (IG-20-005, November 14, 2019).

[25] NASA OIG, *NASA's Management and Utilization of the International Space Station* (IG-18-021, July 30, 2018).

NASA Faces Increasing Risks to Sustaining ISS Operations through 2030

Assessments to Extend the Structural Life of the Station for Operations beyond 2028

The Biden Administration extended the operational life of the ISS through 2030, and in response, NASA obtained commitments from its international partners, except for Roscosmos, which is committed through 2028. NASA and Boeing are working to certify the U.S. segment of the ISS beyond its current 2028 certification date. They intend to extend certifications to the end of life for the ISS structure, such as the Station truss or frame, that cannot be maintained or replaced.

In certifying the ISS to the end of its life, NASA and Boeing will conduct testing and analysis of the Station's critical structures to forecast the earliest point at which one of these structures will fail—signaling the point in time the Station can no longer continue safe operations. This is a change from prior certifications to the Station's structure that were typically done in 4-year increments. NASA officials stated they have confidence in Boeing's ability to make this final certification through robust testing, forecasting, and analysis at levels of utilization and wear-and-tear beyond maximum use to develop the most conservative end-of-life timeline.

Beyond the U.S. portion of the ISS, NASA relies on its partners, including Roscosmos, to certify their segments of the Station. Officials from the NASA Office of the Chief Engineer and ISS Program Office said they were confident in Roscosmos's process and its ability to certify and extend the operational life of the Russian segment to 2030. However, Russia's commitment beyond 2028 has yet to be decided given that the time frame for extension negotiations is not planned to occur until 2025 or 2026, consistent with prior time frames for negotiation and commitment to the partnership.[26]

NASA and Roscosmos continue to work together to address structural issues with the Russian Service Module Transfer Tunnel. Cracks and air leaks in the tunnel are a top safety risk, and as we reported in 2021, both agencies are collaborating to investigate and mitigate the cracks and leaks; determine the root cause, which includes sharing sample metals, welds, and Roscosmos investigation reports; and monitor the Station for new leaks. According to ISS Vehicle Office officials and their Roscosmos counterparts, the Service Module Transfer Tunnel leak is not an immediate risk to the structural integrity of the Station, and there are no current concerns of long-term impacts to the overall structure.

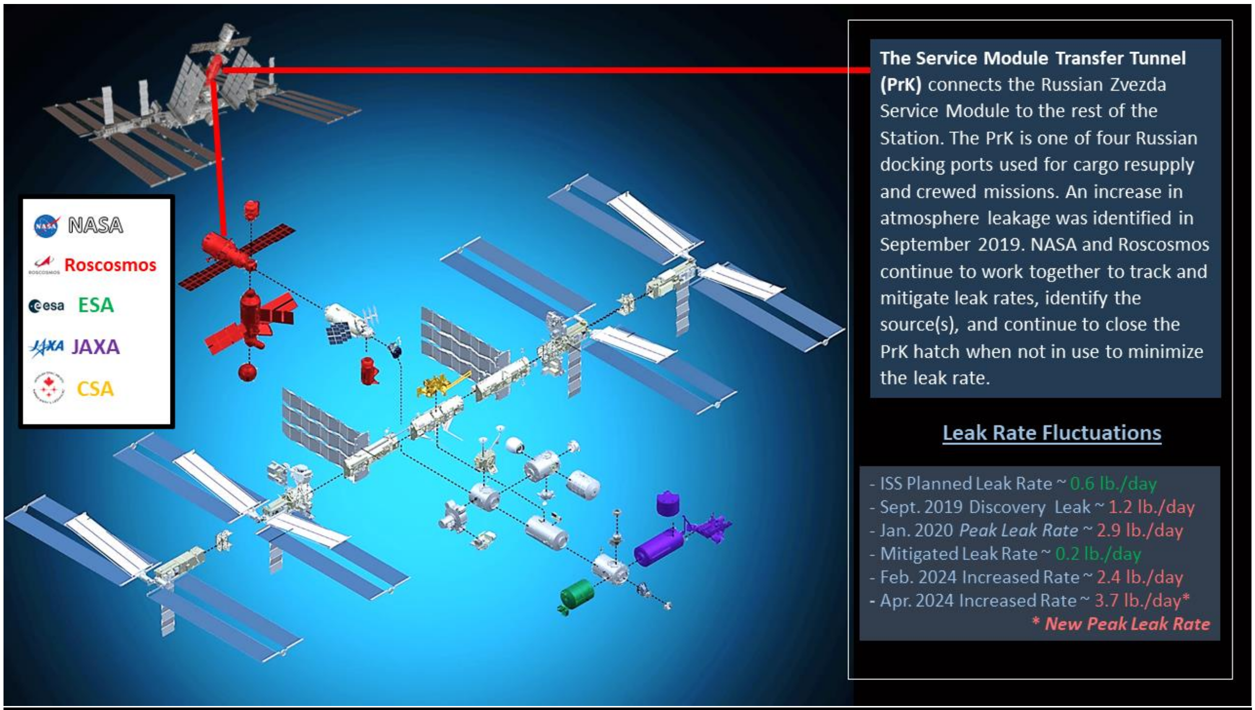
Nevertheless, in February 2024 NASA identified an increase in the leak rate, and the Agency and Roscosmos continue to assess the risk that the increase poses to the module's structure. In May and June 2024, ISS Program and Roscosmos officials met to discuss heightened concerns with the increased leak rate. The ISS Program subsequently elevated the Service Module Transfer Tunnel leak risk to the

[26] Similar to NASA's time frame, Roscosmos makes its commitments in 4-year increments with an extension decision expected in 2026.

highest level of risk in its risk management system.[27] According to NASA, Roscosmos is confident they will be able to monitor and close the hatch to the Service Module prior to the leak rate reaching an untenable level. However, NASA and Roscosmos have not reached an agreement on the point at which the leak rate is untenable.

To mitigate potential impacts from the air leaks, NASA and Roscosmos continuously monitor leak rates and close the hatch to the Service Module when access is not required, sealing the module to minimize air loss while isolating the leak. While it is possible for the ISS to function if the hatch is closed permanently, it could impact cargo delivery because there would be one less cargo delivery port. Closing the hatch permanently would also necessitate additional propellent to maintain the Station's altitude and attitude. Although the root cause of the leak remains unknown, both agencies have narrowed their focus to internal and external welds. As of June 2024, there was no indication of other leaks on the Station. See Figure 3 for a breakdown of the ISS segments by space agency as well as the location of the Service Module Transfer Tunnel leak.

Figure 3: ISS Segments by Space Agency and Location of Service Module Transfer Tunnel Leak (as of May 2024)



Source: NASA OIG presentation of NASA information.

[27] NASA uses a Risk Matrix, or risk scorecard, that is based on risk likelihood and risk impact. Each of these categories are scored on a five-point scale, with a five being the most severe. As of August 2024, the Service Module Transfer Tunnel leak risk is scored as a 5 by 5.

Costly Maintenance and Increasing Supply Chain Uncertainty Impacts ISS Operations and Planning

To ensure the ISS functions properly, its parts and hardware are regularly monitored, repaired, and upgraded. We found that between FY 2019 and FY 2023, NASA's system operations and maintenance costs remained steady at approximately $1 billion per year for the ISS. While ISS Program officials expect continuing demand for repairs and upgrades as the Station ages, key parts required for continued operations may be more difficult to acquire as suppliers decrease or cease production in response to the Station's projected end of life in 2030. These supply chain issues may become more apparent should NASA continue operations past 2030.

To sustain ISS operations, the Agency places an emphasis on anticipating and mitigating risk with a focus on spare parts management. NASA and Boeing conduct annual analyses to develop strategies for future operational needs, including anticipated parts replacement. This annual assessment is done in 5-year intervals up to 15 years out. Critical elements of these analyses include the age and availability of the Station's systems and parts, the rate at which repair or replacement is needed, and the health of the parts' industrial base and supply chains.

Systems and Parts Management. Based on our assessment, NASA and Boeing have an effective process for planned systems maintenance, including spare parts stored on-orbit and parts available to be launched on cargo resupply vehicles when needed. However, on occasion the lack of on-orbit or ground spare parts and flight manifest constraints delay the planned repair or replacement of parts, temporarily limiting full systems usage. For example, in June 2024 the ISS urine processing system lacked a replacement pump on-orbit, resulting in off-nominal stowage of urine until a replacement pump could be flown up to the Station later that month. We found that as of July 2023, current operational Mean Time Between Failure metrics are greater than or equal to original predictions for over 95 percent of the 619 on-orbit parts and hardware.[28] Of those on-orbit parts, approximately 588 are operating beyond their planned operational lifetimes. According to the ISS Vehicle Office, for the parts that are operating longer than their forecasted lifetimes, it is an indication of better overall performance than predicted. The ISS Program continues to utilize this data to help plan for spare parts and are confident in their sparing approach through 2030.[29]

Supply Chain and Parts Availability. While NASA's strategies and predictive models for parts replacement and sparing effectively meet current ISS operational needs, we found the ISS Program faces challenges with future parts needs through 2030 and potentially beyond. These challenges are focused on the availability of on-orbit replacement units and ground inventory of spare parts. For example, we identified four parts with supply deficiencies that the ISS Program flagged and assessed to develop mitigation plans to minimize impact to operations.[30] ISS Program officials told us that they will continue

[28] Mean Time Between Failure is a measure of how long a mechanical or electronic system operates before failing. It is calculated as the average time between inherent failures of a system during normal operation. This measurement is an indication of the reliability and performance of a system. These measurements are conducted annually, and more recent data was not available during the course of this audit.

[29] Sparing is the process of analyzing system use, operational life, and available replacement parts to keep ISS systems operational.

[30] The four ISS parts identified as having supply risks include three related to science facilities and one exercise system. The parts were identified as having no available spare or near-term availability and no mitigation plan if the current operational part were to fail within the next 6 months. None of the parts pose a significant risk that would impact overall ISS research or operations.

to monitor and mitigate these near-term parts supply challenges through the Agency's parts replacement and sparing modeling and analysis.

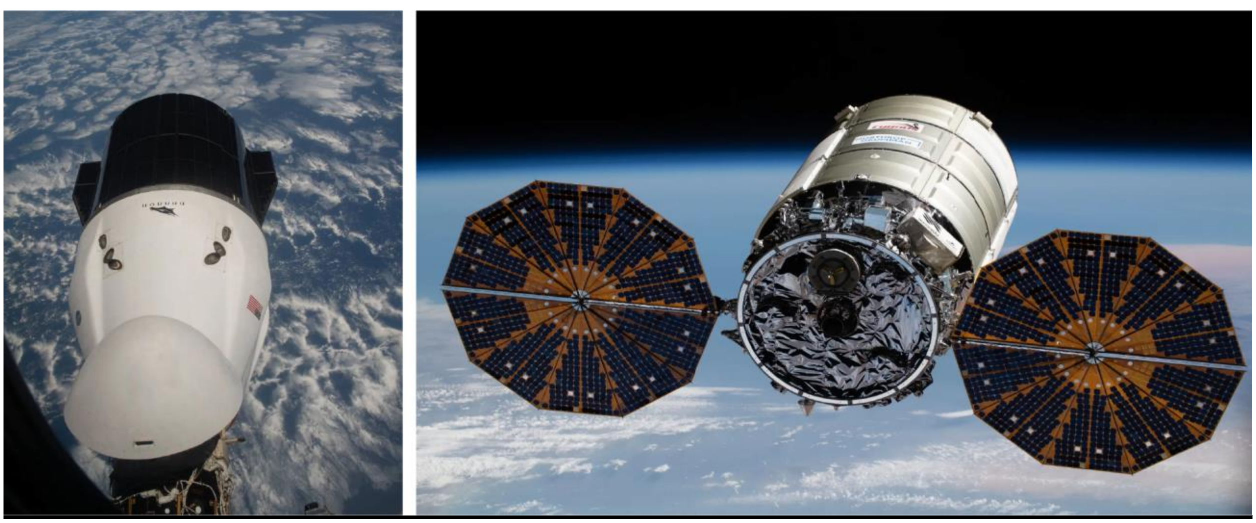
In addition to near-term parts availability challenges, some spare parts have long production time frames and therefore require procurement years in advance. Complicating these procurement matters is that NASA and Boeing are still evaluating the possible effects of their contract extension of Station operations and maintenance of replaceable components beyond 2028. Further, with an uncertain lifetime of the ISS beyond 2030 and its subsequent replaceable component needs, the Agency's ability to negotiate for long-lead time parts and maintain an already limited supplier network may be hindered. In response to this challenge, NASA and Boeing are coordinating, maintaining, and updating the Agency's supplier prioritization list to inform suppliers of ISS Program priority needs—sparing and orbital replacement units—to be able to adjust resource availability.[31]

As the ISS continues to age and NASA and its partners start to reduce the number of operational systems as part of decommission plans, the industrial base will be challenged to remain operational to meet the ISS's evolving spare parts needs while transitioning to post-ISS operations.

Long-Delayed Commercial Transportation Capabilities May Disrupt Planned ISS Operations

Sustaining ISS operations to 2030 will be highly dependent on reliable transportation capabilities. Space Exploration Technologies Corporation's (SpaceX) Dragon vehicle has provided cargo and crew transportation to the ISS since 2012 and 2020, respectively. Additionally, Northrop Grumman Corporation's (Northrop Grumman) Cygnus vehicle has provided cargo transportation since 2014 (see Figure 4).[32]

Figure 4: SpaceX Cargo Dragon (Left) and Northrop Grumman Cygnus (Right) Vehicles



Source: NASA.

[31] Orbital replacement units are parts of the main systems and subsystems of the external elements of the ISS. Examples of the units include pumps, storage tanks, controller boxes, antennas, and battery units. Orbital replacement units can be readily replaced when they pass their design life or fail.

[32] Orbital Sciences Corporation first provided cargo transportation services to the ISS in 2014. However, that company merged with Alliant Technologies in 2015 to form Orbital ATK, which was later acquired by Northrop Grumman in 2018.

NASA also has an ongoing barter agreement for crew transportation through 2025 with Roscosmos to fly its cosmonauts on SpaceX flights in exchange for flying NASA astronauts on Russian Soyuz vehicles.[33] However, additional commercial transportation options—Sierra Space Corporation's cargo Dream Chaser and Boeing's crewed Starliner vehicles—have yet to be certified for cargo and crew launches. In the near term, NASA faces challenges with both cargo and crew transportation from its providers due to the delays in vehicle certification and availability. The lack of redundancy and limited capabilities of both cargo and crew transportation increase the risk to NASA's current and future ability to bring critical supplies, science, and crew to and from the Station to maintain safe operations and full utilization of the ISS.

For cargo transportation, NASA relies on SpaceX's Dragon and Northrop Grumman's Cygnus for cargo upmass transportation capabilities—bringing mass to the Station (see Figure 5). NASA also relies on SpaceX for cargo downmass transportation capabilities—returning mass from the Station.[34] Once certified, Sierra Space Corporation's Dream Chaser will provide redundant upmass and downmass capabilities.[35] Following Northrop Grumman's commercial resupply mission to the Station in August 2023, the heritage Antares rocket engines used to launch the cargo vehicle were exhausted. Until the company's new launch rocket is ready (expected in 2025), Northrop Grumman is utilizing SpaceX's Falcon 9 rocket for cargo resupply missions.[36] In the interim, cargo resupply launches for both SpaceX and Northrop Grumman will be limited to SpaceX's Falcon 9 rocket, and downmass capabilities will be limited to SpaceX's Dragon cargo spacecraft.

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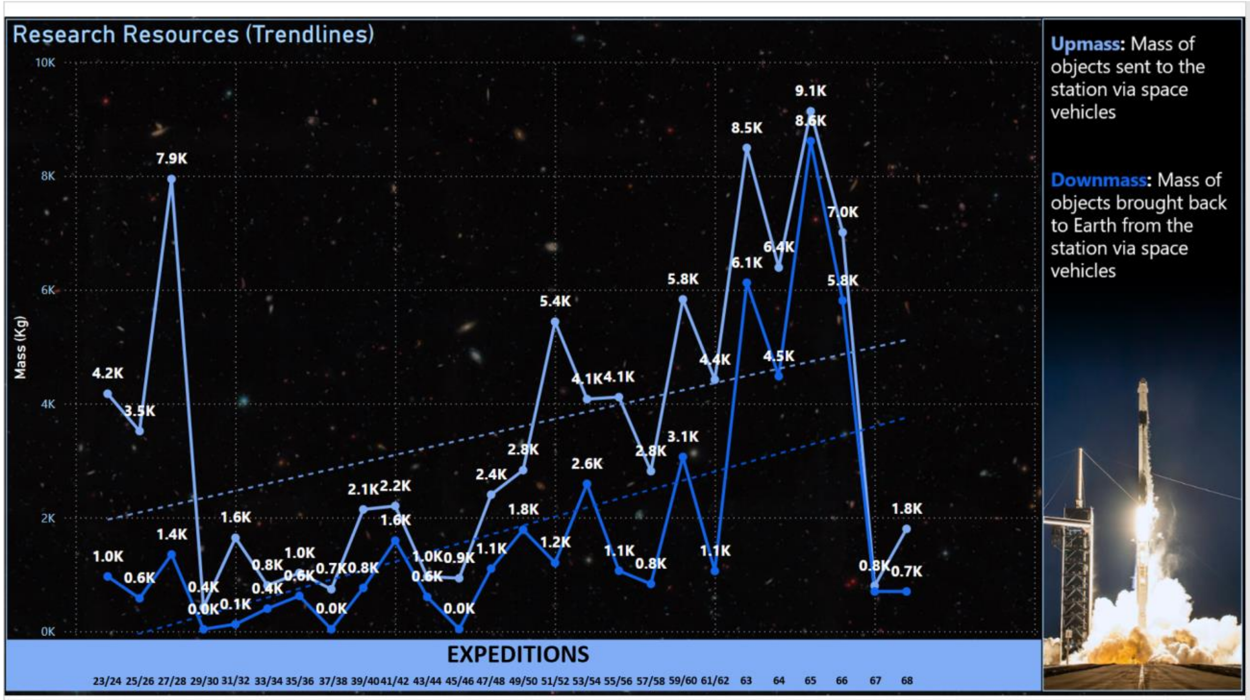
[33] Such "integrated crews," where there is at least one American astronaut on each Soyuz launch and one Russian cosmonaut on each commercial crew launch, is intended to ensure operations of the Station continue should either Soyuz or commercial crew vehicles be unavailable for an extended period. NASA's Office of International and Interagency Relations is currently working with the ISS Program and Roscosmos to facilitate extensions of seat exchanges aboard the Crew Dragon and Soyuz beyond 2025.

[34] Returning cargo from LEO to Earth is known as transporting downmass, the total logistics payload mass that is returned from space for subsequent use or analysis.

[35] The uncrewed Dream Chaser cargo spacecraft is planned to launch its first demonstration mission to the ISS in the fourth quarter of 2024. It will launch aboard United Launch Alliance Vulcan Centaur rockets, which successfully launched for the first time in January 2024.

[36] Northrop Grumman first utilized SpaceX's Falcon 9 rocket for their 20th resupply mission in January 2024. Northrop Grumman has acquired and will utilize a new launch rocket that the company anticipates will be ready in 2025.

Figure 5: ISS Upmass and Downmass Trending Data (2010 to 2023)



Source: NASA OIG presentation of NASA data.

Note: Expeditions 63 through 68 were 6-month periods. Expeditions 65 through 68 figures are based on preliminary data.

Similarly, Boeing's ongoing delays in obtaining certification for crew transportation to and from the ISS leaves SpaceX as the sole commercial provider to transport astronauts. To meet operational needs and provide redundancy for crew transportation, the Agency continues to work with Boeing to certify its Starliner vehicle to safely carry crew.[37] Launch of the first crewed test flight of the Starliner was initially delayed to address technical problems discovered during the first two uncrewed orbital flight tests in 2019 and 2022. In March 2024, NASA officials stated the crewed test launch would be delayed again to May 2024 due to ISS flight schedule congestion.

After nearly one month of delays, in June 2024 the Boeing Starliner crew flight test launched and docked with the ISS. However, several helium leaks and propulsion system failures occurred during the launch and docking. As a result, the Starliner remained docked to the ISS while NASA and Boeing conducted multiple ground-based and docked tests to verify systems and collect data for these failures within the service module's propulsion systems. According to Commercial Crew Program and Boeing officials, the crewed flight test was extended from early June through August 2024 for additional data collection that is needed to certify the Starliner for continued crew transportation to and from the ISS. However, citing lingering concerns about the multiple helium leaks and degraded thrusters, NASA ultimately decided in August 2024 to return the Starliner vehicle uncrewed and move the two crewmembers to the SpaceX Crew 9 Expedition with a planned return in February 2025. In September 2024, the uncrewed Starliner successfully undocked, conducted it's deorbit burn and reentry, and landed in White Sands, New Mexico. Nonetheless, Agency officials are still evaluating the technical challenges revealed in the test flight and the way forward for Boeing's Starliner. As a result of the delays in availability of Starliner,

[37] Boeing's Starliner will launch aboard United Launch Alliance Atlas V rockets.

NASA had to move up previous contracted flights with SpaceX earlier than planned, costing the Agency an additional $17 million to meet expedited launch needs. It is not clear at this point whether additional SpaceX contracted flights will need to be accelerated and at what costs.

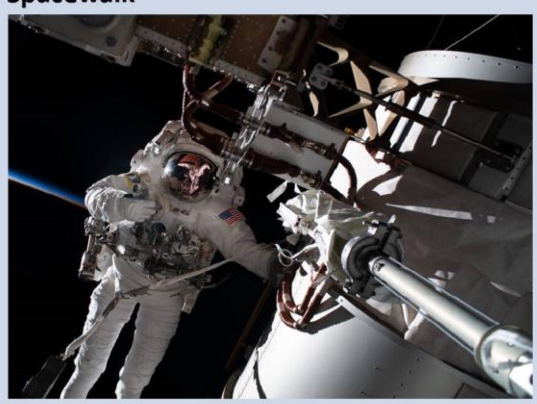
The long-delayed redundant commercial cargo and crew transportation options heighten the risks associated with a single launch provider for cargo and crew and may disrupt planned ISS operations. Should the single launch vehicle be grounded or fail, the United States would not have the ability to transport cargo and crew to the Station. Instead, NASA would be reliant on its international partners, Roscosmos and JAXA, to transport crew and cargo to continue conducting science and research in LEO.

Mitigation of Orbital Debris Risks Is Limited by Current Tracking Efforts

NASA considers the threat of micrometeoroids and orbital debris (MMOD) a top risk to crew safety, the ISS structure, visiting vehicles, and sustained ISS operations. Since we last reported on the threat of orbital debris to NASA operations in 2021, recent events have illustrated the perilous impact of MMOD strikes.[38] In December 2022, a probable MMOD strike on a docked Soyuz led to the termination of a planned spacewalk, a coolant leak on the Soyuz, and months of contingency operations planning for the safe return of the crew that were assigned and transported to the ISS on that vehicle—two Roscosmos cosmonauts and one NASA astronaut.

Making History—the Unintended 12-Month Mission

Astronaut Frank Rubio Conducting a Spacewalk



Source: NASA.

NASA astronaut Frank Rubio, along with Roscosmos cosmonauts Sergey Prokopyev and Dmitri Petelin, launched September 21, 2022, on the Soyuz MS-22 spacecraft to the ISS for a 6-month mission. As a result of a probable MMOD strike to the Soyuz MS-22 while docked to the ISS, Rubio's mission was extended to over a year. NASA did not have an additional vehicle at its disposal and a determination was made to fly the MS-22 uncrewed back to Earth and send an empty Soyuz to the Station to return the crew. Roscosmos sent the Soyuz MS-23 and extended the crew's stay onboard the ISS to the previously planned MS-23 mission end date. Rubio and his crewmates landed back on Earth on September 27, 2023, aboard the Soyuz MS-23, breaking the record of longest single duration space flight for a U.S. astronaut with a mission duration of 371 days. During the mission, he traveled more than 157 million miles and saw the arrival of 15 visiting vehicles to the Station. Rubio conducted three spacewalks totaling over 21 hours. During his extended mission he conducted science and research, repaired experimentation equipment, installed new internal and external hardware, conducted extravehicular activities to upgrade ISS power production, and participated as a subject to study the effects of living in microgravity—all to help inform life on Earth, in LEO, and eventually deep space.

[38] IG-21-011.

Additionally, in February 2024, U.S. and Russian satellites came within 10 meters of colliding. According to NASA, if the satellites collided, it would have resulted in dangerous debris generation—tiny shards traveling at approximately 16,000 miles per hour capable of puncturing a hole in other spacecraft, including the ISS, and potentially putting human lives at risk. Most recently, in June 2024, a defunct Russian satellite broke apart, creating hundreds of trackable pieces of debris that forced the crew aboard the ISS to shelter in their return vehicles for over an hour before it was deemed safe to return to the Station.

NASA mitigates the MMOD risk primarily through shielding and tracking. NASA has installed shields—or barriers—on the U.S. segment of the ISS to protect it from damage by orbital debris 3 centimeters and smaller. However, the Agency has also accepted some risk from MMOD and does not intend to add further protective exteriors to the ISS and vehicle structures due to the high costs and technical challenges associated with doing so. Rather, NASA focuses its mitigation efforts on tracking orbital debris to ensure the ISS is positioned to take appropriate avoidance maneuvers. To this end, NASA relies on the U.S. Department of Defense's (DOD) Space Surveillance Network to provide tracking data on orbital objects in LEO greater than 10 centimeters in size and the probability of collision between an object and the ISS or other NASA assets.[39] According to NASA officials, the procedures in place for tracking orbital debris for the ISS have been effective. Similarly, according to Office of International and Interagency Relations officials, the coordination and collaboration between NASA and other federal agencies, like DOD, is well established and includes agreements to extend tracking capabilities through 2030 and beyond.

In November 2021, Russia conducted a direct-ascent anti-satellite test to destroy one of its own satellites, creating a field of at least 1,500 trackable pieces of debris in LEO.[40] As a result of this test, ISS crew had to seek safe haven in their respective transportation vehicles. Although the event created a temporary increase in orbital debris, the known impact of the smaller pieces of orbital debris to the ISS and its operations was limited to the period of time and object size that DOD's tracking was capable of monitoring. However, small untracked orbital debris was created and posed a risk to the Station and its operations. Despite the procedures in place to track orbital debris, the U.S. Space Surveillance Network can only reliably track objects in LEO down to 10 centimeters—debris smaller than 10 centimeters is not tracked and therefore cannot be actively avoided. NASA estimates that around 100 million pieces of small debris are currently not being tracked or avoided by spacecraft yet are large enough to damage or destroy spacecraft. This safety risk applies to the ISS, its crew, and visiting vehicles.

Acknowledging that current risk mitigation efforts may be inadequate, NASA's Space Sustainability Strategy established six goals to mitigate orbital debris risk—three of which we identified as most relevant to ISS operations.[41] These three goals are (1) prioritize the most efficient ways to minimize uncertainties about orbital debris and operations in the space environment, (2) continue and improve coordination and collaboration outside of NASA, and (3) improve NASA's internal organization to support space sustainability. NASA plans to prioritize the most efficient ways to minimize uncertainties about orbital debris and operations in the space environment include new improvements in debris

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[39] The Space Surveillance Network is a worldwide collection of over 30 ground-based radars and optical telescopes.

[40] Anti-satellite test weapons are space weapons designed for the destruction or incapacitation of satellites. Anti-satellite tests generate space debris, which can collide with other satellites and generate more debris. In November 2021, Russia used an anti-satellite test to destroy its *Cosmos 1408* satellite, causing a debris field that affected the ISS.

[41] NASA, *NASA's Space Sustainability Strategy, Volume 1: Earth Orbit* (2024).

monitoring, advancement of capabilities needed for the sustainable operation of missions in LEO, and better incorporation within NASA of technical advancements made by the broader space community.

In addition to the Agency's orbital debris mitigation efforts, we found academia and the private sector are developing orbital debris tracking technology focused on debris that DOD does not track (objects between 5 and 10 centimeters in size). However, based on our discussions with NASA officials, the Agency's orbital debris tracking approach has yet to leverage this data to mitigate orbital debris risks in LEO and for the ISS. While we are encouraged by NASA's efforts to improve its monitoring and mitigation of orbital debris and the risk it poses to LEO operations, the Agency's efforts may be difficult to achieve without using these emerging technologies. The Agency is still identifying and assessing how it can incorporate these technologies, and therefore it is too early to tell how impactful their inclusion in NASA's MMOD risk mitigation approach will be.

Crew Safety Plans Continue to Evolve but ISS Evacuation Options Are Limited

While the ISS Program has sufficient plans and procedures in place to ensure crew safety in response to routine or emergency threats to Station operations, these plans continue to evolve. The ISS, Soyuz, Crew Dragon, and Starliner vehicles have specific shelter-in-vehicle and safe haven rules, which includes evacuating the Station. For routine threat scenarios, the ISS Program identifies both internal and external risks to crew safety. Internal threats include fire, structural leaks, and gas leaks, and external threats include MMOD strikes. In both situations, crew responses typically entail isolating sections of the Station to contain the threat. With more significant and severe threats that cannot be isolated, ISS Program safety procedures require movement to crew vehicles in the event the Station would need to be evacuated.

For unexpected and emergency events, NASA and its partners have an established process in place to enable prompt action in response to threats. All ISS partners are part of the ISS Mission Management Team, where they coordinate on operational needs and can be convened rapidly if needed.[42] For example, in December 2022, unexpected damage to the Soyuz spacecraft, which was attached to the ISS, caused its coolant to leak, rendering the vehicle potentially unsafe for the crew's return flight. In this case, there were no specific rules or a contingency plan that provided instructions to the crew on evacuation and where to shelter if the return vehicle itself was damaged.[43]

However, the established process and the ISS Mission Management Team allowed for the issue to be rapidly communicated and coordinated across all responsible parties. These included ISS Program offices like the vehicle office, mission integration office, vehicle integration office, international vehicle integration office, and the Flight Operations Directorate; SpaceX, the U.S. commercial vehicle vendor; and Roscosmos. These entities determined the appropriate response was to substitute the damaged Soyuz vehicle for another one. In March 2023, the damaged Soyuz safely returned to Earth without a crew—analysis of the vehicle's systems and performance without coolant is still ongoing by Roscosmos. The crew then returned to Earth in September 2023—extending their space flight mission from approximately 6 months to over 1 year. Overall, we found there was consistent and effective coordination between NASA and its partners to develop a solution to ensure crew safety. Subsequently, NASA developed a contingency plan with instructions for the crew of the Soyuz both for their return and where to shelter in the event of an emergency.

While NASA and its partners successfully mitigated the Soyuz leak, the incident revealed that when a crew vehicle is damaged evacuation options are limited. According to ISS Program and Office of Safety and Mission Assurance officials, NASA and its partners do not have ready-to-launch vehicles for emergency evacuation as they are cost prohibitive and require added certification time in the unlikely event of an emergency evacuation. In the absence of such a vehicle, NASA and its partners analyzed

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[42] The ISS Mission Management Team meets regularly to ensure the ISS carries out its scientific, technology, diplomatic, and educational purposes.

[43] The ISS Program and Flight Operations Directorate have separate flight rules that cover return vehicle damage and sheltering on the ISS.

more limited solutions to evacuation. In response to the Soyuz leak incident, the ISS Program, the Commercial Crew Program, and SpaceX conducted analyses to determine if a seating reconfiguration in the Crew Dragon could safely return additional astronauts from the ISS. Ultimately, NASA and its ISS partners decided that one additional crewmember, for a total of five, could be approved for transport in response to a similar emergency event in the future. However, the fifth crewmember would be at greater risk of injury should the vehicle depressurize as they would not have a helmet, life support connections, or the same seat restraints as the other four crewmembers. Additionally, because the incident with the Soyuz affected transport for three crewmembers, there would be no accommodations for the two remaining crewmembers should there be an imminent need to evacuate the Station in response to an emergency.

In general, if damage renders return crew vehicles unsafe or inoperable, full ISS evacuation would require empty uncrewed vehicles to be readied and launched to dock and safely return crew to Earth—with an unspecified time frame for their availability. While ready-to-launch vehicles for emergency may currently be impracticable solutions for evacuation, a senior NASA official said that the recent introduction of additional vehicles in the flight schedule—including from private astronaut missions and an eventually certified Boeing Starliner—may provide more options for evacuation. Given the continued risk of an MMOD strike and the Agency's experience with the Soyuz leak, NASA and its partners are in better position to ensure crew safety with documented processes for determining crew reassignment and adjustment of crew vehicle launches to accommodate potential emergency evacuation needs. However, due to the high costs and a limited budget, the lack of ready-to-launch vehicles prevent the Agency from having an immediate response capability.

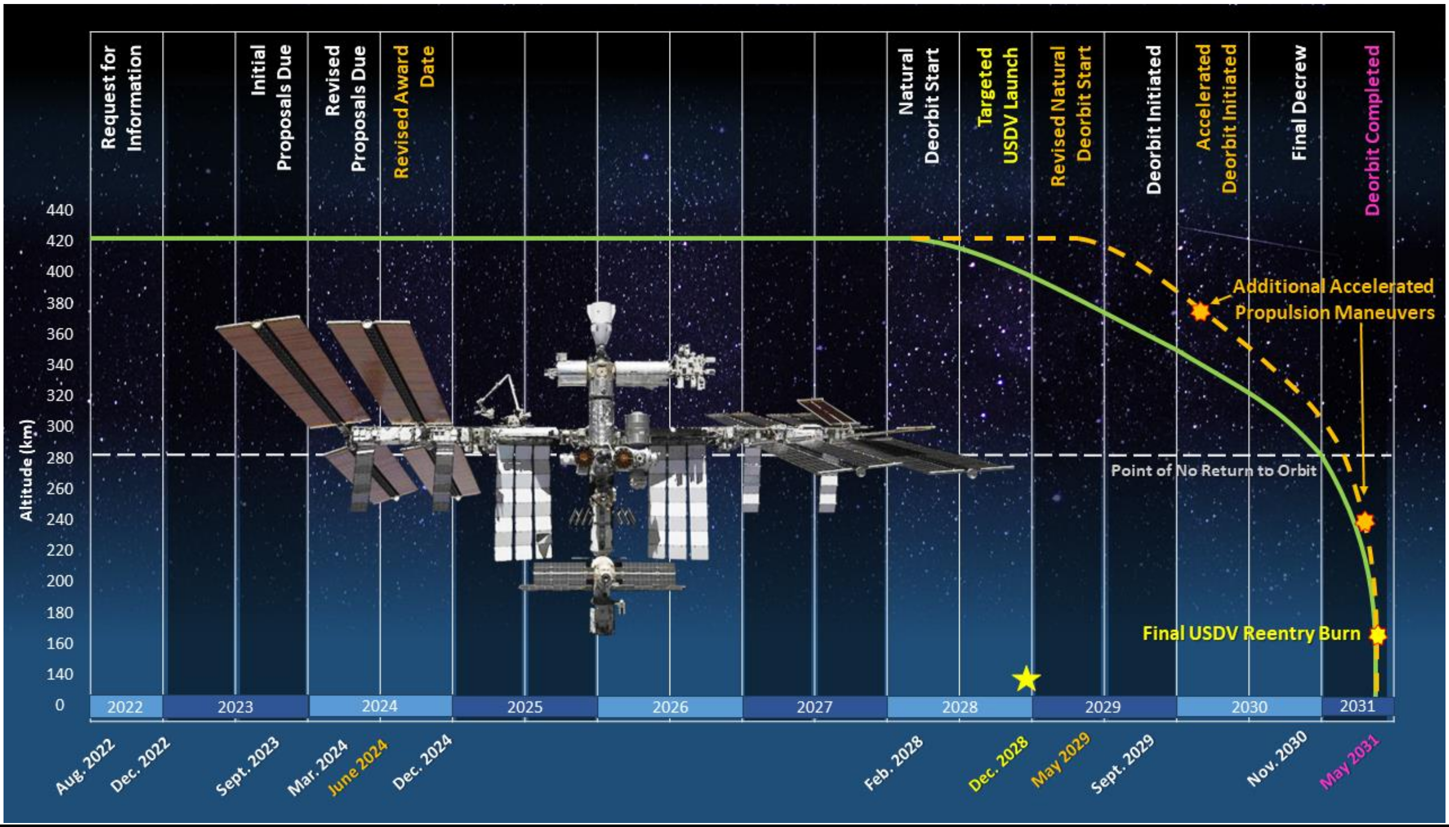
ISS Transition and Deorbit Plans Remain in Development

Transition and Deorbit Plans Are Reliant on Russian Propulsion and the U.S. Deorbit Vehicle

After more than a decade of effort, NASA and its partners continue to develop a transition and deorbit plan to prevent an operations gap in LEO and ensure a safe and controlled deorbit of the ISS.[44] The current plan is to rely on the establishment of at least one reliable commercial LEO destination for NASA to transition to into the 2030s prior to the ISS deorbit. With continued coordination and contribution from Roscosmos, NASA has made multiple revisions to the plan including updating it to reflect the current 2031 deorbit end date (see Figure 6). More recently, it was determined that the original deorbit plan, solely reliant on propulsion from three Russian Progress vehicles, was insufficient to accomplish a controlled deorbit of the ISS due to the Progress vehicles offering less control during deorbit than a vehicle specifically designed to perform a controlled deorbit would offer. In response, NASA introduced a new plan that features a yet to be developed U.S. deorbit vehicle that would work with two Russian Progress spacecraft to initiate and complete the deorbit of the ISS starting in 2029 and concluding in 2031.

[44] The planned deorbit of the Station is a nearly 3-year long process, carefully timed to allow for natural orbit degradation using Earth's gravitational pull over an extended period of time.

Figure 6: ISS Controlled 2031 Deorbit Plan Timeline (as of July 2024)



Source: NASA OIG presentation of NASA information.

Note: USDV is U.S. deorbit vehicle. The above altitudes of the Station's orbit could vary based on environmental states in which the ISS would start to deorbit that is based off modeling forecasts of the LEO environment. These different environmental states impact the timing and rate of natural deorbit altitude decreases that could start in 2026, 2027, or 2028.

Russian Commitment to the ISS Deorbit Plan and Timeline Is Uncertain

Russia is currently committed to ISS operations through 2028 but has not committed through 2030, which includes the deorbit plan and timeline. According to NASA's Office of International and Interagency Relations, NASA and Roscosmos are focused on the technical requirements of a controlled deorbit, and as these requirements become defined, the subsequent roles and responsibilities of the two partners will be determined and eventually coordinated through an official agreement. Tentatively, NASA sees this process ramping up in 2025 through 2026 as the requirements become clearer, and variables like the status of the U.S. deorbit vehicle and readiness of commercial LEO destinations come into view. However, without commitment from Russia to the current deorbit plan, the ability to conduct a controlled deorbit is unclear.

Acquisition of the U.S. Deorbit Vehicle Faces Funding and Schedule Challenges

The current deorbit plan incorporates production of a U.S. deorbit vehicle while Russian Progress vehicles continue to maintain the Station's orbit. According to ISS Program officials, without a U.S. deorbit vehicle, the ISS is at risk of an uncontrolled deorbit into a populated area on Earth if Russia's Progress vehicles are unable to set the Station on a controlled path. Therefore, the U.S. deorbit vehicle will need to be capable of free flight and rendezvous and docking with the ISS. The vehicle is intended to perform ISS control maneuvers and provide the final propulsion to ensure the Station reenters Earth's atmosphere and is disposed of in the Pacific Ocean. In June 2024, NASA awarded SpaceX a contract to provide the U.S. deorbit vehicle. However, several factors—namely budget availability, schedule risk, and the availability of commercial LEO destinations—will impact the ability and timing of deorbiting the Station.

Budget Risk. The availability of a U.S. deorbit vehicle is highly dependent on sufficient and timely funding. NASA submitted a supplemental FY 2024 budget request for $180 million to Congress for the U.S. deorbit vehicle award in March 2023, proposals for U.S. deorbit vehicles were received in March 2024, and a contract was awarded to SpaceX for $843 million in June 2024. This award is for delivery of the vehicle to NASA but does not include the cost of launch and rendezvous with the Station in LEO. Of note, the government cost estimate was initially near $1 billion and was updated in May 2024 to $1.5 billion. Outside of the supplemental funding request, NASA officials are currently investigating ways to reduce overall ISS operational costs over the next 5 years. This includes reducing ISS cargo transportation costs and reallocating that funding to the U.S. deorbit vehicle. Based on our analysis, NASA will be unable to achieve significant savings from its transportation costs for the foreseeable future without a reduction in the number of cargo and crew flights, meaning anticipated cost savings may not be realistic.[45]

Schedule Risk. From June 2024, when the contract was awarded to SpaceX, NASA and U.S. industry have approximately five and a half years to design, develop, test, produce, and launch the U.S. deorbit vehicle in 2029 to meet the planned 2031 ISS deorbit target. We found this development schedule is unrealistic when compared to other major NASA space flight programs that have, on average, taken about eight and a half years from contract award to first operational flight. According to ISS Program officials, the Agency has sought out significant input from industry to help capitalize on proven and existing systems and technology to meet the shortened timeline for a ready U.S. deorbit vehicle.[46] To this point, the award to SpaceX includes modification of their current Dragon vehicle that the Agency hopes will minimize the U.S. deorbit vehicle's development time.

[45] NASA's goal is to reduce its ISS spending by nearly $1 billion from FY 2024 through FY 2030. Given the current contracts and flight plans, this level of savings would only be achievable with significant reductions to operations—fewer cargo and crew flights.

[46] The Agency released three Requests for Information in August, October, and November 2022 to assess industry capabilities and interest in developing the U.S. deorbit vehicle. The Final Request for Proposal was released in September 2023, but a modification to the Request for Proposal was made in December 2023 allowing potential offerors contract flexibilities to attain better solutions in terms of cost and schedule. The Agency previously planned to award a contract by January 2024. However, while NASA's FY 2024 budget request included $180 million for U.S. deorbit vehicle development, a continuing resolution from October 2023 to March 2024, among other challenges, affected the procurement process. As a result, the award of the contract and start of U.S. deorbit vehicle development and production was delayed by nearly 6 months to June 2024.

Destination Availability Risk. The uncertainty of commercial LEO destination-readiness, limited budget availability, and the potential delay in availability of the U.S. deorbit vehicle past 2029 adds more schedule challenges and risks to NASA's 2031 deorbit plan. If NASA decides to extend ISS operations for any reason, the Agency and its partners will need to revise the deorbit timeline. To this end, NASA is currently undertaking planning efforts to address these issues. This includes potential extensions of ISS operations and maintenance contracts to provide additional schedule beyond 2030 to develop the U.S. deorbit vehicle. The current proposed mitigation plan involves keeping the ISS crewed and operating in orbit indefinitely, which introduces additional risks and costs. For example, if the U.S. deorbit vehicle is delayed, the Russian Progress vehicles can help keep the ISS in orbit until the U.S. deorbit vehicle is available. Nonetheless, Russia is currently only committed to ISS operations through 2028.

Contingency Deorbit Plans Updated to Clarify Assigned Roles and Responsibilities

In the event the Station needs to be deorbited before a transition to a commercial LEO destination and controlled deorbit can be implemented, NASA and Roscosmos established a contingency plan in December 2016, revised in September 2023, that is dependent on Russian propulsion.[47] We previously reported on the 2016 plan's shortcomings with respect to the lack of assigned roles and responsibilities for executing a contingency deorbit.[48] Similarly, the 2023 plan lacked assigned responsibility for providing propellant as well as funding commitments. NASA officials have been coordinating with Roscosmos to develop an Implementing Arrangement, documenting both agencies' roles and responsibilities for nominal (planned) and contingency ISS deorbit operations, as NASA does not have unilateral authority to implement such an agreement.[49] In July 2024, NASA and Roscosmos signed an agreement on roles and responsibilities in the event a contingency deorbit needs to be performed prior to the planned deorbit of the ISS.

The recently signed contingency deorbit plan will use both NASA and Roscosmos assets for ISS altitude and attitude control in the event of an emergency deorbit. Further, NASA continues to negotiate various funding agreements with Roscosmos, which include Russian propellant delivery through 2028 along with NASA's corresponding ISS contributions. These agreements will formalize Russian propellant delivery obligations for ISS and include ISS contingency deorbit reserve propellant. We found that over the past 25 years the ISS Program has not encountered any event that necessitated deorbiting the Station. However, NASA's Aerospace Safety Advisory Panel officials noted there is an increasing risk of an unplanned ISS deorbit due to the increasing amount of space objects in the path of the ISS. Nonetheless, in our judgment, the new contingency deorbit plan with assigned partner roles and responsibilities helps to better manage the risk to crew safety as well as to people and property on Earth.

[47] In September 2023, NASA and Roscosmos established a deorbit working group that meets monthly to continue planning and discussions related to partner roles and responsibilities.

[48] IG-18-021.

[49] These agreements must first be coordinated between the respective agencies and then sent to the U.S. Department of State for review and concurrence.

CONCLUSION

For nearly 25 years the ISS has provided researchers the unique ability to study the effects of long-term exposure to microgravity and other extreme conditions to enhance a variety of research pursuits including human space exploration. Nonetheless, maintaining ISS operations, including providing cargo and crew transportation, has proven to be a costly endeavor comprising 16 percent of NASA's annual budget in 2023. NASA expects this expenditure to continue with the Administration extending the life of the ISS through 2030 and potentially beyond. Complicating matters is the likelihood that NASA—like other federal agencies—may continue to face a flat or reduced budget in the coming years.

To its credit, we found the ISS Program is well positioned to continue operations and maintenance of the ISS through 2030. However, as NASA pushes the retirement of the ISS farther into the future, a variety of long-standing challenges will continue to intensify. These challenges include maintaining and upgrading the Station; monitoring the structural integrity of the ISS through ongoing certification efforts by NASA, Roscosmos, and their contractors; managing cargo and crew transportation constraints; solidifying contingency and controlled deorbit plans; extending its partnerships; and managing the continuing threat from MMOD. At the same time, NASA must continue to refine the ISS deorbit plan, which requires a yet to be developed U.S. deorbit vehicle and the participation of Roscosmos that has yet to commit to ISS operations past 2028.

In the long term, NASA is committed to replacing the Station with one or more commercially owned and operated space destinations to maintain its presence in LEO. However, the Agency may need to consider other options, including extending ISS operations beyond 2030, if these destinations are not ready in time to deorbit the ISS in 2031 as planned. It is imperative that NASA position itself to balance the investment into commercial LEO destinations with the continued management of the risks associated with continued operations and the aging of the Station's nonreplaceable structures.

RECOMMENDATIONS, MANAGEMENT'S RESPONSE, AND OUR EVALUATION

To further mitigate risks to crew safety, we recommended the Associate Administrator for Space Operations Mission Directorate, in coordination with the Chief, Safety and Mission Assurance and the Chief Engineer:

1. Report on NASA's progress to reexamine available orbital debris tracking tools and offices to ensure all practicable data sources are leveraged to inform ISS operations and ensure crew safety.
2. Document safety contingency plans and vehicle reassignment rules to help ensure the safe return of crew in the event of an emergency—expanding these efforts to include damage to the Crew Dragon and Starliner.

To inform ISS decommissioning and a safe, controlled deorbit, we recommended the Associate Administrator for Space Operations Mission Directorate, in coordination with the ISS Program Manager:

3. Develop plans that reflect potential cost savings measures and anticipated reductions in operations for ISS decommissioning.
4. Update the controlled deorbit plan and ensure the plan includes key commitments, technical, schedule, and cost challenges impacting the 2031 deorbit time frame.

We provided a draft of this report to NASA management who concurred with our recommendations and described planned actions to address them. We consider management's comments responsive; therefore, the recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions.

Management's comments are reproduced in Appendix C. Technical comments provided by management and revisions to address them have been incorporated as appropriate.

Major contributors to this report include Ridge Bowman, Human Exploration Audits Director; Jamie Smith, Assistant Director; Amy Bannister; Anna David; Tommy Dodd; Joel Rodriguez; and Amanda Perry. In addition, our two interns, Gaby Novark and Jacob Luevanos, contributed to the report.

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

George A. Scott
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George A. Scott
Deputy Inspector General

Appendix A: Scope and Methodology

We performed this audit from May 2023 through September 2024 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

In this audit, we examined NASA's management of risks to sustaining ISS operations through 2030. To perform this audit, we examined ISS Program documents pertaining to the risks of the ISS. Our review was conducted with officials from Johnson Space Center, Kennedy Space Center, and NASA Headquarters. In preparation for the audit, we conducted routine coordination with the Associate Counsel to the Inspector General and the Office of Inspector General's Office of Investigations.

We divided the audit into four subject areas related to sustaining the ISS through 2030 and beyond and managing associated risks: (1) operations and maintenance, (2) orbital debris, (3) safety plans, and (4) deorbit of the Station. Key work completed for each subject area is summarized below.

To assess operations and maintenance risks, we examined NASA Aerospace Safety Advisory Panel reports on the ISS Program, Integrated Risk Management Application reports, the Incident Reporting Information System Report, the ISS Program Risk Matrix, Program Risk Advisory Board Risk metrics, the ISS Extravehicular Activity Plan, Mission Integration and Operation Control Board agendas and minutes, Safety and Mission Assurance Control Board minutes, ISS Mission Management Team meeting minutes, ISS Program Risk Advisory Board presentations, ISS presentations to the NASA Advisory Council and Aerospace Safety Advisory Panel, the ISS Program Vehicle Office Risk Management process, the ISS Chief Engineer Risk tracker, the ISS Functional Availability and Spares Assessment report, the Minimum On-Orbit Spares Compliance Status report, and the Holistic NASA Space Industrial Base/Supply Chain study.

In addition, the Office of Inspector General's Office of Data Analytics extracted data for utilization, crewtime, and cargo mass from ISS utilization statistics reports. Specifically, they manually extracted the crewtime, upmass, downmass, number of investigations, new investigations, completed investigations, and the expedition pairs from the source datasets. The audit team then performed a trace-and-verify of the extracted data to ensure records were accurately captured from the source documents. We also conducted interviews with the ISS Program Director; NASA officials from the ISS Program External Integration, Safety and Mission Assurance, Vehicle, Transportation Integration, Mission Integration and Operations, Program Planning and Control, External Integration, Extravehicular Activity, and Avionics and Software offices; and officials from the Flight Operations Directorate and Commercial Crew Program.

To assess orbital debris risks to the ISS, we examined ISS Program Integrated Risk Management Application reports, the Incident Reporting Information System report, the ISS Program Risk Matrix, ISS Extravehicular Activity Plan, ISS Mission Management Team meeting minutes, ISS Program Risk Advisory Board presentations, a MMOD presentation, ISS Debris Avoidance Maneuver History documents, On-Orbit Debris metrics, the ISS Chief Engineer Risk tracker, the orbital debris overview presentation, and ISS utilization statistics. We also conducted interviews with the ISS Program Manager and Deputy Program Manager, ISS Program Chief Safety Officer, and ISS Chief Engineer. In addition, we spoke with officials from the Office of Safety and Mission Assurance, Flight Operations Directorate, and Orbital Debris Program Office.

To assess the safety plans for the ISS, we examined the ISS Program Flight Operations Directorate briefing on human space flight, Aerospace Safety Advisory Panel reports, Integrated Risk Management Application reports, the Incident Reporting Information System report, the ISS Program Risk Matrix, ISS de-crewing and re-crewing plans, Mission Integration and Operation Control Board agendas and minutes, Safety and Mission Assurance Control Board minutes, ISS Mission Management Team meeting minutes, ISS Program Risk Advisory Board presentations, ISS presentations to the NASA Advisory Council and Aerospace Safety Advisory Panel, the ISS Program Vehicle Office Risk Management process, the ISS Chief Engineer Risk tracker, the ISS Contingency Action Plan, the ISS Safety Review process, and ISS utilization statistics. We also conducted interviews with the ISS Program Manager, ISS Deputy Program Manager, and ISS Chief Engineer. Additionally, we spoke with officials from the Safety and Mission Assurance Office, ISS Transportation Integration office, and the Commercial Crew Program.

To assess ISS deorbit plans, we examined ISS Program procurement documents for the U.S. deorbit vehicle, Aerospace Safety Advisory Panel reports, Integrated Risk Management Application reports, the Incident Reporting Information System report, the ISS Program Risk Matrix, ISS Program Risk Advisory Board presentations, ISS presentations to the NASA Advisory Council and Aerospace Safety Advisory Panel, the ISS Chief Engineer Risk tracker, and the ISS Program Planning and Control Early Warning System report. We also conducted interviews with the ISS Program Manager and Deputy Program Manager, as well as with officials from the Safety and Mission Assurance, ISS Vehicle, and ISS Program Planning and Control offices.

Assessment of Data Reliability

We used limited computer-processed data extracted from NASA’s information technology systems during the course of this audit. Although we did not independently verify the reliability for all information provided, we compared it with other available supporting documents to determine data consistency and reasonableness. From these efforts, we believe the information we obtained is sufficiently reliable for this report.

Review of Internal Controls

We reviewed and evaluated the internal controls associated with the risks to sustaining ISS operations through 2030. We also reviewed appropriate policies, procedures, and regulations and conducted interviews with responsible personnel. While we concluded that the internal controls were adequate, because our review was limited to these internal control components and underlying principles, it may not have disclosed all internal control deficiencies that may have existed at the time of this audit.

Prior Coverage

During the last 5 years, the NASA Office of Inspector General has issued several reports of significant relevance to the subject of this report. Reports can be accessed at https://oig.nasa.gov/audits/.

NASA’s Partnerships with International Space Agencies for the Artemis Campaign (IG-23-004, January 17, 2023)

NASA's Management of Its Astronaut Corps (IG-22-007, January 11, 2022)

NASA's Management of the International Space Station and Efforts to Commercialize Low Earth Orbit (IG-22-005, November 30, 2021)

NASA's Management of the Artemis Missions (IG-22-003, November 15, 2021)

NASA's Efforts to Mitigate the Risks Posed by Orbital Debris (IG-21-011, January 27, 2021)

NASA's Management of Crew Transportation to the International Space Station (IG-20-005, November 14, 2019)

Appendix B: Utilization of the ISS

ISS utilization activities include those from NASA as well as its international partner agencies—CSA, ESA, JAXA, and Roscosmos. NASA groups the planning and execution of ISS research investigations into 6-month periods known as expeditions, with each expedition subsequently numbered. An investigation is defined as a set of activities and measurements (or observations) designed to test a scientific hypothesis, related set of hypotheses, or set of technology validation objectives. Principal investigator(s) and co-investigator(s) work together to achieve the objective of the investigation—this includes NASA and partner astronauts and cosmonauts alongside Earth-based scientists and researchers. Since December 1998, when ISS operations began, through March 2023, the Station has hosted 68 Expeditions with a total of 3,742 investigations, conducted by 5,308 investigators from 116 countries.[50]

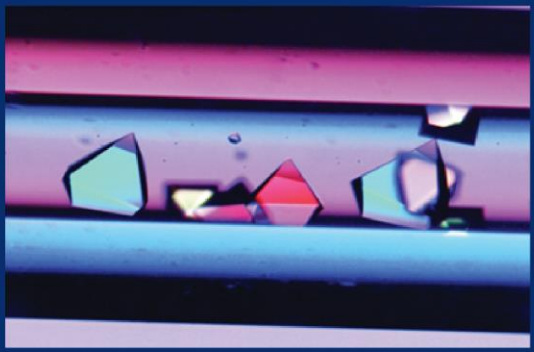
Investigations by Category

The information below provides an overview and examples of ISS utilization through March 2023. The investigations were conducted under the following six categories—Biology and Biotechnology, Earth and Space Science, Educational and Cultural Activities, Human Research, Physical Science, and Technology Development and Demonstration.

Biology and Biotechnology

Scientists onboard the Station have advanced research efforts in biology through protein growth experiments, which have played a key role in formulating new and better treatments for diseases for people on Earth. These experiments contribute to the development of drugs that slow down the progression of diseases like Duchenne Muscular Dystrophy, a currently incurable genetic disorder, and enable quicker methods for treatment, making increased dosages more convenient for patients and caregivers and reducing costs.

Protein Crystals Form in Microgravity in the ISS's Kibo Module



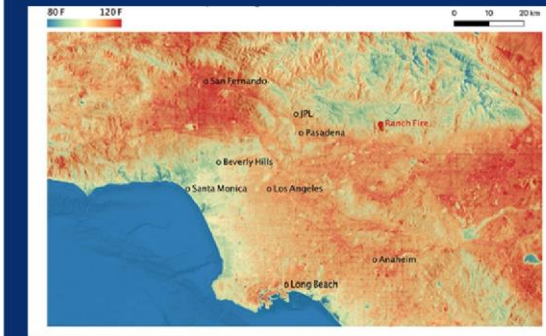
Source: NASA.

[50] The last published data available is through Expedition 68, which ended March 28, 2023. Since that time, there have been three additional expeditions—Expedition 69 (March 28, 2023, to September 27, 2023), Expedition 70 (September 27, 2023, to April 5, 2024), and Expedition 71 (started April 5, 2024, and scheduled to end in September 2024). Data for these expeditions has not been finalized for publication.

Earth and Space Science

The ECOsystem Spaceborne Thermal Radiometer Experiment on the ISS, known as ECOSTRESS, collects land surface temperature data, giving insight into how regions are affected by droughts and heat absorption. This provides data that cannot be measured on Earth, enabling research and identifying efficiencies for plant health, including the amount of water plants use.

ECOSTRESS Imagery of Los Angeles, California, Land Surface Temperature Taken on August 14, 2020



Source: NASA.

Educational and Cultural Activities

Over the past 20 years, 2.6 million U.S. students in primary and secondary schools have designed, launched, operated, and used data from the more than 800 student experiments launched to the ISS. In November 2023, a team of eighth graders designed an investigation launched on SpaceX's 29th Commercial Resupply Services mission that will test whether Limulus Amebocyte Lysate, a component in horseshoe crab blood, can detect bacterial contamination in microgravity the same way it does on Earth. Additionally, NASA's CubeSat Launch Initiative deployed the Puerto Rico CubeSat Nanorocks-2 to study data on collision outcomes at lower speeds and between aggregates or objects with varying sizes and structural properties, like dust, which plays a role in the formation of protoplanetary disks—gaseous masses believed to give rise to planets.

Human Research

In a 2020 collaborative experiment with JAXA, scientists found that amyloid fibrils, strands of filamentous protein which are the molecular formation behind diseases like Alzheimer's, form distinct structures and grow slower in microgravity, making the ISS an ideal environment for a detailed analysis of the mechanisms behind these formations.

Decal for the Amyloid Experiment Photographed Against the Kibo Module Window on the ISS

Source: NASA.

Physical Science

Recent research with the company Proctor & Gamble studied particle interaction and microstructure formation to create and improve products like Febreze Unstopables Touch Fabric Spray, used to help improve the odor of fabrics like carpets and on furniture. The ISS's environment enables analysis, only possible in microgravity, of interactions between tiny particles suspended in liquid where different microstructures can be formed.

Technology Development and Demonstration

Technological initiatives onboard the ISS have supported the demonstration and optimization of new remote sensing technologies—improving disaster response against global hazards and natural disasters. For Artemis missions, NASA engineers at Johnson Space Center, which includes a team of early-career engineers, have developed a device called the Lunar Dust Distributor that can evenly coat simulated lunar dust onto hardware for teams to study designs and develop mitigation strategies to keep lunar dust at bay.

Impact to Space Exploration, Discovery, and Benefits for Humanity

The ISS Program and its partners categorize and track the research conducted on the Station and link these investigations with the benefits they provide. Specifically, ISS research results have benefitted human space exploration, advanced scientific discovery, and benefitted humanity. NASA's most recent annual report from 2023 highlighting ISS results includes descriptions of some of the results that were published from across the ISS partnership during that time.[51]

[51] NASA, *Annual Highlights of Results from the ISS 2023*.

2023 Highlights of ISS Results by Category	
EXPLORATION	ISS investigation results have yielded updated insights into how to live and work more effectively in space by addressing such topics as understanding radiation effects on crew health, combating bone and muscle loss, improving designs of systems that handle fluids in microgravity, and determining how to maintain environmental control efficiently.
DISCOVERY	ISS results provide new contributions to the body of scientific knowledge in the physical sciences, life sciences, and Earth and space sciences to advance scientific discoveries in multidisciplinary ways.
BENEFITS FOR HUMANITY	ISS science results have Earth-based applications, including understanding our climate, contributing to the treatment of diseases, improving existing materials, and inspiring the future generation of scientists, clinicians, technologists, engineers, mathematicians, artists, and explorers.

The following are examples of the benefits for humanity derived from ISS investigations and reflect the continued utilization of the Station as a laboratory in LEO.

Crew Earth Observation Photographs

Crewmembers use hand-held cameras to regularly take photographs of volcanic eruptions, urban areas, bodies of water, and meteorological phenomena. The information gathered by crew photographs supports global-scale investigations related to composition, health, and the future of Earth. In this image, a crewmember is preparing to take Earth observation photographs from the Russian Service Module window.

Source: NASA.

Experiments on Astronaut Safety and Health

Scientists use the ISS as a testing ground to study how to keep astronauts safe and healthy on long-duration missions. These studies also benefit humans on Earth by providing a better understanding of how microbes behave in a sanitized, isolated, and confined environment. In this image, a biomolecule extraction and DNA and RNA sequencing technology experiment is being conducted on microbes.

Source: NASA.

Examinations into Diseases and Human Physiology

Many investigations on the ISS examine the cause, progression, and treatment of a variety of diseases and explore basic mechanisms of human physiology. In this image, a crewmember is installing a bone densitometer that enables the imaging of rodent bones to investigate two proteins that may prevent muscle and bone loss in space.

Source: NASA.

Experimenting with New Technologies

The ISS offers a unique platform for trying out new technology in space. Expertise and hands-on experience gained by astronauts and cosmonauts working and living in space long-term provide an added benefit for future missions beyond LEO, including the Agency's planned expeditions to the Moon and Mars. In this image, a crewmember is utilizing Spaceborne Computer-2, which can advance data processing significantly faster in space using edge computing and artificial intelligence.

Source: NASA.

Educational Opportunities

The Amateur Radio on the International Space Station program provides students from around the world the chance to ask questions directly to an astronaut in orbit, while learning the technical basics of ham radio operations. The program has now connected more than 250,000 participants with the ISS and over 100 crewmembers from several nationalities, inspiring younger generations' interest in space and science. In this image, students and astronauts participate in live education.

Source: NASA.

In addition to NASA and its international partner agencies, the ISS provides a platform for small businesses, entrepreneurs, and researchers to test their science and technology in space. These efforts have contributed to the development of new and improved products, spawned new commercial opportunities, and provided growth for existing ventures. For example:

- *Redwire Space* has created cardiac tissue and conducted research on diseases, plant growth on the ISS, and turbine manufacturing in microgravity.
- *Nanoracks* has conducted research on plant growth and radiation exposure and provided the Station's first commercially owned and operated airlock.
- *Space Tango* has conducted research on plant and agricultural science, organoid observation and growth, and flow chemistry.

Managing Utilization Aboard the ISS

In 2014, the ISS Program updated its crewtime per week metric and established 35 hours as the weekly utilization crewtime goal when there are three U.S. segment (NASA, JAXA, CSA, ESA) crewmembers onboard and 68.5 hours when there are four or five crewmembers onboard. NASA has generally met or exceeded this goal and set a high of 120 average hours per week devoted to research from October 2019 to April 2020. Overall, since 2010 there has been an increase in the time dedicated to science and research utilization—exceeding the weekly 35-hour goal, sometimes by 2 or 3 times. Just prior to the COVID-19 pandemic the ISS was utilized for research nearly 120 hours a week. After the pandemic, starting March 2022 through March 2023, the latest published data, we have seen utilization near 90 hours per week. In addition to the hours spent per week on research, the number of scientific investigations performed on-orbit has increased from a low of 29 new investigations in April 2012 to a high of 168 in October 2019. Table 1 outlines the number of hours crew spent on research weekly and the number of new investigations conducted on the ISS from 2009 to 2023.

Table 1: Research Utilization Statistics for the International Space Station (2009 to 2023)

Expedition Pair (approximately 6 months in total duration)	Dates[a]	Crewtime Spent on Research (average weekly hours)[b]	Number of New Investigations
Target Metric		**35**	**N/A**
21/22	October 2009-March 2010	24.9	87
23/24	March 2010-September 2010	40.65	45
25/26	September 2010-March 2011	37.79	41
27/28	March 2011-October 2011	35.82	87
29/30	October 2011-April 2012	83.47	58
31/32	April 2012-September 2012	54.19	29
33/34	September 2012-March 2013	62.77	51
35/36	March 2012-September 2013	58.66	40
37/38	September 2013-March 2014	66.52	50
39/40	March 2014-September 2014	72.60	111
41/42	September 2014-March 2015	74.63	104
43/44	March 2015-September 2015	73.94	121
45/46	September 2015-March 2016	71.28	39
47/48	March 2016-September 2016	88.28	98
49/50	September 2016-April 2017	84.23	140
51/52	April 2017-September 2017	78.34	118
53/54	September 2017-February 2018	89.80	82
55/56	February 2018-October 2018	87.05	140
57/58	October 2018-March 2019	53.39	99
59/60	March 2019-October 2019	93.89	168
61/62	October 2019-April 2020	120.02	94
63	April 2020-October 2020	20.79	53
64	October 2020-April 2021	65.27	98
65	April 2021-October 2021	65.69	105
66	October 2021-March 2022	59.68	120
67	March 2022-September 2022	93.26	85
68	September 2022-March 2023	81.63	123

Source: NASA OIG summary and analysis of ISS Program information.

Note: Data for Expeditions 65, 66, 67, and 68 are based off preliminary data from NASA and its partners.

[a] Due to month and year Expedition ranges, we assume a month starts on the 16th and ends on the 15th for calculating the elapsed time and total days and weeks in each Expedition or Expedition Pair.
[b] Assumes a 7-day week.

Appendix C: Management's Comments

National Aeronautics and Space Administration

Mary W. Jackson NASA Headquarters
Washington, DC 20546-0001

Reply to Attn of: Space Operations Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Space Operations Mission Directorate

SUBJECT: Agency Response to OIG Draft Report, "NASA's Management of Risks to Sustaining International Space Station Operations through 2030" (A-23-10-00-HED)

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled, "NASA's Management of Risks to Sustaining International Space Station Operations through 2030" (A-23-10-00-HED), dated August 7, 2024.

In this draft report, the OIG examined NASA's management of risks to sustaining International Space Station (ISS) operations through 2030, ensuring crew and operational safety, and conducting a safe, controlled deorbit in 2031. While the OIG found the ISS Program well positioned to continue operations and maintenance of the ISS through 2030, the OIG also reported that a variety of long-standing challenges will continue to intensify as NASA pushes the retirement of the ISS farther into the future.

The OIG makes four recommendations addressed to the Associate Administrator (AA) for Space Operations Mission Directorate (SOMD) to further mitigate risks to crew safety, as well as to inform ISS decommissioning and a safe, controlled deorbit.

Specifically, the OIG recommends the AA for SOMD, in coordination with the Chief, Safety and Mission Assurance and the Chief Engineer:

Recommendation 1: Report on NASA's progress to reexamine available orbital debris tracking tools and offices to ensure all practicable data sources are leveraged to inform ISS operations and ensure crew safety.

> **Management's Response:** NASA concurs. NASA avails itself of a wide range of resources for planning and real-time execution of the ISS Program with regards to micrometeoroids and orbital debris. NASA's Orbital Debris Program Office regularly updates the orbital debris model, currently at version 3.2.[1] NASA also maintains a

[1] The latest version of the NASA Orbital Debris Engineering Model can be found at: https://orbitaldebris.jsc.nasa.gov/modeling/ordem.html.

relationship with the United States (U.S.) Space Command debris tracking function to alert the ISS of any potential conjunctions to inform appropriate responses by the ISS. NASA will report in 12 months any updates to the orbital debris modeling and any updated ISS Program modeling that relies on the inputs from the Orbital Debris Program Office.

Estimated Completion Date: September 30, 2025.

Recommendation 2: Document safety contingency plans and vehicle reassignment rules to help ensure the safe return of crew in the event of an emergency—expanding these efforts to include damage to the Space Exploration Technologies Corporation's (SpaceX) Crew Dragon and The Boeing Company's Starliner.

Management's Response: NASA concurs. NASA will deliver any updated plans affected by the lessons learned from the execution of Starliner's Crewed Flight Test (CFT). NASA will share any updated/created plans no later than nine months from the conclusion of the CFT mission.

Estimated Completion Date: June 30, 2025.

Additionally, the OIG recommends the AA for SOMD, in coordination with the ISS Program Manager:

Recommendation 3: Develop plans that reflect potential cost savings measures and anticipated reductions in operations for ISS decommissioning.

Management's Response: NASA concurs. NASA has been developing plans and budgets for transition and post-transition to commercial low Earth orbit destinations aligned with our budget process and expects to have more refinement for the transition years in the next budget cycle.

Estimated Completion Date: May 30, 2025.

Recommendation 4: Update the controlled deorbit plan and ensure the plan includes key commitments, technical, schedule, and cost challenges impacting the 2031 deorbit time frame.

Management's Response: NASA concurs. NASA has begun working with SpaceX, under the U.S. Deorbit Vehicle contract, to develop the controlled deorbit plan. NASA will provide this plan once concurred on by both NASA and SpaceX and an additional report related to the additional items that are not covered by the deorbit plan. NASA will deliver these products per the agreed-to project development timeline or in 12 months, whichever is sooner.

Estimated Completion Date: September 30, 2025.

We have reviewed the draft report for information that should not be publicly released. As a result of this review, we have not identified any information that should not be publicly released. We did not see any information that should be withheld.

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

Kenneth Bowersox

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Kenneth Bowersox

Appendix D: Report Distribution

National Aeronautics and Space Administration

Administrator
Deputy Administrator
Associate Administrator
Chief of Staff
Associate Administrator for Space Operations Mission Directorate
Chief, Safety and Mission Assurance
Chief Engineer
ISS Program Manager

Non-NASA Organizations and Individuals

Office of Management and Budget
    Deputy Associate Director, Climate, Energy, Environment and Science Division

Government Accountability Office
    Director, Contracting and National Security Acquisitions

Northrop Grumman Corporation

Sierra Space Corporation

Space Exploration Technologies Corporation

The Boeing Company

Congressional Committees and Subcommittees, Chair and Ranking Member

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

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

Senate Committee on Homeland Security and Governmental Affairs

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

House Committee on Oversight and Accountability
    Subcommittee on Government Operations and the Federal Workforce

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

(Assignment No. A-23-10-00-HED)