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Report to Congressional Requesters

November 2009

INTERNATIONAL SPACE STATION

Significant Challenges May Limit Onboard Research

GAO-10-9

GAO Accountability·Integrity·Reliability

Highlights

Highlights of GAO-10-9, a report to congressional requesters

November 2009

INTERNATIONAL SPACE STATION

Significant Challenges May Limit Onboard Research

Why GAO Did This Study

In 2010, after about 25 years of work and the expenditure of billions of dollars, the International Space Station (ISS) will be completed. According to the National Aeronautics and Space Administration (NASA), the ISS crew will then be able to redirect its efforts from assembling the station to conducting research.

In 2005, Congress designated the ISS as a national laboratory; in addition, the NASA Authorization Act of 2008 required NASA to provide a research management plan for the ISS National Laboratory. In light of these developments, GAO was asked to review the research use of the ISS. Specifically, GAO (1) identified how the ISS is being used for research and how it is expected to be used once completed, (2) identified challenges to maximizing ISS research; and (3) identified common management practices at other national laboratories and large science programs that could be applicable to the management of the ISS. To accomplish this, GAO interviewed NASA officials and reviewed key documents related to the ISS. GAO also studied two ground-based national laboratories and several large science institutions.

What GAO Recommends

GAO recommends that the NASA Administrator implement actions, such as increasing user outreach and centralizing decision making to enhance use of the ISS. NASA concurred with the recommendations.

View GAO-10-9 or key components.

For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

The ISS has been continuously staffed since 2000 and now has a six-member crew. The primary objective for the ISS through 2010 is construction, so research utilization has not been the priority. Some research has been and is being conducted as time and resources permit while the crew on board performs assembly tasks, but research will is expected to begin in earnest in 2010. NASA projects that it will utilize approximately 50 percent of the U.S. ISS research facilities for its own research, including the Human Research Program, opening the remaining facilities to U.S. ISS National Laboratory researchers.

NASA faces several significant challenges that may impede efforts to maximize utilization of all ISS research facilities, including:

- the impending retirement of the Space Shuttle in 2010 and reduced launch capabilities for transporting ISS research cargo once the shuttle retires,
- high costs for launches and no dedicated funding to support research,
- limited time available for research due to the fixed size of crew and competing demands for the crew's time, and
- an uncertain future for the ISS beyond 2015.

NASA is researching the possibility of developing a management body—including internal and external elements—to manage ISS research, which would make the ISS National Laboratory similar to other national laboratories. Though there is no existing direct analogue to the ISS, GAO studied two national laboratories and several other large science institutions and identified three common practices that these institutions employ that could benefit the management of ISS research.

- **Centralized management body**: At each of the institutions GAO studied, there is a central body responsible for prioritizing and selecting research, even if there are different funding agencies. NASA's ISS managers are currently not responsible for evaluating and selecting all research that will be conducted on the ISS, leaving this to the research sponsor.
- **In-house scientific and technical expertise**: The institutions GAO studied have large staffs of in-house experts that can provide technical and engineering support to users. NASA's staff members in ISS fundamental science research areas have been decentralized or reassigned, limiting its capability to provide user support.
- **Robust user outreach:** The laboratories and institutes GAO studied place a high priority on user outreach and are actively involved in educating and recruiting users. NASA has conducted outreach to potential users in the public and private sectors, but its outreach is limited in comparison.

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Abbreviations

COTS	Commercial Orbital Transportation Services
CSA	Canadian Space Agency
DOE	Department of Energy
ESA	European Space Agency
ESMD	Exploration Systems Mission Directorate
FFRDC	federally funded research and development center
GOCO	Government-Owned, Contractor-Operated
GOGO	Government-Owned, Government-Operated
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health
NSBRI	National Space Biomedical Research Institute
NSF	National Science Foundation
SOMD	Space Operations Mission Directorate
UNOLS	University National Oceanographic Laboratory System
USOS	U.S. Operating Segment
WHOI	Woods Hole Oceanographic Institute

GAO
Accountability * Integrity * Reliability

United States Government Accountability Office
Washington, DC 20548

November 25, 2009

The Honorable Bart Gordon
Chairman
Committee on Science and Technology
House of Representatives

The Honorable Bill Nelson
Chairman
Subcommittee on Science and Space
Committee on Commerce, Science and Transportation
United States Senate

After about 25 years of design, development, and construction, the International Space Station (ISS) will be completed in 2010. According to the National Aeronautics and Space Administration (NASA), once construction is completed the ISS crew will be able to focus its efforts on dedicated utilization of the onboard research capabilities. Building the ISS has been a long and costly effort; construction has been under way for over 10 years, and NASA estimates total direct ISS costs to NASA from 1994 to 2010 to be $48.5 billion.[1] Though it has budgeted funds to allow for extension of the ISS, NASA is currently following the direction of the previous administration and budgeted to end its participation in the ISS at the end of 2015; if this does not change, there will be only a 5-year window during which the ISS will be available for dedicated research utilization. Congress has directed NASA to take all necessary steps to ensure that the ISS remains a viable and productive facility capable of potential utilization through at least 2020, but no decisions on any extensions have been made to date.[2]

Originally, the ISS was to be used for conducting a broad range of NASA-funded experiments in many disciplines, including the life sciences, combustion science, fluid physics, and materials science as well as

[1] According to NASA documentation, this estimate includes development, operations, cargo and crew transportation, Space Shuttle costs, and costs to other NASA programs, but does not include Freedom program costs of approximately $10 billion or international partner costs.

[2] National Aeronautics and Space Administration Authorization Act of 2008, Pub. L. No. 110-422 § 601. This act is herein called the NASA Authorization Act of 2008.

technology demonstration. In 2004, NASA changed its focus to studying the effects of long-duration space travel on humans and developing countermeasures for these effects and tests of exploration-related technology, and as a result the focus of its research on board the ISS has changed as well. In 2005, Congress designated the ISS as a national laboratory and asked NASA to seek to increase station research utilization by including other federal entities and the private sector through partnerships, cost sharing, and other arrangements that would supplement NASA funding of ISS research, and noted that NASA may enter into a contract with a nongovernmental agency to operate the ISS national laboratory, subject to all applicable federal laws and regulations. In addition, the NASA Authorization Act of 2008 required NASA to develop a Research Management Plan to be used to prioritize research activities and resources. The Research Management Plan was to identify the organization to be responsible for managing United States' research on the ISS. The act noted that the management institution could be an internal NASA office or an external relationship arranged via contract, cooperative agreement or grant. This plan was delivered to Congress in August 2009.

In light of these developments, you asked us to review the use of the ISS for research. Specifically, we (1) identified how the ISS is being used at present and how much it is expected to be used once assembly is complete, (2) identified challenges to fully maximizing research use of ISS, and (3) identified management principles of other national laboratories and other large science programs that could be applicable to management of the ISS.

To identify how ISS research facilities are being used at present, we reviewed NASA documentation pertaining to available on-station hardware and scientific investigations that utilize this hardware. We also interviewed officials from the NASA Space Operations Mission Directorate (SOMD) and Exploration Systems Mission Directorate (ESMD), the Japanese Aerospace Exploration Agency (JAXA), and the European Space Agency (ESA). To identify how the ISS will be used once assembly is completed, we analyzed NASA documentation identifying available on-station hardware planned for the ISS and NASA projections for future requirements, and we compared available research resources to planned requirements.

To identify the challenges to maximizing ISS research, we met with NASA officials in the ISS program office as well as in NASA's SOMD. We also met with and spoke to former, current, and prospective researchers who have conducted research onboard the ISS or who were interested in conducting future research. We interviewed officials from the National Research Council, the Department of Agriculture (USDA), the National Institutes of Health (NIH), the National Space Biomedical Research Institute (NSBRI), and the Universities Space Research Association (USRA). To determine how NASA is managing the ISS, we interviewed NASA officials and reviewed NASA plans and documentation.

To identify management principles of other national laboratories and large science programs that could be applicable to management of the ISS, we interviewed officials at the Department of Energy (DOE) who are responsible for the DOE national laboratories and spoke with officials at the National Energy Technology Laboratory. We also met with officials from the National Science Foundation (NSF) who are responsible for managing the Office of Polar Programs. Further, we visited Argonne National Laboratory (Argonne) in Illinois and Brookhaven National Laboratory (Brookhaven) in New York, and we interviewed officials from the National User Facility Organization, the National Academies, NSBRI, the Space Telescope Science Institute, and the Woods Hole Oceanographic Institute (WHOI).

We conducted this performance audit from November 2008 through October 2009 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.

Background

The ISS—the largest orbiting man-made object—is being constructed to support three activities: scientific research, technology development, and development of industrial applications. Its facilities allow for ongoing research in microgravity,[3] studies of other aspects of the space environment, tests of new technology, and long-term space operations. Its facilities enable astronauts to conduct many different types of research,

[3] A microgravity environment is one in which the apparent weight of an object is small compared to its actual weight; on board the ISS, objects are in a microgravity environment because the ISS is in a continual state of free fall toward the Earth. This state can be achieved for short periods of time through free fall drop towers, aircraft flying parabolic paths, and rockets flying suborbital, parabolic paths, and for longer periods in orbiting spacecraft.

including experiments in biotechnology, combustion science, fluid physics, and materials science, on behalf of ground-based researchers. The ISS also has capability to support research on materials and other technologies to see how they react in the space environment. In general, conducting research in a microgravity environment allows scientists to eliminate the influence of Earth's gravity and can result in discoveries of properties and reactions that would be masked on Earth. Some researchers believe that conducting scientific experiments in microgravity can yield potentially groundbreaking results in areas as diverse as stem-cell culturing, vaccine research, plant and seed research, and targeting drug-resistant microbes. Testing materials and technologies in space allows researchers to determine the impact of the harsh space environment on these items for potential future use in space vehicles or satellites.

There are five main partners involved in supporting the development and manning of the ISS: the United States, Russia, Japan, ESA (which includes a number of participating countries), and Canada.[4] The ISS consists of two separately administered (though conjoined) parts: (1) the U.S. operating segment (USOS), with contributions from its international partners (ESA, JAXA, and the Canadian Space Agency (CSA)), and (2) the Russian segment. Russian research is separate from the USOS operations: Russia has no utilization rights to U.S., European, or Japanese modules and NASA has no utilization rights to Russian modules, though NASA told us there are mechanisms for scientific collaboration and hardware sharing among all agencies.[5] According to NASA, it provides a portion of ISS resources (including crew time, facilities, and launch capabilities) to the partners based on international agreements with each partner in exchange for its contributions to the ISS. Each partner facility has research accommodations that can be used and shared among the partners as stipulated in the agreements.

Scientific research facilities currently available inside the ISS are generally mounted in modular, refrigerator-sized mounts called racks or ExPRESS racks, which provide the utilities necessary for conducting research, including electricity. Each rack contains lockers, drawers, or other inserts

[4] ESA partners include Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

[5] According to NASA, to date every partner agency has implemented research throughout both the USOS and the Russian segment.

that can be used to install research payloads and are changed as necessary. The racks may also contain semipermanent equipment, such as freezers, incubators, or glove boxes. Research payloads are sent to the ISS in a flight-certified piece of hardware that may be small in size. This hardware is generally then installed in one of these racks, and the experiment is operated until the research is completed. Once completed, the payload may be returned to Earth for analysis or research data are transmitted back to Earth for analysis. Research can also be conducted on the exterior of the station in unpressurized facilities; for example, the Materials International Space Station Experiment is conducted in such facilities.

Facilities on board the ISS and NASA's plans for its own utilization of the ISS have changed over time. When NASA adopted *The Vision for Space Exploration* (Vision) in 2004, it set forth a plan to explore space and extend a human presence across our solar system with dual goals of returning humans to the moon by 2020 and later sending humans to Mars and other destinations.[6] It also dictated that NASA focus its research efforts on board the ISS on its Human Research Program supporting future human space exploration, including studying the effects of the space environment on humans; on technology development and test for exploration; and on developing operational protocols for successful long-duration space operations. Though ISS had originally been intended to be a broad-based research facility, the Vision required NASA to focus its ISS research on supporting space exploration goals with an emphasis on understanding the impacts of the space environment on astronauts and developing countermeasures to these effects. As a result, NASA reduced the scope of its ISS research; the agency conducted a zero-based review in the fall of 2005 and determined that some fundamental life and physical sciences tasks were not "highly relevant" to achieving the goals of the Vision. The agency canceled some existing grants in this area and stopped soliciting any new research, which caused affected ISS scientific research communities to shrink or turn to other research areas. NASA also reassigned its personnel involved with the fundamental sciences, including space biology (such as animal, plant, and microbial research), and reduced its portfolio of research on fluid physics, combustion, materials science, biotechnology, and fundamental physics. Table 1 depicts some changes in

[6] National Aeronautics and Space Administration, *The Vision for Space Exploration* (Washington, D.C., February 2004).

ESMD flight research conducted in 2002 and 2008 that illustrate the redirection of focus.

Table 1: Difference in ESMD Flight Experiment Research Areas (Not Including the Human Research Program), 2002 and 2008

Research area	2002 flight experiments	2008 flight experiments
Fundamental space biology (including animal, plant, and microbial research)	26	13
Biotechnology	11	0
Fundamental physics	13	0
Materials science	23	5

Source: NASA.

Hardware needed for research projects was also canceled or delayed by NASA or commercial developers, either because of the change in research priorities or other constraints, such as the pause in shuttle flights after the loss of the Space Shuttle Columbia. This included animal research facilities, the Life Sciences Glovebox, the Centrifuge Accommodation Module, and the Alpha Magnetic Spectrometer (AMS).[7] In 2003, the National Research Council and the National Academy of Public Administration reported that NASA drastically reduced the overall ability of the ISS to support science, and that this reduction limited or foreclosed the scientific community's ability to maximize the research potential of the ISS.[8] NASA's *Plan to Support the Operations and Utilization of the International Space Station Beyond 2015* states that it would cost several billion dollars to reinstate the full scope of planned ISS facilities.

Though the Vision changed and reduced the scope of NASA's goals for its own research on board the ISS, Congress designated the ISS as a national laboratory in 2005 in an effort to increase utilization of the ISS for research. Congress also asked NASA to seek to increase utilization of the ISS by other federal entities and the private sector through partnerships, cost-sharing agreements, and other arrangements that would also

[7] After the delay, AMS is scheduled to be transported to the ISS on one of the last Space Shuttle flights.

[8] National Research Council and the National Academy of Public Administration, *Factors Affecting the Utilization of the International Space Station for Research in the Biological and Physical Sciences* (Washington, D.C., 2003).

supplement NASA funding of ISS research.[9] According to NASA officials, this designation does not guarantee an appropriation specifically for ISS National Laboratory research. The ISS National Laboratory operates in conjunction with the ISS research programs of NASA and the international partners, and utilizes a portion of the USOS resource allocation, including crew time, facilities, and cargo launched to the station. As such, NASA conducts the research it sees as relevant to its mission, and the ISS can also accommodate users from outside of NASA who are not necessarily conducting research relevant to NASA's Human Research Program or other NASA-sponsored research. NASA established the ISS National Laboratory Office in the spring of 2009; this office is part of the existing Space Station Payloads Office and as of April 2009 had five staff members.

In May 2009, President Obama established the Review of U.S. Human Space Flight Plans Committee. Its stated goal is to provide an independent assessment of the nation's planned human spaceflight activities and to ensure that that country is on "a vigorous and sustainable path to achieving its boldest aspirations in space." The committee conducted an assessment of NASA's plans, including plans for the ISS, and developed a number of possible options for the future of the U.S. space activities. In its summary report released in September 2009, the committee developed five options for NASA's human spaceflight program, and of these options, three recommend extending the lifespan of the ISS until 2020. The committee wrote that it would be unwise to de-orbit the ISS after 25 years of design, development, and assembly and only 5 years of operations, and that the return on investment to both the United States and the international partners would be significantly enhanced by an extension of the ISS's life. It is unknown at present which option will ultimately be selected, but the future utilization of the ISS depends on this decision.

[9] National Aeronautics and Space Administration Authorization Act of 2005, Pub. L. No. 109-155 § 507 (codified at 42 U.S.C. § 16767) (herein referred to as the NASA Authorization Act of 2005).

The ISS Will Have Excess Research Facilities Available for Other Users by Construction Completion

The ISS has been continuously manned since 2000, and in March 2009 the crew expanded from three to six. NASA's primary objective for the ISS through 2010 is construction, so research has not been the main priority. Specifically, though the ISS facilities have been used for some research to date, new research capabilities are still being added and are awaiting launch and installation, and resources such as crew time, transportation, and facilities planned for the utilization phase have not been fully available. As such, research is being conducted at the margins of assembly and operations activities as time permits, while the crew on board performs assembly and operations tasks. NASA has identified 197 U.S.-integrated investigations that have been conducted on orbit as of April 2009, though 55 of these investigations were conducted on the Space Shuttle missions to the ISS instead of on the ISS itself (called sortie research). According to NASA, as of February 2009, U.S. ISS and sortie research have resulted in over 160 publications, including articles on topics such as protein crystallization, plant growth, and human research. According to NASA, there have also been approximately 25 technology demonstration experiments flown on the ISS during the assembly phase.

Once construction is completed, NASA projects that its share of the ExPRESS racks will be less than 50 percent occupied by planned NASA research related to the Human Research Program and other NASA-initiated research, with the remainder available for other use. Any facilities that NASA does not plan to utilize are available to the ISS National Laboratory, and the system is flexible so that future rack space can be made available either to NASA-funded or ISS National Laboratory users up to the total capacity. These projections are based on NASA's current ISS research budget and determinations of available resources based on the percentage of ISS resources that are allocated to NASA and the international partners according to established international agreements.[10] Table 2 depicts the NASA projected occupancy of rack space for September 2010.

[10] The ISS partners use a document called the *Consolidated Operations and Utilization Plan* to project resources for strategic planning purposes.

Table 2: Projected NASA Occupancy of ISS ExPRESS Racks and Cold Stowage Racks Research Resources

ISS resource	Projected NASA occupation of racks at assembly completion	Details
ExPRESS racks	48 percent utilized	Of NASA's seven ExPRESS racks, 25 of 59 lockers and 7 of 13 drawers will be utilized after assembly is completed.
Cold stowage racks	66 percent utilized	NASA projects a need for 66 percent of the cold stowage racks. There will be three cold stowage racks on board the ISS; one rack will be utilized by NASA after assembly is completed, a second rack will be maintained as a spare, and the third may be available for the National Laboratory.

Source: GAO analysis of NASA data.

Notes: NASA's three racks for human research are not included in this table. One of NASA's human research racks, called the Muscle Atrophy Research and Exercise System, is a joint venture with ESA and will be used by European researchers or National Laboratory customers rather than NASA's Human Research Program.

Inside the ISS, there are many available interior, or pressurized, sites for research racks and other facilities, though not all available sites will ultimately accommodate a facility. NASA projects that 79 percent (19 of 24) of the available NASA internal payload sites that can accommodate research facilities ultimately will, and that less than 50 percent of these facilities will be occupied by planned NASA research after the ISS is completed, making them available for other users. The ISS also has external, or unpressurized, sites exposed to the vacuum of space on its exterior structure that can accommodate research facilities. NASA projects that these sites will be 33 percent (7 of 21) filled with research facilities when assembly is completed and 62 percent filled (13 of 21) by the end of 2015. NASA's international partners are fully utilizing their ISS allocations; ESA needs more resources than it has been allocated by the international agreements. NASA officials told us that their intention was to build the ISS with sufficient research facility capacity so that they could invite the broader scientific community to use the ISS; they added that had NASA intended to use the ISS to support only its own research, the agency could have truncated construction and utilized 100 percent of its facilities. NASA officials told us that they expect to be able to fill the surplus ISS capacity with research by National Laboratory users.

Several Significant Challenges May Impede Full Use of ISS Research Facilities

NASA faces several significant challenges that may impede efforts to maximize research utilization of the ISS, including (1) the impending retirement of the Space Shuttle in 2010, reduced launch capabilities once the shuttle retires, and the potential for a gap between retirement and follow-on U.S. vehicles; (2) high costs for launches and developing research hardware and a lack of dedicated funding streams for ISS research; (3) limited crew time available for research due to a fixed crew size and other requirements for crew time; and (4) an uncertain future for the ISS beyond 2015.

Impending Space Shuttle Retirement Will Limit Launch Capabilities

The Space Shuttle is currently slated to retire in 2010, and as of November 2009 only five launch opportunities remain. We have previously reported that the ISS will face a significant cargo supply shortfall without the Space Shuttle.[11] Further, since NASA has the few remaining Space Shuttle flights scheduled to carry equipment required for assembly, operations, and maintenance, there may be limited cargo capacity for research payloads. Potential researchers and others have told us that they have faced difficulty in getting payloads scheduled on board the Space Shuttle in a reasonable amount of time.

Following the retirement of the Space Shuttle in 2010, NASA will rely on an assortment of vehicles in order to provide the necessary logistical support and crew rotation capabilities required for the ISS, but none will offer the same cargo capabilities as the Space Shuttle in upmass (delivering cargo to the ISS) and downmass (delivering cargo to Earth). NASA will rely heavily on Roscosmos—the Russian Federal Space Agency—and its launch vehicles to provide crew transport to the ISS once the Space Shuttle retires, and has signed agreements for future service. Some of the other vehicles are already supporting the ISS, while the international partners, the commercial sector, and NASA are developing others. As we have previously reported, NASA expects Russia to launch six Progress flights each year from 2009 through 2011, and that NASA cargo will be spread across the equivalent of four Progress flights in 2009, two in 2010, and one in 2011. NASA currently does not plan to utilize the Progress vehicle beyond 2011.[12]

[11] GAO, *NASA: Commercial Partners Are Making Progress, but Face Aggressive Schedules to Demonstrate Critical Space Station Cargo Transport Capabilities*, GAO-09-618 (Washington, D.C.: June 16, 2009).

[12] GAO-09-618.

International partners' vehicles alone cannot fully satisfy ISS cargo needs. Existing and planned international partner vehicles have much less upmass capability than the Space Shuttle and no downmass capability for research payloads. Overall, NASA now faces a 40-metric ton (approximately 88,000 pound) usable cargo shortfall from 2010 through 2015. To mitigate this shortfall, NASA has turned to commercial developers to provide launch vehicles. These vehicles are known as Commercial Orbital Transportation Services (COTS) vehicles, and two companies, Orbital Science Corporation (Orbital) and Space Exploration Technologies Corporation (SpaceX), are each developing future vehicles. The Russian Soyuz vehicle can transport downmass (though minimal) and return crew from the ISS after the Space Shuttle is retired, and the new commercial SpaceX vehicle is also expected to be able to return downmass. Delay of downmass capability will make it difficult to transport research back to Earth for analysis. Table 3 provides specifics on the available and planned vehicles.

Table 3: Capability of Launch Vehicles in Operation and under Development

Vehicle (ownership)	Upmass capability[a]	Downmass capability[a]	Crew transport	Status	Challenges
Space Shuttle (NASA)	Maximum capability is 37,864 pounds (17,175 kilograms) Can be configured for pressurized, unpressurized, and powered cargo	Maximum capability is 37,864 pounds (17,175 kilograms)	Seven crew members	Operational until 2010	Additional funding required for the Constellation program is not available while the Space Shuttle is in operation Safety concerns
Soyuz (Roscosmos)	66 pounds (30 kilograms), pressurized	132 pounds (60 kilograms)	Three crew members	Completed missions to the ISS Two Soyuz spacecraft continuously docked to the ISS as lifeboats for crew	Limited cargo capacity
Progress (Roscosmos)	Average capability of 5,732 pounds (2,600 kilograms), pressurized	None	None	Completed missions to the ISS NASA planned missions to the ISS, 2009-2011	No downmass capability

Vehicle (ownership)	Upmass capability[a]	Downmass capability[a]	Crew transport	Status	Challenges
Automated Transfer Vehicle (ESA)	Maximum capability is 16,535 pounds (7,500 kilograms), pressurized	None	None	One completed demonstration mission to the ISS to date NASA planned missions to the ISS, 2010-2013	No external capability
H-II Transfer Vehicle (JAXA)	Maximum capability is 13,228 pounds (6,000 kilograms), pressurized and unpressurized	None	None	One completed demonstration mission to the ISS to date NASA planned missions to the ISS, 2010-2015	Limited unpressurized external cargo
Commercial vehicle (SpaceX)	Up to 7,300 pounds (3,300 kilograms), pressurized and unpressurized	3,748 pounds (1,700 kilograms)	Dragon space vehicle is designed to transport crew, but COTS representatives stated that they have not yet received funding for this capability	Under development First mission to the ISS expected in 2010	A delay in availability would lead to a significant scaling back of NASA's use of the ISS for scientific research
Commercial vehicle (Orbital)	4,400 pounds (2,000 kilograms), pressurized	None	None	Under development First mission to the ISS scheduled for 2011	A delay in availability would lead to a significant scaling back of NASA's use of the ISS for scientific research
Ares I and Orion (NASA)[b]	To be determined	To be determined	Six crew members	Under development First crewed mission to the ISS scheduled for March 2015	First crewed mission not likely to be launched by the March 2015 scheduled execution date

Source: NASA and GAO documentation.

[a]These figures depict total cargo capabilities of the various vehicles, not upmass or downmass available for utilization of the ISS.

[b]Ares I and Orion are components of the Constellation program, NASA's effort to develop a replacement for the Space Shuttle. This program currently includes development of the Ares I and V rockets, the Orion Crew Exploration Vehicle, and eventually will include the Altair Lunar Lander.

As we have previously reported, the contractors responsible for the COTS vehicles have experienced delays in demonstration milestones and are at risk for further delays. Both SpaceX and Orbital have had schedule slippage in the development of their launch vehicles. For SpaceX, this has contributed to anticipated delays of 2 to 4 months in most of its remaining milestones.[13] Orbital has recently revised its agreement with NASA to demonstrate a different cargo transport capability than it had originally planned, and delayed its demonstration mission date from December 2010 until March 2011. We have also previously reported that there have been delays with the development of the Constellation program, and that there were likely to be further delays that would make achieving NASA's 2015 first crewed launch date difficult.[14] We have noted that a delay in the availability of commercial partners' vehicles in 2010 would lead to a significant scaling back of NASA's use of the ISS for scientific research;[15] however, NASA officials told us that they believe recent developments (for example, the addition of a Space Shuttle flight) have shifted the horizon for serious impacts from COTS delays into 2011.

NASA officials said that the impact of COTS failures or significant delays would be similar to the post-Columbia disaster scenario,[16] where NASA operated the ISS in a "survival mode" and moved to a two-person crew, paused assembly activities, and operated the ISS at a lower altitude to relieve propellant burden. NASA officials stated that if the COTS vehicles are delayed, they would pursue a course of "graceful degradation" of the ISS until conditions improve or until NASA's commitment to operate the ISS expires at the end of 2015. In such conditions, the ISS would only conduct minimal science experiments.

NASA officials told us that they are basing logistics requirements for the ISS on engineering estimates for component reliability, but will not know the full accuracy of these estimates until further operating experience is gained. NASA has current plans to use 50 percent of the United States' allocated launch capacity to transport research cargo to the ISS and 47 percent of the United States' allocation to transport research cargo returning to Earth for postflight analysis (not including operational cargo). However, these projections may change, and are based on the assumption that all follow-on and replacement launch vehicles will begin operations as

[13] GAO-09-618.

[14] GAO, *NASA: Constellation Program Cost and Schedule Will Remain Uncertain Until a Sound Business Case Is Established*, GAO-09-844 (Washington, D.C.: Aug. 26, 2009).

[15] GAO-09-618.

[16] This refers to the 2003 loss of the Space Shuttle Columbia, which resulted in NASA suspending shuttle flights until 2005 while investigations were under way.

scheduled; significant delays or new NASA requirements to provide logistics and resupply cargo have the potential to alter this projection and, as noted, may result in cargo shortfalls and potentially the scaling back of ISS research. ESA already wants to launch more research cargo to the ISS than it is allotted under international agreements. NASA's planning document states that ESA will have a demand of 1.8 metric tons of cargo beyond its allotment that it wants to send to the ISS.

High Costs and No Dedicated Funds for Developing and Launching Research

NASA officials have stated that it is significantly more expensive to conduct research on board the ISS than on Earth and the agency now views lack of funding for research as the major challenge to full research utilization of the ISS. According to NASA, one of the major cost drivers is the cost to launch payloads to the ISS. When the Space Shuttle retires, Roscosmos and later the commercial launch partners will be able to set the launch costs. Costs to the user of the ISS vary: NASA signed a memorandum of understanding (MOU) with NIH as an ISS National Laboratory user to launch biomedical experiments to the ISS, and NASA officials have stated that the agency will work with NIH to determine the demand for launch services and accommodate NIH payloads on the margins of NASA operations and maintenance flights as space allows. However, NASA officials told us that the agency has set no money aside for ISS National Laboratory payload development or transportation, and it may be unable to provide complimentary launch opportunities to National Laboratory users. We asked NASA for launch cost estimates; officials gave an estimate of $44,000 per kilogram (about 2.2 pounds), along with the caveat that the costs to develop and launch experiments vary widely depending on the experiment. Researchers we spoke with gave higher estimates for payload costs. USDA reported that the average payload cost for its experiments, which were individually contained in a compartment the size of a shoe box, was about $250,000. Though specific figures will vary depending on the nature of the payload, these types of costs may be prohibitive to researchers who are responsible for seeking their own funding.

According to NASA officials, the National Laboratory designation does not guarantee an appropriation specifically for ISS National Laboratory, and it is unclear if NASA or other federal agencies will be able to provide any funding support to facilitate ISS utilization. NASA regards this lack of dedicated funding as the current main limiting factor for utilization of the

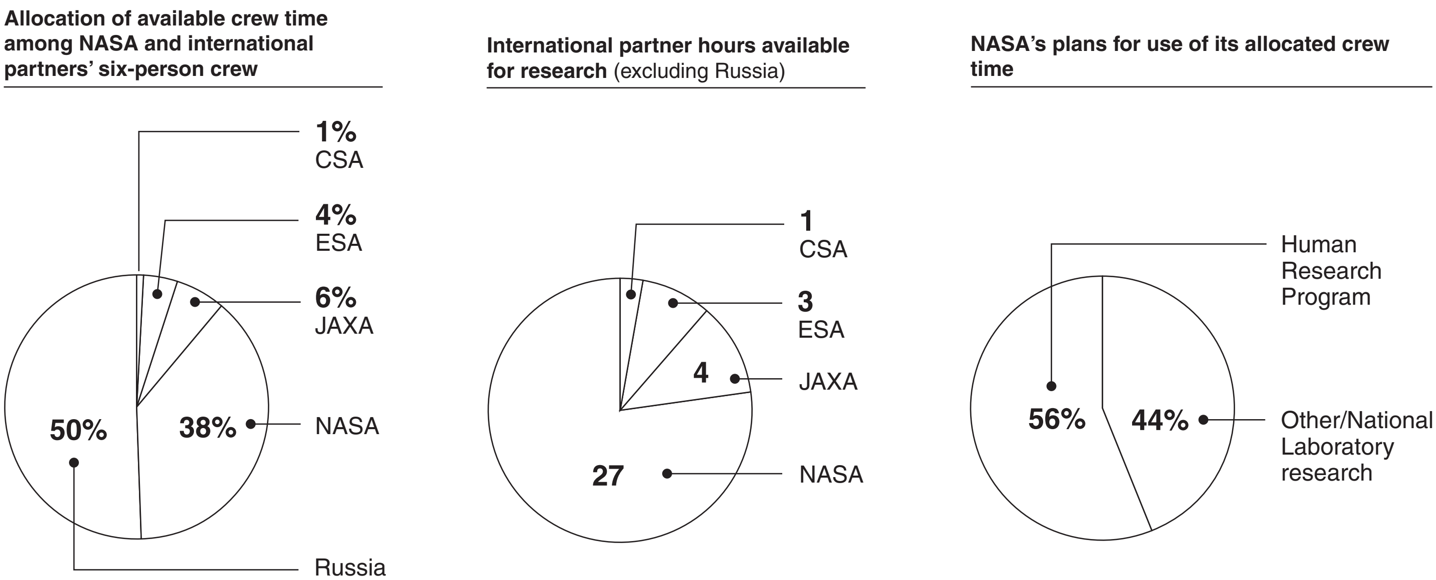
ISS. One positive indication came from NIH, which issued a funding announcement indicating that it may make funding available for selected applicants.[17] Researchers we spoke with agreed that funding opportunities or grants are irregular and limited, and that regular funding opportunities are essential for attracting researchers to any science program. NASA officials told us that funding for ISS research had been $700 million in 2002 and is now approximately $150 million annually. According to NASA this reflects a shift in budget priorities from funding research on the ISS to developing the Constellation program.

Limited Crew Time to Conduct Research

NASA also ranks limited crew time as a significant constraint for science on board the ISS. The size of the crew on board the station is constrained at six by the number of spaces available in the "lifeboats," or docked spacecraft that can transport the crew in case of an emergency. As such, at present crew time cannot be increased to meet increased demand. Further, crew time is shared between NASA and its international partners (JAXA, ESA, CSA, and Russia). According to NASA, the ISS crew members work 8.5 hours a day, and during this time they conduct maintenance, vehicle traffic operations, training, medical operations, human research experiments, and the experiments of NASA and the international partners. NASA documentation shows that the remaining crew time will be spent eating, sleeping, and exercising. Figure 1 depicts the crew time allocations among NASA and its international partners; it also depicts the percentages of crew time available to NASA and its international partners as negotiated in agreements. According to NASA, the USOS is allocated half of the crew time available on the ISS, with the other half going to the Russian segment. NASA told us that it and the international partners (excluding Russia) will have 35 hours per week of scheduled crew time to share in conducting research.

[17] President Obama recently announced that $5 billion in American Recovery and Reinvestment Act funds will be made available to support NIH research; this may provide funding for NIH-sponsored ISS research.

Figure 1: Weekly Crew Time Allocations among Russia and the International Partners



Source: GAO analysis of NASA data.

Note: Percentages may not sum to 100 due to rounding.

As shown in figure 1, NASA's share of crew time will be approximately 27 hours per week to devote to research; of this time, NASA plans to use 56 percent for its own Human Research Program studies. The remaining 44 percent (or approximately 12 hours per week) will be available for other NASA research and National Laboratory investigations.

Though available crew time may increase as the six-person crew becomes more experienced with operating the ISS efficiently or if the crew volunteers its free time for research utilization, crew time for U.S. research remains a limiting factor in that it cannot be scaled up to meet demand. According to NASA officials, potential National Laboratory researchers should design their experiments to be as automated as possible or minimize crew involvement required for their experiments to ensure that they are accepted for flight. For example, NASA told potential NIH grant applicants that an experiment requiring 75 hours or more of crew time over one 6-month period would be too intensive and would likely be rejected, though according to NASA no investigation to date has required that much crew time.[18] Not all ISS research will require much crew

[18] Six months is the standard ISS expedition duration.

intervention or be constrained by available crew time. Areas such as technology development may require less crew intervention; for example, the Materials International Space Station Experiment mounts samples on the exterior of the ISS and once set up requires little crew intervention.

Uncertain Future for the ISS beyond 2015

NASA's budget currently reflects plans for retirement of the ISS at the end of 2015. The Review of Human Space Flight Plans Committee has proposed extension of the ISS until 2020 in three of its five possible scenarios and Congress has directed NASA to take steps to ensure that it remains capable of remaining a viable and productive facility for the United States through at least 2020, but there has not been a commitment yet to continue operations. If not extended, there will be only 5 years between the end of construction in 2010 and ISS retirement in 2015 to utilize the ISS research facilities. Under this deadline, the potential for long-term science and for building a robust ISS user community is limited.

The uncertainty of the ISS program beyond its 2015 retirement date has deterred members of the scientific community from considering the station as a platform for fundamental research. According to researchers, they require sufficient time (months to years) to develop and conduct an experiment and then to replicate their research so they can seek publication in peer-reviewed journals. Officials from each of the other science programs we studied and many researchers we spoke with commented on the importance of having a program with a reasonable and definitive window of available time for scientists and graduate students to fully develop and implement their experiments. They added that having longevity in a research program ensures that prospective and current users, whether academic or commercial, will have an opportunity to work in a viable laboratory where they can invest in their research. Researchers have told us that they may be unlikely to get involved with ISS research if they do not have assurances that the ISS will be around for long enough for them to get their research developed and executed. They emphasized that by knowing they have plenty of time to conduct their experiments, they have not only the time to teach the next generation of scientists—that is, graduate students whose dissertations rely on the completion of research projects—but also the opportunity to reproduce their experiments. Publishing research results, a requirement for many academic scientists, often requires that results can be duplicated, which may not be possible on board ISS if the research utilization window is only 5 years.

NASA's international partners are using their research facility allotments and two have recently expressed interest in extending the operation of the ISS beyond 2015. The Director General of ESA told the Review of U.S. Human Space Flight Plans Committee that he believed that the decision about the future of the ISS should be a joint decision of all the partner nations, and that if ISS research utilization is not successful, the program would be a failure. Similarly, the head of Roscosmos advised the United States to prolong operation of the ISS beyond 2020.[19] Retirement of the ISS is in part predicated on the life of its components. NASA's plan for operating and using the ISS for research through 2020—required by the NASA Authorization Act of 2008—states that while some of the ISS's hardware was originally designed for a 30-year life, most was tested to the 15-year life requirement, meaning that there are unknowns that prevent providing an absolute definition of the lifetime capability of the ISS, and that additional testing and analysis is required. We did not assess the technical issues surrounding an extension of ISS operations.

NASA Is Considering Engaging an Outside Partner for ISS Management, a Key Practice Found at Other National Laboratories

In addition to the transportation issues, high costs and limited funding, and limited crew time—challenges exacerbated by the possibility of retirement of the ISS in 2015—NASA may face challenges in the management and operation of ISS National Laboratory research. There is currently no direct analogue to the ISS National Laboratory, and though NASA currently manages research programs at the Jet Propulsion Laboratory and its other centers that it believes possess similar characteristics to other national laboratories, NASA has limited experience managing the type of diverse scientific research and technology demonstration portfolio that the ISS could eventually represent. If utilized to its full capabilities, the ISS research program could cross multiple research disciplines and involve researchers from the academic, governmental, and commercial sectors, management of which may be outside of NASA's core competencies. We studied other national laboratories and large, multidisciplinary science programs to learn how they are managed and to identify possible lessons learned that could be applicable to management of the ISS. We visited Brookhaven and Argonne National Laboratories and spoke with officials from several other large science programs, including the National Energy Technology Laboratory,

[19] Recent news articles have indicated that Russia may be interested in detaching from USOS and continuing operations if NASA decides to cease its involvement in 2015. NASA does not believe that this is technically feasible.

DOE's only government-owned, government-operated (GOGO) national laboratory; the Space Telescope Sciences Institute, which is a nonprofit science center that works for NASA to coordinate research for the Hubble Space Telescope and forthcoming James Webb Space Telescope; the NSF Office of Polar Programs, which manages research conducted in the Arctic and Antarctica; and WHOI, a private, nonprofit institute that conducts, coordinates, and supports a range of oceanographic research onboard three large research ships, one coastal vessel, and submersible vessels. We identified three common practices that may be applicable to whatever management structure NASA decides on for managing all U.S.-sponsored ISS research: central management of research, robust in-house technical expertise, and significant user outreach. NASA has recognized the potential value of national lab practices—particularly engaging an outside partner for laboratory management.

Central Management of Research

At the research institutions we studied, we found that each has a management structure that typically entailed a contractor or nonprofit consortium of universities that oversee the operation of the laboratory and that researchers deal directly with that management body to initiate and develop their research. For example, Brookhaven and Argonne[20] are federally funded research and development centers (FFRDC) and operate as government-owned, contractor-operated (GOCO) facilities.[21] According to officials at DOE and the national laboratories, the role of the government in a GOCO arrangement is to oversee the contract and the contractor, as well as to provide direction to the management of the laboratory.[22] They added that the contractor manages the science conducted, and can expand and contract easily to bring in needed expertise to support operations as research priorities and user needs evolve, and since the contractor is not constrained by federal General Schedule pay scales, it can offer high salaries to secure world-class scientific talent.

[20] Brookhaven's contractor is Brookhaven Science Associates, LLC, and is in the ninth year of a 10-year contract; the contractor for Argonne is UChicago Argonne, LLC, which has a 5-year contract renewable for 20 years.

[21] For more on the management of FFRDCs, see GAO, *Federal Research: Opportunities Exist to Improve the Management and Oversight of Federally Funded Research and Development Centers*, GAO-09-15 (Washington, D.C.: Oct. 8, 2008).

[22] The alternative structure is a GOGO facility. DOE has only one GOGO laboratory, the National Energy Technology Laboratory.

WHOI has a central management body, but was the only facility we studied that does not manage its own peer-review process or select the research conducted in its facilities. Instead, WHOI has the agency sponsoring the research manage this process, in part because most of WHOI's research ships are owned by NSF and the Office of Naval Research, and the agency that owns a ship gets priority for use of the research facilities. NASA officials told us they think that the ISS falls into a similar model as WHOI because its National Laboratory facilities are open for use by any interested party that can provide its own funding, and while NASA evaluates and selects its own ISS research, it leaves the selection of ISS National Laboratory research to the sponsors of the research. However, WHOI is a member of University National Oceanographic Laboratory System (UNOLS), a central organization that is involved in monitoring, prioritizing, and scheduling research that will be conducted on various ocean laboratory vessels. According to UNOLS documentation, it has an elected UNOLS Council with broad representation—more than 61 academic institutions and national laboratories are part of UNOLS—and it provides some strategic research selection and prioritization functions to make efficient use of finite resources.

According to NASA, ISS National Laboratory research is managed through the Assistant Associate Administrator for the ISS in SOMD, working in cooperation with the ISS National Laboratory Office, which is within the ISS Payloads Office. NASA officials told us that the role of these offices is to optimize and maximize available ISS resources, but that the ISS National Laboratory Office does not determine the content of the science flown to the ISS, but relies on the sponsor to evaluate the research. Instead, NASA prioritizes payloads based on operational or tactical needs, such as if there is a need for parts or spares to be flown to the ISS and if NASA can accommodate the research.

Because of the congressional designation of the ISS as a national laboratory, NASA has opened the ISS up to several additional organizations other than NASA to select and fund science on the ISS. Some existing sponsors include (1) NASA, through either ESMD or SOMD; (2) other government agencies that have signed MOUs with NASA, including NIH, USDA, the Department of Defense (DOD), and DOE; (3) commercial or nonprofit organizations[23] that have signed Space Act

[23] This currently includes Ad Astra Rocket Company; Spacehab Inc.; BioServe Space Technologies; Nanoracks, LLC.; and Zero Gravity Inc.

agreements with NASA;[24] (4) organizations that have other formal partnerships with NASA, for example, NSBRI, which has a cooperative agreement with NASA; and (5) the international partners. According to NASA, as with WHOI, content of the ISS research selected is decentralized and conducted by the sponsor, and each sponsor has its own priorities for the research it supports. Additionally, NASA officials told us that though most research—including NASA, DOD, and NIH research—is subjected to a peer-review process to ensure that the investigation has scientific merit, other (especially commercial) research is not necessarily peer reviewed. Thus, the ISS currently lacks one central body that oversees the selection and prioritization of all U.S. ISS research and that can strategically decide what research should be conducted and at what time. This may become more problematic if there is future overlapping demand for ISS facilities from various users, including NASA, other federal agencies, and the academic and corporate sectors.

NASA has considered management alternatives to coordinate ISS research, including FFRDC or GOCO arrangements, as well as cooperative agreements, a government corporation, and hybrid structures. NASA has also reported several times on this issue, including in its 1998 plan for the ISS where making a special non-governmental organization (NGO) responsible for selecting and planning research onboard the ISS was discussed, and more generally in its 2005 Organizational Model Evaluation Team report. Other entities have also recommended that NASA establish such a management structure. For example, the National Research Council recommended that NASA establish an NGO to manage the ISS under the direction of institutions representing the research community; in 2000, the Computer Sciences Corporation recommended the creation of a space station utilization and research institute to manage ISS utilization. Congress has also directed NASA to develop plans involving an external management body: in the National Aeronautics and Space Administration Authorization Act of 2000, Congress instructed the agency to submit an implementation plan to incorporate the use of an NGO to conduct research utilization and commercialization management activities of the ISS, and the NASA Authorization Act of 2008 required NASA to develop a plan to support operations and utilization of the ISS beyond 2015, including a research management plan that identified who would manage

[24] National Aeronautics and Space Act of 1958, Pub. L. No. 85-568, § 203 (1958). This act is commonly referred to as the Space Act and agreements signed utilizing NASA's other transaction authority are known as Space Act agreements.

United States research. Potential management structures noted by the act included an internal NASA office or an external relationship governed by a contract, cooperative agreement, or a grant arrangement. NASA's plan submitted in response to this requirement did not mention management by any outside agency.

NASA officials told us that they are currently evaluating options for a future management structure for the ISS that may include an external entity, but that they have concerns. For example, they stated that they are concerned that adding a layer of bureaucracy between NASA operations and researchers could further complicate the process of getting investigations onto the ISS. Additionally, they do not think it is wise to establish such a management structure too early, for example, before the transportation challenge is addressed. Further, NASA officials told us that they are concerned that such a structure has an appropriate mix of internal and external expertise, and that having the appropriate personnel is ultimately more important than the type of structure (such as a GOCO versus another structure) selected.[25]

NASA officials also told us that they cannot select all U.S. ISS research because there is funding coming from numerous sponsors with various missions; however, the national laboratories we studied do not have only one funding agency either. For example, Argonne officials told us that they receive more than half of their funding from DOE but that the laboratory accommodates research sponsored by others. According to NASA officials, though it does not centrally select and prioritize all U.S. ISS research, it uses central tracking of research accomplishments and discipline-based working groups to prevent research duplication.

In-house Expertise

The national laboratories and science programs we studied have capable in-house scientific and technical experts (generally provided by the management body) who can consult with and provide guidance to users. These institutions make a concerted effort to hire scientists with expertise relevant to the research conducted at that institute or laboratory. For instance, in addition to conducting their own research, the scientists and

[25] We did not assess the cost implications to NASA of establishing an institute or other management structure. However, in NASA's 2002 *International Space Station Utilization Management Concept Development Study*, NASA evaluators estimated a budget of about $90 million if a national laboratory nonprofit institute were established with a workforce of approximately 350; for a workforce of 1,000, the estimated cost was about $200 million.

engineers who work for the management body are also available to assist visiting researchers in developing their research, drafting their proposals, and ultimately conducting their experiments. In some cases, staff scientists are available to provide user support 24 hours a day and 7 days a week. The national laboratories we studied consider use of in-house scientists and engineers to conduct research and to serve as advisors to lab users as a core competency.

Because of internal restructuring in the recent past, NASA has decentralized its expertise in key scientific disciplines germane to ISS research, and a small number of personnel ultimately left the agency. According to congressional testimony given by an ISS researcher and according to others we spoke with, NASA has reassigned a number of experts within the agency whose experience would have been helpful for biological and microgravity research on board the ISS. Specifically, in the mid-1990s, NASA began making cuts to its gravitational biology program, and in 2004, it merged its Office of Biological and Physical Research, including the Physical Sciences Division, into ESMD. NASA ultimately eliminated research in these areas that was not deemed essential to achieving the Vision.

Though NASA may have decided that these experts were not necessary based on its new internal direction in research goals, lack of these personnel complicates supporting other researchers using the available ISS research facilities and conducting research separate from NASA's goals. For example, according to a senior official from the nonprofit USRA, NASA has a contract with USRA at Glenn Space Center to assist researchers conducting studies at the National Center for Microgravity Research because NASA no longer has the broad base of scientific experts available to provide this service to potential microgravity researchers. NASA directs other users to implementation partners, or companies that have scientific and technical expertise that can assist users in developing hardware and experiments. With NASA having lost scientific expertise in certain areas, there is a shortage of experts able to assist ISS researchers who are not conducting research pertinent to NASA's goals in developing and conducting their experiments.

Significant User Outreach

The national laboratories and other large, user-based science institutes we studied place a high priority on conducting outreach to current and potential users and hold conferences and workshops on a regular basis for this purpose. For example, NSF hosts the New Investigator Workshop to recruit scientists who want to know more about the polar programs, and uses this opportunity to tell them how to draft a research proposal to conduct experiments in the Arctic and Antarctic. The national laboratories reserve portions of their budgets to pay for speakers to attend lectures and workshops, and they will also host "schools" where scientists can come together and stay at the laboratory to study the basic and advanced research techniques applicable to specific laboratory facilities. One facility at Brookhaven has developed a piggybacking concept in which new investigators are paired with an experienced user to learn how the science is conducted at the facility. Educational outreach is a tool used by the national laboratories and science institutes to lure not only scientists and companies but also to generate public interest. The national laboratories also participate in the National User Facility Organization, which consists of representatives from 30 user facilities, attracts about 25,000 users, and provides a unified voice for the scientific community and a forum for them to share their work. Officials we spoke with from several of these facilities told us that managing their user community and ensuring that their facilities were responsive to user needs was critical to ensuring continuing interest in using their facilities.

NASA's ability to do large-scale outreach initiatives on its own has been limited by existing resources and other factors. NASA's ISS National Laboratory Office has a small staff (recently increased to five employees and not exclusively dedicated to outreach; NASA officials expect to eventually have as many as 10 staff), for outreach activities, and NASA conducts outreach with funding from its budget for space operations. NASA has reached out to researchers and other interested parties in an effort to attract users to the ISS National Laboratory. For example, the agency has established National Lab Pathfinders, where designated companies and other entities were identified by NASA for their ability to engage in early utilization of the ISS with the aim of inaugurating the ISS National Laboratory research program. According to NASA, this program has resulted in six flight experiments from commercial partners and two flight experiments from USDA. NASA has also teamed with NIH, which has made a recent program announcement for ISS research. NASA has conducted outreach to potential NIH grant applicants and participated in a meeting in June 2009 where NASA and NIH officials met with potential researchers to discuss ISS research capabilities. This meeting brought potential researchers together with NASA, NIH, and "implementation partners" that are able to supply researchers with specialized hardware for their research, and information about hardware and research capabilities was discussed.

Based on our analysis, observations of outreach practices at other national laboratories and science institutions, and comments from researchers we spoke with, we believe that NASA needs to conduct more outreach and education. We were told that some potential researchers in industry were only informed about the ISS because they already had past employment or business ties with NASA or because they heard about ISS research opportunities via a third party advocating for ISS utilization. Others told us that they knew nothing of the value of ISS research until they had it explained to them on a one-on-one basis and that a broader education campaign might be a good way to interest more users. In addition to their other outreach efforts, the national laboratories we studied both have robust Web sites with considerable information that would be helpful in educating potential users. Though NASA has information on its ISS-related Web sites about the ISS and research conducted, the focus appears to be presenting successes rather than making user educational information—such as complete information on available hardware, available implementation partners, opportunities of microgravity research, and details about research results (including failures and the causes for any failures)—easy to find.

Conclusions

Unless the decision is made to extend ISS operations, NASA has only 5 years to execute a robust research program before the station is deorbited, which is little time to establish a strong utilization program. A viable user base will not develop without sufficient launch opportunities to permit recurring access, consistent funding opportunities, sufficient crew time to conduct research, and longevity of the ISS. However, despite these challenges, the on-orbit laboratory offers the potential for scientific breakthroughs, a unique test bed for new technologies and applications, and a platform for increased international collaboration in research. Having a central body that is able to: represent all the ISS user communities (including NASA, other federal agencies, the commercial sector, and academia); oversee the selection of all ISS research; and ensure that the research being conducted is meritorious, peer-reviewed where appropriate, and not duplicative may assist in achieving full utilization of the ISS and its unique capabilities and maximize the possibility of achieving research successes on board the ISS. There is no direct analogue to how something like the ISS National Laboratory should or could be managed, so the specific structure that should be developed will require further consideration.

If the decision is made to cease ISS operations in 2015 and to not provide additional resources for research, there are management actions focused on education and outreach that could be easily and quickly implemented to allow NASA to better support and inform users. If the decision is made to extend the ISS past its current retirement date of 2015 and to try to fully utilize all ISS research resources, then there are several major actions that NASA can take to build a robust user base and ensure that high-caliber science is being conducted. These actions will take more time—potentially years—and additional resources to implement. Though it may not be possible to establish a management structure similar to those found at other national laboratories that have been in existence for much longer than the ISS in the limited time remaining, NASA may be able to leverage existing agreements with management bodies to provide for a faster solution, or leverage the scientific and technical expertise of other sponsoring federal agencies (such as NIH) that have experience in conducting peer-reviewed research in areas pertinent to their missions.

Recommendations for Executive Action

If the Administration and NASA decide to retire the station in 2015 and to continue utilizing the ISS without increasing resources, we recommend that the NASA Administrator take the following four steps:

- Develop and implement a plan to broaden and enhance ongoing outreach to potential users, including those in the commercial sector, with consideration given to the tight time frames for the ISS.
- Further develop online ISS information materials to provide easy access to details about laboratory facilities, opportunities presented by microgravity, available research hardware, resource constraints, and the results of all past ISS research, including successes and failures.
- As information develops, inform users on how launch capabilities will be provided to users of the ISS, including how regular these launches will be and what the cost will be (if any) to the users.
- If full utilization of available USOS facilities on board the ISS is not possible, consider sharing excess research capacity with the international partners on a quid pro quo basis.

If the administration and NASA decide to extend ISS operations beyond 2015 and to provide the resources required for enhanced utilization of the ISS research facilities, we recommend that the NASA Administrator take the following three steps:

- Implement the first three steps recommended above.
- Establish a body that centrally oversees U.S. ISS research decision making, including the selection of all U.S. research to be conducted on board and ensuring that all U.S. ISS research is meritorious and valid. This

body should also be able to strategically prioritize research proposed by many potential sponsors.

- Ensure that potential and actual ISS users have access to scientific or technical expertise, either in-house or external, in the areas of research relevant to the ISS that can provide assistance to users as required.

Agency Comments

In commenting on a draft of this report, NASA concurred with all seven recommendations. NASA's written comments are reprinted in appendix II. NASA also provided technical comments which were incorporated as appropriate.

We are sending copies of this report to NASA's Administrator and interested congressional committees. The report also is available at no charge on GAO's Web site at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-4841 or chaplainc@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report are provided in appendix III.

Cristina Chaplain
Director
Acquisition and Sourcing Management

Appendix I: Scope and Methodology

To identify how the International Space Station (ISS) is being utilized at present, we reviewed National Aeronautics and Space Administration (NASA) documentation pertaining to available on-station hardware and current scientific investigations that are using this hardware, including the *Consolidated Operations and Utilization Plan 2008-2015*; the *Reference Guide to the International Space Station*; and NASA's *ISS Science Prioritization Desk Instruction*. We also interviewed NASA officials at headquarters and Johnson Space Center, including officials from the Space Operations Mission Directorate (SOMD), and the Exploration Systems Mission Directorate (ESMD). We also spoke with officials from the Japanese Aerospace Exploration Agency (JAXA) and the European Space Agency (ESA). We also met with an official from The Boeing Company, which is the contractor responsible for the design, development, testing, and operation of the ISS.

To identify how the ISS will be utilized once assembly is completed, we analyzed NASA documentation identifying available on-station hardware once assembly is complete and NASA projections for future NASA requirements. We also met with officials from NASA SOMD and NASA ESMD, and we spoke with researchers from academia, specifically researchers from North Carolina State University, Arizona State University, Case Western University, the University of Colorado-Boulder, Medical College of Wisconsin, Georgia Institute of Technology, Northwestern University, and Pennsylvania State University. These researchers were largely selected because they provided congressional testimony about conducting ISS research or because they were recommended as contacts by NASA or the National Academies of Science. We interviewed implementation partners for NASA, including BioServe Space Technologies and the Universities Space Research Association. We also attended NASA presentations to the National Academies of Science Decadal Survey on Biological and Physical Sciences in Space Committee regarding the ISS and its capabilities and utilization. It is important to note that no good metric exists for precisely quantifying the output of scientific research facilities, including the ISS. For example, number of experiments conducted is not a good metric for measuring utilization because it is unclear what baseline should be used for comparison, and the number of publications is not ideal since not all research is ultimately published. We also considered analyzing the use of electrical power on each utilization rack to determine how frequently they were powered up, but the racks do not have power meters and thus these data cannot be collected.

To identify the challenges to fully maximizing the ISS, we interviewed NASA officials in the ISS Program Office as well as in NASA's ESMD and

SOMD and a former NASA official. We reviewed reports from the National Research Council—an organization consulted by NASA on its ISS research program—including *Factors Affecting the Utilization of the International Space Station for Research in the Biological and Physical Sciences* (2003), *Institutional Arrangements for Space Station Research* (1999), *Review of Goals and Plans for NASA's Space and Earth Sciences* (2006), and *Review of NASA Plans for the International Space Station* (2006). We also met with officials from the National Academies of Science—whom NASA consulted on several occasions to review ISS research goals and management—and reviewed their report *Elements of a Science Plan for the North Pacific Research Board*. We reviewed the Computer Sciences Corporation's *International Space Station Operations Architecture Study* (2000) that was prepared for NASA. We also interviewed former, current, and prospective scientists and researchers who have had experience conducting research onboard the ISS or who were interested in conducting future research, including the academic researchers listed above as well as officials from WiCell Research Institute, Zero Gravity Inc, and Ad Astra Rocket Company. We also spoke with officials from the Department of Agriculture, the National Space Biomedical Research Institute, and the National Institutes of Health and the National Space Biomedical Research Institute, which have existing agreements or memorandums of understanding with NASA to conduct ISS research. Further, we interviewed officials from the Universities Space Research Association and BioServe Space Technologies, both of which assist scientists in conducting space research with NASA.

To determine how NASA is managing the ISS, we interviewed NASA officials and reviewed NASA plans and documentation, including its *Consolidated Operations and Utilization Plan 2008*; *ISS Utilization Management Concept Development Study*; *Research and Utilization Plan for the International Space Station*; *Commercial Development Plan for the International Space Station*; *Reference Guide to the International Space Station*; *NASA ISS Prioritization Desk Instruction; Human Research Program: Integrated Research Plan*; *Advanced Capabilities Division: International Space Station (ISS) Science Portfolio*, *Determination and Management*; *NASA Report to Congress: Regarding a Plan for the International Space Station's National Laboratory*; *Plan to Support Operations and Utilization of the International Space Station Beyond FY 2015*; and NASA's *Organizational Model Evaluation Team Process, Analysis, and Recommendations*. We also we reviewed NASA's international partner agreements. We also reviewed various National Research Council reports, including *Factors Affecting the Utilization of the International Space Station for Research in the Biological and*

Physical Sciences (2003), *Institutional Arrangements for Space Station Research* (1999), *Review of Goals and Plans for NASA's Space and Earth Sciences* (2006), and *Review of NASA Plans for the International Space Station* (2006). We also reviewed the Computer Sciences Corporation's *ISS Operations Architecture Study* (2000) and prior GAO reports.

To determine how NASA's management of the ISS compares to the management of other national laboratories and large science institutes, we spoke with officials at the Department of Energy (DOE) who are responsible for the DOE national laboratories. We also spoke with officials from the National Energy Technology Laboratory, which is DOE's only government-owned, government-operated laboratory. Further, we visited Argonne National Laboratory (Illinois) and Brookhaven National Laboratory (New York), and spoke with officials at these laboratories representing the National User Facility Organization. We also spoke with officials from the Space Telescope Science Institute, which is the body that manages NASA's Hubble Space Telescope. We selected these facilities in part because of NASA's suggestions, and in part because they are all multidisciplinary facilities conducting a wide range of research tasks. To understand the challenges posed by conducting research in remote, hostile environments with high logistics costs, we spoke with officials at the Woods Hole Oceanographic Institute, which operates oceangoing research ships and submersibles in remote and potentially hazardous environments, and we met with officials from the National Science Foundation who are responsible for managing the Office of Polar Programs, which manages research conducted in the Arctic and Antarctic. These two programs offer some analogue to conducting research in space.

We conducted this performance audit from November 2008 through October 2009 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.

Appendix II: Comments from the National Aeronautics and Space Administration

National Aeronautics and
Space Administration
Office of the Administrator
Washington, DC 20546-0001

November 18, 2009

Ms. Cristina Chaplain
Director, Acquisition and Sourcing Management
United States Government Accountability Office
Washington, DC 20548

Dear Ms. Chaplain:

NASA appreciates the opportunity to comment on your draft report entitled, "International Space Station: Significant Challenges May Limit Onboard Research," (GAO-10-9).

In the draft report, GAO makes a total of seven recommendations relating to utilization of the International Space Station (ISS). The recommendations are distributed across two potential scenarios of ISS utilization, specifically:

A. If the Administration and NASA decide to retire the station in 2015 and to continue utilizing the ISS without increasing resources, we recommend that the NASA Administrator take the following four steps:

Recommendation 1: Develop and implement a plan to broaden and enhance ongoing outreach to potential users, including those in the commercial sector, with consideration given to the tight time frames for the ISS.

Response: Concur.

Recommendation 2: Further develop online ISS information materials to provide easy access to detail about laboratory facilities, opportunities presented by microgravity, available research hardware, resource constraints, and the results of all past ISS research, including both successes and failures.

Response: Concur.

Recommendation 3: As it develops, inform users on how launch capabilities will be provided to users of the ISS, including how regular these launches will be and what the cost will be (if any) to the user.

Response: Concur.

2

Recommendation 4: If full utilization of available United States operating segment facilities on board the ISS is not possible, consider sharing excess research capacity with the international partners on a quid pro quo basis.

Response: Concur.

B. If the Administration and NASA decide to extend ISS operations beyond 2015 and to provide the resources required for enhanced utilization of the ISS research facilities, we recommend that the NASA Administrator take the following steps:

Recommendation 5: Implement the first three steps recommended above.

Response: Concur.

Recommendation 6: Establish a body that centrally oversees U.S. ISS research decision making, including the selection of all U.S. research to be conducted on board and ensuring that all U.S. ISS research is meritorious and valid. This body should also be able to strategically prioritize research proposed by many potential sponsors.

Response: Concur with comment. NASA agrees with the recommendation. However, as noted by GAO in the draft report's conclusions (p. 27), "NASA may be able to leverage existing agreements with management bodies to provide for a faster solution, or leverage the scientific and technical expertise of other sponsoring federal agencies (such as NIH) that have experience in conducting peer-reviewed research in areas pertinent to their missions." Therefore, NASA will first look to meeting this recommendation by establishing a "centralized management body" internal to the Agency. This is essential to ensuring an effective interface with an external organization(s).

Recommendation 7: Ensure that potential and actual ISS users have access to scientific or technical expertise, either in-house or external, in the areas of research relevant to the ISS that can provide assistance to users as required.

Response: Concur.

Thank you again for the opportunity to review this draft report. We are looking forward to your final report to Congress. If you have any questions or require additional information, please contact Mark Uhran at 202-358-2233.

Sincerely,

Lori B. Garver
Deputy Administrator

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Cristina T. Chaplain, (202) 512-4841 or chaplainc@gao.gov

Acknowledgments

In addition to the contact named above, James L. Morrison, Assistant Director; Greg Campbell; Cheryl M. Harris; C. James Madar; Diana L. Moldafsky; Kenneth E. Patton; Timothy M. Persons; Leah L. Probst; and Alyssa B. Weir made key contributions to this report.

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NASA: Constellation Program Cost and Schedule Will Remain Uncertain Until a Sound Business Case Is Established. GAO-09-844. Washington, D.C.: August. 26, 2009.

NASA: Commercial Partners Are Making Progress, but Face Aggressive Schedules to Demonstrate Critical Space Station Cargo Transport Capabilities. GAO-09-618. Washington, D.C.: June 16, 2009.

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