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BACKING THE STATION

The International Space Station is entering its final decade of international research and operations. NASA often touts the station as a proving ground for technology aimed at deep space — the moon and Mars. Veteran astronaut and station-builder Tom Jones examines what exploration work NASA and its partners are planning at ISS, and whether the results from their orbiting lab will arrive in time to help.

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NASA points to the International Space Station as its test bed for technologies and techniques needed to establish humans at the moon and, eventually, Mars. But continued ISS funding beyond 2024 is uncertain, and may reduce those funds needed for human expeditions into deep space. If NASA wants to eliminate the deep-space unknowns facing its astronauts, and reap a bigger return on the more than $80 billion the U.S. has spent on its construction and operation, it must step up its game at the ISS. That means finding the resources needed to keep the ISS open for research beyond 2024, and accelerating its exploration-focused research there.

▲ The inflatable Bigelow Expandable Activity Module, center, is a potential deep-space habitat in the middle of a two-year demonstration mission at ISS.

Searching for exploration answers

Since crews began living and working on the station in 2000, some research has always been aimed at enabling humans to conduct long-duration expeditions to the moon, near-Earth asteroids, or Mars, such as studies of how to keep astronauts healthy during months spent living in free fall.

For example, physiologists have worked hard to understand and prevent the debilitating effects of free fall (weightlessness) on the heart, lungs, skeletal muscles and bones. Over the past 16 years of ISS habitation, crew health experts have developed a vigorous exercise protocol — 90 minutes per day — that largely maintains cardiac health, lung capacity and muscle tone. Even bone mass loss has been reduced to "tolerable" levels for six months or more in free fall. The exercise machines — a treadmill bicycle ergometer and a strength-training device — are bulky and heavy. Their extensive use and failure history at ISS are aiding the design of smaller, lighter and more reliable fitness machines for service in deep space.

But questions on long-term health in free fall remain. More than half of ISS astronauts experience changes in vision, usually nearsightedness, which sometimes persists well after return to Earth. The retinal changes observed are similar to those experienced by patients with elevated cerebrospinal fluid pressure. Researchers suspect that the headward shift in body fluids seen in free fall puts increased pressure on the optic nerve and retina, changing their shape and altering vision. NASA is just beginning to evaluate countermeasures such as applying negative pressure to the lower extremities to reduce intracranial pressure. Preventing

◀ The International Space Station can be the base of important research before the countries that support it withdraw funding, according to scientist and former astronaut Tom Jones.

NASA

Questioning spending on ISS

The House Committee on Science, Space and Technology cautioned against applying NASA funds to operate the International Space Station beyond 2024. It tweeted on March 22, "The longer we operate the ISS, the longer it will take to get to Mars," and included this chart.

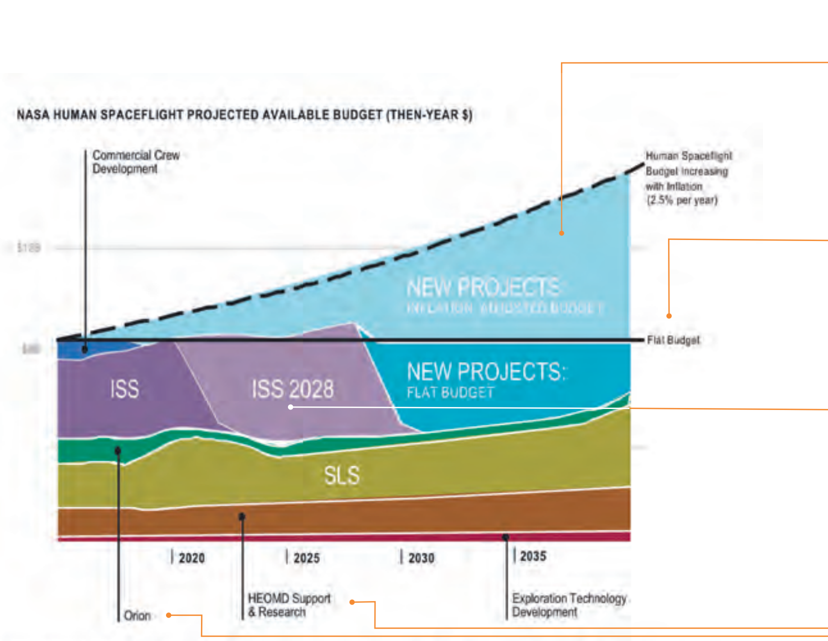


FIGURE 4.29 Projected available budget and costs of the currently planned human space flight program.

Source: "Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration (2014)," National Academies Press

adverse (and perhaps permanent) vision changes is a high priority, and deserves sustained NASA focus.

One of the most highly visible exploration-driven experiments at ISS was astronaut Scott Kelly's 340-day stay in orbit in 2015-16 — longer than a transit to or from Mars. After landing, Kelly showed some deficiencies in muscle dexterity, postural control and fine motor skills. Overall, however, Kelly's experience showed that a year in space is not significantly more stressful than a six-month stay.

Reliable and efficient human life support systems are essential on journeys far from Earth, where spare parts are not available and system performance is a matter of life and death. Future systems may include space-grown plants, which can recycle crew CO_2 and waste while producing oxygen and fresh food. At ISS the Vegetable Production System (Veggie) is testing methods for plant growth in free fall. The experiment grows salad-type crops like lettuce or cabbage to supplement the shelf-stable, preserved foods comprising the astronauts' menu. A new Advanced Plant Habitat will expand farming to arabidopsis, small flowering plants related to cabbage and mustard.

The new plant habitat was to arrive at the ISS on an Orbital ATK Cygnus cargo freighter in April. Crews still grapple and berth arriving cargo ships like Cygnus, Dragon and Japan's H-II Transfer Vehicle using manual robot arm controls. Future modules bound for deep space will probably be assembled robotically, as various components arrive to become integral parts of a larger craft.

To develop such autonomous techniques, NASA launched to the ISS in February a relative navigation sensor suite, called Raven. The size of a roll-on suitcase, Raven will operate from the ISS port truss, tracking arriving and departing spacecraft with visible and IR cameras and a flash LIDAR (laser) ranging system. Using Raven, NASA hopes to mature the sensors, machine vision algorithms and processing needed to conduct autonomous rendezvous and docking, both for satellite servicing and assembly of future Mars-bound spacecraft.

These are all worthy investigations, but NASA's challenge now is to make sure it gets remaining answers out of ISS before its decommissioning, perhaps as early as 2024. Because of the time needed to conceive, develop and launch exploration-driven experiments to ISS, NASA must put its most important research in motion within the next couple of years — certainly before 2020.

Keeping the research window open

The station's programmed demise means NASA must prioritize exploration work there to reap results in time. Although NASA would like four extra years to conduct vital deep-space research at ISS, doing so would force difficult funding choices. On March 21, President Trump signed the NASA Transition Authorization Act of 2017; the new law calls for "maximizing utilization of the International Space Station," including research meant to develop and test exploration technologies. But the law provides no extra funding to do so.

Some in Congress view ISS funding (about $3 billion annually) as diverting NASA's focus from Mars. At a March 22 hearing on the station's future, Rep. Brian Babin, R-Texas, chairman of the House Space subcommittee, said in his opening statement, "We ought to be aware that remaining on the ISS [beyond 2024] will come at a cost." Babin further warned, "Tax-dollars spent on the ISS will not be spent on destinations beyond low Earth orbit. …The longer we operate the ISS, the longer it will take to get to Mars."

NASA associate administrator for human exploration and operations, Bill Gerstenmaier, responded in testimony: "It's ... wrong to assume that ISS and exploration are competing. … They're really helping each other." Gerstenmaier cited the crew health research underway at ISS, but there are many opportunities for exploration technology and science work still unfulfilled. NASA must start planning, developing and flying these investigations as soon as possible, lest its research window close in 2024 with vital questions left unanswered.

Open work

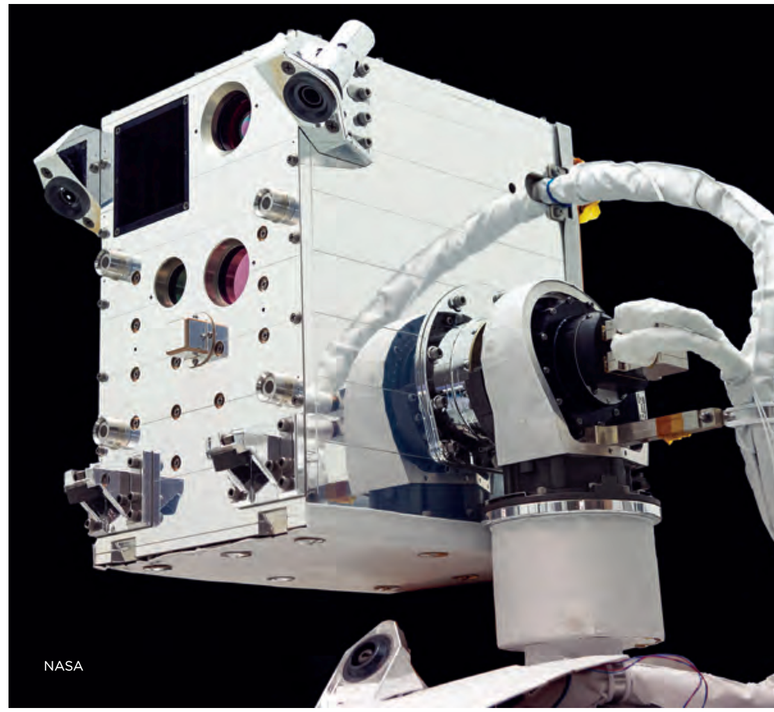
To take full advantage of ISS in solving its exploration challenges, NASA should put new or expanded demonstrations like these on its station "to do" list, shifting funds within the human spaceflight budget as necessary:

• Expanded trials of deep-space habitats, such as the inflatable Bigelow Expandable Activity Module. NASA should commission and fly a full-scale inflatable habitat structure and evaluate it for strength, radiation protection and durability against micrometeoroids.

• Tests at ISS of next-generation life support systems, further closing the recycling loop for wastewater and exhaled carbon dioxide. These systems should demonstrate improved efficiency, reliability and reduced maintenance.

• Rigorous ISS testing of a new exploration spacesuit with greater dexterity, mobility and durability. Astronauts could identify any flaws in its life support system, high-capacity batteries, radiation shielding and human-machine interfaces before committing it to more demanding planetary surface work.

• Evaluation of new radiation protection materials and countermeasures to reduce astronauts' cosmic ray exposure. Promising materials and methods can then be tested further in lunar orbit, outside Earth's magnetosphere.



▲ Raven is deployed outside the ISS to test sensors that may make it easier to operate spacecraft autonomously.

• Introduction of improved food technologies that reduce packaging weight, yet preserve the taste and nutritional value of space fare.

• Deployment of a portable centrifuge at ISS, testing the ability of a rotating, partial-G environment to maintain the health of laboratory animals in extended free fall.

• Tests of free-fall extraction of water and metals from meteorites, and later, returned asteroid material, aimed at in-space propellant production to support Mars expeditions.

Not every deep-space challenge can be solved at ISS. The station's low Earth orbit, for example, is well within Earth's magnetosphere, and so doesn't replicate the solar flare and cosmic ray radiation environment found at the moon and beyond. But if NASA uses a small fraction of its exploration funding to fly and test real hardware at ISS, it can show rapid and sustained progress in eliminating its deep-space unknowns.

By extending station operations through 2028, NASA will be able to demonstrate frequent, visible progress toward deep space, showing the seriousness of its efforts to reach the moon and Mars. By maximizing its technology and operations return from ISS and keeping those answers coming through 2028, NASA can also showcase its value to potential commercial operators, who would ideally take over station operations in the late 2020s.

Instead of treating ISS as a financial millstone beyond 2024, NASA should ensure that its expansive orbital outpost, purchased so dearly over three decades, could deliver the exploration answers we need. ★