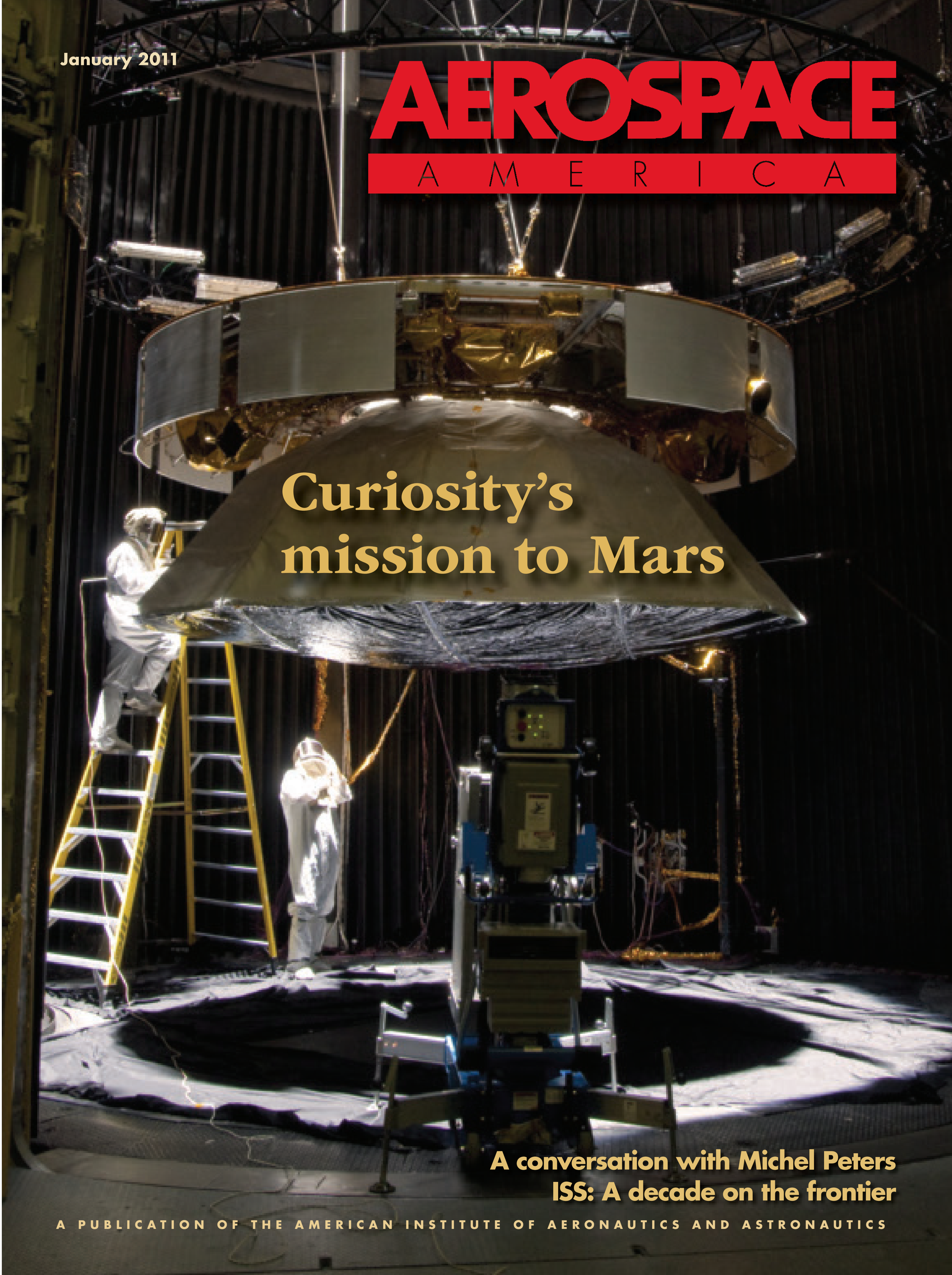

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Curiosity's mission to Mars

A conversation with Michel Peters
ISS: A decade on the frontier

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ISS: A decade on the frontier

THE INTERNATIONAL SPACE STATION is our lone toehold on the frontier of deep space. Sometime after 2020, NASA astronauts may venture again beyond the confines of LEO, perhaps to an asteroid, perhaps to chase other nations to the surface of the Moon. But for the next 10 years and beyond, as it has been since November 2000, the U.S. destination in orbit will be the ISS, humanity's classroom for human spaceflight.

The ISS was born on December 7, 1998, when the first two modules were joined by the STS-88 shuttle crew. The Expedition 1 crew took up residence on Nov. 2, 2000. On October 25, 2010, the ISS surpassed Mir's 3,644 days as history's longest continually inhabited space station. As of last November, more than 196 individuals have visited the ISS, including seven private space travelers.

When I floated aboard in February 2001, the three-person crew already had far more elbow room than the shuttle; today, the station's work and living spaces are the equivalent of a five-bedroom house. Amenities include two bathrooms, a gym, and a seven-pane "bay window" (the cupola) with a breathtaking view of Earth 220 miles below.

Who's in LEO?

The ISS crew complement expanded from three to six in May 2009. Its current residents (as planned at press time) are the astronauts of Expedition 26: Scott Kelly (commander), Alexander Kaleri, Oleg Skripochka, Catherine Coleman, Dmitry Kondratyev, and Paolo Nespoli. The latter trio was due to arrive on December 15, 2010, and will stay aboard through May 2011. With delivery of the permanent multipurpose module Leonardo on Discovery's final flight, the ISS will expand to 12,000 ft^3 of pressurized living space. The last planned pressurized addition is the Russian Nauka multipurpose laboratory module, scheduled for arrival late this year.

NASA marked the 10-year crew presence milestone with November ceremonies. Peggy Whitson, NASA's chief astronaut and, on Expedition 16, the station's first female commander, noted:

"To have constructed something on orbit greater than a football field in length, with more internal pressurized volume than a 747, with parts and pieces and participation from 15 countries around the world, full-time 24-hour/7-day-a-week operations, and human presence for 10 years, fills me with an incredible sense of pride in what our organization can accomplish."

In the Tranquility node, NASA astronaut Doug Wheelock, Expedition 25 commander, works to install the new Sabatier system that will extract more water out of the ISS atmosphere.

Shift to science

That achievement is visible regularly in the evening or morning sky as a brilliant star traversing the heavens [see http://spaceflight.nasa.gov/realdata/sightings/]. The station's truss—its structural backbone—spans 108.5 m (about 0.75 acre), supporting the four immense but delicate solar arrays that generate most of the outpost's power. Much of that electricity will help the ISS achieve its original purpose, scientific research.

Col. Timothy J. "TJ" Creamer, who worked aboard the station on Expeditions 22 and 23, said in an interview that "It was a privilege and a blessing to have served on the ISS on the cusp of its career. During my tenure there, construction was nearly completed, and ISS was shifting from its assembly phase to utilization."

In its first decade, the orbiting laboratory has supported more than 600 experiments in the unique, nearly zero-gravity environment. ISS communication resources give researchers and engineers continuous access for fine-tuning their investigations. Between now and 2020, the research facilities will support not only fundamental science investigations, but also trials of promising exploration technologies.

NASA and its partners are currently using the research facility for long-planned experiments in the three laboratories: the U.S. Destiny, European Columbus, and Japanese Kibo. In the past decade, 59 countries have been involved in research in disciplines as varied as the physical sciences, life sciences, planetary and Earth science, heliophysics, and astrophysics [see www.Nasa.gov/iss-science/]; for example:

•The smoke aerosol measurement experiment found that burning spacecraft materials in free-fall produced soot particles 50% larger than those in terrestrial cabin fires. Studies of smoke propagation identified inadequacies in current spacecraft smoke detector technology, with a goal of improved astronaut safety.

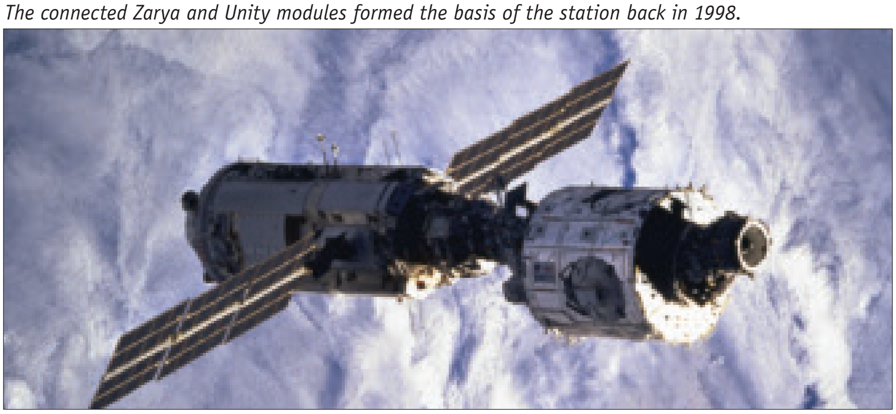
•The Kibo-mounted MAXI (monitor of all-sky X-ray image) experiment uses highly sensitive X-ray slit cameras to survey for energetic sources like neutron stars and black holes. On September 25, the instrument discovered a new stellar nova whose center likely harbors a black hole. Astrophysics research will take a major step up when the massive alpha magnetic spectrometer arrives in early March, searching for energetic atomic particles linked to the cosmos' dark matter and energy.

Astronaut Susan J. Helms works at the Human Research Facility's ultrasound flat screen display and keyboard module in the Destiny/U.S. Laboratory.

•Astronauts were trained in orbit to use the advanced diagnostic ultrasound in microgravity (ADUM) experiment, testing new guiding methods to obtain rapid, accurate diagnostic ultrasound images. The space proven techniques have found application on Earth in remote diagnoses everywhere from Mt. Everest to Inuit maternity clinics.

•The nutritional status assessment study has demonstrated that ISS astronauts, living indoors under artificial lighting for months at a time, are deficient in vitamin D. Resulting vulnerabilities may include depression, chronic fatigue, weight loss, diabetes, heart disease, stroke and osteoporosis. The study also showed that adding omega-3 fatty acids to space food counteracted bone loss, a finding since confirmed by ground-based cellular studies and bed-rest results.

The connected Zarya and Unity modules formed the basis of the station back in 1998.



If on-orbit diet supplements can protect against bone loss, they may eliminate one of the major challenges of extended deep space voyages, as well as aiding osteoporosis patients back on Earth.

•ISS investigations since 2008 into microbial gene expression and virulence have revealed that pathogens like the common salmonella bacterium become more virulent in free fall. The resulting insight into the genetic trigger of this effect has led Astrogenetix to investigate a candidate antimicrobial drug.

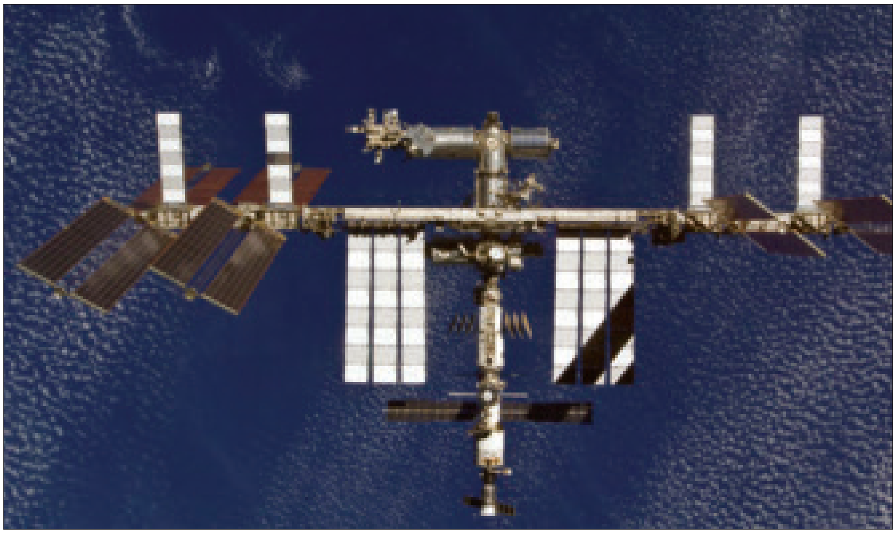
•AiroCide TiO_2, an air purification technique developed for the station's onboard mini-greenhouse, has demonstrated the ability to remove anthrax spores and similar pathogens from indoor spaces like mail handling facilities.

The space station is now engaging the imaginations of future explorers. Already, over 31 million students have viewed educational demonstrations conducted by ISS crewmembers, with 900,000 participating directly in research projects aboard. The careers of some of these aspiring scientists, engineers, and astronauts might one day take flight thanks to the ISS. In the Apollo era, students like me were captivated but passive observers of events unfolding on the Moon. Today, young experimenters can interact with crewmembers and researchers on Earth and aboard the station, participating in the process of scientific discovery.

During Expeditions 25 through 30, astronauts working in the three labs of the U.S. orbital segment will conduct 333 scientific investigations; Russian cosmonauts will operate experiments in the Poisk and Rassvet research modules farther aft. About a thousand scientists have been involved to date in ISS research.

An international panel of research

advisors recently cited the ISS characteristics attracting potential users: continuous access to microgravity, with gravity as a controlled experimental variable; high vacuum and conditions to create ultra-high vacuum; continuous presence in space for long experimental runs and cumulative results; and significant power and instrument support for geophysical and environmental observations from LEO, with an orbit covering over 90% of Earth's populated surface.



An STS-132 crewmember aboard Atlantis captured this view after the station and shuttle began their post-undocking separation.

Exploration testbed

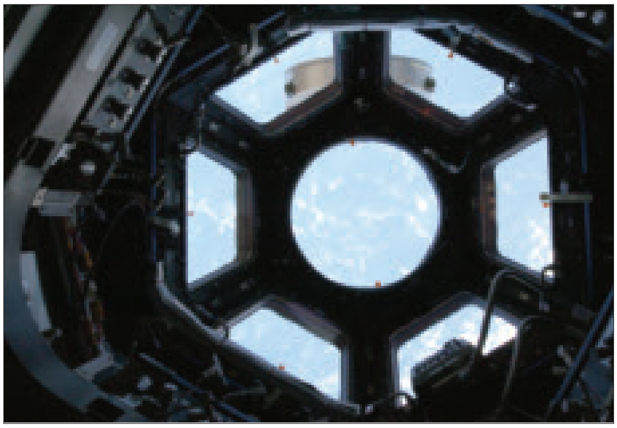
"We're now looking ahead to using the ISS as a platform for teaching us how to get to Mars," says Creamer. "We must extend this platform's original purpose from pure research to help us take on the challenges of deep space exploration. We can use the ISS as a testbed, incorporating challenges like communications delays, onboard autonomy, and new technologies like life support."

Other technology areas include crew health systems for exercise and radiation protection, advanced solar power systems, propulsion innovations, new spacesuits and mobility gear, inflatable habitats, and handling of planetary "ores" for space resource utilization.

One example of such exploration-driven experiments was the October activation of a water-generation system that recycles two ISS waste products. Hamilton-Sundstrand's Sabatier reactor, installed in the Tranquility node, combines hydrogen released by the station's waste-water-to-oxygen system with carbon dioxide exhaled by the crew to produce water and methane gas (CH_4). The water is purified for crew use while the methane vents overboard. The 530 gallons of water generated annually will further close the life support loop, and reduce water demand even as the era of shuttle-supplied water ends.

The crew and flight controllers will work together on simulations to mimic operations during a deep-space voyage. "ISS is a great analog for the Mars transit phase" of an interplanetary mission, says Creamer. Controllers will introduce communications delays caused by extended light-travel times, and the crew will do without real-time interaction with the ground. These exercises should point to command, control, and planning software needed on extended deep-space missions.

Developed and built by Thales Alenia Space in Italy, the cupola is a spectacular technological, robotized control room that allows the astronauts to see and work through seven windows, looking out 360° around the ISS.



A steady stream of exploration testing should follow these first steps aboard the station. The astronauts should check out a new generation of more flexible, comfortable spacesuits. Meteoritic and lunar materials should be fed into resource extraction processors operating in free fall. And lunar rover designs derived from Constellation may evolve into free-flying spacecraft like NASA's space exploration vehicle, to be tested at ISS before ferrying astronauts to the surface of a near-Earth asteroid.

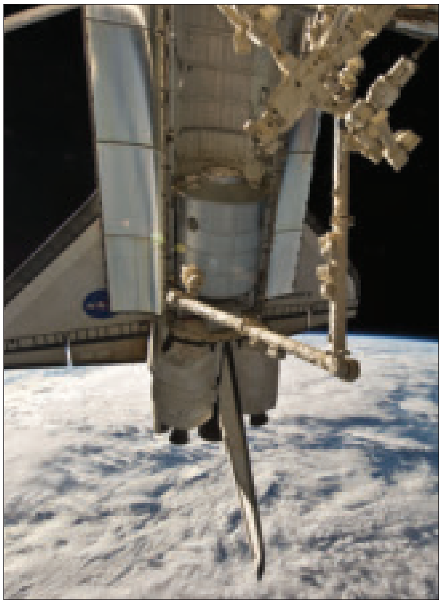
Astronaut guinea pigs are still in demand, too. Creamer notes that "Our return to Earth from the station gives us a chance to explore ways of getting a crew back on their feet in a *g*-field and working efficiently after arriving on the surface of a new planet. We have to deal with re-adapting the inner ear, muscle tone and mass, and strength and coordination to working well in gravity again." He recalls that after landing "it took me about five days to be able to walk a straight line again, and two to three weeks before I considered myself fully competent at driving."

Space station 2020

President Obama's FY11 budget proposes funds to support NASA ISS operations through 2020, in keeping with a goal endorsed last year by the ISS partners. They also agreed to examine the technical and programmatic feasibility of extending the ISS's life through at least 2025.

The station may not be alone in LEO by then: two Russian companies have proposed a commercial space

Parts of Europe and Africa are easily recognizable in this nighttime image shot by one of the Expedition 25 crewmembers flying 220 mi. above Earth.



Canadarm2 grapples the Leonardo MPLM from Discovery's payload bay for relocation to a port on the Harmony node of the ISS.

station, to be launched in 2016, and Bigelow Aerospace plans to use its inflatable Sundancer and BA330 modules in constructing a platform to host tourism and industrial activity sometime after 2015.

NASA hopes the ISS has at least 15 years of useful life ahead. When structural or systems degradation leads to its abandonment, safe disposal will be neither simple nor cheap. The station's small maneuvering engines, even with added thrust from a docked Progress cargo/tug, do not have enough fuel to guide the 900,000-lb hulk into the Pacific. A purpose-built deorbit module will cost hundreds of millions of dollars to launch and dock; an additional cost will be the embarrassing visual of dumping the $100-billion station into the ocean (with many systems still functioning). Such a denouement will be a distinctly unpleasant option for NASA and space policy makers.

A far more attractive plan is to repurpose those still-valuable components and fold them into NASA's exploration infrastructure. Laboratories or life support modules could serve as crew living space on a deep space vehicle; the 358-ft truss might support a future propellant depot or transportation node at the Earth-Moon L1 Lagrange point. Alternatively, salvaged structures might form the nucleus of an assembly garage where deep space vehicles might be constructed and checked out.

In all such proposals, the salvage value of the orbiting hardware must exceed the cost of propellant needed to shift it to a new orbit, or to launch additional support components.

Taking stock of the station

Whatever its ultimate function, the space station's current challenge is to deliver a high-profile return on the tens of billions of dollars invested in its development and construction. Already the ISS has delivered valuable lessons on international cooperation and operations, and forged partnerships that have withstood disaster aloft and shifting geopolitical winds on Earth. But to truly realize its promise, early hints of promising discoveries from the three ISS laboratories must swell into a steady stream of productive research results.

For at least the next five years, ISS will be the sole focus of the agency's human activity in space. NASA has a window of opportunity to shape the public perception of the station's value through a solid record of scientific achievement. If NASA can deliver on its research strategy of providing new scientific knowledge, new exploration technologies, and new products and processes that pay off on Earth, we may judge ISS to be a success long before 2020. But if another decade of research proves irrelevant to improving life here, or is incapable of vaulting humans into deep space, then the space station will likely be NASA's last large venture into human spaceflight.

The NASA of the 1960s had Apollo. Today's agency has the international space station, and can make the ISS an indispensable waypoint in the economic development and scientific exploration of space. It can provide engineers, scientists, and managers the experience needed to project a human presence beyond LEO, to the nearby asteroids, to the lunar surface, and eventually to Mars.

But before it can reach beyond LEO, NASA must deliver on the station's promise. From its ambitious inception through its tumultuous development, the ISS has demanded much treasure, and more than two decades of dedication and personal sacrifice from the designers, operators, and crews who built it and made it their home. The station today is a monument to successful engineering, and a triumph of international collaboration. Matching that achievement with scientific excellence and practical results will demand the same intensity of purpose.

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