

Space station research to get new lease on life

The Obama administration extends operation of the orbiting outpost until 2024 in the hope that other partners will pitch in.

When Millie Hughes-Fulford, a molecular biologist and former astronaut, had an experiment flown on the International Space Station (ISS) in 2006, she and European colleagues helped resolve what had been a mystery: Why did more than half of all the Apollo astronauts acquire infections within a week of their return to Earth? Some reasoned that it was due to stress, and others to in-flight radiation, but her experiment proved that weightlessness had caused astronauts' T lymphocytes to malfunction and had thus lowered their immune response.

This month another Hughes-Fulford experiment is scheduled to fly to the ISS aboard SpaceX's *Dragon* cargo delivery vehicle. Using more sophisticated technology, she and her colleagues will be looking for specific genes that regulate T cells, hoping to find targets for drugs that will not only prevent space-travel infections but also help immune-compromised individuals on Earth.

The Obama administration's decision to extend operation of the ISS through 2024 provides an additional four years for such research. In announcing the extension to an international forum on space exploration on 9 January, White House science adviser John Holdren said the US is "allowing time for full and careful consideration" of extensions by Europe, Japan, Canada, and Russia, whose commitments to the ISS currently run only through 2020. A day earlier NASA associate administrator William Gerstenmaier told reporters that if necessary, the US is "prepared to do what we have to do if the other partners choose to take a different path." But at a minimum, he said, the US will need continued participation from Russia, whose Zvezda service module provides many ISS life support systems.

"I think the extension is a good idea," says Scott Pace, director of the Center for Interna-

tional Science and Technology Policy at the George Washington University. "The ISS is already a technical and diplomatic success. Whether it will be a scientific success will depend on utilization."

A national laboratory

The US alone will spend around \$3 billion this year on ISS operations, including crew and cargo transportation. According to a July 2013 report by NASA's Office of Inspector General, 70% of available US research space inside the ISS was occupied as of mid 2013, and the agency expected to increase utilization to 75% by late last year. But only about a third of the available US exter-

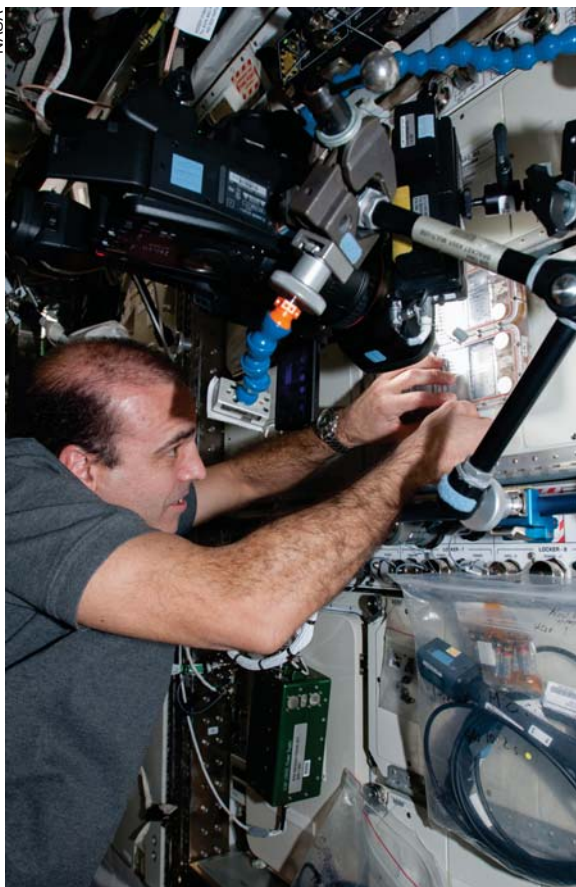
nal research space on the station was occupied last year.

The US Destiny lab module of the ISS was declared a national laboratory by an act of Congress in 2005, making roughly half of the available US lab space and crew time available for peer-reviewed research. NASA's own ISS research program, for which the other half is reserved, is overwhelmingly devoted to understanding and mitigating the human health impacts of long-duration spaceflight. A NASA spokesman says that inside the ISS the US has 18 refrigerator-sized experimental racks. Externally, the US has 22 experiment payload sites, each one square meter in size.

In mid 2011 NASA handed off the job of soliciting and administering non-exploration-related research projects to a newly formed nonprofit entity called the Center for the Advancement of Science in Space. The first cohort of five CASIS-sponsored projects was delivered to the ISS by Orbital Sciences' *Cygnus* cargo vehicle in January. Those projects study antibiotic effectiveness in space; the behavior of ants in microgravity; the movement of particles within colloidal suspensions and the way they crystallize, melt, and undergo phase separation; and a variety of experiments submitted by students.

Warren Bates, CASIS director of portfolio management, says the center selected 28 research projects in fiscal year 2013. In 2012, its first full year of operation, around 10 projects were awarded. But not all of them received funding. Under its contract with NASA, CASIS is obligated to award at least \$3 million in research grants each year; in FY 2013 it spent \$4.9 million on them. About 40% of awarded projects are unsolicited; the remaining awards have been in response to the three solicitations CASIS has released. Letters of intent for a fourth solicitation, covering remote sensing applications, were due last month.

The CASIS program focuses on projects that could provide benefits on Earth. About 40% of



NASA astronaut Rick Mastracchio works on an experiment examining the behavior of ants by comparing groups living on Earth with those in space. It is one of five experiments that arrived at the International Space Station in January 2014.

all proposals that have been submitted to CASIS have passed review and are eligible for funding. Bates, who acknowledges that the ISS is underutilized, says CASIS has formed partnerships with other nonprofit entities, such as Angelus Funding, MassChallenge, and the California Institute for Regenerative Medicine, to seek out alternative sources of funding. CASIS also has business development teams working in high tech areas such as Silicon Valley and Boston.

"If you are a researcher based in the US and you want to perform research on the ISS that's not related to exploration, we are the avenue you come to. Not NASA. Not ESA [the European Space Agency] or JAXA [Japan's space agency]," says Bates. "For the first time an organization other than NASA can grant access to an investigator to the US-owned portion of the ISS." In addition to any grant funding, experimenters get complimentary transportation of their apparatus and crew time from NASA.

No shortage of sponsors

Some ISS research sponsorship by other US agencies continues, at least for the time being. The National Institutes of Health is sponsoring three projects, including Hughes-Fulford's. The others will examine different questions about bone-cell behavior in microgravity: One focuses on cell regulation and metabolism and the other on the role bone cells known as osteocytes play in mechano-transduction. In the latter case, "It's critically important to us [to know] why it is that humans who are inactive from sickness and in bed, and people who are sedentary, lose bone," explains Joan McGowan, director of the division of musculoskeletal diseases at NIH's National Institute of Arthritis and Musculoskeletal and Skin Diseases. "What are the mechanisms that cue the bone cells that there is a gravitational pull?"

Notwithstanding the basic research role of CASIS, in January NASA announced that it had selected seven fundamental physics research projects to be conducted in the cold-atom laboratory, a new facility to be brought aboard the ISS in 2016. Those projects, with such names as "zero-g studies of few-body and many-body physics" and "microgravity dynamics of bubble-geometry Bose-Einstein condensates," will receive a total of \$12.7 million over 4-5 years. The projects are being managed by NASA's human exploration and operations mission directorate.

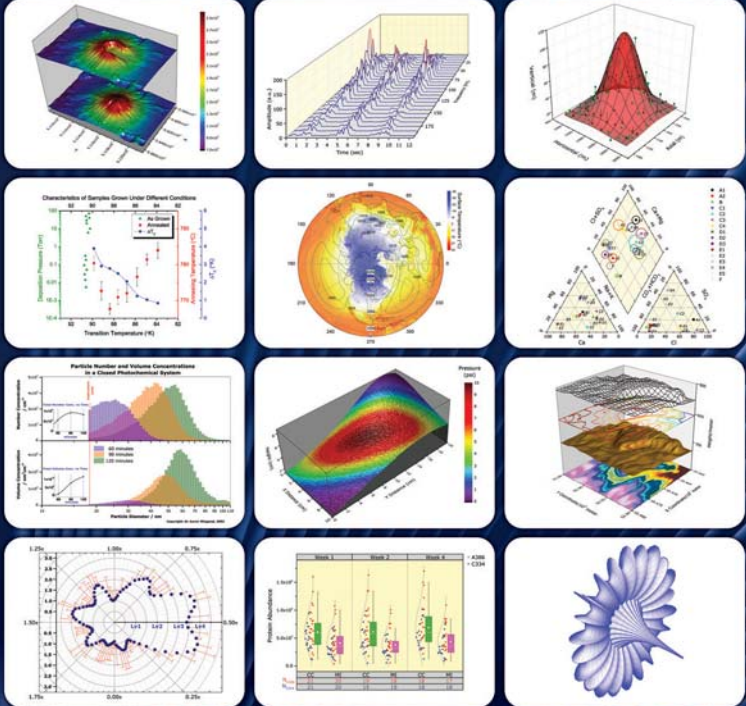
Other ISS partner nations have their own research programs, of course. ESA, for example, has more than 100 space-based research projects under way aboard the station, says Martin Zell, head of ESA's ISS utilization department. The projects are split about evenly between the life and physical sciences. Member nations of ESA have yet to decide whether to continue ISS participation beyond 2020, but Zell says there is "a lot of demand from the user community and certainly highly interesting research themes" for the ISS beyond 2020.

European-sponsored physical sciences projects on the ISS involve 700 researchers from 30 countries, says Olivier Minster, head of ESA's physical sciences unit. Those projects include the Atomic Clock Ensemble in Space, an international collaboration designed to provide improved time and frequency accuracy for testing the theory of general relativity. An electromagnetic levitator facility to be delivered to ESA's Columbus laboratory this year will help to address solidification questions in materials science on Earth by determining thermophysical properties in space. Other ESA

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research is focused on colloids, foams, and emulsions; complex cold plasmas; and heat-transfer processes with phase changes. ESA also has a comprehensive ISS program in the life sciences.

Beginning in 2004, NASA, ESA, and the Canadian and Japanese space agencies have issued joint solicitations for ISS research about every five years; the latest, seeking life sciences proposals for execution in 2017–20, was due for release after *PHYSICS TODAY* went to press. Two 2009 calls for proposals were issued for the physical and life sciences. The 2004 solicitation covered biology, astrobiology, and human research.

Apart from microgravity, the ISS offers day–night cycling of instruments in a harsh space environment, and a stable platform for Earth and planetary science observations. The station is also home to the Alpha Magnetic Spectrometer, a \$1.5 billion particle-physics instrument that is looking for evidence of dark matter and has counted more than 44 billion cosmic rays since its 2011 launch (see *PHYSICS TODAY*, June 2013, page 12).

More perfect crystals

The station's microgravity environment has long been touted as ideal for the

growth of crystals of proteins and other macromolecules. Indeed, protein crystallization was the topic of the first of CASIS's four solicitations, and Bates says the first crystal experiments will be delivered soon. William Duax, CEO of the American Crystallographic Association, says that much of the early interest from crystallographers concerned the hope that more perfect crystals would allow the determination of more precise structural details. Although that turned out to be true, he says, an even better outcome was the development of space robotic techniques that contributed to high-throughput crystallization on Earth.

Edward Snell, a crystallographer at the University at Buffalo who has conducted ISS experiments aimed at determining which crystal samples will be improved in microgravity, cautions against overstating the value of crystallography in space. "I would not like to argue that it justifies a space station on its scientific potential alone, but if a space station is there, it is certainly something to be explored." Although growing crystals in orbit has improved the detailed structure in some samples, those are far outnumbered by ones in which no improvement is seen, he says.

Crystallography on the ISS "tends to

be cited a lot as the experiments are small, a lot can be flown, they don't need astronauts to do much with them, and the potential payoff is very high," says Snell. On the other hand, the need for a very stringent toxicology process and the use of multiple layers of containment—neither of which is required in a terrestrial environment—complicate simple experiments. Such precautions mean that a space experiment might be based on results that are six or more months old by the time the experiment is conducted—"a lifetime in crystallography," he says.

Topping NASA's own list of the most significant results stemming from ISS science is a technology for producing microcapsules of chemotherapy drugs for delivery to tumors. Originating from a 2002 experiment, the technology is nearing the clinical trial stage for treatment of breast cancer. It has been exclusively licensed to NuVue Therapeutics in Fairfax, Virginia, for biomedical applications. Other ISS research results touted by NASA include novel robotic surgical techniques for tumors previously thought to be inoperable and development of new candidate vaccines for salmonella.

David Kramer

Digging into the past without a spade

In a collaboration between geophysicists and archaeologists, large areas of Turkey are being surveyed for archaeological ruins, on a time scale of weeks, not years.

When geophysicist Sirri Seren of Austria's Central Institute for Meteorology and Geodynamics (ZAMG) goes looking for ancient and forgotten settlements, he uses what resembles an oversized lawn mower and an oddly shaped plow. Pushing his equipment at a walking pace, he can either measure the changes in the magnetic field as a function of depth or send radio pulses into the ground to get reflections from stones buried in the soil. The results, after computer analysis, can produce maps of towns, churches, or small cities, all without excavation. "I am the first person to see these buildings in hundreds of years," says Seren. "I find that exciting."

The ground-penetrating radar (GPR) and magnetic field surveying (MS) techniques that Seren uses were not originally developed for archaeology. In fact, GPR's main purpose is for surveying construction sites, nondestructive

testing of structures, and searching for water leaks and ice-flow patterns. MS is used in the mining, oil, and gas industries to look for new mineral deposits. But over the past 15 years, scientists at the Austrian Archaeological Institute (AAI) and the department of applied geophysics at ZAMG in Vienna have customized software and modified equipment to convert the two techniques into valuable archaeological tools to study Ephesus, close to the present-day coastal city of Selçuk in the Izmir Province of Turkey.

The long dig

Ephesus started as an early Greek colony that later became one of the largest cities and seaports in the Roman and Byzantine Empires. The city was famed for the Temple of Artemis, one of the seven wonders of the ancient world. The temple and the city were repeatedly damaged by earthquakes and in-

vaders, but they were always rebuilt because of their strategic coastal location. Only in the 16th century, when the bay and harbor had become buried in silt, was Ephesus abandoned. Today the ruins are 5 km inland from the coast.

Ironically, the same silting that led to the city's abandonment created advantages for archaeologists, who have been excavating the site for more than 100 years. As the coastline built up and the sea moved farther away, the residents moved closer to the sea, rebuilding their city at frequent intervals without disturbing or accidentally destroying other buried settlements, explains AAI director Sabine Ladstätter, who runs the Ephesus dig.

Only something like 15% of Ephesus's estimated 10 km² of ruins has been excavated, and the site's large size presents challenges for archaeologists. In addition, says Ladstätter, "you don't want to keep digging up another rich merchant's mansion. You want to find something new."

Enter GPR and MS. The detectors cost about \$100 000 each. A programmer