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PHYSICS TODAY

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Physics Today **68** (12), 29–30 (2015);
https://doi.org/10.1063/PT.3.3015

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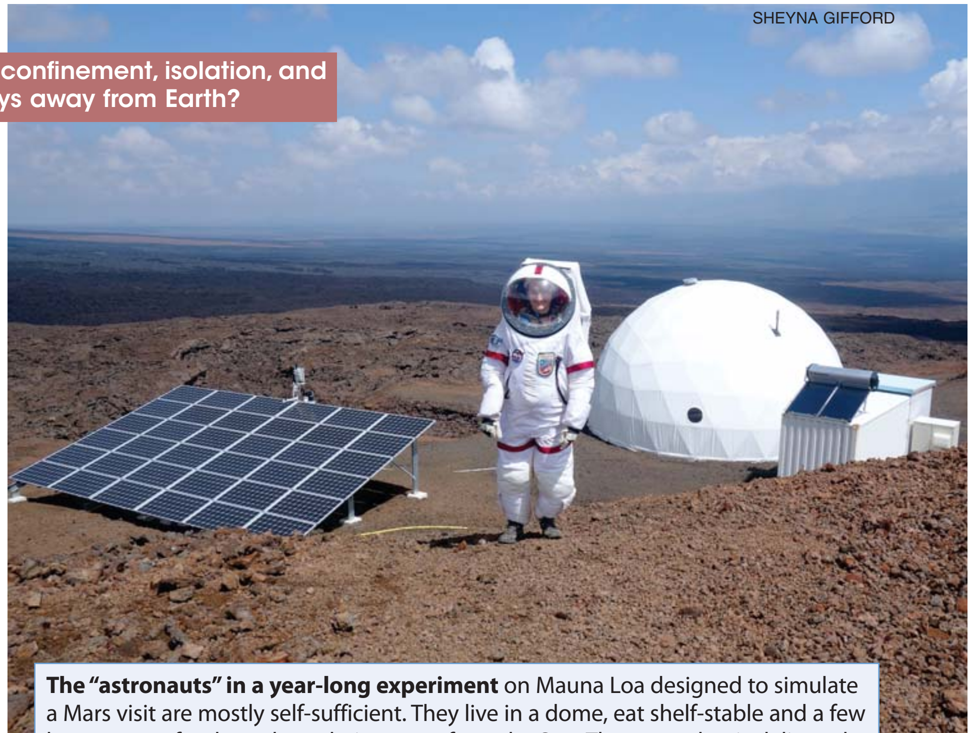

SHEYNA GIFFORD

The "astronauts" in a year-long experiment on Mauna Loa designed to simulate a Mars visit are mostly self-sufficient. They live in a dome, eat shelf-stable and a few homegrown foods, and get their energy from the Sun. The water that is delivered to them every few weeks—without human contact—is used sparingly. Here, Christiane Heinicke is on a space walk, or extravehicular activity.

"Imagine hiking up a 30-degree incline covered in loose basaltic rock in a fully loaded EVA [extravehicular activity] suit, which weighs up to 50 pounds. You are likely carrying tools and equipment, and your visibility is poor. The suit fans circulate some air, but often not enough to keep the suit cool while hiking and carrying a load. It's a challenge, one that will have to be addressed for a real Mars mission."

Sheyna Gifford is speaking from experience. She's one of six people taking part in a simulation of a year-long stay on the Martian surface.

Since late August, the crew members of the Hawaii Space Exploration Analog and Simulation (HI-SEAS) project have lived in a 100-square-meter dome—the "habitat"—at about 2500 meters above sea level on the northern slope of Mauna Loa. They are testing equipment, conducting research, and serving as the subjects of experiments. NASA ponied up $1.2 million for three HI-SEAS studies—the current one is the last and longest—on behavioral health and performance and is also paying for many of the psychology experiments being carried out on the crew.

A trip to Mars would require about eight months' travel each way, plus time there until the planets realign favorably for a return trip. The estimated total time away from Earth comes to two and a half to three years. Because of the distance, communication takes about 20 minutes in each direction—a delay that is built into HI-SEAS; consequently, astronauts on Mars would have to make many decisions on their own. Such autonomy is a big difference from crewed missions to date, for which ground control schedules astronauts' activities almost to the minute.

Actually sending humans to Mars, which NASA aims to do in the 2030s, would cost hundreds of billions of dollars. Why go? To satisfy curiosity, push the limits of invention, learn about planet formation and evolution, and look for answers to the question, Does life exist beyond Earth? And many technologies that would need to be developed to get to and live on Mars—such as for recycling water, conserving power, and protecting DNA from radiation damage—may also be useful for living sustainably on Earth. Says Gifford, "One of my favorite things about space exploration is that it is peacefully and intellectually unifying."

The studies at HI-SEAS and other confined, isolated, and extreme environments are part of the preparation for an extended mission. What can be done to ease the stress of isolation? How do crews make decisions? How can friction among crew members be measured and alleviated? How can problems between the crew and ground-based mission support be avoided? How does the cohesiveness among the crew correlate with their performance? How do such issues change over the course of a long mission?

Real data, make-believe Mars

Kim Binsted, the project's principal investigator, got interested in looking systematically at such questions after serving in 2007 as chief scientist on a four-month-long stay at the Mars Society's Devon Island station in the Canadian Arctic. "It was this very rich environment to answer questions about a Mars mission, but a lot of these missions are one-off. You come away with strong ideas and recommendations, but not really data," says Binsted, a computer scientist at the University of Hawaii.

The HI-SEAS project began in 2012, and behavioral studies lasting four and eight months with different crews have been completed. "We try to select astronaut-like people," Binsted says. "They are stoic. We are trying to figure out where the sweet spot is, when they can't tough out problems anymore. We think it's between eight months and a year."

Most of the HI-SEAS crew members have science backgrounds. And, says Binsted, "We look for people who have experience in a complex technological environment—where mistakes could cost lives—such as in an operating room or airplane cockpit." The current crew includes three women and three men. They are Gifford, a doctor and science journalist; Christiane Heinicke, a fluid physicist; Carmel Johnston, a soil scientist; Cyprien Verseux, an astrobiology PhD student; Tristan Bassingthwaighte, an architecture student who specializes in space design; and Andrzej Stewart, who left his job in a Lockheed Martin control room flying NASA planetary probes to join HI-SEAS. Crew members receive stipends of $15 500.

When they are not working on a dozen or so NASA research protocols, the HI-SEAS crew members mostly schedule their own time. They cook their food from shelf-stable supplies. They exercise. They read and write emails, including answering questions from the media and schoolchildren. They salsa dance and work on personal goals such as learning Morse code, the ukulele, and Russian. They monitor and maintain their solar panels, water use, composting toilets, and other systems. About 40 trained volunteers around the world provide around-the-clock support to the crew.

NASA/JPL-CALTECH/MSSS

The Martian surface resembles the Mauna Loa site (see photo on page 29) where team cohesiveness and performance are being studied in preparation for lengthy trips into space.

Guinea pigs

As a performance metric, the HI-SEAS ground team assigns the crew members a geology task every other week. "We tell them what to do, but not how," says Brian Shiro, who oversees the HI-SEAS geology work and in his day job forecasts tsunamis for the National Oceanic and Atmospheric Administration. "We see how well they do on exploration activities away from the habitat. Each is a mini research project." Examples of the assignments include characterizing the local regolith, mapping terrain to study the volcanic flow history, and exploring such features as lava tube caves. The crew has a lab and some tools, including GPS, range finders, a compass, a spectrometer, centrifuges, a refrigerator, and petri dishes. "The geology tasks are the sort of things we would do on Mars, so they are appropriate stressors," Shiro says.

In parallel with the grading of performance on the geology tasks, the crew's behavior is tracked. Crew members spend a few hours a week filling out surveys about their mood, activities, physical health, and stress levels. Their discussions before and after excursions are recorded on video for studies of team task management. They wear instrumented bracelets to record data about their sleep, motion, and heart rates. They play a video game designed to measure changes in cooperative versus competitive motivations. They freeze samples of saliva, urine, and hair for later evaluation of cell damage and levels of stress and sex hormones.

Crew members also wear badges that measure such variables as how loudly people are speaking, distances between them, and who initiates and disengages from conversations. "Over time, one can identify the sequence, frequency, duration, and degree of arousal associated with patterns of interactions among team members," says Steve Kozlowski, a professor of organizational psychology at Michigan State University. The goal is to learn how to identify "meaningful departures from normative functioning" and, eventually, to help the crew spot stresses before they escalate.

Another experiment has the crew spend time virtually with friends and family. Peggy Wu, a computer engineer at Smart Information Flow Technologies, says that preliminary results comparing the current mission with a prior group at HI-SEAS show statistically significant improvements. Crew members who spend time in an experimental three-dimensional virtual world miss their families and nature less than the ones who don't, she says. "They feel more socially connected."

Crew research

A key aim of the mission is to develop passive, noninvasive ways to monitor crew cohesion and performance. Pete Roma, a psychologist at the Institutes for Behavior Resources and the Johns Hopkins University School of Medicine, leads the experiments with computerized behavioral measurement tools. "At this point," he says, "we need to understand how people perform in environments like this over long periods of time. But more mature technologies will then take it to the next step." For example, objective data could be gathered on whether individuals or teams are sleepy, or grumpy, or not functioning optimally, "even if they don't feel compromised." Ultimately, Roma says, the goal is a three-step autonomous process: monitor and quantify; provide feedback to the crew; and suggest remedies.

The crew members also have their own research projects. Gifford is teaching the rest of the crew emergency medicine and, with Bassingthwaighte, is studying how to prevent repetitive stress injuries. Verseux is working with cyanobacteria to produce food, oxygen, and other resources and to process inorganic compounds that may be found on Mars. Johnston is using hydroponics and other approaches to study how plants might be cultivated on Mars.

Heinicke has built a solar still to extract water from the ground. To increase the still's efficiency she is designing reflectors to collect more sunlight and adding a better trap for collecting condensed water. A nonphysics experiment she is doing relates to how the crew members' sleep changes over the course of the mission.

The HI-SEAS project recently won a new grant from NASA. The researchers' next step will be to study how to pick a crew. Sheryl Bishop of the University of Texas Medical Branch at Galveston, who has been studying space psychology for 25 years, will join the project. The space program "initially started by selecting test pilot jocks," she says. "We found that the 'right stuff' is not the right stuff." The classic "right stuff" astronaut is an adrenaline junky, she explains. But research in Antarctica showed that such personalities became bored and sought out risky behaviors. "You want to pick people who are content with being safe."

Stewart, HI-SEAS chief engineer, says the technology already exists to take humans to Mars—although perhaps not yet safely and affordably—"but there is only so much we can do to prepare humans psychologically for the challenges. I'm proud to be part of a mission that is helping us to understand the stresses and develop methods for coping with them, so that one day we have a chance of sending astronauts to Mars safely."

Toni Feder