What will astronauts need to survive the dangerous journey to Mars?

When space is tight, what should go into the medical bag?

On movie missions to Mars, getting there is the easy part. *The Martian*'s Mark Watney was fine until a dust storm left him fending for himself. Douglas Quaid's jaunt to the Red Planet in *Total Recall* was smooth sailing until he came under fire at Martian customs and immigration.

But in real life, just getting to Mars and back will be rife with dangers that have nothing to do with extreme weather or armed gunmen.

"The mission to Mars is likely going to be four to six individuals [living] together in a can the size of a Winnebago for three years," says Leticia Vega, associate chief scientist for the NASA Human Research Program in Houston. Time on the planet will be sandwiched between a six- to nine-month journey there plus the same long trip back.

Once outside of Earth's protective gravitational and magnetic fields, microgravity and radiation become big worries. Microgravity allows fluid buildup in the head, which can cause vision problems, and adventurers cruising through interplanetary space will be continually pelted with high-energy charged particles that zip right through the metal belly of a spacecraft. Researchers don't know just how harmful that radiation is, but lab experiments suggest it could raise astronauts' risk of cancer and other diseases.

The length of the mission brings its own dangers. "The moon was like a camping trip when you think about going to Mars," says Erik Antonsen, an emergency medicine physician and aerospace engineer at NASA's Johnson Space Center in Houston. Setting aside the social and psychological problems that could arise among people trapped together inside an interplanetary mobile home (*SN: 11/29/14, p. 22*), three years offers a lot more time and opportunity to get sick or injured than a dayslong Apollo mission. And Mars is about 600 times farther from Earth than the moon is. Even light-speed communications will take about 20 minutes to reach Earth from Mars. Phoning Houston for help in an emergency is not an option.

"The reality is, when we do the first missions to Mars, there's a high likelihood that somebody may die," Antonsen says. "If someone goes out and they get an abrasion on their eyeball and it's not responding to whatever [is] on the vehicle, they're coming back one-eyed Jack."

Despite those dangers, the United States, Russia, China and other nations have all voiced their intentions to send people to the Red Planet. NASA is gunning for a mission to Mars in the 2030s. With that deadline in mind, researchers are developing a suite of medical devices and medications to bring on a trip to Mars.

The items on this packing list are in the very early stages of development, and in some cases, still pretty impractical and unproven. Universal diagnostic wands are a distant dream. But researchers are devising artificial-gravity suits, anti-radiation medications and miniature medical tools that scientists hope will be ready in about a decade to keep the first travelers to Mars safe and healthy.

Faking gravity

For something that looks so relaxing, floating in microgravity is surprisingly bad for you. When the body doesn't have to pull its own weight, muscles and bones weaken. This was a big problem in the early days of spaceflight. When the Soviet Soyuz 9 crew returned from a record 18 days in space in June 1970, one cosmonaut was so weak that he couldn't carry his own helmet when he stepped out of the landing capsule (*SN: 6/27/70, p. 615*). Today, astronauts on the International Space Station keep up their strength by exercising for a couple of hours each day. But other problems with life in microgravity remain unsolved.

In space, bodily fluids that Earth's gravity normally keeps in the lower body drift toward the head, increasing intracranial pressure. "If you were to sit down in a chair and put your head between your knees … that's a bit what it feels like," says NASA astronaut Thomas Marshburn, who completed a five-month stint on the space station in 2013.

Researchers suspect that constant elevated pressure behind the eyes is to blame for vision problems, such as farsightedness, that about half of astronauts develop in space. "I had a harder time reading the keys on the laptop," Marshburn recalls.

Weightlessness also confuses the gravity-sensing vestibular organs in the inner ear that play a role in balance and motor control. Upon returning to Earth, "I could walk in a straight line pretty easily by the end of that day, but it took me a few days before I could start to walk around a corner" without running into the wall, Marshburn says.

To make sure astronauts can walk straight and see what they're doing on Mars, a spaceship could be outfitted with artificial-gravity machines. One such machine is a lower body negative pressure, or LBNP, chamber. The device applies vacuum pressure to the lower half of the body while a person is sealed in from the waist down. The vacuum re-creates the downward pull of gravity, planting the person's feet firmly on the floor of the chamber and drawing bodily fluids toward the legs.

In one experiment, 10 volunteers who already had medical devices implanted to measure intracranial pressure sealed their lower bodies inside an LBNP chamber. Participants had to lie down for the experiment to bring their intracranial pressure closer to what it would be like in space. When someone on Earth goes from standing to lying down, their intracranial pressure rises from around 0 millimeters of mercury to about 15 mmHg — closer to what astronauts are thought to experience in space. As the researchers slowly increased the device's vacuum pressure, participants' average intracranial pressure dropped from 15 to 9.4 mmHg, the researchers reported in 2019 in the *Journal of Physiology*.

"We really don't know right now how much time [in LBNP] we need to protect the body" from the harmful effects of fluid shifts in space, says Alan Hargens, a space physiologist at the University of California, San Diego. But in case LBNP becomes a significant part of the day, Hargens' team built a prototype LBNP suit that can be worn during daily activity. The suit consists of a pair of overalls with built-in shoes and a seal around the waist. Vacuum pressure pulls the wearer down onto the shoe soles. "These lower body negative pressure devices are an early form of artificial gravity," Hargens says. Such devices may be easier to send into space than alternatives being tested, such as centrifuges.

A centrifuge simulates gravity through centrifugal force — the effect that keeps water in the bottom of a bucket when you swing it over your head. A centrifuge designed to help astronauts in microgravity looks sort of like a carousel, but with beds instead of ponies. The rider lies on a bed, head pointing toward the center of the carousel, which spins to exert a horizontal centrifugal force out toward the feet that's as strong as the downward pull of gravity. A room-sized centrifuge would be a lot harder to launch in a spaceship than an LBNP suit. But some researchers think the whole-body-centrifuge experience may combat microgravity issues that LBNP doesn't, such as the inner ear problems.

To investigate the effects of a centrifuge on sensorimotor control, Rachael Seidler, a motor control researcher at the University of Florida in Gainesville, and colleagues kept 24 volunteers in bed for 60 days to mimic life in microgravity. Sixteen of the participants spun in a centrifuge for a total of 30 minutes each day, while the other eight got no centrifugation. Before and after bed rest, participants were tested on their balance and were put through an obstacle course. "We've just had a very preliminary peek" at the data, Seidler says, but "it does look like the artificial gravity was helpful" for motor control.

Vocabulary list (A)
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Bracing for radiation

Life in microgravity may be a problem for a Mars crew, but at least it's a familiar challenge to astronauts. Chronic exposure to deep space radiation, on the other hand, is a hazard that no space traveler has faced before.

The solar system is awash in charged particles called galactic cosmic rays that travel at nearly the speed of light. These particles tear through metal like it's tissue paper and can kill cells or create mutations in the DNA within. Astronauts on the space station, like folks on Earth, are largely protected from these tiny wrecking balls by Earth's magnetic field. But a Mars-bound crew will be totally exposed. En route to the Red Planet, astronauts are expected to receive almost two millisieverts of radiation daily — roughly equal to getting a full-body CT scan every six days.

The only people ever fully immersed in deep space radiation were those who went to the moon, but they were exposed for less than two weeks. On a Mars mission, "we really don't know exactly what's going to happen to humans when they get these types of exposures," says Emmanuel Urquieta, a space medicine researcher at Baylor College of Medicine in Houston. But judging by lab animal and cell experiments, this radiation won't be giving astronauts any superpowers.

In tests on animals and in human tissue, beams of particles designed to mimic space radiation degrade heart and blood vessel tissue, suggesting a Mars crew may be at higher risk for cardiovascular diseases, according to a 2018 report in *Nature Reviews Cardiology*. Similarly, observations of rodents exposed to radiation suggest that space radiation impairs cognitive function, researchers reported in a review article in the May 2019 *Life Sciences in Space Research*.

"There's also a good amount of data on radiation's ability to induce cancer" in the lungs, liver and brain, says Peter Guida, a researcher at Brookhaven National Laboratory in Upton, N.Y., who studies the biological effects of radiation.

Scary radiation effects seen in lab animals or cell cultures should be taken with a grain of salt. A mouse is not a person, and brain cells in a dish do not make a brain. Also, animals and cells typically get the entire Mars mission–level dose of radiation in a single session or in a series of radiation exposures over weeks or months, which is not the same thing as getting constant, low-level exposure. But the warning signs from these experiments are worrying enough that researchers are testing various anti-radiation medications.

"The biggest and most promising field for countermeasure development is antioxidants," Guida says. High-energy charged particles can cause damage by splintering water molecules in the body into toxic compounds called reactive oxygen species. Priming the body with antioxidants could help neutralize some of those reactive oxygen species and curb their effects. Options include vitamins A and E, as well as selenomethionine, an ingredient found in some dietary supplements. "All these have shown at various levels to decrease the negative effects of radiation," he says.

Even harnessing the natural antioxidant powers of berries might help. In one experiment, rats fed food laced with freeze-dried blueberry powder for four weeks seemed to perform slightly better on a memory test after exposure to high-energy charged particles than rats fed normal chow before exposure. In the test, the rats were shown two objects: one they had seen before radiation exposure and one they had not. Blueberry-fed rats spent almost 70 percent of their time exploring the new object, as expected of animals that recognized the old object. But the other rats spent about half their time exploring each object, suggesting that they'd forgotten the object they'd seen before, researchers reported in 2017 in *Life Sciences in Space Research*.

Antioxidants, on their own, may not be enough protection, says Marjan Boerma, a radiation biologist at the University of Arkansas for Medical Sciences in Little Rock. Boerma and colleagues are testing whether aspirin and other anti-inflammatories, including a form of vitamin E called gamma-tocotrienol, can help reduce cell damage from high-energy particles. It may take a medley of pharmaceuticals — or perhaps a carefully blended smoothie. Scientists are still far from hammering out the exact ingredients of that anti-radiation regimen, she says.

Astronaut, heal thyself

Pulling shifts in artificial gravity and swallowing antioxidants may become part of an astronaut's daily routine. But Mars visitors will also have to deal with any unexpected illnesses and injuries without mission control to talk them through an emergency.

A Mars crew may include a physician. "But that person could also get sick," Urquieta says, "and that physician is not going to be board-certified in 10 different specialties." Ideally, the Mars spaceship would be equipped with artificial intelligence that could consider an astronaut's symptoms, recommend medical tests, make diagnoses and assign treatments. But a reliable "Dr. AI" is nowhere close to reality.

Right now, the most sophisticated symptom checkers are tools like VisualDx, diagnostic software used by health care workers in hospitals and clinics. The user answers questions about a patient, such as symptoms and demographic features, to winnow down possible diagnoses. For skin conditions, VisualDx can also analyze photos of a patient's skin; it's now being expanded to help users assess ultrasound scans.

Art Papier, a dermatologist and chief executive officer at VisualDx, and colleagues designed a version of the system for use in deep space that works on a laptop without internet. The software doesn't have to account for every possible diagnosis, like infectious diseases from the tropics. Instead, the focus is on medical conditions that astronauts have a fairly high chance of developing, like rashes or kidney stones.

To help walk astronauts through first aid and medical exams, spaceflight physiologist and space medicine scientist Douglas Ebert of KBR, Inc. in Houston and colleagues are developing a tool called the Autonomous Medical Officer Support, or AMOS, system. An early version of the software uses pictures and videos to teach novices how to perform an eye exam, for example, or insert a breathing tube.

The researchers tested an AMOS prototype with about 30 nonphysicians, who learned how to perform several medical procedures. Those people came back three to nine months later to do the procedures again, using the software for guidance as necessary, to mimic how an astronaut would use AMOS for preflight training and in-the-moment support during an emergency.

Around 80 percent of participants accurately performed eye exams and ultrasounds and about 70 percent correctly inserted an IV. When it came to a tougher task — inserting a breathing tube — just about half pulled it off, Ebert and colleagues reported in January in Galveston, Texas, at the NASA Human Research Program Investigators' Workshop. In April, astronauts on board the space station successfully used the software to perform kidney and bladder ultrasound scans without help from ground control.

When performing medical exams, astronauts won't have the starship *Enterprise*'s sick bay at their disposal. They'll need miniature medical devices that fit on the spacecraft.

For medical imaging, space medicine researchers have their eyes on a new ultrasound device called the Butterfly iQ that replaces the variety of transducers usually needed to image different body parts with a single probe the size of an electric razor. Standard ultrasound machinery is around 15 times heavier than the Butterfly iQ, which displays images on a mobile app.

The company 1Drop Diagnostics, which is developing credit card–sized chips to detect chemical markers of different diseases in blood samples from a finger prick, is working on portable blood tests for astronauts.

The medical kit that astronauts use to patch each other up will have to be lightweight and compact. To decide what goes in a spaceship first aid kit, researchers use NASA's Integrated Medical Model, which forecasts which health problems the astronauts on a particular mission are most likely to have.

Researchers plug in mission details, like where the crew is headed and astronauts' genders and preexisting conditions. The model then runs thousands of mission simulations to gauge the risks of that specific crew having anything from constipation to a heart attack so that planners can prioritize medical kit supplies.

Ebert and colleagues have already used this system to build a preliminary first aid packing list for a crewed lunar flyby mission that NASA has planned for 2022. For this three-week trip, the first aid kit is pretty simple: medication for back pain, motion sickness and the like.

Packing for Mars is going to be a whole new ball game, Ebert says. But researchers still have at least a decade to shrink their equipment down to size and figure out what mix of medical supplies will give Mars astronauts the best chance of surviving their epic voyage.

Vocabulary list (B)
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