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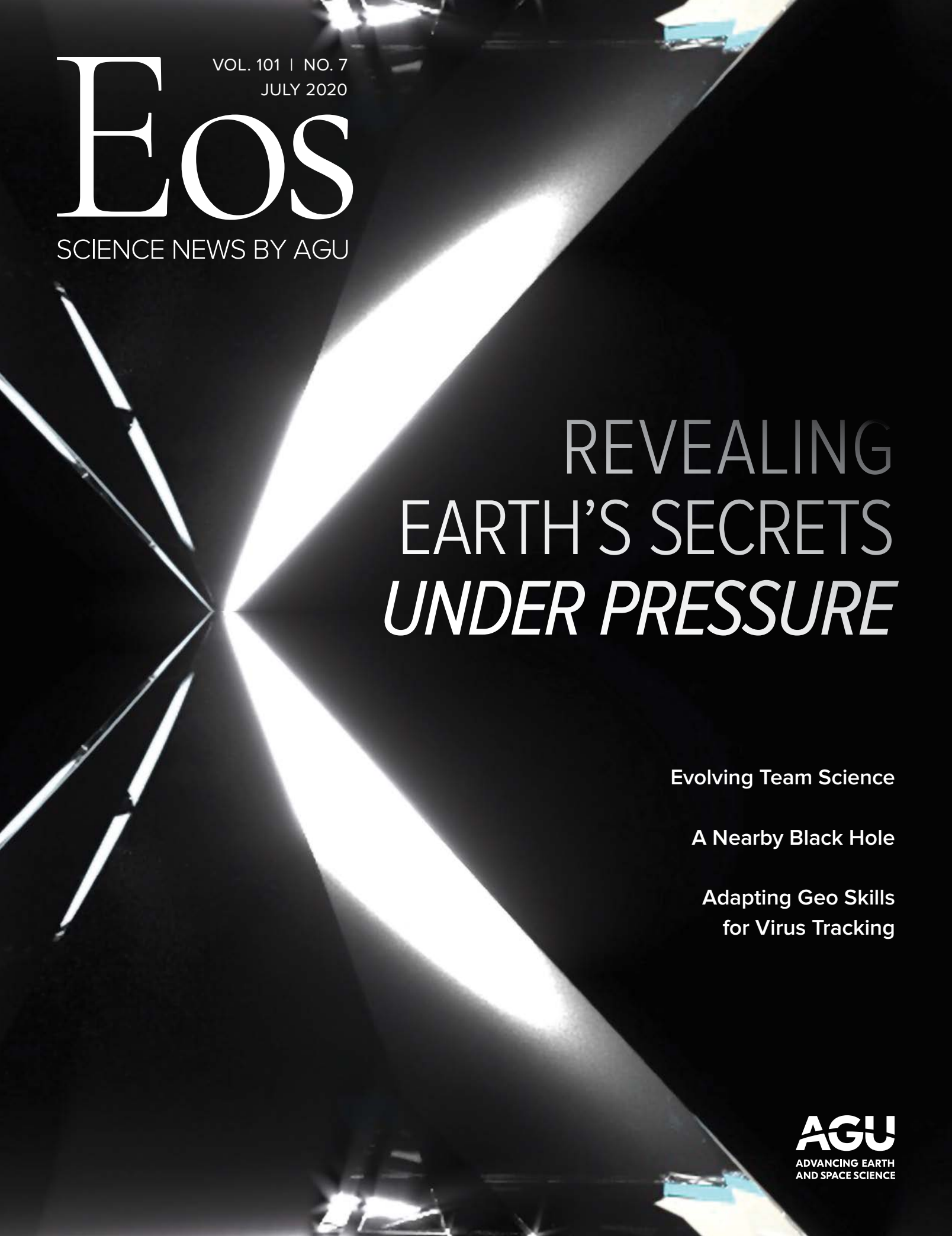

REVEALING EARTH'S SECRETS *UNDER PRESSURE*

Evolving Team Science

A Nearby Black Hole

Adapting Geo Skills for Virus Tracking

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ADVANCING EARTH AND SPACE SCIENCE

rado River. Some of her colleagues have to cross-country ski nearly 20 kilometers to get to their study site. In that case, they decided to drive to the trailhead separately and maintain the recommended 2 meters apart while working.

Henderson's own snowmelt monitoring work can be done solo, she said, so she's comfortable continuing to do her own routine monitoring.

The Weather

Matt Kelsch, a hydrometeorologist and weather enthusiast in Boulder, Colo., is part of the National Weather Service's Cooperative Observer Program, a weather observing network that's been in place since 1891. Across the United States, thousands of volunteers take daily weather measurements of temperature and precipitation. And because many of these stations were set up on private property, Kelsch said the weather network probably isn't much affected by shelter-in-place orders.

These weather stations are used to create long-term climatology records for regions across the United States. The records can be used by a number of groups, including scientists studying climate change and insurance companies confirming whether damage to a car was from hail, Kelsch said.

Weather forecasts could still be affected, however. These days, many commercial flights carry weather sensors, and the airline industry has seen a significant drop in traffic since the novel coronavirus came to the United States. For example, the United States saw a 73.3% decrease in air traffic in April 2020 compared with April 2019. On 7 May, the World Meteorological Organization reported a 75%–80% decrease in meteorological observations from flights. (In the Southern Hemisphere, the decrease is close to 90%.) Before the pandemic, commercial flights provided more than 800,000 meteorological observations per day.

"Even though a decrease in this critical data will likely negatively impact forecast model skill, it does not necessarily translate into a reduction in forecast accuracy, since National Weather Service meteorologists use an entire suite of observations and guidance to produce an actual forecast," said National Oceanic and Atmospheric Administration spokesperson Susan Buchanan in a statement released 24 March.

By **JoAnna Wendel** (@JoAnnaScience), Science Writer

Venus Exploration Starts in the Lab

The inside of the Glenn Extreme Environments Rig (GEER) is 1 cubic meter in volume, or about 3 feet wide × 4 feet long. Credit: GEER/NASA Glenn Research Center

In March of 1982, the Soviet spacecraft Venera 13 landed a probe on the surface of Venus. It sent back the first color photographs from the surface of another planet, revealing that Venus has a desolate landscape to match its hellish atmosphere. The probe collected and analyzed a sample of the rocky surface, and its acoustic detector measured vibrations from the wind.

Venera 13 sent back some of the best data we have to date about Venus's surface. The probe holds the record for the longest-lived Venus surface mission.

It survived for just 127 minutes.

Scientists have been trying to return to Venus's surface since the late 1980s, this time with instruments that will last for days or even months. That's where GEER comes in.

GEER, the Glenn Extreme Environments Rig at NASA Glenn Research Center (GRC) in Cleveland, Ohio, is a test chamber that can create Venus-like conditions to study how materials placed inside the chamber react.

"GEER is a highly adaptable facility that's constantly evolving its capabilities," said Kyle Phillips, an aerospace and mechanical engineer at GRC. Phillips is GEER's primary operator and test engineer. "In past tests, we've simulated conditions all the way from Venus surface conditions—both lowlands and highlands—up through the lower atmosphere through where we expect the cloud layers to be, and just slightly above the cloud layers and the upper atmosphere."

GEER is a test chamber that can create Venus-like conditions to study how materials placed inside the chamber react.

Building Spacecraft to Last

Venera 13, its twin spacecraft Venera 14, and the eight other successful attempts to land a probe on Venus all fell prey to the same thing: temperatures hotter than 450°C, pressures about 90 times that of Earth's surface (90 bars), and a corrosive carbon dioxide–dominated atmosphere. Under those conditions, a spacecraft that might survive for years on Mars or the Moon would break down in minutes on Venus as the outer casing melts or dissolves, wires corrode, and delicate hardware warps.

The GEER team has "tested things like basic materials that one might use in a spacecraft or around the spacecraft," said Tibor Kremic, chief of space science projects at GRC. "How do those interact with the environment? How do they fare? How did their properties and their functions change over time in a Venus surface–like environment?"

Test material is placed inside the 1-cubic-meter, corrosion-resistant stainless-steel cylinder. The test engineers then ramp up the pressure, temperature, and gas composition inside the chamber and hold it steady for days, weeks, or even months. "Currently, GEER can replicate temperatures from near ambient up to 1,000° Fahrenheit—that's 537°C," Phillips said, "and it can replicate pressures from ambient to rough vacuum to…94 bars."

"We have done work over time in understanding what materials would be viable for long-term missions and which are not," said Gary Hunter, a senior electronics engineer with GEER. For example, "copper, you might think, is just fine to use for electrical conductors. Turns out, don't use copper. In fact, gold would be a better material to use because the reactivity on the Venus surface and at those temperatures is different, and the materials that are viable are different, than you might see in standard high-temperature operations on Earth."

GEER has been operational since 2014, and the team has already made huge leaps forward in terms of designing Venus-durable spacecraft. During a test a few years ago, "we demonstrated electronics operational in Venus surface condition for 21 days," Hunter said. Computer chips turned out to be fairly durable. "The longest time anything else had ever lasted before that point in terms of electronics on the surface of Venus…was approximately 2 hours. To go 21 days was showing a significant step up in what might be possible [in] Venus surface exploration."

To Venus and Back in 80 Days

In its longest test to date, the GEER team subjected common geologic samples to a simulation of Venus's harsh surface conditions for 80 continuous days.

"We tested geologic material, so glasses, basalts, minerals, things that we expect might be on the Venus surface," Kremic said, "to understand how they might change or what they might look like if we're trying to identify them remotely." A basalt or a glass or a silicate might have a different spectrum or appearance on Venus than on Earth, the Moon, or Mars.

Some types of metal wiring react at Venus-like surface conditions, causing electronics to break down. Shown here is a metal wire before (top) and after (bottom) a test in the GEER chamber. Credit: GEER/NASA Glenn Research Center

"Copper, you might think, is just fine to use for electrical conductors. Turns out, don't use copper. In fact, gold would be a better material."

Tests that reveal the properties of planetary materials at extreme conditions serve a dual purpose, Kremic explained. Mission scientists can tailor their instruments to measure Venus-relevant signatures, and they can use test results as benchmarks to interpret those measurements.

The 80-day test also underscored the need for a second, smaller test vessel that could be run at the same time as the larger one. "It's a very small, mini GEER," Kremic said. The aptly named MiniGEER went into operation in 2019. It's just 4 liters in volume (250 times smaller than GEER) and can be brought up to temperature, pressure, and gas composition, and back down again, much faster than its larger counterpart.

"Maybe we have two things going on or we have tests that don't require the volume [of GEER]," Kremic said, "and this way [they] can be done quicker and at lower cost."

The Future of Venus Exploration

NASA might be headed back to Venus in the near future—two of its four finalists for a Discovery-class mission are bound for Venus. If one of those missions is selected, the GEER facility will be involved with getting the technology mission-ready.

But the team has already been hard at work designing its own Venus mission, a small probe called the Long-Lived In-Situ Solar System Explorer (LLISSE). LLISSE would weigh about 10 kilograms and last at least 60 days on Venus.

"At Venus you get a day-to-night or night-to-day transition at least once in a 60-day period," said Kremic, who is LLISSE's principal investigator, "and so we want to make sure that we capture one of those….We're going to measure temperatures, we're going to measure pressures, we'll measure winds, maybe 3D winds on the surface of Venus," as well as atmospheric composition and how all of those properties change over time. The team plans to build a full-scale ground model of LLISSE and test it inside GEER for the full 60 days by 2023.

The scientists are also exploring how GEER can adapt to simulate other places in the solar system and beyond. "The beauty and one of the unique things about GEER is that we can mix up pretty much whatever chemistry we want," Kremic said, and new hardware might let GEER reach colder-than-ambient temperatures too.

"The results of what we're doing will change and enhance our ability to do science, our understanding of our solar system, and of other [planetary] bodies, Venus in particular," Kremic said, and we can "be more confident in what we send there."

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By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Writer