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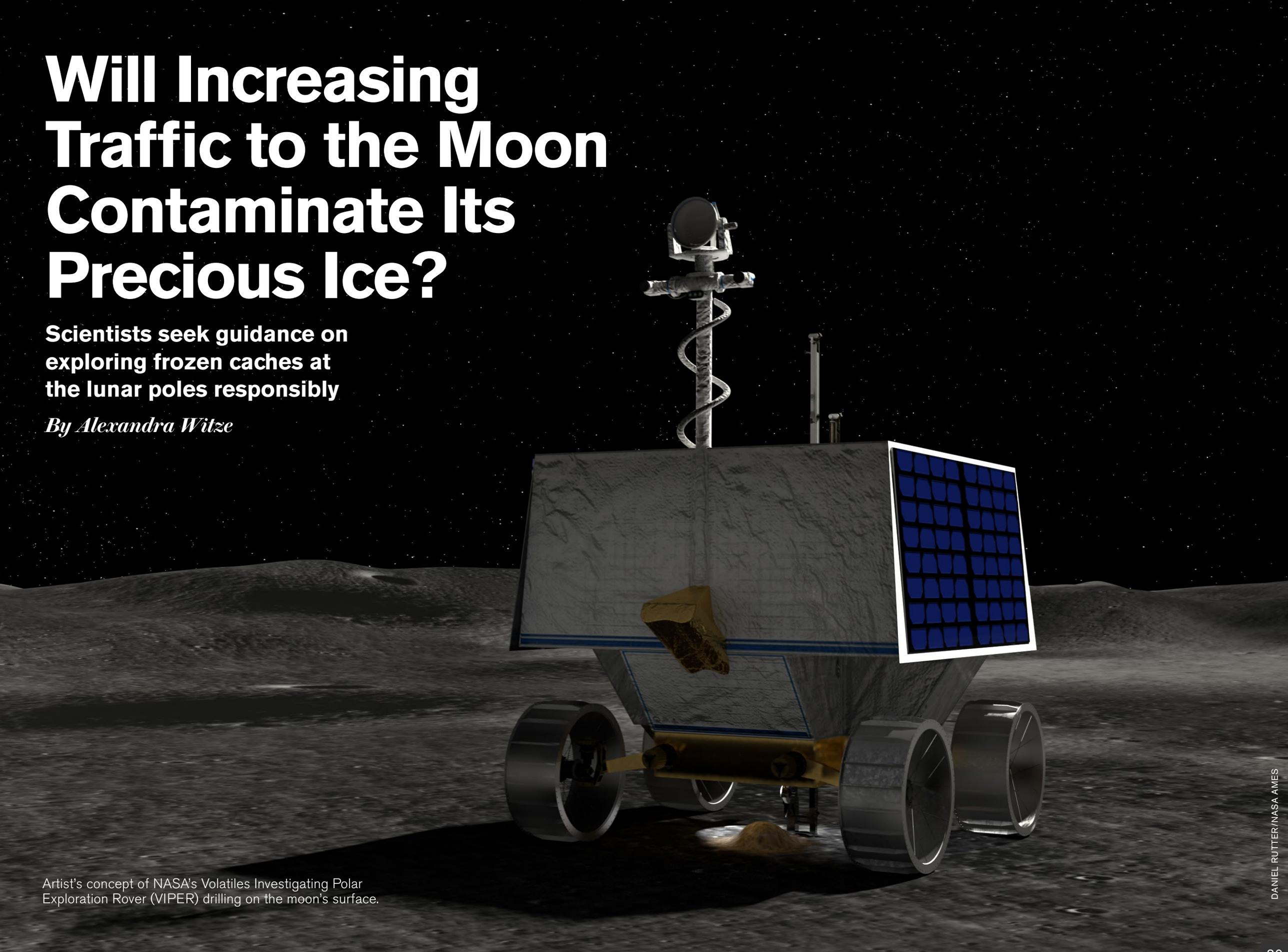
Will Increasing Traffic to the Moon Contaminate Its Precious Ice?

Scientists seek guidance on exploring frozen caches at the lunar poles responsibly

By Alexandra Witze



Artist's concept of NASA's Volatiles Investigating Polar Exploration Rover (VIPER) drilling on the moon's surface.

DANIEL RUTTER/NASA AMES

Alexandra Witze works for *Nature* magazine.

WITH ITS LUNAR SAMPLE-RETURN MISSION LAST DECEMBER, China kicked off a new surge in visitors to the moon. At least eight spacecraft from nations that included Russia, India, China, Japan and the U.S. are set to touch down on the lunar surface in the next three years.

For the first time ever, several of the upcoming missions will explore some of the moon's most scientifically intriguing, yet sensitive areas—those at its poles. Researchers are excited about studying water that lies frozen in shadowed craters in these regions. But they're also worried that increased traffic to the moon might contaminate the very ice they want to study.

The ice is important to scientists for various reasons. Some want to analyze pristine samples to unlock clues to how and when Earth and the moon accumulated water billions of years ago. Others want to mine the ice as fuel for rockets at future lunar bases.

Explorers now face a complicated choice. Do they start digging right away, to work out the processes by which they'll mine the ice and convert it to fuel? Or do they proceed slowly, to carefully preserve the scientific record encoded in the ice? "Right now we've got some scientists saying we can't go anywhere near it because we're going to ruin it," says Clive Neal, a geoscientist at the University of Notre Dame. "And others say we need it, so we're just going to go for it."

These tensions need to be resolved soon—especially as NASA plans to send a series of missions to the moon's south pole, starting with robotic landers in 2022 and culminating a few years later with astronauts stepping onto the moon for the first time since 1972.

At the end of 2020 a report by the influential U.S. National Academies of Sciences, Engineering and Medicine (NASEM) argued that space agencies need to prioritize what science they want from the lunar poles in order to explore them effectively. The international Committee on Space Research (COSPAR), which outlines best practices for space exploration, is also evaluating the situation and will decide in the coming months whether to issue new guidance for spacecraft going to the moon. NASA is waiting for COSPAR's decision and will then probably update its own regulations on how to visit the moon responsibly.

As moon exploration ramps up, "we have an obligation to do no harm to future science investigations", says Lisa Pratt, the planetary protection officer for NASA who is based at the agency's Washington, D.C., headquarters. The question is: "How do we get this right?"

COURSE COLLISION

No spacecraft has ever directly probed the moon's poles and the ice that lurks there. The only mission to get close was India's Vikram lander, which crashed about 600 kilometers from the lunar south pole in 2019 instead of touching down and studying the surface. China is planning a Chang'e-6 mission that might visit the moon's south pole, potentially scooping up ice and rocks and returning them to Earth as early as 2023. It would be the successor to Chang'e-5, which collected rocks from the moon's midlatitudes last December. Japan and India have also been discussing a robotic mission to the lunar south pole, as have Russia and Europe.

Then there's NASA. Under President Donald Trump, the agency had been preparing a suite of missions to the moon that were focused on the poles. According to these plans, NASA would send two robotic landers to the south pole in 2022, followed by a larger robotic rover, called VIPER, in 2023. It would sink its one-meter-long-drill into the lunar dirt to mine for ice. As early as the next year, humans would arrive and begin exploring icy craters. One goal might be to collect ice and fly it, still frozen, back to Earth for study, one NASA report says.

The possibility of explorers contaminating lunar ice is a problem no one anticipated five decades ago, when *Apollo* astronauts became the first humans to walk on the moon's surface. At the time, researchers thought the moon was bone dry. Only in the past decade or so have they realized that there is water in many places, including frozen in dark polar craters. Scientists have even found water in at least one sunlit place on the moon, contained in minerals in the otherwise dry dirt.

All this water could have arrived on the moon by means of water-rich asteroids or comets or by the solar wind bombarding its surface. Some of it might have come from

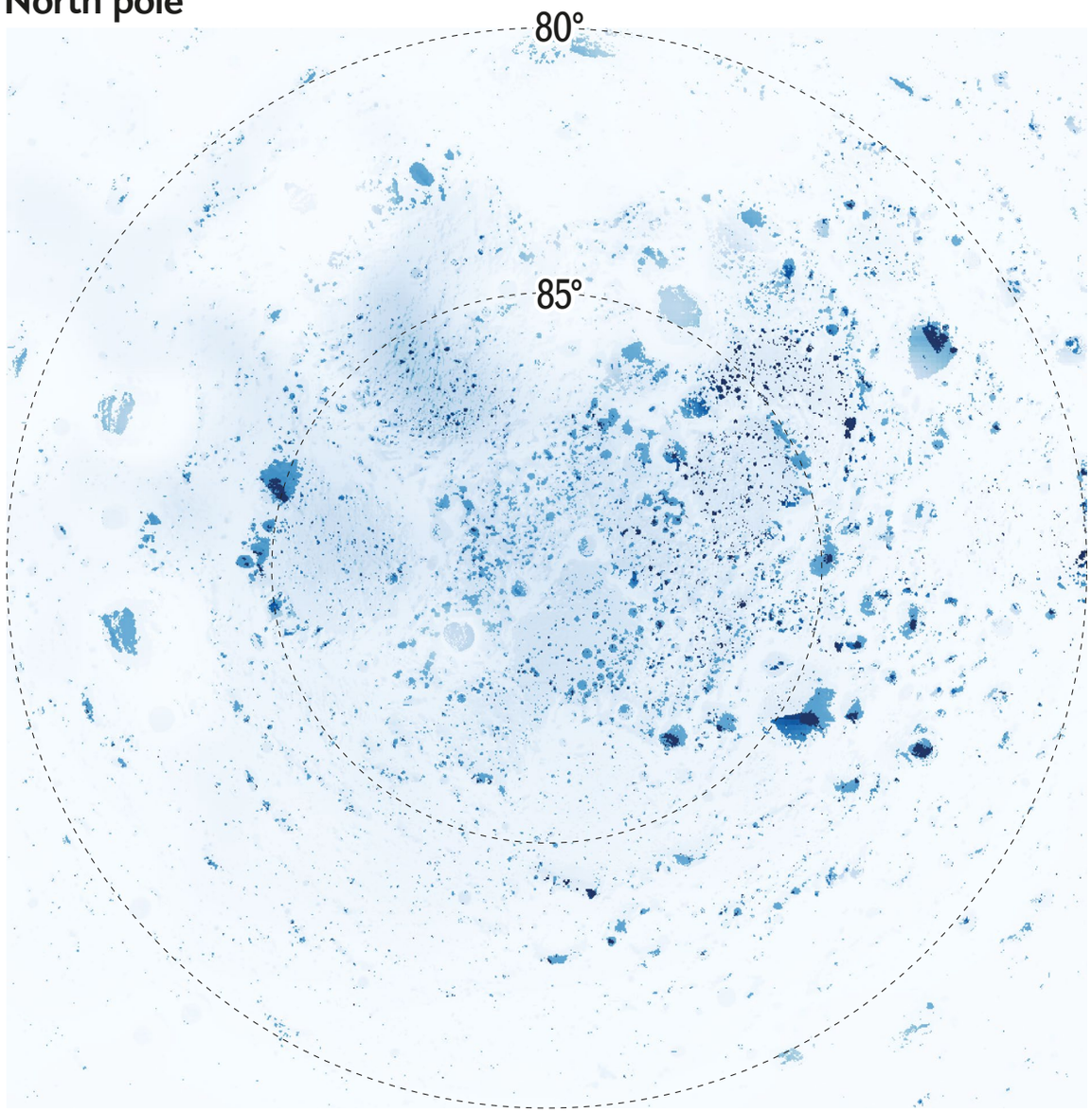
Lunar Ice Caches

An analysis of the moon's poles suggests the places (marked in dark blue) where ice could be most easily mined by future lunar explorers.

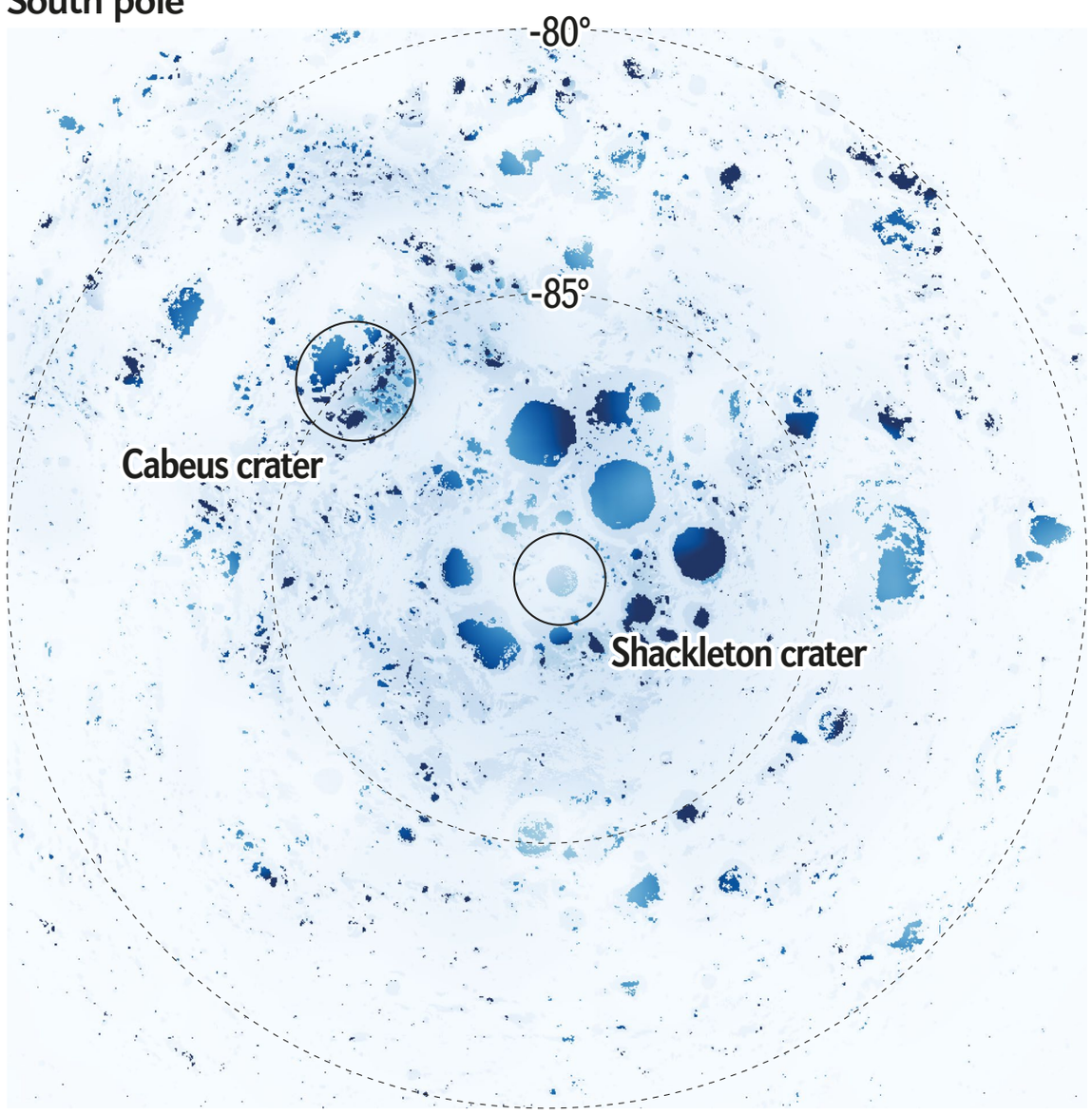
Accessible ice predicted

← Less More →

North pole



South pole



NATURE; SOURCE KEVIN CANNON

inside the moon, spewed out in volcanic eruptions from a water-rich interior. Regardless of its source, the moon's water holds crucial scientific information.

The ice inside the sunlight-deprived craters at the moon's poles might have accumulated over billions of years. If so, it holds not only a record of the moon's early history but also that of Earth's. The moon probably formed when a giant object slammed into the newborn Earth some 4.5 billion years ago, kicking up debris that coalesced into the moon and intimately linking their histories. On Earth, geologic activity, including plate tectonics, has erased much of the record of the planet's early history. But the moon has no such activity—a perfect study subject.

"The history of the moon's water provides a lot of clues to how the solar system has evolved through time," says Ariel Deutsch, a planetary scientist at NASA's Ames Research Center.

CONTAMINATION STATION

Because of the importance of the moon's ice, many researchers are cautious about how to explore it. In particular, some have been examining the possible contaminating effects of rocket exhaust on the frozen caches.

Parvathy Prem, a planetary scientist at the Johns Hopkins University Applied Physics Laboratory, and his colleagues recently simulated a medium-sized lander arriving at the moon at 70 degrees south—a few hundred kilometres from the ice-filled craters of the south pole. The simulation showed that even though a rocket would not release much water, the water it does release would spread all around the moon and stay there for some time. Even after two lunar days—two months on Earth—some 30 to 40 percent of the rocket's water would still be present, mostly frozen on the night side of the moon. "The main takeaway was, the water vapor really goes everywhere," Prem says. So the moon's polar ice has already been contaminated by past explorers.

COSPAR, the international group, has been asking hundreds of planetary scientists how much they worry about lunar exploration potentially interfering with science at the poles. More than 70 percent who responded to a survey in 2020 said they were concerned that contamination could compromise the scientific record held within the moon's ice, says Gerhard Kminek, the planetary protection officer of the European Space Agency in the Netherlands and vice chair of COSPAR's planetary protection committee.

In a white paper submitted to NASA, 19 scientists, including Prem and Deutsch, propose what they call an "origins-first" mission to a shadowed crater at one of the moon's poles. The goal would be to collect reasonably pristine samples of ice before traffic to the moon picks up, to help scientists determine exactly how the ice there accumulated over time. Such a mission would tell them exactly how precious the ice's scientific record is—and whether mining activities should be postponed, says Esther Beltran, a space scientist at the University of Central Florida and co-author of the paper.

NASA doesn't currently have funds allocated for an origins-first mission and continues to plan on sending multiple spacecraft to lunar polar regions. But the agency is listening to scientists who are concerned about getting it right and intends to move carefully, says Pratt, the agency's planetary protection officer."We need to balance the drive for resource utilization with the need for scientific discovery and knowledge," she says.

Meanwhile, if COSPAR adopts new guidelines for lunar exploration, NASA and the space agencies of other nations probably will, too. COSPAR's current guidelines ask nations to keep a list of all organic materials—such as carbon composites, paints and adhesives—onboard missions headed for the moon. Having that kind of list helps alleviate concerns about contamination, Kminek says, because it tells scientists exactly what sort of human-made material has entered the moon's environment. One possible change might be for future missions also to keep a list of the gases that they would potentially emit from their rockets or life-support systems. Relevant players, including the Chinese space agency and commercial companies such as SpaceX and Blue Origin, have been at the table with COSPAR to discuss these possible changes, Kminek says.

DECISIONS, DECISIONS

As these discussions continue, however, some scientists aren't too worried about contamination issues. Neal and others note that water vapor from rocket exhaust settles only as a thin layer on the topmost part of the moon's surface—so it wouldn't take much work to dig below it to reach undisturbed ice beneath. The recent NASEM report also notes that the risk of contaminating buried ice is low. And Kevin Cannon, a planetary scientist at the Colorado School of Mines, thinks that the small amounts of contamination introduced by exploring the moon's ice are far outweighed by the scientific advances of figuring out where and how all the ice is distributed. He has been mapping where the largest, most accessible caches of ice might be.

Others have put forward several ideas for protecting the lunar ice. One proposal is to preserve one of the moon's poles for science while opening up the other for mining and exploration. Another is to define a keep-out zone for some of the ice-filled craters. There are many such craters, from tiny pits smaller than a human hand to others that are 10 kilometers across—and not all of them need to be explored, scientists say.

"One thing we need to do is to make sure we are farsighted," Prem says. "Who knows what sort of science people generations in the future might want to do?" SA

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