

PLANETARY SCIENCE

Mars rover steps up hunt for molecular signs of life

Balky drill could hamper Curiosity's "wet" chemistry test

By Paul Voosen

The controllers of NASA's Curiosity rover have waited patiently—and perhaps for too long—to launch a key experiment. Tucked in the rover's belly are nine stainless steel thimbles, each filled with solvent, that are the mission's best shot for detecting signs of ancient martian life. Now, well into its fifth year on Mars, the rover has reached a mountain thought to be a promising hunting ground, and mission scientists are ready to dump freshly drilled dirt into one of their precious wet chemistry cups. But there's a hitch. Since early December 2016, Curiosity hasn't been able to drill.

The problem, likely a stuck brake on the mechanism for extending the drill bit, is serious. "There is apprehension," says Ashwin Vasavada, Curiosity's project scientist at the Jet Propulsion Laboratory in Pasadena, California. But the drill still responds intermittently. "We're not in a situation where it's completely dead."

Still, the clock is ticking for the aging rover, and some outside scientists regret not having used a wet chemistry cup. Rocks have punctured its wheels, and the output of its decaying radioactive power source has dropped by 15%. Jack Mustard, a planetary scientist at Brown University, says he understands the team's hesitance. But he wished the "mission had moved more quickly with the wet chemistry experiments," he says. "I am eager to see what we can learn."

So is Paul Mahaffy at the Goddard Space Flight Center in Greenbelt, Maryland, who leads the team responsible for the rover's onboard lab, the Sample Analysis at Mars (SAM) instrument. The SAM team has already sniffed organic molecules in surprising abundances, and they have found tantalizing hints of degraded fatty acids—in theory, a possible trace of ancient microbial cell walls. But these and other organic molecules could also derive from earthly contamination, ancient martian volcanism, or meteorites. Now, the team wants to know more. "The signatures are there," Mahaffy says. "And a way to get more definitive in-

formation is with the wet chemistry."

The SAM works by accepting drilled or scooped martian grit into thimbles that can be cooked in an oven up to 1100°C. Scientists sift through the resulting fumes for molecular signatures. Of 74 cups in a carousel, most are quartz tubes slated for "dry" chemistry, and 29 have now been used. But the nine solvent cups, sealed with foil, are designed to tease out organic molecules, like amino acids and degraded fatty acids, that would otherwise resist vaporization.

Even to use the dry cups, the team had to overcome some obstacles. Martian soil is saturated with perchlorate, salts rich in oxygen. Beyond breaking down organic molecules in the surface, the perchlorates make mischief in the SAM, reacting with organics that the instrument would have otherwise sampled. It also became clear early on that one of the wet cups was leaking

solvent, providing a steady background contamination that took several years to tame. But this leak also provided an opportunity: By baking a sample at lower temperatures to release its perchlorates, letting it sit exposed to ambient solvent for 2 days, and then resuming the heating, the SAM team could coax out some of their organic quarry.

Despite these hurdles, several years ago the team discovered chlorobenzene, a ring-shaped molecule containing six carbons, along with other chlorinated organics, using a sample from a mudstone Curiosity drilled at Yellowknife Bay near its landing site in Gale crater (*Science*, 27 March 2015, p. 1402). All the molecules were thought to stem from reactions with perchlorates in the oven, making their precursors mysterious. But their presence was an important clue, says Claude Geffroy, a geochemist at the University of Poitiers in France, who is working on a SAM-like instrument for the European Space Agency's planned ExoMars rover. "It means organics survived in the Mars environment."

In late 2014, Curiosity entered the Murray formation, another mudstone thought to be a lakebed from 3.5 billion years ago, as attested to by recently observed mud cracks. The rover drilled rocks that, baked at high temperatures, released organic

materials containing sulfur. These molecules are unlikely to be contaminants—for one thing, Curiosity had never detected them before. This Murray sample and several others are also yielding organic fragments in startling concentrations, as high as parts per million. Such a result, a hundred times the concentrations seen by the Viking landers in the 1970s, would be "amazing," Geffroy says. Indeed, most SAM scientists now believe "that organics are more prevalent than not in many samples," Mahaffy says.

More intriguing still are a handful of longer chain, heavier organic molecules, detected thanks to the ambient bath of leaked solvent. They have defied identification, but may resemble remnants of fatty acids. Life tends to churn out fats in even numbers, with chains 12, 14, 16, and 18 carbons long; finding hints of such a pattern is the bio-signature that Mahaffy dreams of discovering. Fats are a good target, adds George Cody, acting director of the Geophysical Laboratory of the Carnegie Institution for Science in Washington, D.C.—tough, plentiful, and known to survive in ancient samples from Earth. But they're also a common lab contaminant, left by technicians' fingers; any discovery would face a high bar in verifying its origins.

A wet chemistry test could follow up on those clues. But after pausing for 2 weeks in December 2016 to focus on fixing the drill, the Curiosity team decided to start driving again, leaving behind a promising drilling site and potential wet chemistry target.

Meanwhile, engineers continue to probe why the drill's brake sometimes won't release. Martian grit or shavings from wear and tear inside the drill could be causing it to seize up. So far they have no recipe for fixing it.

Even if the drill ends up a lost cause, NASA scientists have long proven ingenious in adapting to faulty equipment. The rover still has a scooping arm, and they might get lucky and find some recently exposed loose grit that is easy to scoop.

Cody, for one, isn't going to second guess the decision to wait so long to use the wet chemistry cups. "It pays to be prudent," he says. After all, data from orbiting satellites suggest that promising targets lie in the path up the slopes of Aeolis Mons, a 5000-meter mountain rising in the middle of Gale crater. One is a ridge of hills capped with hematite, an iron-rich mineral that could provide energy for microbes. Farther up the mountain's flanks is another stretch of clay-rich mudstone.

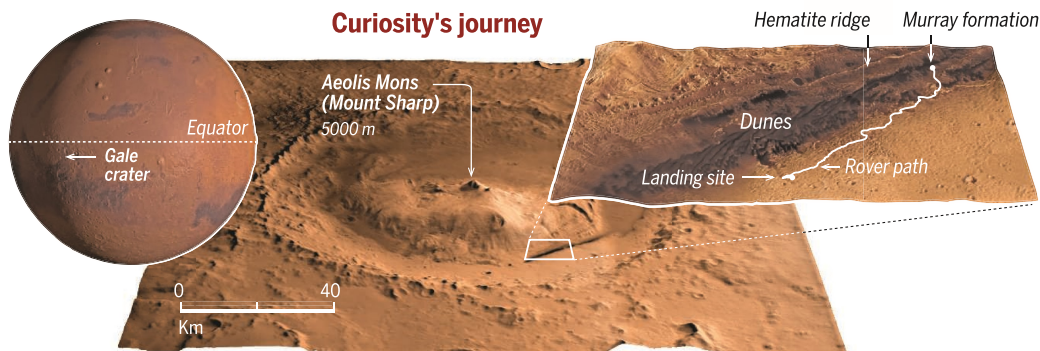
But already, Curiosity has had opportunities to use a wet chemistry cup on two different mudstones that preserve organics. Mahaffy hopes there will be another chance. ■

"Organics are more prevalent than not ..."

Paul Mahaffy,
Goddard Space
Flight Center

A MOUNTAIN TO CLIMB

Since landing in Gale crater in August 2012, NASA's Curiosity rover has traveled 15 kilometers, and is now climbing the flanks of Aeolis Mons. Clay-rich rocks around its base are promising targets for wet chemistry experiments because they can preserve carbon-bearing molecules.

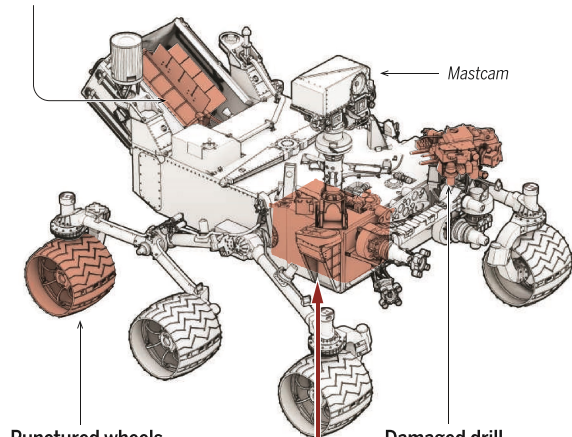
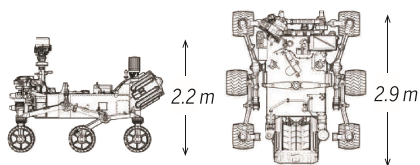


An ailing rover

Five years in the harsh environment on Mars have taken a toll.

Waning power

The radioactive plutonium-238 that powers the rover is decaying. At landing, power output was 112 watts, but now the rover gets 95 watts.

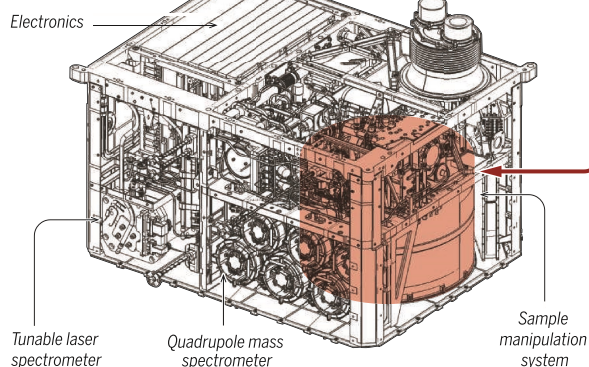


Punctured wheels
Sharper-than-expected rocks have torn holes in the rover's thin aluminum wheels.

Damaged drill
In December 2016, the drill began to have problems moving up and down into its target, perhaps because of a stuck brake.

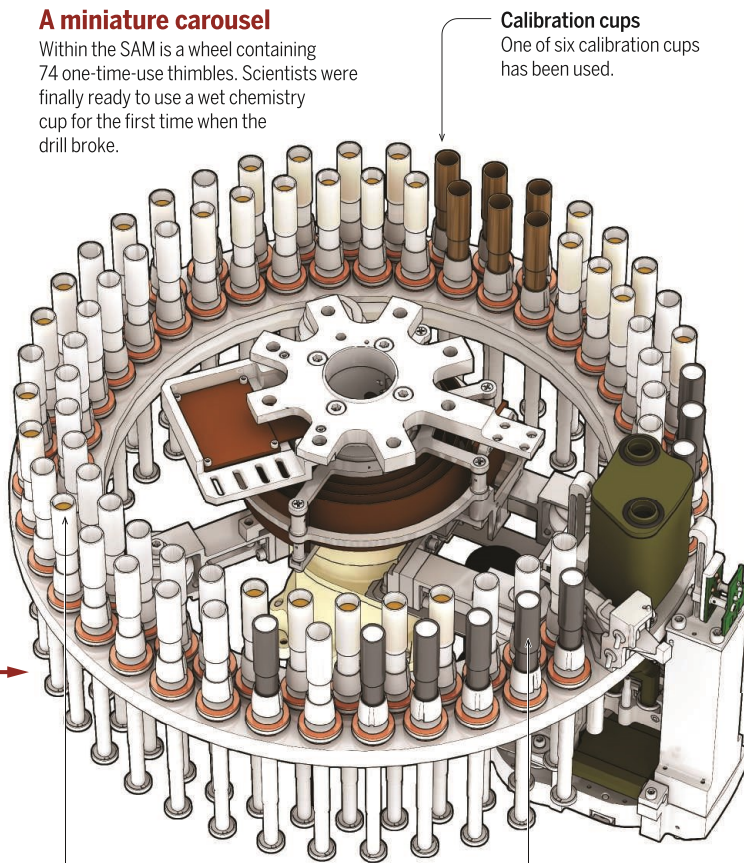
Sample Analysis at Mars (SAM)

The SAM, the largest and most complicated instrument on the rover, has two types of mass spectrometers.



A miniature carousel

Within the SAM is a wheel containing 74 one-time-use thimbles. Scientists were finally ready to use a wet chemistry cup for the first time when the drill broke.



Dry cups

Twenty-nine of 59 dry cups, made of quartz, have been used.

Wet cups

Nine foil-sealed cups contain solvents that make it easier to detect organic molecules.

Easy-bake oven

After being filled with dirt, a cup is raised into an oven that can bake the sample to 1100°C. A stream of inert helium carries any vapors from the cup to mass spectrometers that identify individual molecules based on their weight.

