Drilling Down into Mars

June 8 2010, by Henry Bortman

Honeybee Project Engineer Gale Paulsen adjusts settings for the Mars Simulation Chamber in preparation for a test of the company’s rotary-sonic drill. Credit: Henry Bortman

(PhysOrg.com) -- NASA's Phoenix lander revealed water ice mere inches beneath the martian surface, and chemical evidence from the landing site strongly hints that the region is habitable. But learning whether there is life in martian ice will require drilling — and drilling on Mars will be anything but easy.

A catalogue of places on Earth where one can find Mars-like conditions might include Antarctica's Dry Valleys, Devon Island in the Canadian Arctic, the hyper-acidic Rio Tinto in Spain, and Chile's bone-dry Atacama Desert. But it probably wouldn't include Brooklyn.

And yet it's in Brooklyn where, in an otherwise unexceptional warehouse, Honeybee Robotics has installed a massive stainless steel chamber whose interior environment can be made more Mars-like than most anywhere else on Earth. Eleven feet tall, three feet square, its walls one-and-a-half inches thick, its doors studded with a dozen small square windows, the whole thing looks like refrigerator on steroids.

Which, more or less, it is. The edifice is flanked by canisters of coolant capable of chilling its interior to minus 80 degrees Celsius (minus 112 F) and by pumps that can suck its atmosphere down to a near-vacuum. Honeybee calls it their Mars Simulation Chamber. They use it to test drills, drills that some day may play a crucial role in the search for life on the Red Planet.

Soil on the surface of Mars is generally considered inhospitable to life. The scarcity of liquid water, due to sub-freezing temperature and low atmospheric pressure, and the presence of ionizing radiation, which can damage genetic material, would make it difficult for even the hardiest forms of microbial life as we know it to survive there.

But below the martian surface lies a different story. NASA's Phoenix lander, for example, which in 2008 investigated a small patch of ground near the martian north pole, found water ice mere inches below the surface. Some scientists believe that if there is life on Mars, this subsurface ice, which may contain miniscule amounts of liquid water, is the most promising place to look for it.

Chris McKay, a planetary scientist at NASA Ames Research Center in Moffet Field, Calif., argues, based on the discoveries made by Phoenix, that “the shallow subsurface ground ice in the northern plains is an ideal place to search for evidence of life on Mars and the possibility of organics preserved in the ice.”

McKay is the principal investigator on the IceBite project, which is funded by NASA’s ASTEP (Astrobiology Science and Technology for Exploring Planets) program. It is as part of IceBite that Honeybee is designing and testing a series of drills to determine the optimum configuration for boring into subsurface martian ice. Ultimately, McKay hopes to obtain samples of icy martian soil from as much as a meter deep and to bring them to the surface for chemical and biological analysis.

This color image, acquired by the Surface Stereo Imager on NASA's Phoenix Mars Lander in June 2008 shows lumps of subsurface ice exposed in a trench scraped out by the lander's robotic scoop. Credit: NASA/JPL-Caltech/University of Arizona/Texas A&M University

Later this year the IceBite team plans to test one of Honeybee's drills in Antarctica. There, in University Valley, a mile above sea level, a thin layer of dry soil lies atop subsurface ice that remains frozen year-round. This dry-soil-over-ice arrangement, widespread on Mars but extremely rare on Earth, resembles the stratigraphy at the Phoenix landing site. McKay calls it "dry permafrost."

Experience in University Valley will certainly help scientists understand the physical, chemical and biological interactions that take place in dry permafrost, and will yield valuable lessons about the real-world difficulties of drilling in such an environment. But even hauling a drill to a remote frozen valley in Antarctica won't answer all the questions that need to be answered before sending a drill to Mars - because a drill won't behave the same way on Mars as it does on Earth. On Earth, when ice is heated (by the friction of a rotating drill, for example), it melts; it turns liquid. On Mars, because of the thin atmosphere, heated ice doesn't melt, it sublimes: it skips the liquid-water phase and passes directly from solid ice to gaseous vapor.

This is not a minor point. It complicates the process not only of designing a drill to perform properly on Mars, but also of testing its behavior on Earth. For example, when Honeybee performed an ice-drilling test in a chilled metal cylinder, outside the Mars Simulation Chamber, the combination of the heat generated by the drill bit and the ambient temperature and air pressure in the room caused some of the ice to melt. Then it refroze. Which jammed the drill bit.

That won't be a problem on Mars, because ice there won't melt and refreeze: it will vaporize. And when it vaporizes, it will expand, rapidly. So when a drill bores down into martian ice, tiny soil particles loosened by the drill will shoot up out of the drill hole like a geyser, carried aloft by jets of water vapor.

That’s not necessarily a bad thing. In fact, it may turn out to be a cost-effective way to deliver subsurface material to a lander’s scientific instruments. “Very often what you’ll find,” says Kris Zacny, senior scientist at Honeybee Robotics and a co-investigator on the IceBite project, “is that getting the cuttings out [of a drill hole] is even more difficult than breaking the rock.” But despite its potential usefulness, the vapor-jet effect, among others, is impossible to test for under Earth conditions. That’s why Honeybee built the chamber.

Antarctica's University Valley, where later this year the IceBite team will field-test Honeybee Robotics' rotary-percussion drill, boring as much as a meter into the subsurface ice. Credit: M. Marinova

Honeybee is investigating three types of drills: rotary, rotary-sonic and rotary-percussive. A rotary drill is the most basic: it’s like the drill you might use at home to poke holes in wood. Don’t try to use it on rock or concrete, though. “Without pressing really hard,” says Zacny, all you’ll succeed in doing is wearing out the bit. Subsurface ice or icy soil on Mars will be “as hard to drill as medium-strength sandstone,” says Zacny. And because the drill most likely will be attached to the end of a robotic arm, there won’t be any way to apply the required weight to make a rotary drill practical.

In a rotary-sonic drill, a pair of off-center weights at the head of the drill rotates, 100 to 200 times per second, inducing a small vertical vibration in the drill string (the entire length of the drill from its head down to the bit). Zacny compares this to an electric toothbrush. “Imagine this big toothbrush going down into the rock,” he says. Because of the vibration, “the forces between the bit and the rock are much higher than the force that you’re pressing with.” A meter-long rotary-sonic drill built by Honeybee for IceBite is currently being tested in the Mars Simulation Chamber.

But still being assembled on a lab bench in Honeybee’s main office, slated for testing in the Mars Simulation Chamber this summer and in Antarctica later this year, is a newly designed rotary-percussive drill. Like a rotary-sonic drill, a rotary-percussive drill adds a vertical component to the rotary motion of the drill bit, but instead of relying on vibration, a rotary-percussive drill adds force by, roughly 30-40 times a second, tapping the top of the drill with a weight, the equivalent of whacking it with a hammer.

Most rotary-percussive drills, however, use compressed air to accomplish this hammering effect. That won’t work on Mars: martian air is too thin -- less than one-hundredth of the air pressure on Earth -- so Honeybee is experimenting with an unconventional spring-loaded mechanism whose spring gets slowly compressed and then suddenly released to produce the hammering pressure.

The temperature and pressure on Mars mean that nothing about drilling there will be easy. But McKay hopes that all the lab and field testing planned as part of the IceBite project will ultimately produce a flight-ready drill. And where does he propose to send it? Back to the Phoenix landing site.

"The Phoenix landing site … is arguably the most likely site to support recent life on Mars," McKay says. But, he adds, going back to the same place a second time won't be just a dull rerun of the Phoenix mission. The goal of his proposed future mission will be "to explore a completely new place - the subsurface environment. A place that no previous mission to Mars has investigated."

Source: Astrobio.net

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