The Inferno Revisited

An eight-legged Dante will explore inside an active volcano

By RICHARD MONASTERSKY

"There was a very large eruption and the two of us down there were just blasted to the ground. Big rocks were everywhere, whistling through the air," recalls volcanologist Philip R. Kyle with the wry detachment of someone describing a dangerous encounter long since past.

That was 1974, when a combined New Zealand, French and American team attempted to make the first descent to the crater floor of Mt. Erebus, a smoldering volcano stuck in the frozen world of Antarctica. The crew of scientists and climbers had hoped to reach a rare lava lake within Erebus' crater to collect samples of the gases escaping from the volcano. But the storm of flying rocks convinced Kyle and his comrades to abandon that venture.

Four years later, the persistent volcanologist went back again. He and a group of fellow New Zealanders actually succeeded in lowering a scientist by rope to within 30 meters of the crater floor. Once more, though, the volcano turned uncooperative. "Lo and behold," says Kyle, "we had a small eruption again that showered everyone on the crater rim with rocks. A rock — a volcanic bomb — actually went by the legs of the guy who was hanging on the rope down in the crater. Burned a hole in his pants. And there was a little burn in the rope that he was hanging on," says Kyle, now at the New Mexico Institute of Mining and Technology in Socorro.

Two serious attempts, two failures. "We haven't tried since," laments Kyle.

Until now.

Kyle is preparing for yet another mission to explore Erebus' lava lake, but this time with little risk to human life or limb. Instead, an eight-legged robot named Dante will dare the descent.

The project springs from the mind of William "Red" Whittaker, a risk-taking robotics expert at Carnegie Mellon University in Pittsburgh. Not only has Whittaker decided to challenge his mechanical progeny with some of the worst weather conditions Earth has to offer, he has also pledged to carry out the entire project, from conception to completion, in the span of a year.

"It's a major-league gutsy move," comments David Akin, a robotics researcher from the University of Maryland in College Park.

Whittaker's robotics team chose the name Dante for the crater explorer to recall a literary descent into another Erebus, described by the fourteenth century poet Dante Alighieri. In classical Greek mythology, the name Erebus refers to a region of darkness that forms part of the underworld, where dead souls must go. This is the land visited by Dante in his *Divine Comedy.* Having strayed from life's path and lost his way, Dante seeks to return home by climbing down into the underworld and then out the other side. For part of his journey, Dante is guided by the ghost of the Roman poet Virgil.

Whittaker's robo-Dante will have its own Virgil. This truck-like robot will serve as a transporter, carrying the smaller Dante from the coast to the mountaintop, a distance of about 60 kilometers. For most of the journey across the ice and snow, human operators will pilot Virgil. But when it reaches a base camp on the flank of Erebus, the eight-wheeled transporter will largely drive itself the last 2 km to the crater rim.

Like the ghost, this Virgil cannot accompany its partner for the entire journey. Only Dante can complete the quest.

In truth, Whittaker's creation looks more like a web-spinning spider than a poet. The gangly Dante with its eight legs will lower itself into the crater by a tether anchored to Virgil.

Not only a rappelling rope, the tether also serves as the robotic equivalent of an umbilical cord. Through it, Dante can both receive electrical power from the diesel-powered Virgil and send up images and information. The transporter can then transmit that information to the field camp and possibly back to the United States via satellite.

Down on the crater floor, Dante will play the role of field geologist, collecting information that Kyle and his colleagues have long desired. Most important, the robot will study the vapors rising from volcanic vents called fumaroles. A gas chromatograph on Dante can quickly relay information about these gases back to the scientists, while the machine also collects direct samples for later analyses in the lab.

Escaping from inside the Earth, these gases contain clues about the source of the magma feeding Mt. Erebus. "For volcanoes, these gases — the volatile elements like carbon dioxide and water — are like blood for a human being. They are the life body of a volcano," says Kyle.

The volcanologist believes Erebus exhales copious amounts of carbon dioxide, but it is impossible to test that theory high up on the crater rim. "In order to really know what the composition of the gas is, samples have to be collected from high-temperature vents, which are in the crater."

The robotics team also hopes Dante will collect samples of an unusual powdery material that rings the fumaroles on the crater floor. Scientists have spotted the powder from above, and they believe it forms when escaping gases cool, causing vaporized metal molecules such as gold, copper and zinc to solidify on the ground. A similar process occurs inside the volcano, creating what will become ore deposits over thousands of years. By studying these minerals in an active volcano, geologists can learn more about ancient ore deposits that are mined today, says Kyle.

As Dante explores the crater, researchers will monitor its progress

Kyle

A plume of smoke rises from the floor of Erebus' inner crater. The steep-walled pit, about 150 meters across, sits within a wider, outer crater. Although scientists have explored the outer crater, no one has made it to the floor of the inner crater. The robot Dante will descend from the rim of the outer crater to the floor of the inner crater.

through color videocameras mounted on top of the robo-geologist. Black-and-white high-resolution cameras will serve as the eyes of the robot, providing stereoscopic vision to help it navigate. The crater crawler will also sport an instrument for analyzing the mass of small particles in the gases, as well as an electronic thermometer that can measure the temperature of the lava lake from a distance, says project manager James Osborn of Carnegie Mellon.

Climb down, take a few samples, then climb out again. Though it sounds simple, the Erebus mission is pushing the very bounds of the robotics field. Whittaker describes the project as the hardest he has tackled in over a decade of building robots.

That appraisal comes from someone who has seen plenty of challenges. In the mid-1980s, Whittaker designed a series of robots to assist in the cleanup of radioactively contaminated areas at the Three Mile Island nuclear power station. He has also created a six-legged walking robot called the Ambler and outdoor navigation vehicles that can drive themselves down a road at speeds of up to 50 miles per hour.

When asked to describe the difficulties of the Erebus project, Whittaker laughs, launching into a half-hour-long list of problems confronting the small army at Carnegie Mellon constructing the explorers. In a sense, the project represents one big exercise in applications: taking lab-proven technology and thrusting it into the harsh reality of the outside world. Inside a laboratory, engineers can tailor the environment, smoothing out the rough edges to give a robot every chance at success, whether it be walking across a smooth floor or bouncing a balloon. Not so in nature. If a boulder or crevasse lies between a robot and its quarry, the machine must maneuver around the obstacle.

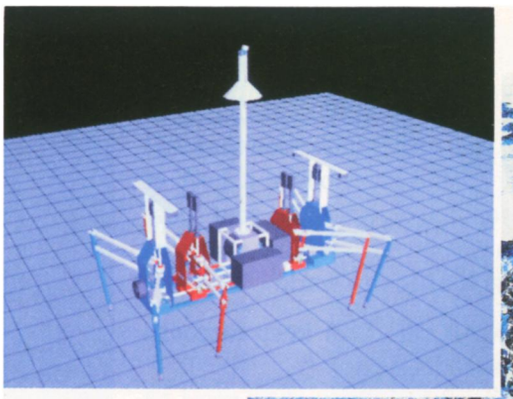
All field missions face this problem, but Mt. Erebus presents a particularly daunting landscape. While in the crater, Dante must negotiate cliffs, overhangs, fractures, soft ash beds and other nightmarish terrain rarely seen outside geologically active areas. "It's as bad as it gets," says Whittaker.

Because minor eruptions are continually reshaping the crater, the engineers cannot even provide the explorer with terrain maps to guide its journey. What's more, the plumes of gases coming from the crater make it difficult to get clear aerial photographs, removing another source of information about the volcano's interior.

The formidable weather at Erebus further complicates the task. At an altitude of 3,700 meters on the crater rim, the temperatures will hover around -25°C, with strong gusts of wind. The explorer must go from freezer to oven as it descends into the crater, where it might encounter temperatures as high as 800°C inside the fumaroles. Making matters worse, says Whittaker, the gases rising from these vents also create corrosive hydrofluoric, hydrochloric and sulfuric acids. A wrong turn into the lava lake or a steaming fumarole would spell an ignoble end for Dante.

"You're talking about an extremely nasty environment," comments Roger Quinn, a mechanical engineer who designs walking robots at Case Western Reserve University in Cleveland. Because of the conditions on the mountain, the Carnegie Mellon team must create what robotics engineers call a robust system, one capable of functioning even after problems arise, says Quinn. "It's a very difficult problem," he adds.

The project also requires new developments in an arena of robotics known as task control — basically, the system that makes decisions for the robot. Human operators camped on Erebus' flank will control some of the broader aspects of the mission, such as choosing the best site for collecting scientific samples. But decisions about where to place a foot are best left to software and silicon, says Whittaker. If difficulties arise, though, humans can intercede and pilot the robots.



Eric Hoffman/Matt Arnold

Kimberly Faught

An artist's conception of Dante (right) shows the robot beginning to rappel into the crater. Since the time of the illustration, plans for the robot design have changed. A computer model of the robot walking (above) provides a truer sense of Dante's shape.

Of all the challenges the Erebus team faces, the most worrisome is the calendar in Whittaker's office. Because the $2 million for the project comes from a one-time appropriation to NASA's robotics division, the Carnegie Mellon team has only a limited time to show some fruits of that funding. The short field season for Antarctic missions further constrains the timing, requiring the Dante-Virgil team to be ready by October.

"A lot of people wouldn't give this thing very good odds," says Whittaker. "People have said it's impossible [to build the robots] in the time frame and that the technology is not available."

Dismissing the naysayers, Whittaker turns the tables, saying that short projects offer the greatest potential for advancing robotics. "The idea of a hard commitment, of focused and intense research, sets an environment for a particular quality of invention so that you really come up with the great ideas out of necessity."

Contrary to the popular vision of robots — fueled by such characters as R2D2 on "Star Wars" or the android Data on "Star Trek" — robotics is a fledgling field, still struggling to design machines that can walk on their own without getting stuck in a corner. Because each project teaches something new, researchers stand to gain most by completing short, intense ventures, Whittaker argues.

Standing near the edge of Erebus' crater, a scientist provides some sense of scale.

Kyle

He views the Erebus project as a natural stepping-stone toward designing robots that could explore other planets. After all, the harsh environment of an Antarctic volcano provides a natural testing ground for units that will negotiate the cold, rock-strewn surface of Mars. "I believe the order of accomplishment is going to be Erebus on the way to the moon on the way to Mars," says Whittaker, who plans to be working on a lunar walker by this time next year.

With so much future potential, there's a lot riding on the Erebus mission. Success on the volcano would give the Carnegie Mellon team a leg up on other robotics groups racing to design autonomous walkers that could serve future space missions.

A stalwart defender of the project, Whittaker does his best to convince others that Dante and Virgil will return with samples of the gases from the crater bottom. But even if the machines accomplish only part of the mission, he believes they will succeed in pushing robotics toward new frontiers.

Maryland's Akin agrees that the act of trying may be enough. "As far as I'm concerned," he says, "if this thing gets halfway down the crater and sends back some data and then a leg falls off, it's still a success." □