

Diamond drilling on Mars

In February this year, history was made when a specially designed diamond tool made the first of many drilling operations on the surface of Mars as part of NASA's latest mission to uncover the secrets of the planet. This report by **Brian Cline** outlines the background behind the development of this extraordinary tool.

NASA's twin 2003 Mars Exploration Rovers, which are now on the surface of the planet, are equipped with the Rock Abrasion Tool (RAT) designed, developed, and operated by Honeybee Robotics (New York City, USA). The Rovers (named Spirit and Opportunity) will explore parts of the Gusev Crater and Meridiani Planum regions on Mars.

The RAT is a robotically-controlled abrasion tool weighing about 685 grams and measuring around 7 cm (2.7 inches) in diameter and 10 cm long (4 inches). It is carried by the rover's mechanical arm. The primary purpose of the RAT is to remove dust and weathering rind from Martian rocks to reveal fresh underlying features.

On Friday, 6th February, Spirit employed its RAT equipped with a diamond drill bit to drill the first exploratory hole on a rock nicknamed Adirondack. The three-hour procedure resulted in a hole 45 mm in diameter and 2.7 mm in depth. By taking readings on both the interior and the surface of the rock, scientists hope to gain a better understanding of its history.

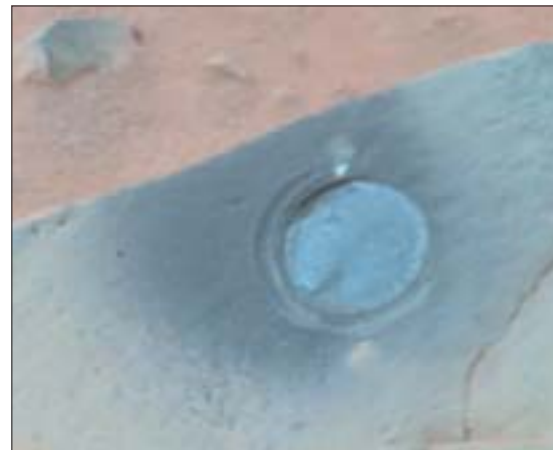
Cline Innovations (Sterling, MA, USA) served as a consultant on the design of the diamond-machining component used on the RAT. After supporting Honeybee Robotics' efforts to design, procure, and test several diamond grit, polycrystalline diamond, and single-crystal diamond designs, a resin-bonded diamond bit was found to perform best in test rock including basalt and limestone. Given the extremely low down-force applied by the robot, an extra-soft resin bond formulation was required to maintain grinding efficiency.

Additionally, a reduction in the wheel contact area and optimization of the diamond grit size and concentration was necessary. The final bit design uses two pad contacts oriented 180 degrees from each other with a total contact area of 26 mm².

The diamond bit is mounted to one of two separate 3000 rpm spindles in the RAT design. A brush is mounted to the second spindle. Prior to grinding, the rover arm generates 10 to 100 Newtons of stabilizing force ('pre-load') using butterfly contacts with the Mars surface. Grinding is then performed using a contact-to-rock force of only about 5 Newtons (1.1 lbs Earth equivalent). After the initial plunge of the diamond bit creates a ring-shaped cut in the rock, both spindles are orbitally rotated about the center of the RAT axis to create a blind hole with a 45 mm diameter (approximately 2 times the diamond bit diameter). After iterative plunging and slow rotation about the RAT axis, a 1 to 5 mm deep hole can be created within 2 to 4 hours using a 30 Watt-hour daily power ration from the rover.

Honeybee Robotics is a leading developer of highly customized robots, smart machines, and related technologies used for space exploration, industrial automation, and exhibition and entertainment. Founded in 1983 as a systems integrator using off-the-shelf robots, the company quickly gained a reputation for its innovative design skills and creative problem solving. Honeybee received its first NASA contract in 1986 and has subsequently worked on more than 75 others in addition to completing projects for companies such as Coca Cola, 3M, Nike, and IBM.

Cline Innovations, LLC offers materials consulting services focused on the use and integration of advanced materials for wear resistance and other extreme applications. The company works with a range of materials including advanced surface treatments, coatings, cemented carbides, industrial ceramics, and superhard materials. Diamond materials technology and applications is a specialty of Cline Innovations. ♦



Top: Close up of the working end of the RAT including the diamond bit, mechanical brush, and two butterfly contacts

Middle: Image depicting Rover design with the Rock Abrasion Tool (RAT) mounted on the end of the robotic arm

Bottom: The RAT has completed its first dig into a Martian rock - this is the crater that Spirit's RAT left in Adirondack

Acknowledgment:

All images courtesy of Honeybee Robotics, NASA/JPL, and Cornell University.

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www.honeybeerobotics.com
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