PLANETARY SCIENCE

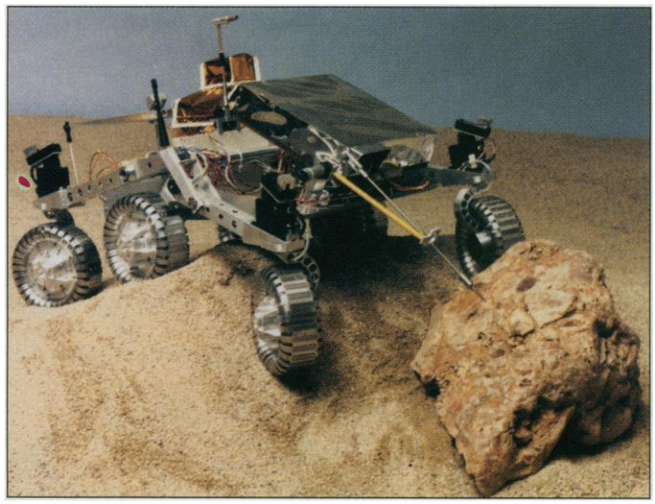
Swarms of Mini-Robots Set to Take on Mars Terrain

Last week at a Washington, D.C. exposition center, a group of children fell in love with something that looked like the Christmas present of their dreams: a toy dump truck on space-age wheels. And it was just child-sized, too. As the small mechanized wonder circled around a patch of rock and dirt set up to emulate the rough surface of Mars, the kids poked and prodded, some roughly enough to worry a nearby adult. "Kids—Don't touch the solar panels!" called out a concerned scientist from the Jet Propulsion Laboratory (JPL) in Pasadena, playing the role of Scrooge.

The JPL scientist was right to be protective. Program managers at NASA are seriously considering this miniature robot and some of its brethren, which go by the name of "microrovers," as the next explorers of Mars. A handful of designs was on display at the Washington D. C. Rover Expo. "There's been a paradigm shift in the last year," says Donna Pivirotto, who manages the small rover program at JPL. "We've gone from thinking these little things are scale models and toys to knowing they are the real thing." In particular, NASA officials are enthusiastic about sending a fine-tuned version of one of a series of microrovers that go by the name of Rocky on the next proposed U.S. Mars mission: the Mars Environmental Survey, scheduled to land in 1997. NASA officials envision sending up a pack of advanced Rockys to chip at rocks with tiny picks, scoop up rock samples, and even carry around pint-sized seismometers and spectrometers.

NASA has only recently started taking a serious interest in Mars-bound robots this small—Rocky 3, for example, weighs in at 18 kilograms and is 30 centimeters long. Robot design programs used to focus on larger specimens, built for their ability to range over large distances, move large objects, and carry out complicated tasks. But several factors have combined to shift attention to miniatures like Rocky. One is cost. Rocky and the related microrovers are cheaper to launch by a factor of 1000 than traditional large robots, according to JPL's chief Rocky designer David Miller. That means project managers can send out a fleet and still come out ahead in their budgets. "Launching instruments costs millions of dollars per pound," says David Lavery of NASA headquarters. "So if it's a 10-pound robot versus a 100-pound one, the little one wins."

Another factor has been the rapid shrinkage of scientific instrumentation, a trend that has gone far enough so that compact vehicles like Rocky can carry lots of scientific punch in the form of 50-gram seismometers and even a "proton x-ray spectrometer" that bombards rocks with protons and analyzes them by the spectrum of x-rays that come bouncing out. These things were "unthinkable," even 3 years ago, says JPL scientist Rajiv Desai, one of Rocky's codesigners.



NASA

Rock and roll. Rocky 4, a "microrover" only 60 centimeters long, built by the Jet Propulsion Laboratory in Pasadena for NASA's Environmental Survey of Mars, which is scheduled for 1997.

These trends—cost and instrumentation downsizing—have lured several other organizations into the field. Rocky 3 of JPL was joined at the expo by small robots designed at MIT, Sandia labs in New Mexico, and a Boston-based company called ISRobotics. (Many of the JPL robots crew also work for this company.) Most of the little robots developed so far are guided by radio controls. Only Rocky 3 and one of the ISRobotic designs called Genghis 2 move under their own direction.

If the idea of a swarm of little robots maneuvering over the Martian landscape conjures up images of an anthill, you're on the right track: Rocky 3 and its kin owe their inspiration to insects. In the mid-1980s, MIT computer scientist Rodney Brooks concluded that the behavior of insects was much easier to simulate than that of human beings; he soon had insect robots crawling around his lab (*Science*, 25 May, 1990, p. 959). "Insects manage pretty well in life," says Desai. They don't do many things, he adds, but their simple neurological wiring enables them to follow a chemical trail, avoid obstacles, pick things up, and return safely to home base. That's a philosophy that suits the Mars mission just fine, adds Desai: "What's our goal? We want to go to Mars, pick up a sample and come back—without getting stuck."

Desai says he, Miller, and a handful of other JPL scientists first demonstrated what they could achieve with small robots by building a 30-centimeter-long creation called Tooth, which was essentially a mechanical golden retriever. "You could leave it for hours, and it would keep running around, picking things up and bringing them back to a light bulb, which acted as a beacon," says Desai. But Tooth was strictly an indoor robot, unable to negotiate the rough Mars terrain.

At the same time, other JPL scientists were developing Rocky 1, a dumb but quite rugged machine that used a specially balanced six-wheeled design invented by their JPL colleague Donald Bickler that could easily handle rough terrain. The next step? "We needed to combine Tooth's brain with Rocky's body," says Pivirotto. The result was Rocky 3, and the more agile Rocky 4, which wasn't ready for display at the expo. Rocky 4 has a little pick it uses to chip into rocks, a skill that may help scientists understand the weathering processes of the rocks on Mars. Because that process is so slow "you can see back 10,000 years with 1 millimeter," says Desai.

These creatures have won the hearts of more than just small children—even Washington bureaucrats are impressed. "NASA loves the idea of going to small rovers because of the cost," says Carl Rouff, a JPL mission technologist. David Lavery of NASA headquarters agrees. "Large robots are not in the immediate future." That doesn't mean researchers aren't continuing to work on bigger robots though. At the show, Pivirotto points to the antithesis of Rocky: a 17-foot-tall monster looming over the spectators. "That's Ambler," she says, a creation being built at Carnegie-Mellon University with a NASA grant.

But even if Rocky is winning its battle against the Frankenstein-like Ambler, victory has its down side: The Mars trip is a suicide mission. "We think they might last from 2 days up to a week," says Desai. Then the cold Martian nights will crack their bodies and break their little circuits. But a worse fate could await the big robots—they might end up rusting away in a university warehouse, never making the big trip to Mars at all.

–Faye Flam