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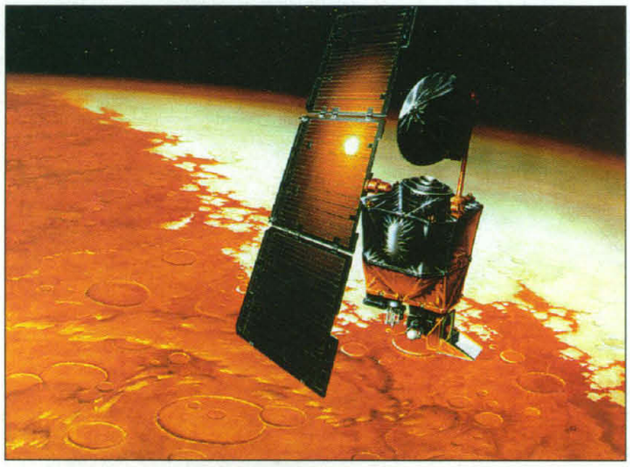
PLANETARY SCIENCE

# No Easy Answers in Mars Probe's Fiery Death

Did the world's best spacecraft navigation team simply miss? When the Mars Climate Orbiter (MCO) spacecraft, scheduled to enter orbit for a 2-year mission to study martian weather, dipped too far into the atmosphere on its arrival last week and perished, officials at the Jet Propulsion Laboratory (JPL) in Pasadena, California, pointed a finger at the lab's navigation experts. "It looks like something was wrong with the ground-based navigation," said project manager for spacecraft development John McNamee of JPL.



**What might have been.** Mars Climate Orbiter may have perished because of its unusual one-armed solar panel design.

Yet some outsiders suspect that may not be the full explanation, noting that the team has been unfailingly flawless in shepherding spacecraft to their destinations. "I've never heard of a problem like this," says spacecraft navigation specialist Robert Farquhar of the Applied Physics Laboratory in Laurel, Maryland. "That's why I'm so amazed. It could end up it was the navigation team's fault, but it would surprise me." He suspects that there was a good deal more to losing the $87 million spacecraft than a navigation team member slipping a decimal point.

Over 4 decades, navigating spacecraft across hundreds of millions of kilometers of space to hit targets a few tens of kilometers across has become routine, if still spectacular. In the case of MCO, a small navigation team at JPL tracked the spacecraft using Doppler data—radio frequency changes that yield spacecraft velocity and acceleration—and range data from radarlike signals that made a round trip from Earth to MCO and back, giving the distance between the two. The team compared the craft's actual position and its intended position so that short burns of the onboard rocket engine could bring it on target.

Last week, after four trajectory adjustments based on tracking data, navigation team members thought they knew the location of MCO to within 20 kilometers—and it appeared to be on target to pass 140 kilometers above the martian surface, safely skirting the atmosphere before going into orbit. But after reviewing tracking data from the final 8 hours before arrival, spacecraft controllers realized that their spacecraft had come in 80 kilometers too low—a huge, 10-sigma error. More than 55 kilometers low would have been fatal.

Because MCO seemed to be working perfectly as it disappeared behind the planet on its way to the planned close approach, "we're ruling out a spacecraft problem and looking at the possibility of human error and software problems," said Richard Cook, JPL's project manager for operations, at a press conference. The next day team members, acknowledging that MCO's brush with the martian atmosphere must have overheated it or torn off parts, abandoned the search for radio signals from the craft.

Farquhar suspects, however, that it was a lot more complicated than the simple catastrophic navigation error implied at the press conference. According to Farquhar, who has talked with JPL staff, the navigation team's calculation of MCO's trajectory "was bouncing around" during the last 2 days far more than the spacecraft itself should have been moving. That created some concern about just how low MCO was going to pass by Mars. Any number of problems could have contributed to last-minute uncertainties, notes Farquhar. Fuel jetting into space from a leak could have pushed the spacecraft off course. Adjustments for the unbalanced effect of solar radiation hitting MCO's single solar panel might have unintentionally altered the trajectory. Or the drive to economize on one of NASA's "faster, cheaper, better" missions might have left too little tracking data. At this point, says Farquhar, "I think we all have to withhold judgment as to who is at fault."

Whatever the ultimate cause or causes of the loss, planetary scientists will have to live without observations of clouds, dust, and water vapor that would have helped them understand the martian hydrological cycle. But it could have been worse: Mars Global Surveyor, which has been in martian orbit for 2 years, will continue to return images of clouds and dust. It will also be able to fill in for MCO in another role: serving as a radio relay station between Mars Polar Lander and Earth when that probe rockets onto the surface in December. The most immediate impact of the disaster may be felt on Capitol Hill, where scientists are trying to head off deep cuts in NASA's space science budget. "This isn't going to help," observes one scientist. **–RICHARD A. KERR**

PALEOANTHROPOLOGY

# Neanderthals Were Cannibals, Bones Show

Neanderthals were skilled hunters, working together to fell deer, goats, and perhaps even woolly rhinos with wooden spears. After the kill, they expertly butchered the carcasses, slicing meat and tendons from bone with stone tools and bashing open long bones to get at the fatty marrow inside. Now, on page 128, a French and American team reports that 100,000-year-old Neanderthals at the French cave of Moula-Guercy performed precisely the same kinds of butchery on some of their own kind.

Marks on the bones clearly reveal that these early humans filleted the chewing muscle from the heads of two young Neanderthals, sliced out the tongue of at least one, and smashed the leg bone of a large adult to

CREDIT: JPL/NASA