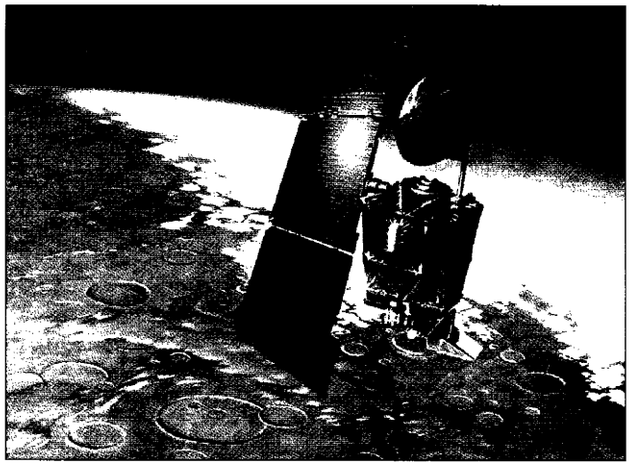
PLANETARY SCIENCE

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

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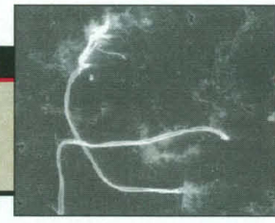

get at the marrow. The bone fragments were apparently then dumped amid the remains of deer and other butchered mammals. "Human and mammal remains were treated very similarly," says first author Alban Defleur of the Université du Mediterrané at Marseilles. "We can safely infer that both species were exploited for a culinary goal."

Tantalizing hints of cannibalism have been spotted at other Neanderthal sites for decades, but this is far and away the best documented case, say other researchers, who praise the team's careful comparison of breakage and cut marks in deer and human bones. "Quite convincing," says anthropologist Fred H. Smith of Northern Illinois University in De Kalb, noting that there's little sign of gnawing or other indications that carnivores rather than people mauled the bones. "And the documented cut marks seal the deal."

Flesh-eating feast? A teenager's jaw and an adult thigh bone bear cut marks.

Smith and a few others say that without an eyewitness, we may never know exactly why Neanderthals handled corpses so seemingly brutally. But most paleoanthropologists are unfazed by the idea of early humans eating each other. As Milford Wolpoff of the University of Michigan, Ann Arbor, puts it, "Why should modern humans be the only violent ones?"

Defleur began to zero in on cannibalism after he saw cut marks on human bones from a test pit sunk into the cave at Moula-Guercy, a site that had previously yielded stone tools characteristic of the Neanderthals' Mousterian culture. He teamed up with paleoanthropologist Tim White of the University of California, Berkeley, to rigorously compare the pattern of marks on the human bones with those on bones from red deer, presumably hunted for meat, at the same site.

The bones—78 pieces identified as belonging to at least six humans and almost 400 fragments attributed to other mammals—were scattered over 20 square meters. All the braincases and long bones of both deer and humans were smashed open, presumably to allow brains and marrow to be extracted. "In both taxa, marrow bones were systematically broken, and bones without marrow were not damaged," says Defleur.

Analysis of three pieces of a large thigh bone showed how, after its muscles were sliced away, it was set on an anvil stone and hit repeatedly with another stone. Telltale striations mark the bone's outer surface on the anvil side, directly opposite "percussion pits" made by the hammerstone. Cut marks on the clavicle also show where the Neanderthals disarticulated the arm at the shoulder. Others reveal where they cut out tongue and jaw muscles, severed the Achilles' tendon, and sliced other tendons below the toes and at the elbow. The bones bear few signs of burning or roasting, says White, suggesting that even though the Neanderthals had fire, they ate this flesh raw or hacked it off the bone before cooking. "The circumstantial forensic evidence [of cannibalism] is excellent. No mortuary practice has ever been shown to leave these patterns on the resulting osteological assemblages," he says.

In White's view, this well-documented case strengthens other reports of Neanderthal cannibalism, from sites such as Krapina and Vindija in Croatia. Modern humans ranging from Fijians (see p. 39) to ancient southwesterners (not to mention the best selling Hannibal Lecter) apparently had a taste for human flesh. But the evidence implies, says White, that "the incidence of this behavior among the Neanderthals and their ancestors may have been higher than among modern people." Other researchers have suggested that Neanderthals might have been desperate for dietary fat by winter's end—and brains and marrow are rich sources of fat, Wolpoff notes.

Still, White says, "we are not claiming that all Neanderthals were cannibals, rather, that there were some cannibals among the Neanderthals." Indeed, sometimes Neanderthals buried their dead, arranging bodies in a fetal position in semicircular graves. At the moment no one knows why the Moula-Guercy corpses were handled so differently—whether they were enemies or because of some different cultural practice. "Actions fossilize, intentions don't," says Smith.

Far from implying that Neanderthals were brutes, Smith and others say that the finding of cannibalism may indicate sophistication of a sort. The varied treatment of the dead at different Neanderthal sites, Smith says, demonstrates cultural variation and therefore complexity: "When you see some Neanderthals practicing intentional burial and others practicing cannibalism, that is a clear indication of behavior that is multidimensional—a pattern that mirrors the behavior of more modern people."

"To me this is, paradoxically, a very human behavior that indicates a human mind," says anthropologist Juan Luis Arsuaga, excavator at the Spanish site of Atapuerca, where there is evidence of cannibalism among 800,000-year-old humans. "Cannibalism is very old in human evolution." Other animals such as chimps sometimes kill and eat parts of their own kind, but "only humans practice systematic cannibalism," says Arsuaga. "This is the dark side of the human coin." **–ELIZABETH CULOTTA**

CREDITS: DEFLEUR *ET AL.*

BIOMEDICAL FUNDING

Senate Tops House Panel In Raising NIH's Budget

Sometimes it pays to be patient. After months of delays that had made science lobbyists anxious, House and Senate spending committees this week were expected to approve hefty increases in biomedical research funding for the fiscal year that starts today. The increases for the National Institutes of Health (NIH)—$2 billion, or 13%, in the Sen-

Pumped up. Porter's bill gives NIH an 8.5% raise; Senate colleagues offer 13%.