JPL News Clips

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TIME

JULY 3, 2000

Martian Waterworks

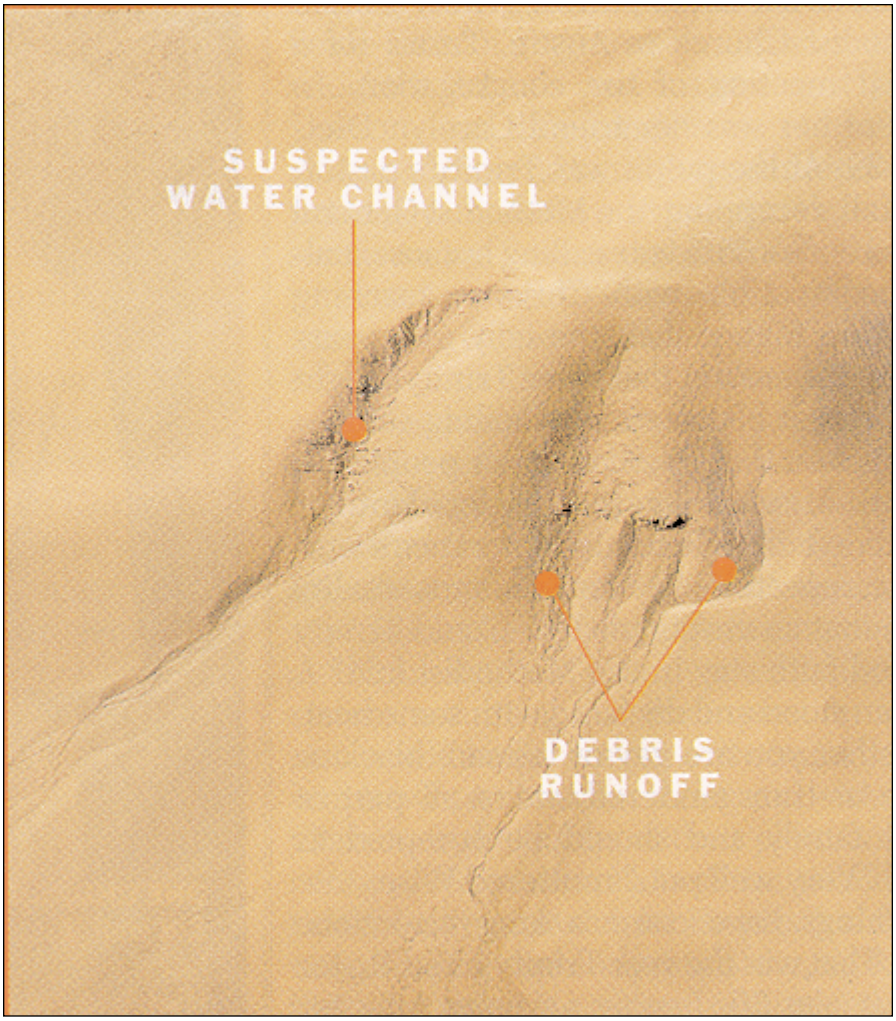
New findings suggest the Red Planet may also be a wet planet--just the kind of place to look for life

BY JEFFREY KLUGER

Time was when the solar system had two watery worlds. Directly next door to the warm, wet, loamy Earth was the warm, wet, loamy Mars, both planets sloshing with oceans and running with rivers--and both possibly teeming with life. Billions of years ago, however, the low-gravity Mars had both its air and water leak away, causing the planet to become the dead, freeze-dried place it is today.

That, in any case, is what the prevailing thinking has been. Now, however, it appears that thinking may be wrong. Last week NASA released a flurry of new images from the Mars Global Surveyor spacecraft that suggest that even today, water may be flowing up from the Martian innards and streaming onto the Martian surface-- dramatically increasing the likelihood that at least part of the planet is biologically alive. “If these results prove true,” says Ed Weiler, associate administrator of NASA’s Office of Space Science, “[they have] profound implications for the possibility of life.”

Finding liquid water on Mars’ surface has never been easy--mostly because it simply can’t exist there. The modern-day Martian atmosphere has barely 1% the density of Earth’s, and the planet’s average temperature hovers around a paralyzing -67[degrees]F. In an environment as harsh as this, any water that did appear would either vaporize into space or simply flash-freeze where it stood. What scientists studying Martian history have always looked for instead are clues that the planet’s ancient water left behind--tracks where vanished rivers once flowed, basins where vanished seas once stood.



Go with the Flow: New photos show what may be water channels and aprons of debris in Mars' Noachis Crater. Similar formations have been seen all over the planet's northern and southern reaches

The 65,000 or so images the Surveyor orbiter has beamed home in the nearly three years it has been circling Mars are full of this kind of expected hydro-scarring. But a handful of the pictures took scientists by surprise. In general, the older a Martian formation is, the more likely it is to have been distorted over the eons--smoothed by the planet’s periodic windstorms or gouged by the occasional incoming meteor. A few of the newly discovered water channels, however, look as fresh as the day they were formed, leading astonished

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researchers to conclude that that day may have been remarkably close to the present one. Says Weiler: “The water could have flowed perhaps a million years ago, perhaps 10,000 [years ago], perhaps yesterday.”

If the pristine nature of the formations was unexpected, their unlikely location was even more so. Planetologists have long assumed that if underground water was going to bubble up on Mars, it would have to be somewhere in the comparatively balmy equatorial zones, where temperatures at high noon in midsummer may approach a shirtsleeves 68[degrees]F. Almost all the new channels, however, were spotted at the planet’s relative extremes--north of 30[degrees] north latitude and south of 30[degrees] south--and all were carved on the cold, shaded sides of slopes.

Paradoxically, this finding may increase the chances that the gullies are water related. Any water that appeared on the sunny sides of hills would be likely to evaporate almost instantly. Moisture that seeped out in shadow would form a temporary ice rind that would last only until the pressure of upwelling water behind it caused it to burst. When it did, there would be a sudden downward gush that would leave precisely the kind of clean-cut channel Surveyor spotted. If features like these were discovered on Earth, says Michael Malin, principal investigator for the Surveyor’s camera system, “there would be no question water was associated with [them].”

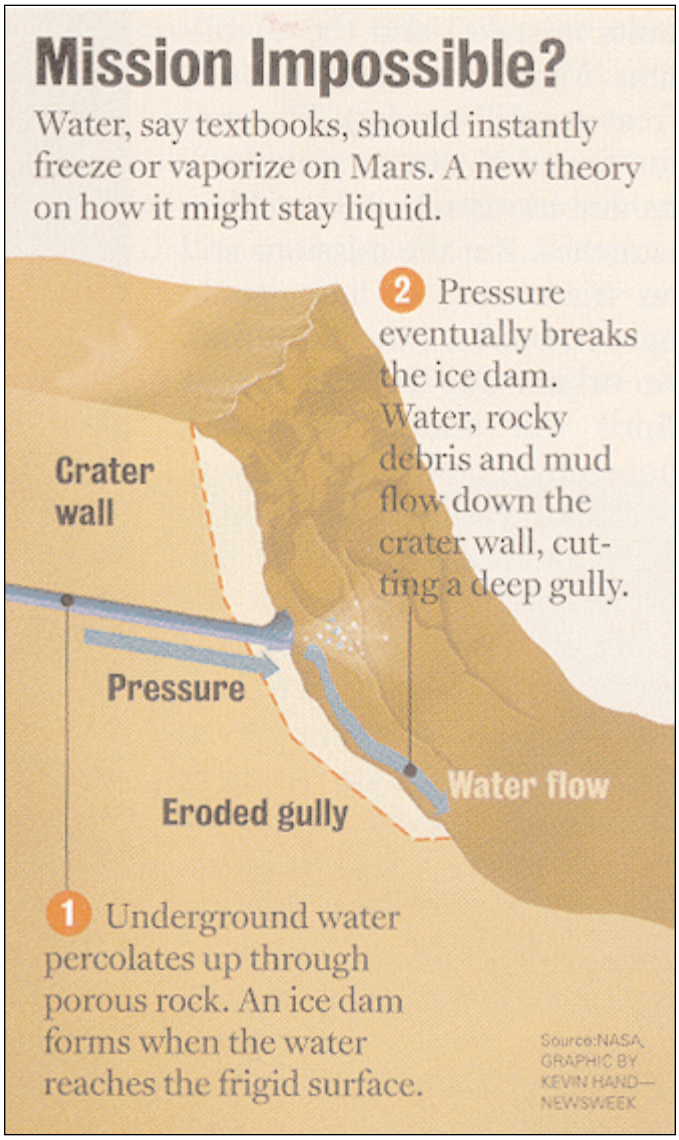
For a beleaguered NASA, the new findings couldn’t have come at a better time. After the recent spectacular flops of two unmanned Mars probes, the agency’s entire planetary-exploration program came under fire. The possibility of a wet Mars, however, suggests that not only might the planet be home to indigenous life, it could also more easily support human life. Visiting astronauts would need water for a variety of purposes--including manufacturing air and perhaps even rocket fuel. Pumping up what’s on site rather than hauling supplies from home could dramatically slash the cost of a mission. All this, NASA hopes, will increase the odds that a hitherto reluctant Congress will green-light future Mars missions--both unmanned and manned. “In exploring Mars,” says NASA program scientist Jim Garvin, “we have always used a follow-the-water approach.” That approach, it appears, may be starting to pay off.

NASA: Mars Is All Wet

Hints of recent water flows on the Red Planet raise new hope that life once existed there--and could still

Almost as soon as Mars Global Surveyor slipped into orbit around the Red Planet in late 1997, its main camera began snapping pictures that made scientists do a double take. The walls of some otherwise nondescript craters in Mars's southern hemisphere looked as if they had been chiseled out recently by running water. But that was impossible. The atmosphere of Mars is so thin and so cold, say the textbooks, that surface water would immediately vaporize or freeze. Eager to spy more of the enigmatic features, Michael Malin and Kenneth Edgett of Malin Space Science Systems, which built and operates the camera, scrutinized the thousands of photos that Surveyor snapped during its 1998 orbits. Nothing. But in March 1999 the camera began shooting images 10 times sharper. And there they were again: deep gullies, winding channels and deltas of debris. Malin still wouldn't believe that he was seeing evidence of running water. Instead, he tried to explain away the weird landscapes as the handiwork of dry landslides, avalanches--anything but water. Finally, he could no longer avoid a conclusion that threatens--or promises--to turn decades of conventional Martian wisdom on its little green head. "We see features that look like gullies formed by flowing water," Malin said last week. "We think we are seeing evidence of a groundwater supply, similar to an aquifer."

NASA has lost more than a billion dollars' worth of hardware on and around Mars since 1993--but finding water there might right the balance sheet. The driving principle of the Mars program has been clear: follow the water. The mundane rationale is that a supply of water would make human exploration of the Red Planet far more feasible. Water is not only useful for keeping humans alive and for growing crops. It can also be broken apart, with high-school chemistry, into oxygen (good for breathing and, in liquid form, a rocket propellant) and hydrogen (which also makes a dandy rocket fuel). The more visionary rationale is that finding liquid water on Mars would take scientists a step closer to answering whether we are and always have been the lone forms of life in the vast universe. The hint of water-carved gullies on Mars, says Bruce Jakosky, director of the astrobiology program at the University of Colorado, "is the smoking gun that says there's liquid water and that Mars meets the environmental requirements to support life."



Rumors about the discovery stirred such a frenzy last week that NASA had to swat down speculation that Surveyor had spotted bubbling hot springs full of Martians. The discovery was to be announced in a paper in the June 30 issue of Science, but leaks forced the journal to release the news nine days

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early. What excited space enthusiasts was the possibility that Surveyor had found evidence not of just any old water flows, but of recent water flows. The notion that Mars coursed with rivers and floods billions of years ago dates back to 1972, when the Mariner 9 spacecraft returned photos of giant flood channels. But today Mars is an arid, windblown desert. “Ever since [Mariner 9], Mars science has focused on the question ‘Where did the water go?’ “ says Edgett. “The new pictures from Global Surveyor tell us part of the answer: some of that water went underground, and quite possibly it’s still there.” The gullies seem to be relatively recent decor: they are not scarred by impact craters, freeze cracks or windblown deposits, as a Martian landform more than a few million years old presumably would be. “These gullies could be on the order of a million years old,” says Malin, “or they could have formed yesterday.”

Scientists are far from unanimous on that, however. Because any liquid water reaching the Martian surface should either boil away instantly or freeze, Mars expert Michael Carr of the U.S. Geological Survey remains unconvinced that Surveyor’s gullies were carved by water. But Malin and Edgett have a hunch about how Mars might have achieved an aqueous mission impossible. Pent-up groundwater, they say, might rise to the surface from porous rock 300 to 1,300 feet below. The first water to break the surface might freeze, forming a small ice dam. So far, so by-the-textbook. Now for the ingenious part: the groundwater would keep seeping toward the surface, building up pressure behind the dam until the water burst out and thundered down the slope like flash flood in a desert arroyo. As it happens, more than 90 percent of the rivulets lie near Mars’s south pole. In these frigid areas, the cold may slow down evaporation enough for ice dams to form.

NASA is being careful not to overplay its life-on-Mars card. Assistant administrator Ed Weiler harrumphed last week that the discovery of gullies “has nothing to do with the possibility of life on Mars.” But other scientists can hardly contain their enthusiasm. “Mars may have had a groundwater system for most of its 4 billion years,” says astrobiologist Jack Farmer of Arizona State University. “There could be a whole biosphere going on under the surface.” John Priscu, a biologist at Montana State whose study of microbes frozen in Antarctic lakes has given him respect for the tenacity of life, notes that “ice can be a great refugium for bacteria; they can stay frozen for a long time and still survive.”

The hints of water coursing over Mars has given a much-needed morale boost to NASA’s beleaguered Mars team. These are the guys who lost the $165 million Mars Polar Lander last December (too few people, too much work, too many miscalculations), the $125 million Climate Orbiter last September (that amazing English/metric units mistake) and the $1 billion Mars Observer in 1993 (reasons still murky). The snafus forced NASA to scale back its ambitious schedule of Mars launches. But the missions still on track can, as luck would have it, build on the latest find. An orbiter due for launch next April will search for water, hopefully confirming Surveyor’s find. The 2003 mission is far enough away that it can be reconfigured to exploit the hints of water even more directly. One possibility is to look for water-related minerals at the Martian surface. A more tantalizing one is to deploy a little roving lab to scoot around. If life ever did get going on Mars, the gullies would be great places to look for it--as fossils or, maybe, something livelier.

U.S. News & World Report

JULY 3, 2000

The red, red mud of Mars

Newly formed gullies imply a wet planet

BY CHARLES W. PETIT

Mars the red planet has been looking more like the dead planet in recent decades. Successive spacecraft painted it as a bone-dry world of extinct volcanoes, sand dunes where oceans once lapped, and ancient craters, where nothing much has changed in a billion years or so except for the occasional meteor thump or dust storm and the frost cycles on the polar caps. Hence the near disbelief from scientists who announced last week that they see what look like fresh springs in many areas of Mars, where water has recently gushed to form gullies and flood plains.

The images, from a spacecraft orbiting the planet with far better cameras than any there before, prompted hosannas from NASA leaders, who welcome this tonic for their beleaguered drive to look for life-- past or present--on Earth's neighbor. They also left startled scientists debating just how recently the washouts could have formed- -whether it was last year or many thousands of years ago--and how water could possibly be flowing at or close to the surface of the planet, where the average temperature is well below freezing and the atmosphere is so thin that water would quickly evaporate.

Stuff of life. The rumors of a watery Mars started circulating early last week on the Internet, prompting the journal Science to release a paper about the discovery a week early and NASA to hold a press conference. If the planet is wet just under its frozen surface, said Ed Weiler, NASA's space science chief, the odds would be better that Martian life may cling to existence underground, within reach of future drill-packing space probes. And that possibility has life- giving implications of its own for NASA's Mars program. After two probes--a lander and an orbiter--failed in the past 12 months at Mars, its leaders have gloomily endured barbs in Congress while promising to do better.

The paper's authors are Michael Malin, leader of the camera team for NASA's Mars Global Surveyor spacecraft, in Mars orbit since late 1997, and Ken Edgett, a scientist at Malin's San Diego-based company. In mid-1999, poring over photos from the craft, the pair began to see occasional, unusual streaks of dark material on sides of canyons and crater walls. A closer look at some slopes revealed what geologists call weeping layers, where water trapped along a rock layer has burst out to the surface. The features typically include a collapsed pit or "alcove" at the top, as though the water had broken through ice sealing the cliff's face. Eroded gullies a few hundred yards long run downslope to "aprons" or plains of debris below.

Edgett said the pictures blew his mind, but that the sheer quantity of evidence--several hundred sites seen so far--dragged him "kicking and screaming" into a belief in recent, running water. Each washout probably lasted a short time and may have involved enough water to fill several Olympic-size pools. The features would dry rapidly in the thin air, but they must be recent. No meteor craters have formed atop them, they often overlie sand dunes or other relatively young Martian features, and they even seem free of the usual patina of Martian dust.

Most recent theories hold that all water from Mars's ancient oceans was lost to space or is now locked in its polar icecaps or frozen deep underground. "We were quite surprised and confused by this new pattern," Malin said. "It didn't quite fit our models." Among the mysteries are what source of heat could keep water liquid so close to the frigid Martian surface, and why water should most typically spring from slopes facing away from the warming sun. And the researchers cannot absolutely rule out the possibility that some fluid other than water, or a mix of gas and dry material that acts like a liquid, created the gullies.

Answers will require a closer look, by future probes and perhaps, eventually, by people. NASA plans to release its revised plans for Mars exploration this fall. The soonest another landing attempt could be launched is 2003, with other efforts due every 26 months after that. The original Mars exploration plan was aimed mainly at bringing back a few rocks from Mars for analysis here. It was drawn up after NASA scientists asserted, in 1996, that a meteorite from Mars seemed to contain fossilized, alien microbes, a claim that still meets deep skepticism. The new theme is "follow the water," Weiler said.

Astronomy

JULY 1, 2000

Missing the mark

BY REX GRAHAM

Several failed missions to Mars have forced NASA into a sobering reality check.

More than 30 years after Apollo 11 astronaut Neil Armstrong took that one giant lunar leap for mankind, NASA is stumbling in its efforts to explore the next solar system frontier - Mars. Scientists want to search for signs of life, retrieve rocks, and eventually send astronauts to the Red Planet, but NASA's 16-year plan to accomplish those goals is in turmoil. Why? In 1999, NASA lost three missions back to back to back: Mars Climate Orbiter, Mars Polar Lander, and Deep Space 2.

And that's not all. Several other recent NASA missions have been lost because of embarrasing navigational miscalculations or technical glitches. NASA plans to launch a Mars orbiter on schedule in 2001, but it postponed a 2001 Mars lander and other missions while it tries to get in touch with its inner Right Stuff.

The faster-better-cheaper NASA, the NASA that lost the trio of Mars probes, the NASA that is supposedly doing more science with less money, is overdue for its current reality check. Of course, it's a much less wrenching psychoanalysis than that which followed the 1986 Challenger disaster, but no less necessary A slightly more expensive and more successful path to Mars has already begun to emerge.

President Clinton and congressional leaders continue to support NASA Administrator Daniel Goldin, the architect of the faster-better-cheaper approach to space and Earthscience missions. The hard-charging Goldin has accepted responsibility for the recent spate of failures, but that hasn't improved his standing among planetary scientists.

Possibly no group is as important to NASAs recovery as the engineers, scientists, and managers of the Jet Propulsion Laboratory (JPL) in Pasadena, California. Overseen for NASA by the California Institute of Technology, JPL provides day-to-day management of the United States' robotic exploration of the solar system from a 177-acre campuslike setting 12 miles northeast of Los Angeles. As much as NASA itself, JPL suffered a humiliating loss on December 3, 1999, as Mars Polar Lander and its piggyback Deep Space 2 probes arrived right on target. TV cameras, called in to capture a joyous celebration at JPL mission control, were ready. To the camera operators' surprise, they captured disbelieving expressions frozen on the faces of JPL and NASA employees, including Goldin. Polar Lander and its twin Deep Space 2 microprobes vanished without a radio peep.

NASA may never know what happened because Mars Polar Lander didn't have a device to transmit radio signals to Earth during its final descent. (A mishap-investigation report states that not including the transmitter "helped Mars Polar Lander meet cost, mass, and schedule constraints, but failed to provide feedback that would be useful in the design of future missions.")

Simulations conducted in February by Lockheed Martin Astronautics, prime contractor for the three recently failed missions, revealed that Polar Lander most likely shut off its descent thrusters too soon and crashed. The finding takes into account a nettlesome problem involving the spacecraft's three landing legs: When they deploy, they generate signals that falsely indicate they have touched down. The problem was known, but its affect on the main computer's decisionmaking process was not. The Lockheed Martin tests, which involved a simulated landing of a similar spacecraft, suggest that the fatal glitch occurred when Polar Lander's descentengine thrusters slowly lowered it to 132 feet above the planet's surface. At that point, the onboard computer interpreted the signals from the landing legs to mean that the craft had landed. The computer immediately turned off the thrusters and the spacecraft began to fall. A moment later it would have smashed into the surface at 50 miles per hour.

The Deep Space 2 microprobes carried aboard Mars Polar Lander most likely failed for different reasons, according to a JPL review board. They either ricocheted off the planet's surface (an inch of dusty material covering the rocky impact area may have acted like a lubricant and prevented penetration), suffered an electronic or battery failure (the batteries were delivered too late to be impact tested before launch), or the antennae broke down in the martian atmosphere (they were never tested in a similar environment).

The Mars Climate Orbiter failed upon its rendezvous with the planet on September 23, 1999. Edward Weiler, NASA's Associate Administrator for Space Science, initially said a "simple error" involving the use of English instead of metric units in navigation-modeling software made the spacecraft fly in too low. Indeed, a report by a mishap-investigation board confirmed that the units error was the "root cause" of the failure. However, the board also noted eight "contributing causes:' For example, the report says JPL assigned only one employee to the critical task of navigating the spacecraft. Unexpected complications quickly overwhelmed that person.

Like a highway motorist adjusting a car's steering wheel to keep the vehicle in the proper lane, the navigator initiated four trajectory-correction maneuvers during the mission. Because the spacecraft was too far away to be observed directly - even with a telescope - the navigator used special software to plot the craft's trajectory after each thruster firing. Unfortunately, the software had the English-units error.

Like other spacecraft, Mars Climate Orbiter held itself in proper alignment toward the sun, its energy source, by a series of "momentum wheels:' These rapidly spinning, electrically powered flywheels take advantage of the law of conservation of momentum: When a motor spins a heavy disk slightly faster in a given direction, the spacecraft turns slowly in the opposite direction. An unforeseen complication arose from Mars Climate Orbiter's solar-power panel: It was mounted asymmetrically. This architecture made the radiation pressure coming from the sun continually

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turn the spacecraft like a rowboat being rowed with one oar instead of two.

The momentum wheels counteracted the effect of the panel asymmetry. The navigator periodically slowed the wheels to keep them working optimally. These maneuvers are called angular momentum desaturations (AMDs). The navigator performed each AMD by simultaneously applying a brake to a given momentum wheel and gently firing the spacecraft's thrusters to exactly cancel the effect of the braking on the spacecraft. The navigator had to perform 10 times more AMDs than expected because of the solar-panel asymmetry. Unfortunately, the use of English instead of metric units in the navigation software led the navigator to underestimate the effect of each AMD by a factor of 4.45.

While each of the four trajectory corrections put the spacecraft back on course, the navigator didn't know that each subsequent AMD caused more trouble. The navigator simply knew that there was an unsolved problem and told his supervisors about it. They met with their Lockheed Martin counterparts and repeatedly asked them which units - English or metric - they had used. Lockheed Martin officials repeatedly reassured them that they had used metric.

The spacecraft picked up speed the closer it got to Mars. The navigator kept track of the speed by monitoring the Doppler shift of its signals sent back to Earth, but that signal gave no measure of the spacecraft's movement perpendicular to its line-of sight with Earth. The navigator and the project scientist proposed an unplanned, fifth trajectory-correction maneuver, but mission managers overruled their recommendation. It is uncertain whether a fifth trajectory correction would have saved the spacecraft, but it would likely have increased its chances of survival.

The final main-engine "insertion" burn at the end of the 9%-month trip was designed to slow the spacecraft and drop it into a 226-kilometer-high elliptical orbit around Mars. Unfortunately, the spacecraft entered Mars's atmosphere 170 kilometers lower than planned and either overheated or bounced off the atmosphere into space.

Breathtaking Risks

In theory, Goldin's faster-better-cheaper idea was a good one: cut development times (although congressional budget cuts and a freeze on launches after the Challenger disaster were responsible for delaying some missions), reduce mission costs (which was relatively easy because most missions were scientifically stripped down), and increase the pace of discovery by flying more missions in less time (although the pace of discovery has been slower than the public might think because the scientific payload on each mission is smaller).

In practice, investigative panels found that NASA pushed JPL employees too hard. "The focus on cost and schedule reduction increased risk beyond acceptable levels on some NASA projects," says a report on the faster-better-cheaper approach written by a team of experts led by Mars Pathfinder mission leader Tony Spear. Under the cost and schedule pressures, the panels found that in some cases mission managers relied on one person - such as the Climate Orbiter navigator - to perform tasks that on less challenging missions had been accomplished by a team. Managers also failed to provide for adequate communication among stressed team members, and they launched spacecraft with equipment they knew had been inadequately tested. In hindsight, the conduct of the managers looks breathtakingly risky. "Even now, NASA may be operating on the edge of high, unacceptable risk on some projects," says the Spear report.

Thomas Young, a retired Lockheed Martin executive who led a team that examined NASA's entire Mars program, says the failed missions were at least 30 percent underfunded. Mission engineers were forced to work 60 hours a week or more. Still, many didn't have enough time to recheck their work in the painstaking way they would have preferred. "The mistakes that took place on Mars Climate Orbiter and Mars Polar Lander were mistakes in areas where we know how to do things correctly," says Young. "Taking risks with things you know how to do are not the kind of risks to take:'

Another report signed by 11 top NASA managers was a more direct rebuke to Goldin. Arthur Stevenson, Director of NASA's Marshall Space Flight Center, led the group, which included colleagues at Marshall, NASA's Ames Research and Goddard Space Flight Centers, and NASA headquarters. After reviewing eight NASA missions, particularly Mars Climate Orbiter, the group recommended "Mission Success First" as a new NASA mantra. The Stevenson report states that the faster-better-cheaper approach "shortchanged" critically needed testing and scrapped "old, proven" management techniques in favor of "new, unproven" ones.

Republican Senator John McCain said during a senate committee hearing on March 22 that he was "startled" by the recurrent problems. "Over the past year, I have continually been amazed by the reports coming out of NASA about mission failures and program delays," McCain told Goldin. In testimony before the panel, Goldin conceded that NASAs workforce reduction during the past seven years from 25,000 to 18,500 employees left the agency "too thin:' He told senators that the agency plans to hire 2,000 new workers and make a host of improvements.

After testifying, Goldin traveled to Pasadena a week later and quoted Theodore Roosevelt in a speech intended to rev up the JPL troops. "We may have pushed too hard," Goldin said in the speech broadcast by NASA TV to NASA and JPL offices nationwide. "We expected two or three setbacks for each 10 missions, but we're well aware that the failure rate has gone up significantly in the last few years." He promised that, for space missions, NASA will require more training, better communications, and enhanced oversight and review. JPL employees applauded politely as the TV cameras filmed.

Years Spent for Naught

Meanwhile, astronomers grumble. Their careers, personal lives, and enthusiasm for research have suffered as mission after mission didn't deliver. "I have seen years of preparation go for naught," says James Bell, an astronomer at Cornell University whose instruments flew on the successful Mars Pathfinder mission and the ill-fated Mars Climate Orbiter and Polar Lander missions. "I can sympathize with both perspectives - faster, better, cheaper is the way to go, and faster, better, cheaper is

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cutting corners too much:'

NASA's troubles extend beyond the missions to Mars. Some low-profile missions have failed with little attention. For example, in 1999 the ionosphere-research satellite called TERRIERS was lost. It, like the Mars missions, would have benefited from a budgetary cushion as engineers and scientists grappled with a host of unexpected problems before launch. "There are a million details in one of these things and you must pay attention to every single one," says Daniel Cotton, a physicist at Boston University's Center for Space Physics and principal investigator for TERRIERS. "It takes time, it takes effort, and, at the bottom line, it takes money"

More than four years of Cotton's and his students' efforts went for naught when their $6.1-million satellite spun out of control and died almost immediately after it was launched in May 1999. Cotton says that an aerospace company under contract to NASA mistakenly used a minus sign instead of a plus sign in the software of the satellite's computercontrolled navigation system. Although Cotton's group subjected the system to laboratory tests, it didn't have enough money to perform a dynamic test that would have exposed the mistake. "I think of the Apollo program [which cost roughly $200 billion in 2000 dollars] and it blows me away that NASA could actually do that," says Cotton. "It doesn't take much to bring everything down:'

The $73-million Wide-Field Infrared Explorer (WIRE), built by JPL and Utah State University and designed to study galaxy evolution, failed shortly after its March 1999 launch. A mishap-investigation report said a premature electronic instruction caused the faster-better-cheaper spacecraft to prematurely jettison the aperture cover of its cryogenically cooled 30-centimeter telescope. The motion of the heavy aperture cover caused the spacecraft to spin out of control and lose its four-month supply of solid hydrogen coolant in 36 hours. Investigators found that an unexpected power surge from a $2,000 electronic circuit made the cover pop off:

Of course, NASA successfully managed projects such as the Hubble Space Telescope and its upgrades (thanks in part to astronauts who helped fix the telescope's optical flaw), the Galileo spacecraft (whose main communications antenna failed to open, requiring that data be transmitted to Earth with a much slower backup antenna), the Chandra X-Ray Observatory, Mars Global Surveyor, Mars Pathfinder, Lunar Prospector, and the Stardust mission.

The price tag of the three recently failed Mars missions was roughly $350 million. That amount is relatively small compared with NASA's $14-billion annual budget, which includes about $3 billion for the space shuttle program and $2.2 billion for the International Space Station. The relative bargain of faster-better-cheaper projects has enabled them to fly under the radar screen of the General Accounting Office (GAO), the investigative arm of Congress. "No, we have not looked at smaller, faster, better, or whatever that stuff is how successful that approach is and how far you can take it," says Richard j. Herley, assistant director of the GAO's National Security and International Affairs Division, "All of our auditing work is mandated by the congressional committees, and the overwhelming interest of Congress is in the International Space Station and the space shuttle:'

The recent Mars-mission losses were more troubling because they came after the 1993 failure of the Mars Observer. That spacecraft was estimated to cost $450 million at most (an increase from the $300 million original estimate), but the price tag rose to $1.3 billion due to the added cost of the launch vehicle - the space shuttle. Following that failure, NASA managers thought it would be prudent to relaunch Mars Observer in three pieces - Mars Global Surveyor, Mars Climate Orbiter, and Mars Orbiter 2001 aboard rockets. Interestingly, NASA estimated the cost of replacing the three spacecraft at roughly $450 million. In this case the savings of faster, better, cheaper were nil. Indeed, the risk of a failure may arguably have risen because three launches were required instead of just one.

No Small Issues

Daniel Harel, vice president of Space Systems and Operations at GE American Communications Inc. (GE Americom), says space is a challenging place to do business as well as conduct planetary science. GE Americom's fleet of satellites transmits communications for a variety of clients, including Internet providers, TV and radio networks, and print media companies. "The bottom line is this is a risky, difficult, and complex business," says Harel. But he adds that every operational or testing result that deviates from the expected, no matter how minor, is a red flag. "For example," he says, "if a guy calls me from the floor of a manufacturing plant and says, `The thermal predictor is riot really matching the thermal vacuum test. It's only 1 degree, but it's not really matching it: We will stop and investigate because the discrepancy is a symptom of something. Is your assumption wrong? Is your model wrong? Is the parameter to which you tested wrong? We don't leave it until we know:'

Harel attributes his company's unblemished record of 18 successful communications-satellite launches since 1975 to a culture of open communications and perfection. Rather than relying on management by contract, remote management, or quarterly `milestone' reviews, his managers continually walk the floors of every subcontractor's plant. They watch not only how technicians solder wires together, but also check that they first warm the solder to the optimal temperature. In addition, his company won't permit its subcontractors to cover those wires with a popular, easy-to-mold Teflon insulation because recent tests have shown that the insulation can break under stress and expose wires, possibly causing a short circuit.

"There are no small issues," says Harel. "Everything is important because these missions go into hostile environments for long periods:' He says a faster-better-cheaper mantra misses the mark when customers judge a company based on its record for reliability. "Give me the best satellite you can make at the best price with the highest quality," says Harel. "Nothing is more expensive than failure."

Rex Graham is a senior editor at Astronomy.

AVIATION WEEK & SPACE TECHNOLOGY

JUNE 26, 2000

Lander Development Paced By Mars Science Results

BY BRUCE A. SMITH

Finding evidence that there may be current sources of liquid water at or near the surface of Mars is a significant development, but getting a robotic spacecraft to land near such a point-target could prove to be difficult, NASA officials said.

"It's going to be the key challenge in the future,'' according to a Jet Propulsion Laboratory (JPL) official, who added that any precision landing system will have to be tested extensively to demonstrate its accuracy and consistency.

The last successful U.S. landing on Mars was by Pathfinder in 1997, which set down close to the center of its expansive 300 X 100-km. (186.4 X 62.1-mi.) landing error ellipse, hoping in the process to avoid large rocks or rugged terrain that might pose a hazard to the spacecraft.

The ultimate landing site within the ellipse was determined in part by such factors as navigation errors on approach to Mars, the point of atmospheric entry, the entry angle and perturbations within the atmosphere.

Commenting on the Pathfinder landing error ellipse, a JPL official said, "It's a huge footprint. It's just not acceptable if you are going to a place like Valles Marineris.''

Lander technology currently under study is aimed at improving the accuracy of the vehicle and actively avoiding any possible hazards on the surface. The latter capability--or the development of a more robust lander--would be especially important because some of the sites identified as possibly having sources of liquid water in the recent past are located in rugged terrain.

Edward J. Weiler, NASA associate administrator for space science, said landing accuracy currently is on the order of 10s of kilometers, but that it should be increased to a few meters' accuracy for studying point-targets. Weiler said the space agency is beginning to invest in a technology development plan.

"We're not going to be able to land on Mars with meter accuracy on the next mission, but, hopefully, by the time we get to the 05 [and] 08 missions, we will be starting to build up that capability,'' he said.

JPL officials said the recent announcement could help speed-up technology development and the site selection process for Mars landing missions, as well as provide an overall boost for lander missions.

Prime candidates for technology investment in the next few years include hazard avoidance, smart guidance and precision landing techniques. Some of the concepts JPL has looked at include:

-- Pallets that look like large, upside-down Frisbees to serve as shock absorbers for landers.

-- Para-guidance similar to a parafoil to provide control during descent.

-- Lander capability to move across the surface in order to reach a better location for scientific work once it has landed.

-- Continued study of advanced and hybrid airbag landing systems, comparable to the system used by Pathfinder.

-- A controlled descent propulsion that would be capable of significant lateral shifts in movement.

-- Hazard detection capability to enable the vehicle to be able to steer to a safe landing spot.

Brian Muirhead, a former Pathfinder project manager, said a smaller "scout'' lander might be considered as a means of surveying a site in advance of the lander mission to more precisely determine the requirements for the lander. Imaging from the system would provide a "ground truth'' to supplement imagery from orbit, according to Muirhead, who currently is project manager of Deep Impact, a Discovery mission designed to impact and study the interior of a comet.

The sample return mission that had been scheduled for the 2003 launch opportunity had a planned precision landing capability of about 10 km. To achieve that level of accuracy, the lander was to have had such features as precision approach navigation and aeromaneuvering during entry phase of the mission. Aeromaneuvering is a new technology for use during hypersonic entry to compensate for variations in the atmosphere by using thrusters on the vehicle's backshell.

The lander was to carry an ascent vehicle to the surface, which would later carry a sample return canister into orbit around Mars where it would rendezvous with another spacecraft for return to Earth in a direct reentry. NASA is evaluating whether to send the sample to Mars orbit or take it directly back to Earth.

The sample return mission, however, was postponed indefinitely in the wake of the Mars 98 orbiter and lander mission failures, and replaced with the advanced technology development effort in preparation for a possible future mission (AW&ST May 22, p. 32).

Frank Jordan, manager for advanced studies and program planning in JPL's Mars Program Office, said on-board control on landers primarily has been for deceleration of the lander through deployment of a parachute and retro-maneuvers for a soft landing. The next stage was to have been a refinement of the guidance through the upper atmosphere during the hypersonic phase of the mission.

That maneuvering would increase the accuracy of the lander from on the order of several 10s of kilometers. to approximately 10 km. The system was discussed for use on the 01 lander.

NASA decided to go ahead with the 01 orbiter, but scrubbed the 01 lander mission after failure of the two Mars 98 missions. The 03 mission will either be an orbiter based to some degree on the design of the 01 orbiter, or a lander that would duplicate the design of the Pathfinder airbag landing system and carry a larger rover vehicle. A NASA decision is expected in July.

The Boston Globe Online

JUNE 26, 2000

Mars Puzzle: How to Get to that Water

BY DAVID L. CHANDLER
Globe staff

Prospects for the exploration of Mars got a lot more exciting - and a lot harder - with the news last week that there may be liquid water near the planet's surface.

On both counts - the renewed urgency of Mars exploration, and the new challenges that accompany it - some scientists argue that it may be time to send humans, not just robots, to explore the red planet.

"Humans can do a lot more than robots can, let's face it," said Jack Farmer, an astrobiologist at Arizona State University. "Ultimately, I think humans have to go to Mars. It's our nature to explore."

One of the biggest questions that an armada of robotic craft has been sent to Mars for decades to address has now been answered, at least tentatively: Is there liquid water on Mars today, and if so, where? But the exciting answers revealed last week have been enigmatic and daunting.

About 200 pictures taken by the Mars Global Surveyor have been found to show clear evidence of recently flowing water down the steep slopes of craters and canyon walls, but their location and orientation are so puzzling that it may take scientists some time to truly understand where the water is coming from and why it flows where it does.

Whatever the explanation for why and where water is present, most scientists agree that it greatly improves the odds of finding living microorganisms there.

"There could be life in the subsurface of Mars today, in a way that we didn't think was possible," said Bruce Jakosky, a planetary scientist at the Southwest Research Institute in Boulder, Colo.

The discovery also poses a daunting challenge for those planning future missions. The sites that show signs of water, considered to be the most important locations for future research, happen to be in some of the most inaccessible and inhospitable places: on cold, sunless, steep, crumbling slopes that no existing or planned spacecraft could land on or near.

The discovery of scattered sites showing signs of water near the surface, Jakosky said, "really says that's where you want to go. The problem is, these things are not accessible."

Steven Squyres, a planetary scientist at Cornell University, said, "Nature has played a nasty trick here. I'd be hard pressed to imagine a more difficult place" for spacecraft to visit. "This is a massive technical challenge."

Some scientists argue that it is a technical challenge that may be too much for unmanned space missions.

As good as robots may be at giving scientists a planetary overview, scientists say, they can't be counted on for the intricate work of drilling for water in such a harsh environment.

There is no doubt about the importance of trying to go to the "wet" areas of Mars.

Scientists agree that it is clear that Mars has had all of the ingredients necessary for life: solar energy, the necessary chemical building blocks, and now liquid water.

Scientists have also known for many years that life began on Earth as soon as the needed ingredients were present, virtually within the blink of an eye.

Once life began, it spread wherever conditions were even remotely favorable. One discovery after another has shown that life is far hardier, more persistent, and more able to adapt to seemingly hostile conditions than biologists had ever imagined.

Just last week, for example, a team of Russian scientists reported finding living microbes in ice miles below the surface of Antarctica.

And so, if life ever did get a toehold on Mars, the new evidence means that "there's no reason to think that the life is not still there," Jakosky said.

There's an even more amazing implication to this and the other recent findings about Mars: Whatever forms of life scientists find there, if they ever do, could turn out to be our ancestors.

Not in the way the recent movie "Mission to Mars" portrayed it, with intelligent Martians deliberately seeding the Earth.

Rather, some scientists suggest that life might actually have originated on Mars, which cooled earlier and became a possible abode for life earlier than the Earth in the formation of the solar system.

Life almost certainly never had a chance to progress beyond the level of bacteria there, though, because the planet probably cooled to the point that life could exist only in limited underground "oases."

But those bacteria could have hurtled through space inside meteorites, providing the original forms of terrestrial life from which everything else on Earth evolved.

One reason for believing that scenario, said Robert Zubrin, president of the Mars Society, a group that advocates increased exploration, is that "despite centuries of investigation, no one has ever found any free-living life

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form on Earth simpler than the bacteria."

Yet, bacteria are so complex biologically that they must have evolved from simpler forms, he said.

"Believing that bacteria were the first form of life is like believing the Concorde was the first machine," Zubrin said.

Since earlier life forms typically go on living side-by-side with later forms, it is surprising that we don't find any more primitive forms of life today. But that would make sense if those more primitive forms got their start on Mars, then were blasted to Earth in rocks lofted into space by an asteroid whose impact seeded the Earth.

If that theory turns out to be true, scientists may find our distant ancestors on Mars, and perhaps the crucial clues to understand just how life got started.

The fact that meteorites do reach the Earth from Mars is now well established, and some kinds of bacteria have been shown to be capable of surviving the rigors of space flight - high radiation, years of dormancy, and dehydration.

If scientists do someday travel to Mars and find signs of "not only bacteria, but prebacteria," Zubrin said, those could be "the missing links between life and non-life."

If so, that could help solve "one of the deepest mysteries of science: How life came to be," he said.

Because that evidence might be located in the rugged, steeply sloped terrain, and in many scattered places, some scientists think finding it might be too far beyond the capability of any present or near-future robotic missions, and might argue strongly for the need to send humans.

"There isn't a robot on this planet right now that can take your laundry down to the laundromat, wash it and dry it and bring it home," Zubrin said.

Drilling for water a few hundred feet deep, where signs of Martian microbial life might be found, would be a relatively normal task for humans, but "is a lot more complicated than a trip to the laundromat," he said.

AVIATION WEEK & SPACE TECHNOLOGY

JUNE 26, 2000

‘Water’ Images Trigger New Concepts of Mars

By MICHAEL A. DORNHEIM

Scientists are scrambling to understand new pictures of Mars unveiled last week that strongly suggest there has been liquid water springing from the surface within the past million years, and perhaps still today. Liquid water is the final element required to say Mars has conditions conducive to life. The other two--organic compounds and an energy source--were already known to be present, and they are all close to the surface.

The conflict presented by the images from Mars Global Surveyor (MGS) is this: On their face they provide “incredibly compelling’’ evidence of erosion from liquid water, but the -100 to -150F average temperature and 6-millibar pressure conditions now at the planet’s surface do not allow water to exist in the liquid phase. Either the erosion channels were cut by a substance other than water, or there is a mechanism by which liquid water is supplied to the surface in significant quantities, however briefly.

Equally interesting is how recent the erosion appears to be. Some is located on features that are inherently young, such as sand dunes or fields of polygonal bumps likely formed by freeze/thaw cycles, said Kenneth S. Edgett, a staff scientist on the Malin Space Science Systems (MSSS) team that analyzed the images. There are few if any meteorite craters on the features, also suggesting they are young. This evidence places an upper limit of 10,000-1,000,000 years on their age, said Edward J. Weiler, NASA associate administrator for space science.

This limit can be cut drastically to tens of years if Edgett’s interpretation of the eroded areas themselves is correct. Some of the areas are distinctly darker than surrounding terrain, which he posits may be because they have not yet been covered with the light-colored Martian dust that paints much of the planet an even tone. Dust accumulation is considered to be rapid, and the lack of dust suggests that the area is at most years to tens of years old, Edgett speculated.

This and other results were becoming the subject of vigorous debate as scientists outside the Malin team got their first look at the images on June 22. Most scientists believe the findings are much more supportable than the 1996 claim that tiny life fossils had been discovered on a Martian meteorite found in Antarctica (AW&ST Dec. 9, 1996, p. 59).

The basic morphology of water flow eroding a slope that is seen on Earth appears to be repeated on Mars, said Michael C. Malin, president of MSSS. Erosion starts at the source of the water and undercuts the material above it, creating an alcove (see top photo, p. 59). This is shown on a large Martian crater wall (left image) and in a 10-ft. stream in the volcanic ash from Mt. St. Helens, Wash., (right image). The stream cuts a channel, and spreads into an apron.

This structure can be seen to some extent in all the images, and is evident in the bottom picture on p. 62. There, the aprons empty into what appears to be a field of sand dunes. Note the almost complete absence of impact craters in this image.

The wet erosion areas found by the Malin team have been located in the mid to high latitudes, from 30-70 deg., and not in the warmer 0-30 deg. equatorial belt, where many thought the best chance for liquid water lay. Most of the areas found so far have been in the southern hemisphere. Not only are they found in the colder regions of the planet, but they are also found in the colder locations within those regions, on poleward-facing shadowed areas, such as inside the north rim of a crater in the southern hemisphere. This preference for the coldest areas of an already frozen planet goes against conventional thinking that liquid should be found in the warmest places, but scientists have speculated on several possible causes.

Malin and Edgett reason that the flows must be a rapid pulse for the water to remain liquid long enough to travel extended distances before freezing and subliming. Also, the way some of the channels and aprons appear to be swept clear suggests a flash flood. They speculate that liquid water is somehow conveyed underground to an exit point, where an ice plug immediately forms. Water pressure builds up behind the ice plug until it is forced out, releasing the rapid pulse. Somehow the colder conditions are more conducive to this mechanism.

Previously seen flows along Mars’ sloped surfaces were generally considered to be dry slides. The wet erosion has stronger features, deeper channels and the characteristic alcove-apron shape. A comparison between the two in one crater shows the differences, and the poleward-facing trend. The 10-km.-dia. crater is on the northern hemisphere at 36.7 deg. latitude on the Elysium Planitia (see p. 60, bottom photo). The image has been rotated 90 deg. so that north is to the left. The soft-featured dry flows are on the north, equator-facing side, while the more strongly featured wet flows are

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on the south, poleward-facing side. Note in the upper image how the downstream material from the wet erosion appears distinct from the dry erosion.

Recent examination of other pictures shows a few wet erosion features on east and west slopes, but still essentially none on equatorial-facing slopes, Malin said.

Most of the pictures show the water emerging from a well-defined layer ranging from 100 to several hundred meters deep, Malin said. On Earth this would be interpreted as being a water-bearing semi-permeable aquifer layer, but the difficulty with Mars is that freezing temperatures are believed to penetrate down 3-6 km. Scientists wonder how water could get to the shallow exit points. One idea is that there may be a shallow ice layer that is periodically heated to form water. In warmer areas, the exposed parts of this layer may have been evaporated away eons ago such that they no longer produce wet erosion, whereas colder areas may still have enough ice close to the surface to produce water, speculated Richard W. Zurek, Jet Propulsion Laboratory project scientist for the Mars Surveyor Orbiter 03 study. Stephen Saunders, JPL project scientist for the Mars 01 orbiter, joined Zurek in speculating that Mars may have climate "blips" of warm temperatures for a few centuries, perhaps induced by a greenhouse effect from a meteor impact. Scientists are just beginning to grapple with the new data.

The high-resolution picture in the middle of p. 60 provides a compelling case for wet erosion. The right image shows a darker field where large boulders cast shadows, next to a smoother, lighter field. The exposed boulders appear to Earth eyes to have been produced by fluid flow. The dark area is very distinct, suggesting not much dust deposition or erosion has occurred, meaning the surface is young.

The picture is a closeup of a crater rim photographed by MGS in December 1997 that was the first clue to the wet erosion features. Then, the resolution was not good enough to see the wet-type structure, and some thought it might be lava, but the image piqued Malin's interest. The new picture has 10 times better resolution.

Zurek wondered how much water would be required to expose the boulders. Perhaps a small amount started the erosion, and the wind finished the job. He noted that wind might upset the dust theory--that wind might sweep dust away more quickly from a rough area, leaving it darker. He also noted that areas get darker again within years after a dust storm has passed. But despite this skepticism, the images still have water appeal. "It looks like a duck, it walks like a duck, maybe it's a duck," one scientist said. "But Mars has fooled us before," he added.

One alternative idea to avoid the freezing-water concern is that the erosion fluid might be gas from a subterranean blend of solid water and carbon dioxide called a clathrate. A water-CO2 clathrate could evaporate at surface pressure but could be stable at shallow depths, said Michael Carr, a leading expert on Martian water at the U.S. Geological Survey. If it were exposed by a landslide, it would rapidly gasify to possibly create a gas-lubricated flow. Carr noted this idea was put together in three days in a rush to provide counterpoint to the data, and said it needs to be digested by the scientific community.

Liquid CO2 is ruled out because it also can't exist at Mars conditions. Lava is ruled out because the features are far from active volcanic areas, the source seems to be an aquifer layer that is atypical for lava, and the color, form and perimeter shape are wrong for lava, Edgett said.

Scientists will try to examine the area with the laser altimeter on JPL's MGS to measure the slope. By comparing this with the photos, especially of the apron, they will try to deduce the viscosity and density of the fluid that produced the flow. However, the 100-meter-dia. spot size of the altimeter may be too coarse. MGS' infrared spectrometer has a 3-km. spot size, which is probably too coarse to evaluate materials at an erosion site.

Photograph: Photos above show newly imaged Mars erosion features (left) are similar to water flow on Earth (right). Below is the poleward-facing wall of a 7-km. crater within Newton Crater with many narrow gullies, formed possibly by hundreds of water outbursts. One estimate is that each gully produced at least 660,000 gal. per outburst.

Photograph: Top image shows likely wet erosion on a trough wall in the Gorgonum Chaos region. Note overhang at top and debris aprons below. Image at left is on rim of 50-km. crater in Noachis Terra region and shows sharp contrast between eroded and smooth area. Dark tones in all images are not water but suggest newness.

Photograph: Sunlight-facing dry erosion (left) and shadowed wet erosion (right) are compared in a crater on Elysium Planitia.

Photograph: This is one of the most southern sets of gullies, at 70.7 deg. S. Lat. Deep channels and debris aprons are characteristic of wet, instead of dry, erosion.

Photograph: Nirgal Vallis gullies are one of the closest to the equator, at 29.7 deg. S. Lat. Note alcoves, aprons, and lack of impact craters.

Los Angeles Times

JUNE 29, 2000

Invasion of the Sensor Pods

Science: The plastic boxes look like the kind used to store leftovers. But inside are sophisticated devices to record scientific data—whether in the Huntington Gardens or on the surfaces of other planets.

KENDALL S. POWELL
TIMES STAFF WRITER

A sensor pod nestled in a Huntington Gardens nursery keeps track of the environmental conditions that support carnivorous plants around it. Such pods, linked by electronic webs, could be used to study life in remote places on Earth--or to look for life on other planets with more precision than satellites could manage.

The shiny green hummingbirds and huge bumblebees at Huntington Botanical Gardens probably won't even notice the silent invaders imported from the Jet Propulsion Laboratory. Twelve plastic pods hidden among exotic greenhouse plants are part of a field test of a new technology called a wireless sensor web. The pods constitute an infrastructure that researchers hope will be useful in looking for life on other planets or studying life in hard-to-reach places on Earth.

The idea may fulfill part of NASA's goal to set up a "virtual presence" throughout the solar system. The scientists imagine that one day, groups of pods can be deployed or dropped from rovers or landing spacecraft (or from planes in remote corners of Earth).

These webs of pods could monitor biological activity--in the form of released respiratory gases--on a planet's surface with a resolution and sensitivity not attainable by satellites.

Each pod consists of a solar-powered rechargeable battery, a communication board and a microprocessor with several sensor wires extending from it. All of this is housed in a small plastic box like those that you might use to hold leftovers.

Through the sensors, the pods at the Huntington collect data on the various microclimates in the greenhouses. The sensors can detect humidity, soil and air temperatures, soil moisture, light levels and oxygen and hydrogen sulfide gases.

Every five minutes, each pod records this information and then transmits it back to a "mother node." This node is a specialized pod connected by a serial port to a field computer. The mother node synchronizes the pods with one another.

Kevin A. Delin, project leader, and Shannon P. Jackson, project engineer, developed the technology at JPL.

Jackson and Delin started out with scaled-down versions of the pods housed in toy containers from gum ball machines. When four of those tiny pods and a mother node worked in the lab, Delin knew they could proceed with building the prototypes.

Jackson--whose hands, according to Delin, "can do almost anything with electronics"--began constructing a pod. He had to think of a way to keep the sensitive hardware dry and still expose the device's solar panels to sunlight.

"I thought, 'We have to put this in something,' so I went to hardware stores. And then, as I was walking down the grocery store aisle, I thought, 'This is perfect--clear and waterproof,' " Jackson said.

He attached solar panels to the bottom of a plastic box (which would become the top of the pod). He then painted the rest of the box white to keep the inside from heating up.

All of the hardware for the pods can be bought off the shelf, which makes mass production highly feasible, he said. The pods "talk" to each other

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like walkie-talkies over a radio frequency with a range of about a quarter-mile. Because wireless technology is progressing rapidly, producing pods with greater range can only get easier, Delin said.

JPL chose Huntington Gardens in San Marino as the field test site because the microclimates there range from desert to semitropical to cool. One pod is in what's called the "carnivorous bog," a box filled with insect-trapping pitcher plants and Venus' flytraps.

The experiment has been running continuously since May 18, with excellent results. "We're actually taking good data, and this is just a field test," Delin said.

Theresa Trunnelle, nursery manager at the Huntington, said the pod data are as accurate as temperatures recorded by her standard equipment, a sensor hanging in the middle of the greenhouse. And, she added, the pods have the advantage of being portable, so they can take measurements in different areas of the structure.

"We like to think [this will give] us a greater understanding of the world around us," said Jim Folsom, director of the Huntington Gardens. Folsom said he believes the wireless sensor web has "remarkable potential" in the areas of agriculture, horticulture and the study of local environmental changes. In one possible use, he envisions a web of pods tracking heat changes in a city.

Folsom is not the only one who sees possibilities for the new technology. "We're most interested in the potential for sensors on other planets. We have every hope that it will allow us . . . to detect life," said Pamela Conrad, an astrobiologist at JPL.

The search for life on other planets in our solar system is focused on detecting microbes within rock or ice. With a wireless web of sensors, scientists say, a pod placed directly next to a rock could detect trace amounts of gases given off by any microbes inside.

Kevin A. Delin of the Jet Propulsion Laboratory displays a tiny sensor that can be used to study microclimates.

Conrad also sees a wide range of possibilities on Earth, including studying the evolution of the atmosphere and monitoring seismic activity. She noted that one advantage of web technology is the ability to take many measurements over a large area simultaneously.

The wireless sensor web is extremely versatile, developers say, because pods can be added, removed, repaired or upgraded without interrupting the flow of information from the rest of the web.

The technology can be adapted to fit almost any situation. Right now, it can cover a range about as big as a football field.

And because the web operates essentially on its own, it will allow noninvasive measurements in sensitive environments and continuous measurements at remote locations, such as the bottom of the ocean.

Another special feature of the sensor webs is that each pod communicates with its neighbors. Because the data must "hop" from one pod to the next on the way to the mother node, each pod receives and uses information from others in the web. "You can think of each little pod as a pixel in a bigger picture," Delin said.

This sharing of information not only lets the web "heal" itself if one member breaks down, but also permits pattern recognition. For instance, a sensor web could be an "intelligent" smoke detector that tells exactly where and when a fire started and how best to evacuate the area.

JPL scientists see this as an additional NASA application for monitoring conditions on space shuttles and stations. However, Delin said, he believes the commercial and environmental uses on Earth are much more likely to speed the development of the technology than a trip into space.

"The bus to Mars is expensive and crowded [with other experiments]," he said. And, like most buses, who knows when the next one will come along?

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More information on wireless sensor web technology is available at: http://sensorwebs.jpl.nasa.gov.

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The New York Times

JULY 1, 2000

Let's Not Put a Man on Mars

BY PHILIP BALL

Supporters of a manned mission to Mars have been out in force since NASA's announcement last week that there are recent, perhaps even current, sources of liquid water on the planet. They argue that water will enable human colonies to thrive. But it would be foolhardy to bend the findings to justify a manned mission.

The quest for life has become the focus of NASA's Mars program, and without question, the discovery of persuasive evidence for it (there is none yet) would have profound implications for our perception of our place in the universe. If life is not even unique to Earth within our solar system, it may be common in the cosmos at large.

Finding life (or the fossilized signs of it) means ''following the water,'' for without liquid water, life cannot exist. By this reasoning, we should perhaps be looking instead to Jupiter's moon Europa, which seems to have a global ocean of salty water beneath its icy crust. But Mars is nearer and in many respects more Earth-like. Besides, it has sentimental attractions, dating from the astronomer Percival Lowell's claims in the 1890's to have seen canals built by a dying civilization to the later fantasies of H. G. Wells and Edgar Rice Burroughs.

The evidence that water once flowed on Mars is all but incontrovertible. The planet is covered with sinuous channels that cannot easily be interpreted as anything other than dried-up river valleys. These features are at least a billion years old, but the new findings reveal that at least some of this water went underground. The gullies now seen by the orbiting Mars Global Surveyor appear to be ''young'' in geological terms, which means they might be anywhere from a million years to a week old.

The discovery, another triumph for the Global Surveyor, demonstrates just how effective unmanned missions can be. And at $165 million it is something of a bargain. But NASA knows too well that cheap missions can be false economies. In September last year the Mars Climate Orbiter was lost, followed in December by the Mars Polar Lander, the victim of human calculation errors.

These experiences have forced NASA to rethink its strategy. It was trying to do too much with too little: to answer a barrage of scientific questions with budget spacecraft that, in the end, cut too many corners.

Yet the impulse to use unmanned craft was the right one. Simple, focused missions can pay rich dividends, as the 1997 Pathfinder mission demonstrated by successfully landing on Mars and returning new images of the planet's environment. There is much more science to be reaped from unmanned orbiter and lander missions than from the hubristic endeavor, at many times the cost, to put people on Martian soil.

NASA would do well to resist the temptation to act upon the invitation inherent in the words of Dr. Michael Malin, who heads the Global Surveyor imaging team. ''One of the most interesting and significant aspects of this discovery is what it could mean if human explorers ever go to Mars,'' he said, explaining how useful water would be for drinking or splitting into hydrogen and oxygen for rocket fuel.

While ''cathedral science'' -- huge projects that are more inspirational than useful -- has its place, we must not allow ourselves to be blinded by the supposed glamour of manned space flight. The unmanned Mars missions are themselves ''cathedrals'' of which NASA can be proud, and they needed no passengers to make that so.

SKY & TELESCOPE

JULY 1, 2000

Mars Polar Lander

BY JONATHAN MCDOWELL

The independent panel studying last year's Mars Polar Lander failure issued its report in March. Since the lander had no way of sending signals during the descent phase - a design decision criticized by the panel - we will never be sure what really went wrong, but the review discovered a probable cause for the failure. Preflight tests indicate that unfolding the crafts landing legs probably triggered the sensor designed to detect touchdown. Eighty seconds later, when still 2 km above the surface, the descent engines were to switch on and keep firing until landing. However, because the software didn't reset the touchdown sensor after leg deployment, MPL may have thought it had already landed and therefore never fired its braking rockets. If so, it would have been in free fall during the descent's final 30 seconds, impacting the surface at 14 meters per second. More broadly, the report concluded that the failure was caused by significant underfunding and by having too few people working each part of the project. For example, the review panel felt that the two Deep Space 2 surface probes, which had accompanied MPL to Mars, were not flightworthy at the time they were launched.

Newsday JUNE 23, 2000

Pool of Evidence Indicates Water Flowed on Mars

By EARL LANE

With striking photos of gullies descending the steep walls of Martian craters and channels cut through sand dunes, two scientists made the case yesterday that such features could have been carved only by recently flowing water.

That conclusion, if confirmed, would have implications for the search for possible signs of life on Mars, specialists said.

"Over the last two decades, biologists have come up with an intriguing result," said Edward Weiler, NASA's associate administrator for space science. "Just about any place they find liquid water that's below the boiling point, organic molecules and energy, they find life." On Earth, "life seems to find a way to exist," Weiler said, whether in hot springs, lakes beneath Antarctica, deep underground rocks or highly saline lakes.

Whether Mars follows the same rules remains to be seen, but confirming that liquid water has flowed on Mars in the recent geologic past and perhaps even today would bolster the case for intensive exploration of the Martian surface in search of primitive life, scientists said.

The new photos come from a high-resolution camera aboard NASA's Mars Global Surveyor spacecraft, which has been in orbit around the planet since September, 1997. Michael Malin of Malin Space Science Systems in San Diego, the manufacturer of the camera, announced the team's findings at a NASA news briefing yesterday.

The planet today is so cold, with an average surface temperature of 64 degrees below zero Fahrenheit, and the atmospheric pressure so weak that any water at the surface should quickly freeze or sublimate to a vapor, specialists said.

So when Mars Global Surveyor began sending back images of cliff faces on Mars with features that looked very much like some of the "weeping layers" in Colorado plateaus where underground springs flow outward, the researchers were a bit baffled.

"We were quite surprised and confused by it because it doesn't really fit our models of what Mars is like," said Malin. Kenneth Edgett, his co-author, agreed. "I was dragged kicking and screaming to this conclusion," he said.

Scientists generally agree that water flowed abundantly on Mars billions of years ago, carving deep channels and canyons at a time when the planet was perhaps warmer and wetter.

But in combing through 65,000 images that Mars Global Surveyor has returned, Malin and Edgett found about 250 photos showing about 120 different locations, usually in crater or valley walls, where there is evidence "of fluid seepage and surface runoff." The channels and debris areas look sharply etched, with no small meteor impact craters on or near them. The lack of weathering by such impacts suggests the features are very young geologically, scientists said. Weiler said that could mean a million years, 10,000 years or even yesterday .

Federal Computer Week

JUNE 26, 2000

NASA builds a nose for bad news

BY Paula Shaki Trimble

While space shuttle astronauts are busy tending to their duties and scientific experiments, NASA can smell trouble 250 miles away.

An electronic nose that uses computers and specialized sensing film to work much like a human nose is being tested by researchers at NASA's Jet Propulsion Laboratory as a way to detect unsafe chemical levels on the International Space Station.

After a space shuttle flight in October 1999 successfully demonstrated the technology, called E-Nose, researchers at JPL and the California Institute of Technology began working to expand its sensitivity and shrink its size.

Amy Ryan, principal investigator for E-Nose at JPL, said the instrument could be an event monitor on the International Space Station to alert the crew if there is a spill or leak. "There's a lot of room on the space station," Ryan said. "The more automated you can make this kind of thing, the better off the crew is."

Ultimately, E-Nose will identify an unsafe element in the air and send a signal to the space station's environmental control system, and a central computer will decide how to react, she said.

Nathan Lewis, a professor at Caltech, designed the E-Nose sensing films, and NASA designed the instrument's hardware and associated processing software. NASA adopted a commercially available Hewlett-Packard Co. handheld for E-Nose. The instrument also has a sampling chamber and air filters, and NASA designed the data acquisition system and wrote data analysis software.

NASA has been developing E-Nose for about four years, but the concept of an electronic nose has been around for about 20 years, Ryan said. It has taken off in the commercial market as well, with Cyrano Sciences Inc. offering Cyranose 320, a product built around the Caltech sensing films, primarily to the food and petrochemical industries.

Scientists at JPL are beginning to talk to other NASA departments and other agencies about new applications for E-Nose, Ryan said. The Environmental Protection Agency and defense agencies would be prime candidates, she said. E-Nose has been identified as a possible environmental monitor in aircraft cabins and on submarines, as well as in the oil, gas and food industries. The size will be easy to condense, Ryan said. The E-Nose NASA used on the shuttle is the size of a large paperback book and weighs about 3 pounds. Ultimately, it could be the size of a tennis ball, she said.

Much like the human nose, E-Nose's sensors identify smell based on patterns that it already recognizes. "Part of the power is the ability to train it," Ryan said.

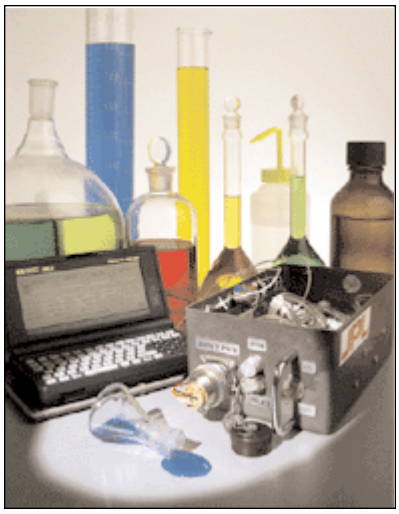
The E-Nose software has been trained to recognize 12 scents, and scientists are planning to train it to identify 20 to 30 common contaminants. It is also trained to detect contaminants based on the maximum level to which astronauts can be exposed for one hour. Ryan said she hopes to expand that capability to the maximum level of exposure for 24 hours. For example, astronauts can be exposed to 30 parts per million molecules of ammonia for one hour but 20 parts per million of ammonia for 24 hours.

"What we envision...is several [units] distributed on the space station connected to a central computer, which will take the data and control the environmental controls," Ryan said.

Cyrano, meanwhile, has not begun to pursue applications outside the food and beverage and petro- chemical industries, but Rick Sill, Cyrano's vice president of sales and marketing, said he envisions markets in government agencies and private industry for detection of narcotics, explosives and land mines.

The Cyranose product is a handheld and sells for about $8,000. Cyrano is also working with Welch Allyn Inc., a medical instrumentation firm, to develop sensing technology that could detect cancers and ulcers based on changes in the makeup of breath.

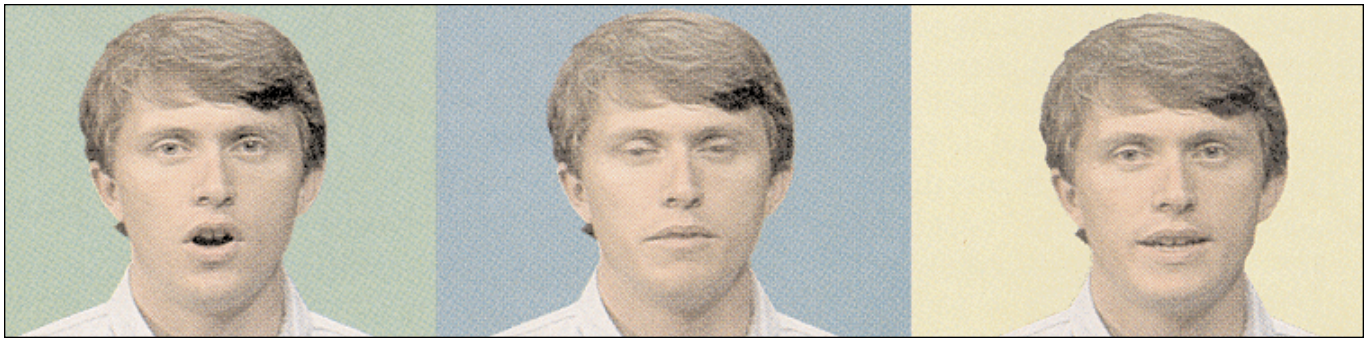
How it Works: The Smell of Success



The electronic nose got its name because it operates similarly to a human nose. Both contain a large number of nonspecific sensors. NASA's Jet Propulsion Laboratory created the E-Nose, an array of chemical sensors made from 16 polymer films. Each film has been loaded with carbon particles, which make it electrically conductive. The polymers swell and shrink as the composition of the air changes, and those changes alter the electrical resistance of the films. The E-Nose measures the change in resistance when the films swell or shrink.

The sensors are not specific to any one vapor. All of the sensors respond to a change in the air, and the pattern of response is recorded. By comparing the pattern of response of the array with patterns that have been recorded in the laboratory, gases and gas mixtures can be identified.

Let Your PC Do the Talking



Coming soon to a Web site near you: A few frames of Digital Personnel being put through its paces

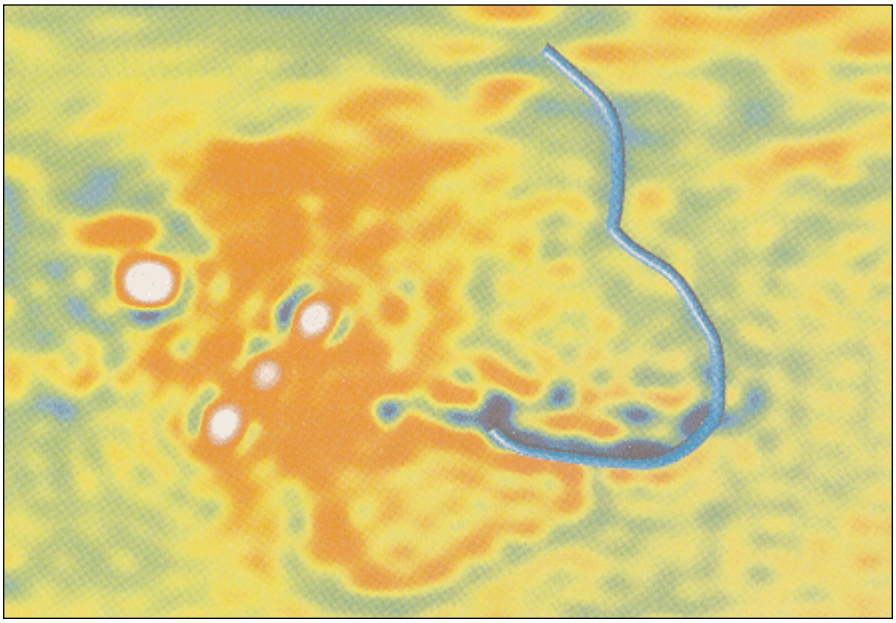
Max Headroom, move over. A Newtown, Pa., company called Graphco Technologies has licensed new technology from Caltech and NASA's Jet Propulsion Labs that will result in computerized talking heads that look more natural. The process, dubbed Digital Personnel, requires a short video of a real person reading a few sentences into the camera, in order to capture that person's making each possible sound in the English language. The video is used to build a library of every "viseme," or visual phoneme, that can be recombined in any order. After that, any recorded speech from the original speaker can be plugged into the Digital Personnel software, which will match the facial expressions to each sound, resulting in a fairly realistic talking head. Graphco plans to market a Web-oriented version for things like virtual celebrities (less time in the studio), or putting a human face on tech support. But it's the future applications that are trippy: when the technology gets fast enough to work in real time, people could videoconference in their pajamas and let their virtual selves put on a sharp-dressed front.

Discover

JUNE 1, 2000

The great buried floods of Mars

BY KATHY A SVITIL



Gravity map of Mars shows what photographs cannot: a deep buried channel (blue), possibly carved by floodwaters pouring into an ocean.

Mars today is a barren world, but Maria Zuber suspected that deep beneath the surface the Red Planet still bears the scars of a blue, watery past. So when images from NASA's Mars Global Surveyor failed to show clear signs of former oceans on the surface, she decided to take a deeper look. As Surveyor orbits Mars, it bobs up and down slightly because variations in the thickness and composition of the planet's crust affect the local pull of gravity. Zuber, a planetary scientist at MIT, joined with a group of colleagues to chart those movements and then subtract the influence of big surface geologic features such as volcanoes. When they were done, the researchers found several enormous channels, buried beneath as much as two miles of sediment, in Mars's northern hemisphere. The channels, more than 100 miles wide and 1,000 miles long, might have formed when floodwaters poured from the southern highlands into an ocean covering the northern lowlands.

The Global Surveyor's interior views also uncovered what could have triggered the flood. Mars's outer crust is thin in the northern hemisphere, possibly because of a rapid release of heat that melted away part of the crust in the first few hundred million years after the planet formed. "An early, hot interior might have liberated frozen water or water just below the surface and maybe expelled gases that produced a thick atmosphere and a greenhouse effect," Zuber says. These days the planet is quiet, but its vital signs still register to those who know where to look.

Pittsburgh Post-Gazette JUNE 26, 2000

The Wet Planet

Let's cut to the chase: If two young scientists are right, Mars is inhabitable; in fact, may even be inhabited.

The inhabitants would not be what science fiction has led us to expect, but ocean floor-like organisms that can survive savage extremes of temperature and pressure, everything but the absence of water in liquid form.

Space scientists Michael Malin and Kenneth Edgett say they have found gullies and deltas in a crater near a Martian region called -- talk about your cool sci-fi names -- Gorgonum Chaos. These are forms of erosion that could only be caused by fast-moving water.

There is abundant evidence that water used to exist on Mars, and these findings, based on photos taken by NASA's orbiting Global Surveyor, indicate that it may still be there, perhaps in some form of aquifer.

Humans cannot survive without water, but it is heavy and bulky to transport. The importance for Mar-tian exploration of having water in place is not only that it doesn't have to be hauled there but that its constituent elements would provide a local source of oxygen for breathing and hydrogen for fuel.

For now, these are exciting what-ifs but, as NASA launches more probes, they become less speculative and more in the realm of the possible. Back on our own planet, the infectious enthusiasm with which Malin and Edgett discussed their findings showed that space science may not be the best paid field on Earth, but it may be one of the most rewarding.

SKY & TELESCOPE

JULY 1, 2000

Asteroid Kleopatra: Wild and wonderful

For two decades, Steven J. Ostro (Jet Propulsion Laboratory) has used powerful radar antennas to ping dozens of minor planets from afar. But few if any of those studies can top what he found last November when the main-belt asteroid 216 Kleopatra had a particularly close opposition that brought it into view of Arecibo Observatory's giant radar-equipped dish. As Ostro and eight colleagues report in Science for May 5th, Kleopatra is every bit the bizarre object that astronomers had suspected for decades."The asteroid is shaped like a dumbbell," they write,"with a handle that looks substantially narrower than the two lobes when seen pole on but not when seen from within the equatorial plane." Kleopatra's overall size is 217 by 94 by 81 kilometers (+/- 25 percent).

The portrayals seen here are not true images but instead show a shape model carefully derived by team member R. Scott Hudson (Washington State University). The two-lobed shape is unambiguous even in the raw radar echoes. However, the observations can't rule out the possibility of a small, empty gap in the central "handle" (very unlikely, notes Ostro), which would mean the two big lobes are orbiting very close together.

Past spectroscopic studies have suggested that Kleopatra either consists entirely of metal or is a mixture of metal and the silicate mineral enstatite. Based on its strong radar reflectivity and the polarization of the returned signal, Ostro's team leans toward an all-metal object that is deeply blanketed with impact rubble and is highly porous throughout. If so, it must be from the interior of a much larger body that melted and separated into layers including a metallic core - before being smashed to pieces.

Is Kleopatra a huge mass of pure nickel-iron fragments just waiting to be mined by future spacecraft? The idea is appealing, but asteroid specialist John S. Lewis (University of Arizona) points out that Kleopatra's orbit is too eccentric and inclined to be easily accessible.

space.com sm

JUNE 29, 2000

Scientists Urge Caution In Mars Water View

BY GREG CLARK
Staff Writer

Amid the excitement caused by last week's announcement that water may have been active on the surface of Mars in the very recent past, top planetary geologists are stressing that the conclusions are still very much speculative. While water could be responsible for the striking gully-like features seen in recent pictures from the Mars Global Surveyor spacecraft, there are other explanations, the scientists said.

NASA touched off worldwide excitement last week when it held a press conference to announce results of research conducted by Mike Malin and Ken Edgett, of Malin Space Sciences Systems, the independent company that built and operates the camera aboard the Global Surveyor.

Malin and Edgett discovered features that looked like they were created by groundwater seeping from the edges of steep hillsides on Mars. Land at the top of these features seemed to have collapsed into theatre-shaped alcoves, and deep gullies appear to cut into the hillsides below these features. The gullies often end in fan-shaped debris deposits that look very much like river deltas on Earth.

The findings are presented in the June 30 issue of the journal Science.

"Had it been on the Earth, there would be absolutely no question that water was associated with the formation of this feature," Malin said during the press conference.

A chauvinistic worldview?

That is true, acknowledges Ken Tanaka, a planetary geologist at the United States Geological Survey, but he warns that it isn't productive to always grab at the first available earthly explanation to explain extraterrestrial geology.

"We shouldn't forget that this is another planet." Tanaka said. "We haven't set foot on it. And even though we have robots that have been there, their observations have been very limited. The very fact that these [features] were such a surprise demonstrates how naive we are."

Scientists should proceed with caution, careful to notice when an earthly bias might be influencing the interpretation of Martian features, Tanaka said. "I think we are eventually more likely to find the right answer if we continue to inspect all the possibilities."

Proposing that water existed on the surface of the planet is problematic, because Mars is so cold that whatever water is there should be deeply frozen, as deep as a few miles (kilometers) below the surface. Plus, the atmospheric pressure is so low that there is only a minute difference between water's melting point temperature and its boiling point. Even if ice were to melt, the water would become vapor almost immediately.

Thus, it is a challenge to explain how water could be stable enough on the surface of Mars to create the outflow channels and debris-flow features that Malin and Edgett show in their pictures.

Liquid of choice on Mars may not be water.

A different possibility, which Tanaka suggests, is that the features are not caused by water, but by some other liquid, say, carbon dioxide, or a substance closely-related to water called clathrate. Clathrate is a special crystal in which water forms a lattice structure that can hold larger molecules, such as methane or carbon dioxide, in its center.

On Mars the water may be locked up in the form of a carbon dioxide clathrate, Tanaka said. This molecule has certain characteristics that cause it to behave somewhat differently from water. For instance, water can be melted by a sudden exertion of pressure. Squeeze an ice cube with enough force, and it will suddenly melt. Clathrate has the opposite property. With a sudden drop in pressure, clathrate ice could quickly turn to water.

If clathrate were buried underground, and a landslide suddenly uncovered some of this subsurface clathrate ice, the pressure release might be enough to cause a violent chain-reaction of melting. This could dump out a fizzing and bubbling wave of liquid that would pour down the hillside, carrying debris and boiling away as it gushes downward.

It is also possible that the now-famous gully features are created not by liquid at all, but by explosive flows of hot gas or water vapor that might be related to volcanism. Outbursts of gas might create fluid-like flows, which could rush downhill, carrying dust and debris and creating the newfound features.

These might be small-scale versions of the kinds of hot gas and ash flows witnessed in the 1980 eruption of Mount Saint Helens, Tanaka said.

Age not settled

Whatever the real mechanism that created these features is, Tanaka said they are exciting because they appear to be so young.

Continued on next page

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But other scientists said it is important to remain cautious about the ages. Tim Parker is a planetary geologist at NASA's Jet Propulsion Laboratory. He studies Martian geological processes, and has been involved in analyzing landing sites for past and future NASA Mars missions.

Scientists arrive at the rough ages for planetary bodies by counting the craters left in their surfaces. The older a surface is, the longer it will have been exposed to the destructive impacts from meteorites, and the more cratered it will be.

Counting the number of craters on a surface is a relatively reliable method for judging the surface's age, Parker said, but it is not foolproof. It is best when used across large areas, and less reliable at small scales. Also, it is not always clear whether a surface looks devoid of craters because it is fresh, or because it has been freshly uncovered.

For example, a region of rock could be protected from cratering processes because it is covered by sand dunes. If the dunes were to retreat, or be cleared by wind, an old surface could be exposed and appear new.

It is possible that some of the so-called water-influenced features were actually caused by landslides, Parker said. "As much as I would like to believe that water is involved, some of them look like they could be dry-debris-flow features."

Parker and others said these features need to be studied in more detail by scientists throughout the planetary science community before the water hypothesis is confirmed.

Ultimately, it could take future Mars landers to settle the question for certain.

space.com sm

JUNE 29, 2000

Mars Hides Much More Water, Study Suggests

BY ANDREW BRIDGES
Pasadena Bureau Chief

New research claims the crust of Mars may harbor up to three times more water than previously thought, providing the latest blow to the tarnished notion that the planet today is a dry, lifeless place.

The study suggests that Mars may have lost far less water to space over time than scientists have believed. That leaves the tantalizing possibility the planet still holds sizable reservoirs of water that future space missions could tap in the search for life.

The paper describing the work, by Arizona State University geochemist Laurie Leshin, comes on the tail of a report last week that vast stores of liquid water may lie just below the surface of Mars.

Leshin's work compared the amount of deuterium, a heavy form of hydrogen, found in water in the Martian atmosphere, to that in a meteorite blasted from the planet's surface 3 million years ago and discovered in Antarctica in 1994.

Leshin found that ancient water-bearing crystals in the meteorite QUE 94201 were richer in deuterium than expected and thus similar to the water in the planet's present-day atmosphere. The unexpected similarity in deuterium ratios suggests the planet has held on to two to three times as much water as previously estimated.

"They are more similar than we thought they were, although they are still different," said Leshin, an assistant professor at the Arizona State's Tempe campus. "It's the size of the difference between the two that's less than previously thought." Leshin's report will be published in the July 15 issue of the journal Geophysical Research Letters.

Many scientists have assumed that water on Mars and Earth began with comparable deuterium-to-hydrogen ratios. With the passage of time, however, the Red Planet's atmosphere lost much of its comparatively lighter hydrogen, leaving behind the heavier deuterium, boosting in the process its overall proportion.

Today, the water in the atmosphere of Mars has a deuterium-to-hydrogen ratio 5.2 times that on Earth. To reach that level, scientists have suggested Mars lost as much as 90 percent of the water in its upper crust and atmosphere.

But Leshin found in analyzing minute amounts of ancient water in the 0.42-ounce (12-gram) meteorite that its deuterium-to-hydrogen level was not equal to but actually double the ratio found in terrestrial water.

Leshin's finding implies that once Mars began to lose hydrogen to space, it did so from a reservoir that was already twice as rich in deuterium as water found on Earth.

"You lose some of it, but you don't have to lose as much to get to where the atmosphere is today," said John Jones, a planetary scientist at NASA's Johnson Space Center.

David Paige, a University of California, Los Angeles planetary scientist, called the concept a reasonable one.

"This is only thing I have seen that has the potential of tracing back and giving us a snapshot of what those conditions were," said Paige.

Deuterium's origin

How Mars started off with deuterium-rich water is a far trickier question.

Leshin suggests that early in Mars' history it lost significant amounts of hydrogen to enhanced extreme ultraviolet radiation from the then-young sun. Alternatively, she said, comets could have pummeled the planet in large number to re-supply it with water that already had elevated deuterium levels.

Nor does the new work answer the most pressing question of just how much water Mars has today.

"It's an incredibly evolving field right now," said Bruce Jakosky, a professor of geology at the University of Colorado. "There isn't a single good estimate."

Scientists also caution that even tripling the estimate of how much water Mars might have does not necessarily mean the planet is swimming in the stuff.

"The real story is that, hey, you've still lost as much as 70 to 90 percent of the water," Jones, of NASA, said. "That could be big news to someone who wants to go to Mars and drill a well."

space.com sm

JUNE 24, 2000

NASA's Mars Mantra: Follow the Water

BY ANDREW BRIDGES
Pasadena Bureau Chief

PASADENA, Calif. – In the immediate weeks, months and years to come NASA will employ a slew of spacecraft to continue to hammer away at the tantalizing possibility of liquid water – and life – on Mars.

One of those missions, the Mars Global Surveyor, is already at the task, returning to Earth on a daily basis virtually hundreds of high-resolution images of the planet's surface.

It was in at least 200 of those images that scientists announced Thursday that they had spied gullies apparently formed by the comparatively recent flow of torrents of water, soil and rocks spilling down the walls of craters pocking Mars.

"If this were on Earth there would be no question water was associated with these features," said Michael Malin, the principal investigator on the spacecraft's Mars Orbiter Camera and president of Malin Space Science Systems.

Eyes on the prize

A flood of similar images continues to pour in from the Global Surveyor and will do so until the mission ends in February 2001, although it could well win a one-year extension.

The continued coverage will allow the satellite's eagle eye to image many gully features on a repeated basis, tracking any present-day activity.

"If we see one that changes, wow, we'll be back," promised Ken Edgett, staff scientist at Malin Space Systems.

More water on tap

The discovery of sources of liquid water neatly dovetails with NASA's ambitious strategy to explore Mars, the planet that most closely resembles our own.

"We feel vindicated," said Jim Garvin, NASA's Mars program scientist.

"Follow the water," has been the agency's Martian mantra of late: Where it flowed, when and where it might have gone. NASA lost two missions – the Mars Polar Lander and the Climate Orbiter – last year that were to have contributed to that quest. Later this year, NASA will sketch out a 20-year plan that reprises the theme.

"For once, we seem to be on the right track," said Richard Zurek, the project scientist on the two ill-fated missions who is now at work on a proposed orbiter to be launched in 2003.

Water, water everywhere

Although water on Mars is nothing new – tons of the stuff is locked up in the planet's poles and atmosphere – it is the suggestion that it exists in a liquid form so close to the planet's surface that jazzes scientists.

"We're seeing the potential of that water being more accessible to our robotic tools than ever before," Garvin said.

The vast quantities of water – at one point, Malin spoke of a feature that required the outpouring of as much as 66 million gallons (250 million liters) of water to form – further buoy the prospects that Mars may harbor life.

The water could also support human life on future missions to the planet. Once on Mars, astronauts could use the water for drinking, air to breathe and fuel for the return trip home.

"Before we send humans to Mars, there is a lot of homework we have to do," cautioned Edward Weiler, NASA's associate administrator for space science.

Robots do the homework

NASA will pick up the thread again in April 2001, with the launch of another orbiter to Mars.

The Mars Surveyor 2001 Orbiter will carry a suite of science instruments. They will be able to map the mineralogy, morphology and elemental composition of the Martian surface, as well as determine the abundance of hydrogen – and thus water, frozen or liquid – in the top few feet (meters) of the soil.

Although the resolution of some the instruments precludes the targeting of the narrow features announced on Thursday, they will allow the global mapping of minerals that are characteristic of the interaction of water and rock, said R. Stephen Saunders, the 2001 mission's chief scientist.

"We'll be able to nail down at last what the water left behind," Saunders said.

Whether it is truly water behind the features remains to be seen.

"This story, I don't believe, will be answered until someone goes to one of these cliffs with a pick and shovel and digs into it," Malin said.

Fly or drive?

Actually accessing those materials sloughed off by the landslides is the multi-million-dollar question, however.

The earliest NASA will return to the surface of Mars – a place it has not successfully landed a spacecraft since 1997 – is 2003. The agency is a month away from deciding whether to send an orbiter or a lander – or neither – during that launch opportunity, Weiler said Thursday.

While an orbiter could continue the high-resolution reconnaissance work begun by the Global Surveyor, a large rover carried to the surface aboard a lander could roam far afield, collecting and analyzing samples.

"I'd buy stock in the rover, I guess," Saunders joked.

But if Athena -- the rover being readied -- is called up for Martian duty in 2003, it probably could not reach the seeping crater walls and floors imaged by the Global Surveyor, scientists associated with the project said.

"This is a very exciting result, but we have to have realistic expectations," said Steven Squyres, a Cornell University astronomy professor and the Athena rover's principal investigator. "I don't think in 2003 you're going to see a rover neatly deposited at the bottom of these things, climb up and pound a pipe into the rock."

The problem, said Ray Arvidson, a Washington University geologist and Athena's deputy principal investigator, is that NASA does not have the technical ability to land a spacecraft close enough to such a small feature that a roaming rover could travel the remaining distance to it.

"It may be we need a couple of years to design a mission -- a scout or small lander -- that can target these areas and penetrate them vertically," Arvidson said.

CNN.com

JUNE 26, 2000

Mars Express, other probes to expand search for water

BY RICHARD STENGER
CNN.com Writer

Within the next three years, several nations will attempt to dig deeper into the mystery of liquid water on Mars with an array of spacecraft, including a European probe that could land near a theoretical wet spot on the red planet.

Mars currently hosts only one active spacecraft, NASA's Mars Global Surveyor, which took pictures that scientists say provide compelling evidence that water lurks near the surface.

At least three spacecraft slated to visit the martian system over the next few years could widen the search for water, an ingredient considered necessary for life.

Only the European Space Agency has firm plans to land a spacecraft on the red planet. The Beagle 2 will hitch a ride aboard the Mars Express orbiter, due to arrive in the Mars system in December 2003.

ESA is reviewing landing targets for the Beagle 2 lander, which will sniff the surface and atmosphere for signs of past or present life.

'Southern hemisphere a bit tricky'
Given that all known life requires liquid water, the chance of searching near a wet spot on Mars intrigues Beagle 2 scientist Colin Pillinger. But landing near such a location would prove daunting.

"The southern hemisphere, where most of these (possible water sources) seem to be, is a bit tricky for Beagle 2. It will be going into autumn and winter in the southern hemisphere when Beagle arrives," he said.

The Beagle 2 would require more batteries to survive the deep cold, and the landing system cannot spare the additional weight.

Pillinger held out hope that the Beagle 2 could descend near one of the rare wet spots found in the northern hemisphere relatively close the equator.

But with a landing window 62 by 31 miles (100 km by 50 km), could the Beagle 2 hit one of those targets?

"That's a whole new ballgame. To pinpoint land you would need a communication system around Mars, so you can target it. But we could at least target for the general vicinity. That would be a smart move," he said.

From orbit, the Mars Express satellite will look for signs of water below and above the surface using ground-penetrating radar, infrared and other instruments.

"The latest evidence that liquid water has flowed on Mars very recently makes Mars Express even more relevant," said Agustin Chicarro, a project scientist with the European Space Agency.

Global Surveyor scientists have calculated martian groundwater might lie at a depth of 100 meters to 1 km (109 yards to 0.6 mile).

"This means that the radar on board Mars Express should be able to detect it quite easily," said ESA project scientist Jean-Loup Bertaux.

A boost for slumping NASA
The loss of two Mars probes in 1999 compelled NASA to revamp its Mars office. The new discovery could give the slumping program a needed lift.

"It has obviously precipitated a lot of interesting thinking in our science community," said Jim Garvin, a NASA staff scientist involved in the selection process for future Mars missions.

The Global Surveyor, which has taken more than 20,000 pictures since it began circling Mars in 1997, could extend its mission at least a year beyond its scheduled retirement in February, said orbiter scientist Michael Malin, who announced the discovery.

NASA will likely decide this summer whether to send an orbiter or a roving lander, or neither, to Mars in 2003.

"There is no chance (the water discovery) will change any of the instruments on those spacecraft," said NASA spokesman Don Savage. The planning phases for the missions are too far along.

However "there are ways that we can use the suites of instruments on them to look at those sites," he said.

The 2001 orbiter will use an infrared imager to look for water-related minerals around seepage sites identified by Surveyor.

A lander in 2003 could perhaps send a rover closer to a wet spot, although scientists caution that most of the sites seem dangerous, along steep gully walls and crater rims.

The proposed 2003 orbiter could magnify the visual search, snapping pictures with a resolution two or three times better than Surveyor, which already can distinguish objects as small as a sport-utility vehicle.

Japan's Nozomi en route to Mars
Only one spacecraft is in transit to Mars now, a Japanese robot ship that will rendezvous with the red planet in 2003. The Nozomi orbiter was to reach Mars orbit in 1999 but sputtered during a slingshot maneuver around Earth.

Nozomi, also known as Planet-B, guzzled so much fuel during a course correction that it must wait four additional years. It will focus its instruments on the upper atmosphere, a study that could shed light on how

Continued on next page

From previous page

Mars lost water over time.

Scientists have long thought Mars' surface coursed with water billions of years ago, based on evidence of liquid erosion and signs of ancient channels and seas. But the water all but disappeared as the planet cooled and its atmosphere thinned.

Water exists today as ice in the northern polar cap and as vapor in faint clouds. But until last week's announcement, few scientists held out hope that the cold, arid planet could possibly have retained liquid water into the recent geologic past.

Given that European and Japanese spacecraft should reach the martian system in 2003, the United States might feel pressured to join the exploration party, one NASA scientist acknowledged.

"I'm sure the U.S. would like to have a presence there," said Richard Zurek. A researcher at NASA's Jet Propulsion Laboratory, he is working on the proposed 2003 orbiter.

'Friendly competition' among nations

But scientists dismiss suggestions of a serious rivalry among government space agencies. "The instruments that are arriving (in 2003) have influenced our selections. We're trying to complement, not duplicate them," Zurek said.

Pillinger agreed. He acknowledged a "friendly competition," but added, "We are good at sharing our resources."

The world community should have plenty of time to cooperate on the search for martian water. No one will know exactly what the theoretical wet spots hold until probes study them directly, scientists said.

Such a search will require major advances in technology. Mars landing windows are currently measured in kilometers. A precise landing to search a nearby source for water would require a far more precise target touchdown area, one measured in meters.

Such a pinpoint landing will not happen until 2005 or 2008 at the earliest, said NASA deputy administrator Ed Weiler.

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JUNE 29, 2000

Revolutionary Robots Gear Up for Mars

BY LEONARD DAVID

TUCSON, ARIZONA -- Getting a leg up on Mars requires muscle power. But if you are a robot, using muscle wire will put spring into your step.

The University of Arizona is home to a mechanized menagerie of sorts. Need a pick-me-up burst of power on Mars to hop over a rock? How do you refill your fuel tank when the nearest gas pump is millions of miles back on Earth?

These are a few of the challenges being tackled here by Professor Kumar Ramohalli and his students at the school's aerospace and engineering department.

First, there is LORPEX, for Locally Refueled Planetary Explorer. Then there's the cute and cuddly BiRoD -- a short way to say Biomorphic Robot with Distributed power. It seems that in space any good acronym is left to its own devices.

Ramohalli also directs the Space Engineering Research Center at the university. This group studies how to use on-the-spot resources on the moon, Mars, or the asteroids.

Pit stop on Mars

Having a space robot make its own gasoline and oxidizer so it can keep on going…and going…and going is the thought behind a planetary explorer that refuels itself.

"That is particularly nice for a planet like Mars where there are no gas stations," Ramohalli told SPACE.com.

The refillable robot also has the ability to generate power bursts. The need for quick and snappy surges of power is a direct message from earlier robots sent to the Red Planet, Ramohalli said.

"We have learned that you need power surges on Mars. That is critical if you are going to crush a rock to see what's inside, or if you have to drill deep below the surface. Maybe you need to jump over an obstacle. Any one of those things means you need a power surge. To this day, not even robots in the Star Wars movies have been able to do that," Ramohalli said.

Outburst of power

The key to power-on-demand is cranking out fuel from local resources. "Living off the land," is critical for future space explorers, be they robots or humans, Ramohalli said.

For example, the LORPEX carries a lightweight unit to suck in oxygen and carbon monoxide from the martian atmosphere. Panels of photovoltaic cells mounted on the robot convert solar energy into electrical power to energize this fuel-making hardware.

Placed on Mars, this equipment would extract oxidizer and fuel slowly over a period of a month. With gauges on full, a burst of energy can be released, offering a millionfold increase in power. A power train relays this outburst of energy to whatever device is required, be that a drill, auger, crusher, wheels, scooper or other tool.

"Energy has not been a factor. We can always have energy. But when you need that certain power surge, the robots to date cannot do that. That's a very big limitation and why we built LORPEX," Ramohalli said.

Look under the hood

A robot of a different stripe is the cute and cuddly BiRoD. Meant to mimic biological systems, this little critter is far simpler than past robots, explains Roberto Furfaro, an aerospace engineering student at the university.

As a micro-beast of burden, BiRoD features the latest innovations, such as muscle wires, chemical energy storage, mechanical conversion concepts and sensors. Everything is packed within a 12-inch (30-centimeter) long box, set atop a combination wheel/leg system.

Furfaro said that the robot reproduces the movement of the animal world. That is why it's tagged a "biomorphic" robot.

Muscle wires are used in the robot, made of a melding of nickel and titanium, to produce a memory alloy. "They have a nice property. When you heat it up, it changes its structure. When muscle wire contracts it produces a force, and you can use this action for moving the robot," Furfaro said.

Ramohalli beams when talking about BiRoD, the biomorphic robot.

"The big deal is that there's nothing under the hood. No gears, no levers, no transmission, no motors -- that's what makes it light and reliable," Ramohalli said.

Limping along

BiRoD is designed to ride on larger spacecraft. In fact, 25 of this breed of robot can occupy the same space and has the same payload weight as the single Sojourner robot that was part of the Mars Pathfinder, which landed on the Red Planet in July 1997.

Scattering an army of these tiny robots across Mars would be ideal. If one breaks down, others in the fleet can keep going.

"If a limb of BiRoD breaks, that's okay. The other limb will still work because there is no central power location. We have distributed power. It can limp along on the other legs," Ramohalli said.

BiRoD also has the ability to produce bursts of power, making it all the more valuable for a wide range of planetary exploration duties, Ramohalli said.

Furfaro said that space robots and robots used in a terrestrial setting are much the same.

"Actually, some of the robots built for Earth are more complex than those designed for space," Furfaro said, particularly those devices designed to work on the ocean floor.

The philosophy of "faster, better, cheaper" is being adopted for building space robots -- and "cheaper" means using something commercial.

"There's an inversion going on. I see commercial robots as doing something good for space, and not vice versa," Furfaro said.

Federal Computer Week

JUNE 26, 2000

Metric Matters

Keeping a promise he made during a hearing on NASA's Mars program failures, Rep. Vernon Ehlers (R-Mich.) introduced a bill that would require federal agencies in each contract, grant or research agreement to clearly state what unit of measurement they will use. The bill, H.R. 4414, would amend the Metric Conversion Act of 1975.

Ehlers introduced the bill in response to what he called a "freshman" mistake that proved to be a disaster in calculating the distance traveled by the Mars Climate Orbiter. The orbiter's contractors used nonmetric units of measurement for the spacecraft's navigational calculations, while NASA scientists used the metric system. The result: Contractors' inability to differentiate between a yard and a meter cost taxpayers $122 million.

SPACE NEWS JUNE 12, 2000

Automated systems monitor NASA's QuikScat

Most of the information being sent to Earth by NASA's Quick Scatterometer mission are being monitored by software systems. Instruments on board the Scatterometer spacecraft provide detailed information on ocean winds, waves, currents, polar ice and other meteorological phenomena. The software systems are used in monitoring 13 of the satellite's 15 daily polar orbits. The other two orbits are used in sending commands to the spacecraft.

Astronomy

JULY 1, 2000

Hyakutake's giant tail

BY ROBERT NAEYE

In the spring of 1996, people around the world watched in amazement as Comet Hyakutake's tail stretched more than halfway across the sky. But it turns out that the tail was a lot longer than it appeared from here on Earth.

Recently analyzed data from the joint NASA/ European Space Agency solar probe Ulysses shows that most of Hyakutake's tail was invisible, meaning that comet tails may typically extend hundreds of millions of miles longer than scientists had previously thought.

Two teams of scientists independently made the discovery while sifting through Ulysses data taken on May 1, 1996. The team in charge of the spacecraft's solar wind ion composition spectrometer found that the solar wind suddenly and unexpectedly became hotter and calmer, while the number of charged particles skyrocketed by a thousandfold. The solar wind is a stream of charged particles from the sun that at the time was blowing by Ulysses at more than 450 miles (730 km) per second.

The other team, which studies data from Ulysses's magnetometer, found that the magnetic field lines of the solar wind suddenly changed direction. The distorted readings from both instruments occurred simultaneously and lasted for just a few hours.

"Although the change in the magnetic field was typical of what we would expect from a comet tail, there was no known comet in the area, so we initially discounted the event," says Geraint Jones of Imperial College in London, England, who led the magnetometer team's study of the episode. "When we looked again at the instrument readings we were convinced it was a comet, so we decided to look farther out into space and realized Ulysses had crossed the tail of Comet Hyakutake, which was then far away in another part of the solarsystem."

If measured along the curvature of the comet's tail, Ulysses was more than 350 million miles (570 million km) from the "dirty-snowball" nucleus of Hyakutake, meaning the tail's length must have been at least 3.8 times the Earthsun distance. "The discovery was made quite by accident, a bit like finding a needle in a haystack when you weren't even looking for the needle in the first place," says spectrometer team leader George Gloeckler of the University of Maryland.

Magnetometer team member Edward Smith of the Jet Propulsion Laboratory adds, "The odds that Ulysses's flight path would intersect the comet tail were probably less likely than someone breaking the bank at Monte Carlo."

Because comet tails are probably much longer than previously thought, future spacecraft should have a much easier time sampling comet material. "We now believe that with a much more sensitive version of the ion composition spectrometer found on Ulysses, a spacecraft could travel through regions of the solar system picking up ions from the many invisible comet tails that probably crisscross our solar system," says Gloeckler.

Both Ulysses teams reported their findings in the April 6 issue of Nature.