For years NASA Administrator Dan Goldin has demanded that scientists and engineers do more with less. Now several reports say that the strategy, while good in theory, was poorly implemented

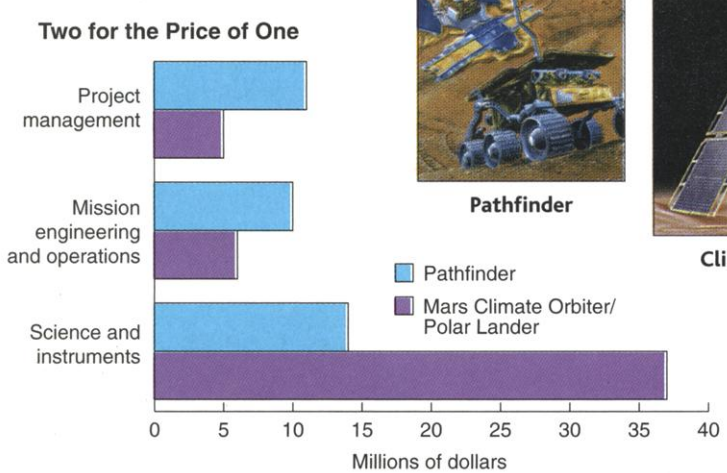
'Faster, Cheaper, Better' on Trial

When Dan Goldin visited the Jet Propulsion Laboratory (JPL) 8 years ago as the new NASA chief, he brought a harsh message to the people responsible for the world's most successful planetary program: Evolve or face extinction. Last week he was back at the lab, nestled in the hills above Pasadena, California. But this time he had shed what he has called his "tough love" approach to management. Instead he made self-deprecating jokes about his reputation for abrasiveness, told a touching story about his 88-year-old mother, and urged employees to speak their minds.

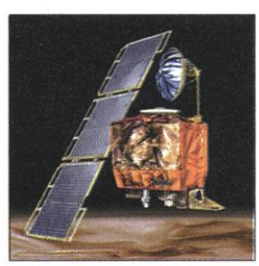
Goldin showed that kinder, gentler face 1 day after the release of a cluster of internal and outside reports* describing ill-trained engineers, inexperienced managers, stubborn bureaucrats, and a workforce apparently paralyzed by a fear of displeasing their boss. The reports' immediate focus is NASA's handling of recent Mars missions, including last year's failures of the climate orbiter and polar lander. But the documents also raise broader questions about Goldin's take-no-prisoners approach to a concept that has been the centerpiece of the agency's space science programs for nearly a decade—"faster, cheaper, better."

"I pushed too hard," Goldin told JPL employees in an uncharacteristically apologetic tone. That pressure, he added, "may have made failure inevitable." Panel members add that agency employees at all levels were unwilling to tell their superiors that the challenges facing the Mars missions were simply too tough—and unwilling even to admit that fact to themselves. "There was a flawed process and self-deception from Goldin on down," says one panelist. "Everyone became convinced they could do this."

Goldin was brought into NASA to shake up an agency plagued by cost overruns, technical glitches, and a ponderous bureaucracy. And all the recent reports—which include a National Research Council (NRC) study, three internal NASA investigations, and one NASA-sponsored external effort chaired by retired Lockheed Martin manager Tom Young—endorse his attempt to reduce paperwork, speed up mission preparation, and reward innovative solutions. But they point out severe shortcomings in the way faster, cheaper, better was carried out. In the next month a battery of congressional hearings will air these issues, while NASA scrambles to come up with a new plan for Mars exploration (see sidebar).



Pathfinder



Climate Orbiter

Polar Lander

No bargain. NASA spent less on key elements of Mars '98 than on Pathfinder, despite the challenge of building two spacecraft at half the weight.

Hubris

Just a short time ago, Mars was the bright star in NASA's firmament. A year after tentative evidence of fossilized life on a meteorite from Mars was discovered in 1996, the Pathfinder spacecraft and rover made a daring landing—on Independence Day—encased in an airbag. The successful missions made national heroes of the JPL team at a time when budget cuts and space station battles were dogging the agency. JPL had pulled off a science mission for just $165 million, a small fraction of the cost of previous efforts like the successful billion-dollar Viking. And even though the $273 million Mars Global Surveyor swung tardily into its proper orbit last year, it is providing riveting data about the planet's surface at a quarter of the cost of the Mars Observer mission, which failed in 1993.

Mars '98 was to be the triumphant next step. JPL was given the job of putting a spacecraft in orbit around Mars to gather data on the planet's climate while a second spacecraft dropped to the geologically complex surface of the south pole, releasing two basketball-sized probes along the way to plow into the soil as the main lander set up shop to scratch the surface for water. All that was to cost about the same as the single Pathfinder lander (see graphic). What's more, it had to weigh half as much as Pathfinder and be ready on a tight schedule to meet the biannual Mars launch window of 1998.

However, those requirements from NASA headquarters, accepted without protest by JPL, doomed the mission from the start, according to members of the Young panel and the other investigative teams. "They embraced an impossible dream and then shut off the alarm bells," says former JPL director Bruce Murray, a California Institute of Technology planetary geologist and consultant on the Young report.

What appears self-delusional in hindsight seemed bold at the time. Goldin was eager for more space spectaculars to offset a flat budget, and his headquarters managers were reluctant to contradict him, say members of the Young panel. At the same time, JPL managers were terrified of losing their monopoly on planetary missions to the Applied Physics Laboratory in Laurel, Maryland, or NASA's Ames Research Center in Mountain View, California. "There were competitors out there," says John McNamee, the Mars '98 project manager at JPL. "And Goldin would show up and threaten to kill [JPL's Saturn probe] Cassini or say he might shut JPL down," recalls Donna Shirley, the original leader of the Pathfinder team and the lab's Mars manager before she left NASA in August 1998. She is

CREDITS: JPL

* See www.nasa.gov/newsinfo/publicreports.html for the NASA reports. The NRC report is at www.nap.edu/catalog/9796.html

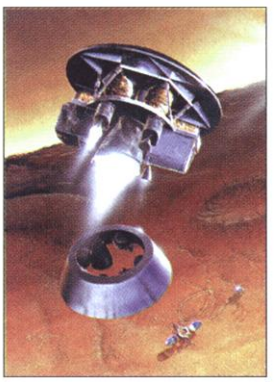
NASA Returns to the Drawing Board to Plan Next Wave of Mars Missions

Last week NASA embarked on a new course for its Mars missions. But coming up with the details will be a challenge. "Everything is on the table," says agency space science chief Ed Weiler about a review that will take place over the next few months.

The changes will affect a complex program that was set to send orbiters and landers to Mars every 2 years, culminating in a 2008 return of a martian soil sample conducted jointly with France's space agency, CNES. Last month a team led by the Jet Propulsion Laboratory (JPL) in California proposed keeping the basic plan but delaying each mission by 2 years while adding some communications satellites. However, neither Weiler nor the Mars assessment panel led by retired Lockheed Martin manager Tom Young were impressed with the JPL plan. "It was not ready for prime time, to say the least," says Young panel member Maria Zuber, a Massachusetts Institute of Technology geophysicist.

Weiler has ordered a NASA headquarters team to come up with a more detailed alternative that the Young panel can review this summer. He has already canceled plans to launch a lander next year, but he has retained the orbiter (*Science*, 10 March, p. 1722). The most immediate concern now is whether to go ahead with the 2003 lander, which shares a design similar to the failed 1998 lander. And a decision must be made quickly. "As time passes, your options dwindle," says Steven Squyres, the Cornell University astronomer who is principal investigator of the rover that could fly in 2003. As a result, Weiler says the team may speed up this portion of the review and deliver its recommendations by June.

Another question mark is whether to attempt a sample return. NASA officials now say it is too complex and need not be the centerpiece of the exploration program. "The sample return is not the end-all," says Weiler. The old plan was to use a French Ariane 5 booster to send a combination of NASA and CNES hardware to retrieve two samples from the martian surface. But NASA, burned by Russian delays in delivering parts for the international space station, may not be willing to trust the work to others. In February Weiler warned a group of U.S. scientists that "I will not sign up to a program with a foreign partner in the critical path. ... I'm not about to go to my boss and say that everything depends on another country." Weiler says that he still wants French involvement but is weighing alternatives that would limit NASA's dependence on CNES.



Back burner. Sample return faces postponement.

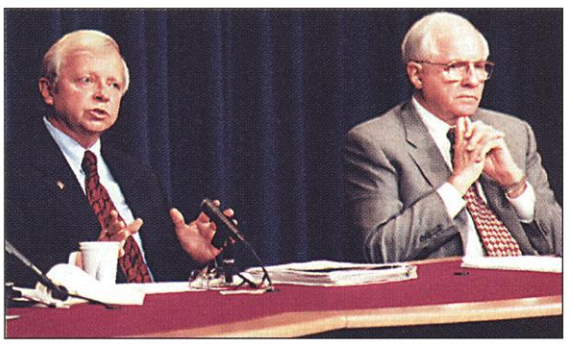
That attitude disturbs French scientists. "If NASA wants to go it alone, good luck," says Francis Rocard, CNES's solar system exploration chief. "It would be disastrous for all of us—and for scientists in France in particular." But a French diplomat says that NASA must have a chance to rethink its planning and that a close collaboration between the two countries is still likely.

Managers at the European Space Agency in Paris say that NASA's decision won't alter their plan to send up a Mars Express orbiter and rover in 2003. Meanwhile, the Japanese spacecraft Nozomi that was launched in 1998 will reach the Red Planet in the same year to study its upper atmosphere. **–A.L.**

now assistant dean of engineering at the University of Oklahoma.

The demanding cost, schedule, and science requirements proved even more toxic when mixed with what Shirley calls the "hubris" from Pathfinder's success. Another problem was that the team of enthusiastic JPL and Lockheed Martin engineers and managers lacked direction from older mentors. Instead of one or two major missions, JPL was working on two dozen, and there was a shortage of experienced managers, the reports state.

Despite this daunting combination of pressure from the top and inexperience at the bottom, no one except Shirley squawked publicly. "It never occurred to anyone to say they couldn't do this," says Maria Zuber, a Massachusetts Institute of Technology geophysicist and member of the Young panel. In April 1998, just months before she resigned, Shirley warned in an International Academy of Astronautics presentation of the dangers of "overoptimism engendered by successes," worker burnout, and increasing payloads without a corresponding growth in the budget. "In many areas we are at the limit," she said. NASA managers ignored the warning.



Emphasis on better. Space science chief Weiler, left, says NASA took "cheaper" too far as panel head Young listens.

Circling the wagons

The failure of the Mars Climate Orbiter last September shook up the team, but confidence remained high on 3 December, the day the Polar Lander was slated to set down. The prospects seemed so rosy to space science chief Ed Weiler that television cameras were allowed in the operations room. But instead of recording triumph, the cameras recorded the indelible image of stunned mission controllers and a glum Goldin.

Two separate software glitches are the likely immediate culprits in the failure of both the orbiter and lander. Both mistakes were made at Lockheed Martin's Denver plant, where the spacecraft were built. "There is no doubt that we are responsible for both these errors," says Ed Euler, the company's project manager for the mission.

A poorly trained young engineer was given the job of coding navigational software for the orbiter. "The company felt [it] was a not-so-critical job," says Art Stephenson, director of NASA Marshall Space Flight Center in Huntsville, Alabama, who chaired the panel that investigated the orbiter failure. The engineer failed to use metric units in the coding of a ground software file. JPL, which was overseeing the company, did not catch the error. Once the orbiter was on its way to Mars, a JPL navigator—described by Stephenson as "reserved"—noticed a problem with the trajectory. But his e-mails to Lockheed Martin were ignored, and he did not pursue the matter with his superiors, says Stephenson.

The leading theory on why the lander crashed is that a software error caused the engines to shut down prematurely during descent. But "other failure modes cannot be ruled out," states the Polar Lander investigation board chaired by retired JPL manager John Casani, because there are no corroborating flight data. A telemetry package that would have provided that information was deleted because of cost and size constraints, an omission that the Young panel calls "a major mistake." An incomplete test of the lander's leg before

CREDITS: (TOP) JPL; (BOTTOM) WILLIAM K. GEIGER

launch failed to uncover the problem. The glitch was noticed only during a recent test of the 2001 lander, which has the same design. The cause of the failure of the small probes—designed to be released by the lander in flight to bury into the martian soil—remains unclear. What is clear is that they were inadequately tested. "The microprobes were not ready for launch," states the Young report bluntly.

But the technical glitches are only part of a much larger story. According to members of the investigative teams and the Young panel, Lockheed Martin also bid too low, forcing it to rely on younger and, thus, more affordable workers. Even then, the company was unable to hire them in a timely fashion. A stressed and overworked team at JPL could not oversee the contractor's effort properly. And the JPL team received little guidance from experienced system engineers and support from senior managers, the reports state.

Both JPL and Lockheed took to "circling the wagons," states the Young report, at a time when they "deviated from accepted and well-established engineering and management practices." There was, the Young panel found, "a failure to clearly communicate" between JPL and NASA headquarters. Headquarters, for example, ordered new instruments to be added to the lander without boosting the budget. "JPL management did not effectively express their concerns" about the tight constraints, and "NASA headquarters did not seem receptive to receiving bad news," states the report. "This combination of inadequate management oversight and violations of fundamental engineering and management principles became the underlying contributor to mission failure," the Young panel concluded.

Those words harken back to the report of the commission that investigated the 1986 Challenger accident. Its authors cited Marshall Space Flight Center's penchant "to contain potentially serious problems and to attempt to resolve them internally rather than communicate them forward." They also laid much of the blame for the shuttle disaster on NASA's insistence on an aggressive shuttle launch rate.

No turning back

Senator John McCain (R–AZ), chair of the Senate Commerce Committee and former GOP presidential hopeful, calls the Young findings "an embarrassment to the agency" and has threatened to conduct his own investigation. "It may be time to amend NASA's mantra of 'faster, better, cheaper' to include 'back to the basics,' " sneers Senator Bill Frist (R–TN). Representative Ralph Hall (D–TX), ranking Democrat on the House Science Committee, says that "it is a shame that we are stalked by ineptness. I hope that NASA heeds this wake-up call."

Goldin insists he will—up to a point. "These failures are not a basis for reversing our course in pursuit of revolutionary change," he told McCain at a hearing just before the Young report was issued. However, some observers fear that the mounting attacks on NASA could roll back that policy. "I'm concerned about it getting sunk," says Alan Binder, director of the Tucson-based Lunar Research Institute and principal invesigator of the Lunar Prospector, a mission described by many as the "poster child" of the philosophy.

But others say there is no going back to the way NASA did science in the 1970s and 1980s, with multibillion-dollar probes that took more than a decade to build and could swallow a good chunk of a scientist's career. "Faster, cheaper, better is the only game in town," says Zuber. "It can work—you just can't get rid of prudent testing."

Although many researchers were highly skeptical of Goldin's revolution in its early days, the NRC study says it has led to more launch opportunities, more flexibility, and a chance to play a larger role in the development of missions once largely the domain of engineers. "I was dubious at the start," says Donald Brownlee, an astronomer at the University of Washington, Seattle, and principal investigator for the $205 million Stardust mission to collect comet material. "I thought cheaper missions were not scientifically worthwhile." But now he's a convert, cautioning that it is "really important that people not overreact" to the Mars failures.

A revamping of the way faster, cheaper, better is managed could actually improve NASA science, believes Steven Squyres, a Cornell University astronomer and principal investigator of the Mars 2001 mission. "Now when a project is in trouble, it will get help," he says. "And as someone who has spent the last years devoted to building instruments for Mars missions, I find this absolutely delightful."

For NASA to increase its chances of success, however, alarms must be sounded—and answered. Zuber and others say that Goldin, who was unavailable for comment for this story, was taken aback by the Young panel's finding that people were afraid to speak up when trouble was brewing. "Make sure you say something," he pleaded with JPL employees. "Don't hold it in." Congress and the scientific community will be watching closely to see if the new Goldin can jump-start his old revolution. **–ANDREW LAWLER**

CONSERVATION

Bringing Science to the National Parks

A new program aims to bolster the science underlying park management, but it will require a culture change among agency leaders

When Alaska's snow machine association last year challenged a new policy to ban snowmobiles in an 800,000-hectare wilderness at the heart of Alaska's Denali National Park, the park's managers were thrown into a quandary. They could marshal plenty of studies from the Rockies and northern U.S. states showing that the machines damage vegetation and harm wildlife. But when it came to demonstrating those effects in Denali—where they suspected that the fragile subarctic ecosystem was even more vulnerable—park officials came up short. Even when they needed basic information on where caribou and moose overwinter, the most they could find were piecemeal data, for example, from a student's master's thesis about one corner of the park and from a wolf predation study. "There just isn't the information base there," says Joe Van Horn, a park natural resource manager.

The scramble to collect data in Denali is just one example of how inadequate science is hampering management decisions in the national park system, which includes some 270 major parks with natural resources stretching from the Alaskan mountain ranges to the coral reefs off Florida. Critics have long charged that the National Park Service (NPS) manages parks to make them look good to visitors—a strategy that can lead to very different decisions from those ecology might dictate. With few exceptions, critics charge, agency officials have tended to view science with anything from benign neglect to outright hostility. The result has been a number of decisions that have been slammed by scientists, challenged in court, and even debated in Congress, involving everything from elk management in Yellowstone, to pollution in Oregon's Crater Lake, to the restoration of the Florida Everglades.

All that is about to change, says Robert Stanton, director of the NPS. Last summer he launched a new program, the Natural Resource Challenge, to bolster the science underlying park management. Just getting under way, the plan will invest millions more dollars in inventorying species and monitoring park conditions, hiring more scientifically trained managers, and enticing academics to conduct research in the