tests risky technologies aimed at making future missions smaller, faster, and cheaper—a mantra of NASA Administrator Daniel Goldin. "We need these technologies for the kind of science missions NASA would like to conduct," says Marc Rayman, chief mission engineer at the Jet Propulsion Laboratory in Pasadena, California, which is managing Deep Space 1 for NASA. Budgeted at $152 million, Deep Space 1 will fly by a little known asteroid called 1992 KD in July 1999, sending back information about its shape, size, surface composition, and mineralogy. Coming within 5 to 10 kilometers of the asteroid, the flyby will be the closest ever attempted of a solar system body. The mission may be extended to skirt Wilson-Harrington, an object in transition from a comet to an asteroid, as well as the comet Borrelly.

The autonomous control concept getting its first big test on Deep Space 1 could eventually relieve pressure on ground-based controllers, who will have to cope with a rising number of small missions in an era of restricted budgets. Greater autonomy could also lead to bigger scientific payoffs, for example, by allowing a spacecraft to modify observational plans after it spots a surprising and particularly interesting feature.

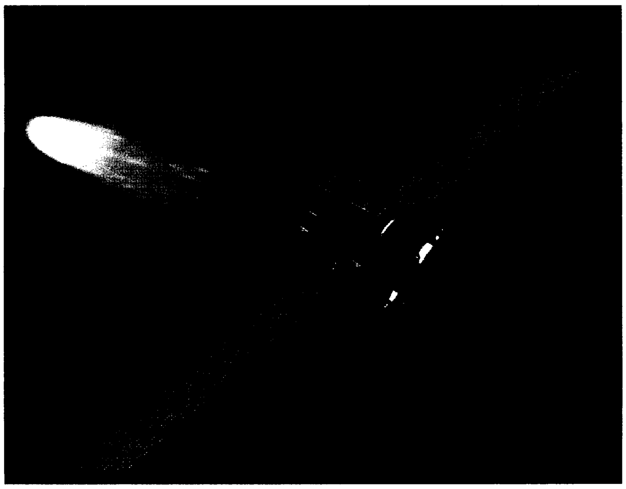
The most straightforward chore Deep Space 1 will handle is navigation. The spacecraft's autonomous navigator will determine the spacecraft's position by comparing observed patterns of asteroids and background stars with patterns stored in its memory. It will plot trajectory adjustments and fire the engines accordingly. A more ambitious experiment involves turning over responsibility for the entire spacecraft to a HAL-like autonomous agent. Given a goal, the remote agent works out the details and executes the operations needed to achieve it.

The remote agent for Deep Space 1 was jointly developed by NASA's Ames Research Center in Mountain View, California, the Jet Propulsion Lab, and Carnegie Mellon University in Pittsburgh, Pennsylvania. Its software package consists of four modules, dubbed mission manager, planner/scheduler, smart executive, and mode identification and reconfiguration. The work is carried out through operational plans that cover either a length of time or a set of tasks to be accomplished.

The mission manager begins its planning by reviewing what tasks have been completed and what lies ahead, the craft's location, and the condition of its subsystems. It then compiles a list of goals for the next plan segment—making a course correction, photographing a certain object, or transmitting data to Earth, for example—and sends them to the planner/scheduler. The planner/scheduler works out a sequence for achieving these goals and sends the information to the executive. The executive then expands the sequence of steps into detailed commands for the software controlling each of the spacecraft's subsystems. The mode identification and reconfiguration module monitors systems, identifies problems, and offers alternatives.

Martha Pollack, a computer scientist at the University of Pittsburgh, says most of these elements are established AI techniques. But Deep Space 1 "breaks new ground in showing that [such techniques] can indeed make the transition from the laboratory to the very complex application of space travel." Although the agent will control Deep Space 1 for only a week, the experiment "is a great leap for remote agents," says Barney Pell, a member of the agent design team at Ames.

Although the remote agent has captured the attention of the AI community, the flashiest of the dozen technologies onboard Deep Space 1 is probably the experimental ion thruster, which for the first time will be used as a spacecraft's primary engine. Ionized xenon atoms are accelerated out into space by charged metal grids at the rear of the engine chamber. The resulting thrust is equivalent to the pressure exerted by a sheet of paper resting in an open hand, according to NASA. But over time the ion engine can deliver almost 5 times the thrust per kilogram of traditional liquid or solid rocket fuels, making it ideal for extended space flights.



In command. Deep Space 1 will use its own software to fly itself for a week.

Deep Space 1 will also conduct experiments involving new low-power electronics systems and solar arrays fitted with lenses that concentrate sunlight. Although such technologies may not be the stuff of science fiction, they do add up to increased capabilities for future real space operations. "These will be the tools in the toolboxes of future mission designers," says Rayman.

–DENNIS NORMILE

COMMUNICATIONS

Quantum Encryption Takes First Step to Orbit

For sending a secret code, nothing beats quantum mechanics—at least in the laboratory. To be useful, however, quantum messages, such as the numerical "keys" required to decode secure messages sent by other means, will have to travel long distances, for example, from the ground to a military or telecommunications satellite. Now a team of nine physicists from Los Alamos National Laboratory in New Mexico have taken a first step in that direction by transmitting a key over a distance of 1 kilometer in the chill night air of the New Mexico desert.

"What we've done is demonstrate a protocol and the physics of a system that will do that," says team member William Buttler. The system involves transmitting the key with a broad laser beam that is yet so faint that each bit of data is represented by the polarization of a single photon. "It is really something," says Nicolas Gisin of the University of Geneva. John Rarity of Britain's Defence Evaluation and Research Agency in Malvern calls the feat, described in the 12 October issue of *Physical Review Letters*, "a key step on the way to uploading keys to satellites."

Quantum mechanics has caught the eye of encryption experts because it offers a way to guarantee the security of the key—the ran-

The long view. Photon transmitter (bottom right) and receiver (center) of prototype quantum encryption system.

CREDITS: (TOP) JPL; (BOTTOM) WILLIAM BUTTLER/LOS ALAMOS NATIONAL LABORATORY dom string of ones and zeros added to a message to make it unintelligible. Before the receiver of the encrypted message can read it—by simply subtracting the key string—the key somehow has to be sent to the receiver. If it is simply sent along the same route as the message it protects, it might be intercepted. In top security situations, says Rarity, the solution "is basically a man on a motorbike"—not a very practical solution if you want to transmit messages to a satellite.

In the Los Alamos scheme, the sender of the secret information, traditionally dubbed "Alice," sends a key by dispatching a stream of single photons, whose wave orientation, or polarization, is assigned one of two values. The receiver, known as "Bob," sets out to detect the photons through a filter system that randomly switches between two other, related, polarizations. Because of the choice of polarizations used, and the vagaries of quantum mechanics, even with a perfect experimental setup Bob would only be able to detect 25% of the photons that Alice sends.

Alice and Bob can then compare notes, via a public communication channel, on which photons Bob was able to measure. It does not matter if someone eavesdrops on this conversation, because they do not reveal the polarization results, just the occasions when Alice sent a photon and Bob received one. Hence, Alice and Bob now know the sequence of polarization results that Bob detected, and this serves as the key. It won't do a potential eavesdropper any good to tune in to the quantum channel either. Quantum rules mean that anybody who attempts to listen in to the string of photons will reveal themselves, because Bob will notice a rise in his photon error rate.

Although quantum keys have previously been transmitted across labs and, 2 years ago, over 75 meters in the open, until now nobody has confronted the type of real, swirling atmosphere that would be encountered on the way up to a satellite. In the Los Alamos work, Alice is a source of laser pulses, each just a nanosecond long and so dim that the average pulse contains less than one photon. Once polarized at random in one of two ways, each pulse makes the half-kilometer journey along a disused particle accelerator cutting to a mirror and then back to Bob, a receiving telescope plus optical analyzer stationed alongside Alice.

The big problem is turbulence, says Buttler, which "causes the beam to wander" and so miss the telescope. To beat turbulence, the team spread the beam to a diameter of 5 centimeters, greatly improving the chance that the telescope will pick up at least some of the beam. The team was able to successfully transmit a key code, at a hit rate of around one key bit for every 400 laser pulses.

Transmission over a single kilometer may seem a modest achievement, given that satellites are at least 200 kilometers above Earth's surface. But in fact "the real difficulty is the first kilometers," says Gisin, because above about 3 kilometers the air becomes purer and turbulence is less of a problem. The Los Alamos team is now trying to repeat the feat over longer distances and even in daylight, when the ambient brightness confuses the receiving signal. So far, "our results are encouraging," says Buttler. The main challenge, says Rarity, will be actually hitting the satellite with enough beam to do the job. "Given that you only want a few kilobits of key, it can be done," Rarity believes.

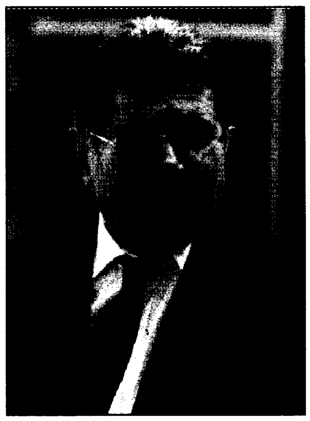
–ANDREW WATSON

Andrew Watson is a writer in Norwich, U.K.

FRANCE

Researchers Rail Against CNRS Reforms

PARIS—Geochemist Claude Allègre, France's minister of national education, research, and technology, had his hands full last week. While high school students across the country were marching in the streets for improved conditions in schools, some French scientists were threatening to stage their own protests over proposed reforms of the Centre National de la Recherche Scientifique. The CNRS, a huge public agency that employs 11,600 full-time researchers, is the bedrock of French science, and—as Allègre quickly learned—government ministers meddle with it at their peril.



Meeting resistance. French Research Minister Claude Allègre.

The controversy began on 10 October, when physicist Edouard Brézin, president of the CNRS's executive board, presented an early draft of the reforms to a board meeting. The confidential document, which Brézin had prepared in collaboration with Allègre and other ministry officials, outlined a number of proposed changes in the agency's statutes, most of which were designed to create closer ties between the CNRS and university labs. The document was quickly leaked to researchers' unions, who raised the alarm about what they saw as a threat to the independence of CNRS labs, despite the fact that most of the agency's research units are already located on university campuses. In an interview with the daily newspaper *Le Monde*, Jacques Fossey, secretary of the National Union of Scientific Researchers, accused Allègre of trying "to turn the CNRS into a granting agency for university research," which many CNRS researchers believe is inferior.

Another noteworthy feature of the reforms was a provision that would strengthen the role of the executive board and place it squarely in charge of CNRS's overall scientific direction, a responsibility it now shares with the organization's director-general. It is no secret that Brézin has not seen eye to eye with CNRS Director-General Catherine Bréchignac, who has been much more lukewarm about moves to reform the organization. Brézin says that this power struggle within the agency is of "little interest to people who don't work at the Rue Michel-Ange [CNRS's Paris headquarters] and will have no effect on the labs." Bréchignac was unavailable for comment.

Vincent Courtillot, Allègre's chief adviser, says that the unions have misunderstood the intentions behind the reforms. "We want to bring [CNRS labs] closer to university [labs], not to dissolve one or the other," he says. Courtillot also argues that 90% of CNRS labs already have the status of "associated units," meaning that they include scientists from universities, other public agencies, and industry. The remaining 10% are made up solely of CNRS researchers. However, Brézin told *Science* that a key feature of the reforms would ultimately be to give all CNRS labs associated status.

But chemist Henri-Edouard Audier of the École Polytechnique near Paris, a member of the CNRS executive board, says that protests arose because the government was trying to push the reforms through without sufficient debate. With 90% already associated, he asks, "why are they making such a big deal out of the other 10%? ... We are all for reinforcing links between the CNRS and the universities, but CNRS labs must retain their own mission."

In response to scientists' criticisms, Brézin has drawn up a second draft of the proposals, which would allow unassociated CNRS labs to be created and continue to exist for 4 years if there is no obvious partner lab for them. And as *Science* went to press, Courtillot was due to meet with researchers' unions this week to calm the waters. "We are not against reforms," says Audier. "But we must first have a discussion of the principles behind them. We need to understand where we are going."

–MICHAEL BALTER

CREDIT: D. NIVIÈRE/SIPA