stone, California, by expanding it from 64 meters in diameter to 70 meters in diameter. However, the same expansion that will help the antenna hear that distant whisper from Neptune also makes it into a more efficient transmitter. And with time to spare before Voyager 2's arrival, Muhleman and his co-workers took the opportunity to send 360 kilowatts of radio energy blasting toward Titan on three successive days: 3, 4, and 5 June 1989. That is a little more than seven times the power allowed to commercial radio stations. The researchers used the same 3.5-centimeter wavelength that Voyager does, and they transmitted continuously for 5.5 hours each day.

Meanwhile, NASA has also recently equipped the 27 antennas of the National Science Foundation's Very Large Array (VLA) near Socorro, New Mexico, to function as another giant receiver for Voyager 2 at Neptune. It was here, some 2.5 hours after each transmission began, that the team detected the infinitesimally faint radar echoes from Titan returning to Earth.

The result: in the first and last sessions Titan produced a very weak echo, consistent with reflection from a smooth, deep ocean. But in the 4 June session Titan returned a much stronger echo, reminiscent of radar reflections from the rocky surface of Venus. Since Titan rotates about 23 degrees each day, says Muhleman, each day's data sampled a different face of the satellite. "We concluded that these differences in reflectivity are real, and that we were seeing evidence for surface variability," he says.

The Caltech/JPL team is already planning a fresh round of observations for next summer, when Saturn will again be closest to Earth. By then NASA plans to have boosted the Goldstone antenna's power to 500 kilowatts. Moreover, the agency is considering boosting the power again to a full megawatt sometime in the early 1990s. And that means, in turn, that the researchers could begin to produce crude maps of Titan. The VLA's resolution at that distance is about one-fourth Titan's diameter. "With more signal to noise, we'll be better able to define where the continents and oceans are," says team member Martin Slade of JPL. "We can even be more definitive as to whether the surface is water ice, methane ice, solid carbon dioxide, or silicate rock."

Meanwhile, he says, these results strengthen the case for putting an imaging radar aboard JPL's proposed Cassini mission, which would orbit Saturn in the late 1990s and which could study Titan's surface in detail. "Would there be any point if it were just a global ocean?" he asks. "No." But now there appears to be something to see. ■ M. Mitchell Waldrop

Sun-Powered Pollution Clean Up

Sunlight may not yet have lived up to its promise in generating cheap electricity, but scientists at Sandia National Laboratories have demonstrated a second potentially valuable use for it. A team headed by Craig Tyner has cleaned up polluted water with a sun-powered detoxification system.

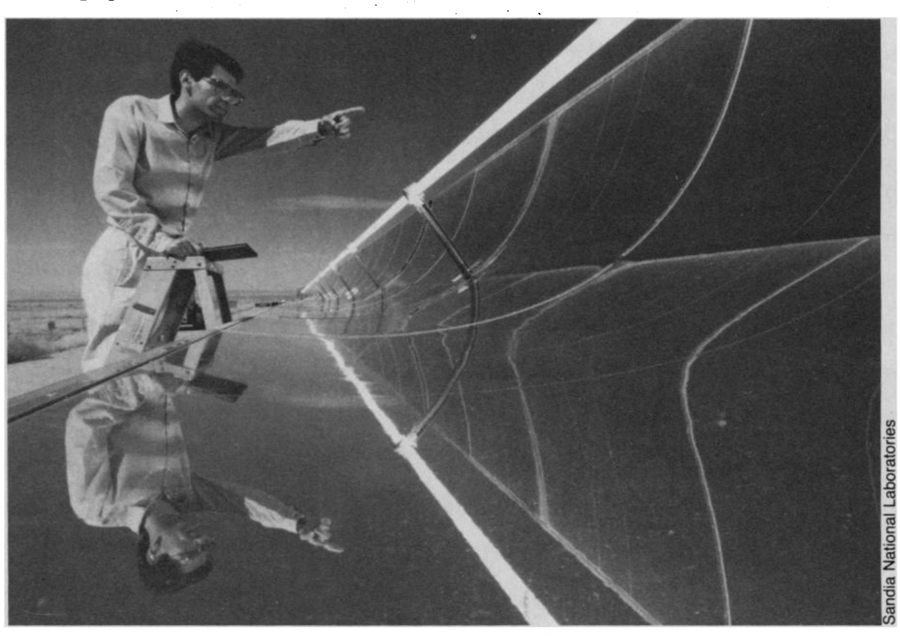
"We believe this process will destroy most organic materials," Tyner said; these include industrial solvents, pesticides, dioxins, PCBs, and munitions chemicals. He added that because the process breaks these toxic chemicals down into smaller, safer molecules, it offers an advantage over conventional waste disposal systems which do not destroy the waste products, but instead leave them still to be disposed of one way or another. (The two most common methods of removing organic wastes from water are bubbling air through the water in order to release the volatile chemicals into the air or running the water through carbon filters.)

In Sandia's solar-powered detoxification process, developed in cooperation with the Solar Energy Research Institute, grains of titanium dioxide are mixed into waste water and the mixture is run through a long glass tube, which sits at the focus of a 720-foot-long parabolic trough. When concentrated ultraviolet light from the sun hits the solution in the tube, it frees electrons from the titanium dioxide, creating electron "holes"—the absence of electrons. These holes combine with water, dissolved oxygen, and a small amount of hydrogen peroxide to create hydroxyl radicals and peroxide ions. These in turn attack the organic wastes, breaking them down into water, carbon dioxide, and some very dilute acids which can easily be neutralized.

The system cleans about 30 gallons of water a minute now, and Tyner said he expects to be able to increase that by a factor of 2 or 3. Initial tests were run on salicylic acid, a nonvolatile organic compound that is easy to work with and that has similar reaction rates to a number of the compounds the system is likely to be used on. The Sandia group has begun a second series of tests using trichloroethylene, a solvent used in electronics processing and one of the most common toxic organic pollutants.

Eventually, the system should be able to reduce the concentration of organic pollutants to a few parts in a billion, said Sandia engineer James Pacheco. At this level, the water would be suitable for drinking or discharging into lakes or rivers.

The successful detoxification signifies an engineering breakthrough rather than a scientific one, Tyner said, because the chemistry behind the reactions has been known for some time. "We have demonstrated that the process can work very well even on a large scale," he said. The ultimate commercial success of the process will depend on how economical the system is compared with other methods of removing organic pollutants from water, Tyner said, adding that so far cost analyses indicate it should stack up quite well. ■ Robert Pool



Sandia scientist Jim Pacheco *in front of solar detoxification system.*