THIS JUST IN
by Stuart F. Brown

Man Fixes Tape Recorder*

Here's a NASA story with a happy ending. It's a tale of heroic knowledge-harvesting machines and the resourceful people who attend to their well-being across the frigid vastness of space. Last December controllers monitoring the Deep Space Network—a trio of radio telescopes located in California, Spain,

and Australia—realized that they could no longer download images and scientific data from the *Galileo* spacecraft orbiting Jupiter. The radio link for issuing commands to the probe and receiving confirmation on those results was still working. But *Galileo* could no longer relay to Earth the big chunks of data that it had been sent 500 million miles away to collect. Chewing their fingernails, mission scientists wondered if *Galileo* would be able to complete its eight-year tour of Jupiter's neighborhood and its fascinating moons.


FERGUS GREER

*Orbiting Jupiter. NASA troubleshooter Greg Levanas, above, found the way to a historic repair.

The fix-it assignment fell to Greg Levanas, a lanky engineer at NASA's Jet Propulsion Laboratory in Pasadena, which runs the flock of unmanned space probes the nation has sent out to explore the solar system and beyond. The only evidence Levanas had when he began the assignment was a controller's report. It said that when *Galileo* was commanded to download data to Earth, the magnetic-storage tape aboard the craft didn't seem to be moving at all. Three hours after the command—the time it takes radio signals to travel to Jupiter and back—the Deep Space Network wasn't scooping up any data.

Fortunately for the people charged with nursing planetary probes, the machines are peppered with sensors that can report on all sorts of components and systems. "The spacecraft can take hundreds of measurements, and you can program which ones you'd like to see," Levanas explains. He asked a controller to try starting up the tape recorder, this time with the craft set up to report on electrical functions inside the suspect device. After studying the data for days, Levanas decided that something was indeed wrong with the tape recorder, an exquisitely crafted machine built by the specialty firm Odetics Inc. in Anaheim. But what, precisely, was the problem? He's got a duplicate recorder at the lab to tinker with while thinking through malfunctions. Apart it came.

On a November flyby of a Jovian moon, the spacecraft had passed through a region of high-energy proton radiation. Knowing the damage radiation can inflict on electronic gear, *Galileo*'s designers had given it special shielding and "rad-hardened" circuitry originally developed by the military for equipment that needs to keep working in the vicinity of a nuclear-bomb blast. But when the probe was on the drawing board, its creators had to make an educated guess about the amount of radiation it would encounter. Their guess turned out to be low—and the craft's original mission was extended by several years, adding to its radiation exposure. By last winter, *Galileo* had received a cumulative dose of more than 600 kilorads, four times what it was designed to tolerate.

Aware that some of *Galileo*'s parts were showing signs of radiation damage, Levanas delved into the guts of the duplicate tape recorder and mulled over motor-amperage data sent by the probe. He concluded that the problem seemed to reside in a circuitboard with servo-drive electronics that control the tape's motion. "I looked at the tape recorder and asked, What's going to die because of radiation in a machine that was working perfectly before we flew through it?"

Levanas wondered about the optical encoder, a motor-position-sensing device used by the control circuitry to make the tape move. It consists of a light shining through an etched-glass wheel at a photo detector. The encoder's light source is a trio of gallium-arsenide semiconductor light-emitting diodes, or LEDs. "We have some smart radiation guys at the lab, and I asked them what they knew about LEDs. And they said when LEDs get damaged by radiation, you can at least

partially fix them though annealing. 'Annealing,' I said. 'Tell me more.'"

That was a lucky day. First a radiation specialist explained the bad news: Radiation can knock loose impure "doping" atoms, which are embedded in the semiconductor's microscopic crystal lattice and give it the ability to emit light. And out it goes. But he also offered good news: Running current though the LED over time can push enough of the doping atoms back into their proper places that the widget will glow again. Unlike all the other exotic components packed into spacecraft, LEDs might actually be *repaired* by a guy 500 million miles away on Earth. What a concept! Cautiously at first, ordering up brief LED "burn-ins" aboard *Galileo*, Levanas ran current through the optical encoder for a total of 89 hours. Now the LEDs would stay lit for an hour before winking out. That's enough, said the scientists, who need to move the tape for only a few minutes at a time anyhow.

A very bad thing had happened to *Galileo* a year and a half after it was launched in 1989. Controllers sent a command to open its umbrella-like high-gain antenna, which was to send back pictures and data from Jupiter. The antenna never opened. The best guess is that metal pins became "cold welded," a phenomenon in which adjacent metal parts exposed to the frigid vacuum of space become permanently stuck together. *Galileo*'s engineers reconfigured the craft so that it could send back data by a secondary antenna with a much lower transmission rate. That's how the tape recorder became essential to the mission. Intended originally as a data buffer for moments when planetary alignments made it impossible to send data to earth, the tape recorder suddenly became an indispensable repository for files waiting to be sent through the go-slow secondary antenna. And now it works again. "I've been here for 26 years, and I've worked on three programs," reflects Levanas. "This is the only failure where we actually fixed something instead of doing a workaround."

The *Galileo* probe is now on an end-of-mission collision course with Jupiter, where it will crash this September, having sent back scads of stunning pictures and electromagnetic data. A round of applause, please, for NASA's robotic explorers and their ingenious handlers.