Not everyone thinks NASA has done enough, however. An aide to a congressional committee says the shuttle payload list could still be trimmed by 40 to 50%. For example, he says the large data relay satellites (TDRSSs) could be modified for about $2 million each to fit aboard the powerful Titan III rockets used by the military. The TDRSS, says Ray Williamson of the U.S. Office of Technology Assessment, "is a beautiful example of a satellite that never needed to be on the shuttle."

Although NASA may soon get the shuttle up and running, the fuel leaks and prolonged stand-down do not inspire confidence for the big role the shuttle will soon be playing. In a series of 19 to 26 flights beginning in 1995, it will be required to run with unparalleled regularity as Space Station Freedom is assembled and supplied on orbit. The job may be made easier when a fourth, brand new orbiter is completed in 1992. But recent risk analyses make clear that the chance of a major setback will remain high.

For example, a December 1989 study for NASA by L Systems Inc. of El Segundo, California, found that, with a fleet of four orbiters, the chances are 50–50 that a shuttle flight to the station will fail. Based on the record so far, the overall risks of a "mission failure" (with or without death of the astronauts) is greater than 1 in 100. The findings trouble some observers, including Jerry Grey of the American Institute of Aeronautics and Astronautics. He points out that NASA has no contingency plan to replace a space station segment if one is lost on its way into orbit, even though the chances of this happening are large.

Many people have proposed solutions to NASA's transportation problem. The trouble is that all of them require "new" federal money, a scarce commodity right now. A robot version of the shuttle, called shuttle-C, could be built in 4 to 5 years for about $1.5 billion, NASA says. It would be tremendously helpful in building the space station, but might have few other uses. Another idea that is getting attention at the White House is the program to create an "advanced launch system"—more efficient and more reliable than the shuttle, but more expensive to develop than shuttle-C. NASA and the Air Force are working together on this project, but the Administration's funding requests for it were lower for 1991 than for 1990, and Congress seems even less interested at the moment. This idea is a long shot, and an underfunded one at that.

NASA's immediate challenge for the 1990s, therefore, is the same one it has had since the 1970s: to get the shuttle running.

■ ELIOT MARSHALL

A Leaky Mystery for NASA

When you have a leaky pipe, how long does it take to find the hole? If you're NASA and the pipe in question carries liquid hydrogen at a temperature of about 16 K, the answer seems to be, quite a while. Nearly 2 weeks after detecting a hydrogen leak in the space shuttle *Atlantis* (and 6 weeks after grounding *Columbia* for the same reason), NASA engineers identified a "primary suspect"—the main seal in the 17-inch fuel pipe connecting the orbiter to its external fuel tank. But the agency has been unable to explain exactly where the leak is—much less how it came to be or how to fix it.

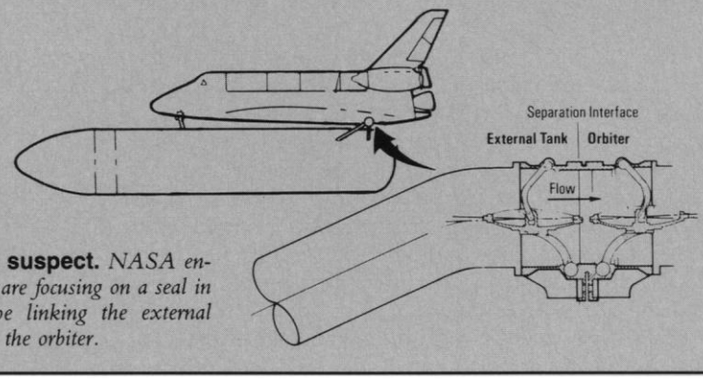
The leak was first detected on 29 May, when liquid hydrogen from *Columbia*'s fuel line flooded the engine compartment of the orbiter. The shuttle was rolled back into its hangar and disassembled for testing. Then, on 29 June, engineers pressurized the external fuel tank on *Atlantis* in a special fueling test. It, too, sprang a leak, leading NASA officials to ground the entire shuttle fleet while they assessed the problem.

High on the list of suspect components has been the 17-inch pipe's "quick disconnect," which lies in the middle of the pipe between the external tank (ET, in NASA parlance) and the orbiter. When the ET is jettisoned during the shuttle's ascent, the disconnect is responsible for closing valves on both sides and then separating cleanly. In the present case, it appears that the disconnect's main seal—a 0.231-inch-thick teflon ring—may have somehow been dislodged from its milled groove, allowing hydrogen gas to escape during fueling. This diagnosis is preliminary and somewhat speculative, however.

In a best-case analysis, NASA would locate an easy-to-fix leak, fix it, and launch the next shuttle (which would probably be *Atlantis* and its secret military payload) within a month. No one at NASA is predicting such a schedule, however, and nobody is even willing to guarantee that the Ulysses solar spacecraft will be able to get off through a narrow launch window in October. Engineers won't even be prepared to find the exact source of the leak until 13 July, when they set up test stations on *Atlantis*'s launch pad at the Kennedy Space Center. In subsequent "baggy" tests, engineers will place plastic bags around each potentially leaky joint, pressurize the fuel lines, and then measure the hydrogen concentration within the baggies.

Only then will NASA be able to address the question of the hour: does the leak result from a previously unnoticed design flaw? NASA officials profess agnosticism on the subject, but are quick to point out that the disconnect has worked well for more than 30 shuttle missions. Even so, disturbing details about the design and testing of the disconnects keep surfacing. One set of eight ET-side umbilicals manufactured in 1984 failed an initial pressurization test with a "slave unit" simulating the orbiter connection—and two of the eight are now mated to *Columbia* and *Atlantis*. William Lenoir, NASA's associate administrator for space flight, says, however, that the initial test failure was attributable to problems with the slave unit and they all passed a subsequent test. These tests were also performed with liquid nitrogen rather than more volatile liquid hydrogen, itself a questionable procedure. "Testing with liquid nitrogen doesn't tell you anything but whether you have gross hardware failure," admits Robert Crippen, director of the shuttle program. Another sobering thought: the ET-side of *Columbia*'s disconnect failed a stand-alone liquid hydrogen test just last week. While about 300 times smaller than the original leak (and therefore probably unrelated), this failure suggests that the shuttle may have more problems than a single leaky seal can explain.

■ DAVID P. HAMILTON



Prime suspect. *NASA engineers are focusing on a seal in the pipe linking the external tank to the orbiter.*