

neering tolerance, but decided to fly the vehicle anyway. "What if [that flight] had been done at a cold temperature? Wouldn't it have maybe taken it over the edge?" Sutter asked. The response, from Allan McDonald, Thiokol's booster program manager, was "I don't know. It is possible. I certainly don't feel good about that."

As recently as last November, Robert Blount, chairman of the Johnson Space Center Payload Safety Panel, decried this "fly as is" philosophy in an internal memo to senior program officials, and concluded that with respect to two upcoming scientific missions with a potentially hazardous radioactive cargo, "schedule pressure is forcing solutions [to problems] which might otherwise be rejected." His remarks troubled the agency's executive board enough for Jesse Moore, NASA's associate administrator for space flight, to write another memo noting that "there is cause for concern" and that "the 'fly as is' decisions on the flight hardware for our first two missions must be monitored very closely." Moore noted pointedly, however, that "the wagon is loaded."

With respect to the Challenger, no one disputes that the decision to launch was made in the presence of considerable technical uncertainty. As Mulloy has testified, "We did not conclude on that night that the primary would not function and seal. That was inconclusive." Some uncertainty is normal, of course. The question that the commission is presently trying to address is whether the uncertainties that day were unusually great, and if so, why a decision was made to proceed.

According to testimony, Thiokol's initial judgment—that defects in the seals rendered any launch below 53° unsafe—raised concerns in part because cooler temperatures are common not only in Florida but also at a launch site in California, potentially forcing a major disruption of the existing schedule. Thiokol's senior vice president Jerry Mason suggested that the company's recommendation was changed in part because of an unwillingness to be the skunk at a garden party. "From a schedule standpoint, we take a lot of pride in the fact that we have supported all of the launches to date, and if there was any pressure, we wanted to continue to do the job we had been doing," he said. "And that kind of situation exists every time. We have to say, are we ready to fly or not, and we want to be ready to fly."

Criticism of these pressures is hardly new. In 1978, Herbert Grier, the chairman of NASA's safety advisory board, told a congressional committee that "we feel one of the important safety considerations is the effect of the schedule driving technical people to make 'fixes' rather than engineer a

solution to the problem." In January 1983, the board noted that "the pressure of schedule seems to relax the rigor" of safety certifications, and a year later, it criticized NASA's management for "a continuing strong bias" in this direction.

According to a senior NASA engineer who specializes in rocket boosters, over time the pressures contributed to a reluctance by lower echelon officials to raise concerns that would have the effect of disrupting settled plans. There was "a tendency to treat repair problems as bad news, and a pronounced reluctance to bring bad news to higher levels," he says. Last autumn, for example, a senior scientist at Thiokol wrote several memos to his company's senior engineer suggesting a prompt effort to repair seal defects. Although one memo warned explic-

itly of the danger of "a catastrophe of the highest order—loss of human life" and another suggested that future flights be postponed until the repairs were made, the depth of this concern was never conveyed by the company to rocket program managers at the Marshall Space Flight Center. Similar safety concerns, expressed by Rockwell International, the chief shuttle contractor, on the day of the Challenger's launch also got watered down as they traveled through the corporate hierarchy.

Key facts were somehow not circulated to the right people. Allan McDonald, who has been with Thiokol for 26 years and chairs a senior review board for the boosters, said that he only recently became aware that a redundancy requirement in the seals had been waived. "I was a bit shocked by that,"

## NASA Faces Budget Crunch

Recovering from the loss of the space shuttle Challenger will place the National Aeronautics and Space Administration (NASA) under a severe financial strain even if the agency does not ask for a replacement shuttle, according to a new analysis by the Congressional Budget Office.\*

Based on NASA's own figures, the budget office estimates that the agency will need an extra \$142.5 million this year, and another \$115 million over its fiscal year 1987 budget request, just to deal with the costs of the accident and its aftermath. Extending the estimates for several years beyond that, the budget office finds a total net cost of \$463 million—but only when the actual costs are offset by such "savings" as not having to operate the Hubble Space Telescope, the Galileo and Ulysses spacecraft, or any of the other science and applications missions that are currently grounded.

However, the budget office also emphasizes that these numbers are very preliminary and probably on the low side. Under the category of "reconstitution" costs, for example, NASA estimates \$341 million for the expenses involved in the accident investigation plus the replacement of equipment lost in the accident (other than the orbiter itself), and some \$350 million for any shuttle system modifications suggested by the investigation. But the investigation is not over. Moreover, the budget office points out that modifying the shuttle solid rocket booster alone will cost more than \$200 million. NASA is also reviewing an additional 2300 critical items at the direction of the presidential commission investigating the Challenger accident. If only a few of these items require substantial redesign, says the budget office, the total cost of the modifications could easily rise much higher than \$350 million.

Given the general determination in Washington to reduce the size of the federal deficit, this money may have to come out of existing NASA programs. The budget office points to the space station project, for example, which could be slowed down. Or cuts could be made in space science and applications, since missions in this category will have to be delayed anyway.

These measures would be painful, and the report states specifically that the budget office is not advocating them. But by taking such measures the added costs could be accommodated within the existing NASA budget. A \$2.4-billion replacement orbiter, however, is a different story. While the budget office did not look at this issue in detail, the report does estimate that providing NASA with a new orbiter, while keeping the space station on track and continuing with a full range of space science and applications, would require an increase in the agency's budget of \$1 billion a year until 1990. Thus, unless NASA is exempted from efforts to cut the federal deficit—a prospect considered highly unlikely in Washington—something is going to have to give. ■ M. MITCHELL WALDROP

\* "Budget Effects of the Challenger Accident," Congressional Budget Office, March 1986.