Commission Finds Flaws in NASA Decision-Making

Some members think the moments before the launch of the Challenger were filled with sloppy discussions and dubious technical assertions

In the last hours before the ill-fated launch of the space shuttle Challenger, senior officials of the National Aeronautics and Space Administration (NASA) were gathered in a corner of the launch control center to supervise final preparations. Four of them knew of a highly contentious discussion the previous evening about the effect of low temperatures on the performance of the shuttle's booster rockets, and of a unanimous initial recommendation by Morton Thiokol, Inc., that the launch be postponed because some rocket seals might fail.

But none of the four—who were directly responsible for the booster program's success or failure—thought to inform the others in the control room of Thiokol's anxieties. As a result, Jesse Moore, Arnold Aldrich, and Gene Thomas, the three principal agency officials empowered to arrest a launch and to rejuggle the shuttle's schedule, were kept in the dark about a problem that could, and apparently did, lead to a catastrophic accident and a lengthy setback for the manned space program.

Even after the accident occurred, the booster program managers from NASA's Marshall Space Flight Center apparently failed to disclose details of the discussion to senior agency officials. Aldrich, the manager of space transportation programs at the Johnson Space Center, says that he first learned about the initial Thiokol recommendation during testimony by the company's engineers before a closed session of the White House commission investigating the Challenger accident.

This is but one of several reasons why the chairman of the commission, former Secretary of State William Rogers, has termed the agency's decision-making process "clearly flawed." A lively week of testimony about the shuttle's boosters recently revealed considerable confusion and disagreement about the tests that key shuttle components, such as the boosters, must pass before they can be considered flightworthy, and about the procedures to be followed in the event that some of the tests are flunked. Rogers suggested that many of those involved had displayed little "common sense."

About the only point on which there was complete agreement was that the Challenger's destruction was caused by a failure of the aft seal between two segments of its right-hand booster. According to a scenario spelled out in the hearing, hot gases created by the booster's ignition breached the seal in two stages. At the outset of the flight, they bored through a ring of putty and portions of two rubber gaskets, creating a thick black cloud of smoke clearly visible in photographs. Remnants of the first of the gaskets may then have "seated" in the joint, but only until 59 seconds into the flight, when a rapid buildup of pressure and abruptly changing aerodynamic forces jarred them loose, and gases erupted anew. Ultimately, the errant plume weakened a strut attached to a larger fuel tank, and the crew perished in the ensuing explosion.

At issue before the commission is exactly why the failure occurred, and whether it could reasonably have been foreseen. The answers to these questions, it developed, turn in large part on the speed with which the gaskets could move 0.03 inch or so, into a joint less than 0.04 inch wide, in the presence of temperatures that were 20 to 30 degrees below normal. Amazingly, virtually everyone participating in the key deliberations on the eve of the launch had a different understanding of their ability to do so.

A principal thesis advanced by a parade of engineers from Morton Thiokol, the booster manufacturer, for example, was that cold temperatures could make the gaskets traverse this distance in more than 0.18 second. This is considered a crucial moment, because by then the pressures of combustion begin to "rotate" or widen the joint, making a seal increasingly unlikely, and the gaskets begin to erode badly from the "blow-by" of hot gases. A secondary thesis advanced by the engineers was that even if one of the gaskets extruded into the gap in time, its resilience would be so low that any movement of the joint would cause it to become unseated. As Roger Boisjoly, Thiokol's senior seal specialist, says it would be "like trying to shove a brick into a crack instead of a sponge." Some thought this could lead to the destruction of the shuttle on the pad.

The thesis advanced by officials of the Marshall Space Flight Center, in contrast, was that one of the gaskets could traverse this distance and extrude into the gap before it widened; that the second gasket might then traverse the same distance; and that one or both would be resilient enough to stay put when the joint moved. This claim was based, they said, on an assumption that one of the gaskets was always pre-positioned near the gap; on a series of resilience tests in temperatures as low as 30°F; and a series of

Wide World

Former astronaut Neil Armstrong, *a member of the White House commission, passes a cross section of a booster seal to David Acheson as William Rogers looks on.*

motor firings as low as 36°F, as well as the lack of any apparent pattern in previous instances of gasket erosion.

Boisjoly, along with Allen McDonald, the manager of Thiokol's solid rocket motor program, argued strenuously at the time that the resilience tests were invalid because they were done in stationary joints with cold, not hot, gases. They also said that the coldest joint in any motor firing was considerably warmer than 36°F, and that in any event, direct inspection of gaskets used in several previous launches indicated that erosion was considerably worse at lower temperatures. Members of the commission also questioned the assumption that one of the gaskets would be positioned near a gap, after the booster had been transported bumpily to the pad and made to sit in the rain for a lengthy period of time. In any event, everyone agreed that the data were not conclusive. "What we said is that [with lower temperatures] it was away from the direction of goodness," Boisjoly says.

Intertwined with this discussion was a tortuous debate about the lowest temperature at which the boosters were officially qualified to fly. Initially, Stanley Reinartz, manager of the shuttle projects office at Marshall, suggested that the boosters were officially qualified to operate between 40° and 90°F. But everyone quickly agreed that this specification applied only to the booster propellant, not the seals. George Hardy, Marshall's deputy director for science and engineering, next asserted that "the point at which the weather affects risk is not until 40 or 50 below [zero]," when official gasket specifications indicate that they will begin to fall apart. But McDonald considered this "absolutely ridiculous," and pointed out that the specification applies only to storage, not use. Others, including Robert Lund, Thiokol's senior engineer, noted that the entire shuttle vehicle was officially qualified for operation between 31° and 99°F, but this proved irrelevant because the boosters had in fact never been tested at these extremes.

Only in the weeks after the accident has Thiokol recommended that official operational launch criteria be drawn up for the booster seals. Beforehand, it apparently never occurred to anyone.

The vigor with which NASA criticized Thiokol's observations that night has been a topic of considerable discussion. Lund, McDonald, Boisjoly, and two others from Thiokol testified that they felt considerable pressure from negative comments by Larry Mulloy, Marshall's booster program director, who 6 months earlier had told his superiors in Washington that he considered the seal problem "closed." Additional pressure was felt from a remark by Hardy that he was "appalled" by the initial Thiokol recommendation, and from repeated requests that Thiokol's managers offer their *own* opinion about the risks of seal failure.

"They were under a lot of commercial pressure to give you the answer you wanted," commission chairman Rogers told NASA officials.

Hardy explained that he is always "likely to probe and sometimes even challenge either a pro position or a con position. The objective of this is just simply to test the data, test the degree of understanding. . . . I think anybody that knows me would realize that that is not interpreted as coming on strong or applying pressure." Similar explanations were offered by Mulloy, but commission chairman Rogers did not buy them. Noting that NASA had recently invited other firms to compete for Thiokol's contract, he noted that "they were under a lot of commercial pressure to give you the answer you wanted. And they construed what you and Mr. Hardy said to mean that you wanted them to change their minds."

Of course, nothing seems as clear-cut before a mistake as afterward. But the commission at present is showing little patience for the space agency's arguments. ■

R. JEFFREY SMITH

A Mixed Fleet for NASA

IN the aftermath of the Challenger disaster, the National Aeronautics and Space Administration (NASA) appears to have reversed its long-standing insistence that the space shuttle be the nation's primary launch vehicle.

Testifying before the House space science subcommittee on 26 February, acting administrator William Graham called for a supplementary fleet of expendable launch vehicles and indicated that NASA might even be willing to place government payloads on privately operated launchers.

"Both NASA and the Defense Department feel that the country requires a broad enough launch capability that we don't find ourselves handicapped again by a major accident," he later told *Science*. "We want to explore all the courses open to us."

Graham's testimony represents a major change from NASA's previous opposition to expendable launchers. But the agency appears to have little choice. Even if it is given an immediate go-ahead to spend $2 billion replacing Challenger—a subject that is still controversial at the White House—the replacement orbiter would not be ready to fly until 1989 at the earliest. Nor will expendable launchers be available in significant numbers before 1988. In the meantime, the backlog of scheduled missions will continue to grow.

The most detailed account of the backlog was given at the same hearing by Air Force under secretary Edward Aldridge. If the remaining three shuttles stay grounded for only 6 months, he said, the near-term effect would be minor. But even so, the backlog would grow to some 15 to 20 missions by 1989. A replacement orbiter coming into the fleet at that time would stop the growth, he added, but would be hard-pressed to cut into the backlog.

Aldridge also said that if the shuttles are grounded for a year or more, as seems likely, the backlog would increase to some 25 to 30 flights. Thus, he told the subcommittee that the Defense Department is strongly in favor of procuring a replacement for Challenger, in addition to the increased use of expendables.

There remains the question of how NASA can find $2 billion for a new orbiter in the era of Gramm-Rudman-Hollings. Graham told the subcommittee that NASA is "actively seeking" private commercial proposals to fund a new orbiter. On 25 February, in fact, agency officials met with Willard Rockwell, chairman of General Space Corporation, to discuss a proposal to build one or more shuttles with private capital and lease it to the government. Rockwell is the former chairman of Rockwell International, NASA's prime contractor on the original shuttle. ■

M. MITCHELL WALDROP