Inquiry Faults Shuttle Management

Rogers Commission calls for sweeping reforms in NASA's operations, as well as substantial changes in the design of the solid-rocket seals

THE accidental destruction of the space shuttle Challenger was caused by a flawed rocket seal, left unrepaired as a result of persistent short-sighted and negligent decision-making by federal officials and shuttle contractors, according to the final report of a special presidential commission.

The report, released on 9 June, notes that the National Aeronautics and Space Administration (NASA) had received ample warning of the seal's defects, beginning with an internal memo prepared in 1977, 4 years before the shuttle's first flight. But many of these warnings failed to reach the agency's senior management, and enthusiasm for the repairs was continually short-circuited, the report indicates. Confusion and ignorance were prevalent in the launch deliberations on 27 and 28 January, and the final approval was partly influenced by economic pressures.

Prepared by a 13-member commission under the direction of former Secretary of State William Rogers, the 256-page report uses temperate language to convey these conclusions, but its message is nonetheless clear. It recommends sweeping reform of NASA's management structure, safety organizations, and flight operations, in addition to substantial changes in the seal itself. Most of the recommendations have been enthusiastically received on Capitol Hill.

Although the commission's detailed description of the accident and its cause contains few surpises, it provides a powerful official record of America's most costly space calamity. The Challenger, which carried two satellites in its payload bay and a crew of seven, was launched in an ambient temperature of 36°F, well below the coldest previous launch. Prior to 28 January, its launch had been postponed four times, twice because of delays in the launch of a previous mission a few weeks earlier, once because of inclement weather, and once because a hatch door malfunctioned.

At the time of launch, the critical portion of the seal in the right booster rocket was shaded from the sun and so its temperature was approximately 28°F, more than 20° cooler than another portion in direct sunlight on the other side of the booster. Although the commission found that neither NASA nor Morton Thiokol, Inc., the booster's manufacturer, "fully understood the mechanism by which the joint sealing action took place," both had received ample notice of the deleterious effect of low temperatures on a pair of rubber O-ring gaskets in the seal.

In particular, useful tests had been conducted at Thiokol the previous summer, which demonstrated that the gaskets became increasingly sluggish as temperatures declined, and that as a result, they could potentially fail to fill a gap in the seal and allow hot rocket gases to escape. Significantly, the commission concluded that even though this effect could not be quantified, this information was "sufficiently detailed to require corrective action," a point that NASA had disputed in commission hearings.

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Only after the disaster did experiments prove conclusively that sealing is poor to nonexistent at temperatures below 40°, due to diminished gasket resilience; and that the problem is exacerbated by stiffening of the putty that lies ahead of the gaskets. The commission faulted Thiokol, as well as NASA's rocket managers at the Marshall Space Flight Center headquarters, for not conducting these tests earlier. Its report emphasizes, however, that the mistakes were not simply ones of omission but also of commission.

"Neither Thiokol nor NASA responded adequately to internal warnings about the faulty seal design," the report says. "As the joint problems grew in number and severity, NASA minimized them in briefings and reports; as tests and then flights confirmed damage to the sealing rings, the reaction by both NASA and Thiokol was to increase the amount of damage considered 'acceptable.' " In particular, post-flight gasket analysis in June 1985 demonstrated seal erosion of 0.171 inches, about 60% worse than the "worst case" predicted. Yet no direct action was taken. At another point, tests indicated that the safety margin for seal erosion was only 0.005 inches; still the shuttle continued to fly.

Official designations for such serious safety hazards were formally observed but informally ignored. The seal, for example, was formally designated as a nonredundant critical item, but many officials continued to behave as if it were redundant, even up to 5 weeks after the accident, according to documents unearthed by the commission at the Marshall center. The attitude of Howard McIntosh, a Thiokol engineer, was apparently typical. Asked if he knew that the seal was nonredundant but was "hoping" that it retained redundancy, McIntosh said, "Yeah, I was hoping for 1R [redundancy]."

Some of the senior officials at the agency were not informed about these matters because of a decision made by the Johnson Space Center in 1983 to curtail official reporting on flight safety and schedule difficulties. Martin Raines, a safety, reliability, and quality assurance official who proposed the idea, told the commission that the purpose was to "streamline the system" for the shuttle's "operational phase." But the commission found it "difficult to understand" why the idea was either proposed or approved. In any event, many were kept in the dark or victimized by false information as a result. For example, Jesse Moore, NASA's senior shuttle official, did not know that the gaskets were considered nonredundant, and at one point he was "obviously misled" about defects in the putty, the report says.

Little attempt was made to look at significant trends as the flight rate increased. For example, "each of the launches below 61°F resulted in one or more O-rings showing signs of thermal distress," the report said, primarily in joints similar to the one that failed. Program officials and engineers testi-

fied that they had no time for such studies because they were always too busy preparing for the next flight. This disturbed the commission members, who noted that shuttle program resources were continually "strained to the limit" and focused far too much on near-term difficulties.

The commission ultimately concluded that the program would have been slowed or interrupted for a variety of economic and safety reasons, even if the accident had not occurred. But the mistakes all came home to roost only a few milliseconds after the Challenger was launched, when a leak of hot gases through a booster seal generated the first of 9 distinct puffs of black smoke (not just one, as previously reported), corresponding roughly to natural flexing of the rocket casing. It apparently erupted at the coldest point on the joint, according to the report. Even now, experts are unsure if the leak was continuous or momentarily plugged by debris from the gasket and putty combustion. But 58 seconds into the flight, after some severe wind shear was encountered and the thrust of the boosters sharply increased, the first flickers of flame appeared between the orbiter and an enormous external fuel tank.

The flame was deflected down and around the booster rocket and onto the surface of the external tank, as well as onto a strut connecting the two. A portion of the tank containing liquid hydrogen was breached in the 64th second, creating a "bright, sustained" glow on the Challenger's belly, memorable in later slow-motion television pictures. Moments later, the strut was detached, the hydrogren tank seriously ruptured, and a membrane isolating a tank of liquid oxygen was breached. Almost simulataneously, the loose rocket booster struck the same tank, exacerbating the damage and causing the Challenger to be "totally enveloped in an explosive burn," the report says.

"There was nothing that either the crew or the ground controllers could have done to avert the catastrophe," the commission noted, pointedly fixing the blame elsewhere. The failure may have been exacerbated by the presence of ice in the joint, deposited when the rocket was exposed to seven inches of rain while sitting for a month on the launch pad. It might also have been exacerbated by the presence of debris and contamination in the seal, or the fact that the gaskets were subjected to unusual pressures during and after assembly. But these were not the principal cause, the report suggests.

One of the commission's recommendations is that the rocket joint and seal be redesigned under the supervision of the National Research Council. Another is that an independent safety organization be established within NASA to conduct oversight and report problems directly to the administrator. Perhaps most important, it says, NASA must "establish a flight rate that is consistent with its resources."

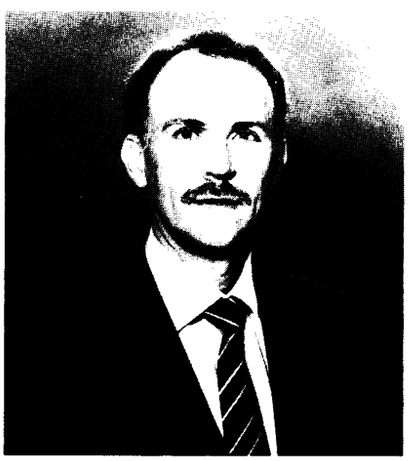
At a press conference on 9 June, NASA Administrator James Fletcher declined to endorse any of these specific ideas. But he promised that "where management is weak, we will strengthen it; where engineering or design or process need improving, we will improve them." The conclusions, he said, "are not unexpected and certainly not entirely undeserved." ■ **R. JEFFREY SMITH**

Science Adviser Named

President Reagan has nominated William R. Graham, currently deputy administrator of the National Aeronautics and Space Administration, to be his science adviser and director of the Office of Science and Technology Policy (OSTP). Graham, 48, has spent most of his professional life as a defense analyst, first with the RAND Corporation and since 1971 with R&D Associates, a California company he cofounded.

The appointment has been greeted with less than total enthusiasm by members of the science policy establishment, who were hoping to see a better-known scientist installed in the job. However, several prominent industrial scientists who were sounded out for the post said they were not interested, and a search has been going on halfheartedly since the previous incumbent, George A. Keyworth II, left on 1 January to start a consulting company.

In the meantime, the job was filled on an acting basis by John P. McTague, who informed the White House 3 months ago that he would be leaving for a top research job at Ford Motor Company. Finally, McTague decided he could not hang on any longer and left Washington on 23 May.



William Graham: *Going to OSTP after a brief and stormy tenure at NASA.*

Graham, who has a B.S. degree from California Institute of Technology and a Ph.D. in electrical engineering from Stanford, has had a short and stormy tenure at NASA. He was confirmed as deputy administrator on 22 November last year. Within days, he was elevated to acting administrator when James Beggs took a leave of absence to defend himself against charges of fraud arising from allegations of contract mismanagement when he was a top executive of General Dynamics Corporation. Six weeks later, the shuttle Challenger exploded.

Beggs is reported to have opposed Graham's nomination to the number two job because of his lack of management experience, and Graham never won the support of NASA's senior officials. To make matters worse for Graham, Beggs maintained an office in NASA for several weeks after he took a leave of absence. When Beggs finally resigned, Graham was passed over for the job, and the White House instead nominated James C. Fletcher. Graham then went back to being deputy administrator, but it was widely assumed that Fletcher would eventually bring in a deputy of his own choosing. The White House has paved the way by moving Graham to OSTP.

Graham has been a consultant on a variety of weapons programs for the Defense Department and in 1980 worked on Reagan's transition team for DOD. He is said to be a firm supporter of the Strategic Defense Initiative (SDI). He served as chairman of the President's General Advisory Committee on Arms Control and Disarmament from 1982 until his appointment to NASA last year.

His nomination to be director of OSTP requires confirmation by the Senate Committee on Commerce, Science, and Transportation. Hearings have not yet been scheduled. Approval is expected, though he is likely to get tough questioning from some Democrats on the committee who oppose SDI. ■ **COLIN NORMAN**