Challenger Disaster: 'Rooted in History'

Two distinct causes led to the Jan. 28 explosion of the space shuttle Challenger, according to the findings of the presidential commission that has just spent four months investigating it. One is a specific technical flaw, likely to lead to the redesign of the shuttle's solid-rocket boosters. The other is far more widespread — a set of attitudes and management philosophies that kept the technical problem from being remedied despite nearly a decade of warnings, and which may result in the redesign of NASA itself.

The 13-member commission's investigation resulted in some 15,000 pages of transcript from public and closed sessions, as well as the compilation of more than 6,300 documents totaling about 120,000 pages more, plus hundreds of photographs and the results of numerous specially conducted tests. One staff member quoted by Associated Press said that more than 6,000 people were involved in one way or another with the investigation, which cost "in the $2 million to $4 million range."

The technical culprit, as expected, turned out to be the O-ring seal between the rearmost segments of the shuttle's right-hand solid-rocket booster (SRB). The failure, concludes the commission's 256-page report released June 9 (four more volumes of supporting material will be released in coming weeks), "was due to a faulty design unacceptably sensitive to a number of factors."

Included among these were temperature — Challenger's Jan. 28 liftoff took place in the coldest weather of any of the 25 shuttle launchings ever conducted — and "the character of materials." The temperature at the point on the SRB's circumference from which hot exhaust gases began spewing forth and led seconds later to the explosion was estimated at 28± 5°F. And the O-ring's resiliency, affecting its ability to maintain a tight seal when initially compressed out of shape, "is directly related to temperature," notes the report. Measurements cited by the commission, in fact, showed that "a compressed O-ring at 75 degrees Fahrenheit is five times more responsive in returning to its uncompressed shape than a cold O-ring at 30 degrees Fahrenheit." The O-ring, in other words, did not rebound quickly enough to keep in the hot fumes from the propellant firing just inside it.

The faulty joint and its seal must be changed, says the report, though the commission made no recommendation of a particular design. "No design options should be prematurely precluded because of schedule, cost or reliance on existing hardware." An advisory panel has been formed by the National Research Council to advise on the process, in response to a request from NASA administrator James C. Fletcher. This paralleled a recommendation from the commission urging that Fletcher send a progress report to the president in a year.

But modification of the SRBs is only the nuts-and-bolts detail of the commission's findings. Far more damning are its conclusions that prelaunch misgivings by engineers from Morton Thiokol, Inc., the SRBs' builder, never found their way to top NASA management who might have postponed the launch, and furthermore, that the explosion that killed seven people was what the report labels "an accident rooted in history."

Thiokol was selected on Nov. 20, 1973, from among four competing contractors to build the SRBs. The NASA board that made the choice noted in its report only three weeks later that Thiokol had finished last of the four in the "design, development and verification factor." However, the company finished first in the "management factor" and second in the "manufacturing, refurbishment and product support factor," and the board's report described Thiokol's O-ring approach as "an innovative design feature" that "increased reliability and decreased operations at the launch site, indicating good attention to low cost . . . and production."

During a 1977 test of the rocket motor, Thiokol discovered during a simulated firing of the engine (using pressurized water) that the joint incorporating the O-ring was "opening rather than closing as our original analysis had indicated," according to testimony before the commission by a company official. At that time, Thiokol engineers, says the commission report, did not believe (as some of them would by the 1980s) that the test results really posed a significant problem, and reported them to NASA's Marshall Space Flight Center in Huntsville, Ala., which was responsible for the SRB design and development.

Reaction from Marshall, says the report, was "rapid and totally opposite of Thiokol's," resulting in a memo in which the chief of Marshall's Solid Rocket Motor (SRM) Division said, "I personally believe that our first choice should be to correct the design in a way that eliminates the possibility of O-ring clearance." The memo called the finding a "design deficiency" and "a very critical SRM issue." About seven weeks later, a report from another Marshall engineer characterized "no change" in the design as "unacceptable," and subsequent documents to higher-level Marshall management continued to press the point. Yet no change was either sought by Marshall or initiated by Thiokol, even when the shuttle's second flight, in 1981, revealed evidence of O-ring erosion.

The lack of communication of the recurring problem, particularly while the shuttle was being driven toward ever more frequent flights, is characterized by the commission's report as "the silent safety program." The commission's second recommendation — right after the redesign of the SRBs — is a tightening of NASA's management structure, placing the responsibility directly in the hands of the shuttle program manager instead of in what have been the relative autonomies of Marshall and NASA's other field centers. In addition, the commission adds its voice to the growing chorus of calls for expendable launch vehicles to supplement the shuttle. Yet NASA's budgets are still tight, and the timetable for a U.S. return to space is, if anything, murkier than ever. — *J. Eberhart*

NASA's Graham to be science adviser

President Reagan last week announced he will name electrical engineer William R. Graham as his new science adviser. Currently, Graham is deputy administrator of NASA. The advisory post, which requires Senate confirmation, would also make Graham head of the White House Office of Science and Technology Policy.

"Long overdue" is how Philip Speser, executive director of the Washington, D.C.-based National Coalition for Science and Technology, greeted the Graham announcement. Speser was referring to the fact that it has been six months since George A. Keyworth II resigned both posts to start a consulting business (SN: 12/7/85, p. 358). Speser, who heads the only registered lobby of scientists on science policy, says that "under the Reagan administration, the science adviser has changed from being more of a spokesperson for science in the White House to more of a spokesperson for the White House to the scientific community." He adds, "We all hope that Dr. Graham will reopen more of a two-way channel of communications."

Graham is a founder of R&D Associates in Marina Del Rey, Calif. Graham has described his activities there and while on the staff of the Rand Corp. in Santa Monica, Calif., as involving primarily work on strategic missile and aircraft system survivability (in war environments), studies of nuclear weapons' effects on other weapons and communications systems, the design of systems to simulate nuclear weapons' effects (such as electromagnetic pulse) and analyses of supercomputer capabilities.

Graham has chaired the General Advisory Committee on Arms Control and Disarmament, under an appointment from Reagan, and is an executive member of the Washington, D.C.-based Committee On The Present Danger, a private, nonprofit group that studies issues relating to the U.S.-Soviet military balance.

— *J. Raloff*

Altamira cave art: Low-vent district?

The Altamira cave near Santander, Spain, is famed for its "Paintings Room," a chamber decorated with Stone Age paintings from more than 10,000 years ago. The cave was closed to visitors in 1977, however, due to deterioration of the artworks presumably caused in some way by the constant stream of tourists.

Scientists at the University of Santander now report that the wearing away of paleolithic paint and its limestone backing may have been promoted by carbon dioxide exhaled by people inside the chamber. Carbon dioxide buildup can lead to the dissolution of limestone. An initial charting of natural ventilation in the Paintings Room indicates it is weak and thus allows carbon dioxide to collect even without humans present, write physicist P. L. Fernández and his colleagues in the June 5 NATURE.

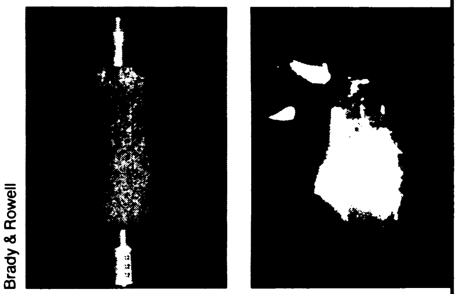
The researchers measured the concentration of radon gas in the chamber three times per week from February 1983 through January 1984. This, they say, is the best available means to assess ventilation. Radon escapes to the atmosphere through cracks in the earth, they note, and concentrates in the air of places with little ventilation. While ventilation of radon is weak throughout the year in the Paintings Room, it is lowest in May and peaks in July.

Furthermore, say the researchers, the carbon dioxide concentration in the Paintings Room, which originates from gas dissolved in underground waters, is at its lowest during July, August and September, and peaks in May and November. Taking into account the estimated average volume of carbon dioxide exhaled by one person, the scientists calculated the maximum number of people who could visit the cave for one hour each day in the summer months without raising the carbon dioxide level beyond the peak seen in May: 43 in July, 74 in August and 80 in September. The number of daily visitors in the summer was considerably greater before the cave was closed. — *B. Bower*

The light side of rock fractures

For centuries, miners have dreaded the occasional, mysterious flashes that would erupt from rock faces to light up underground diggings. The air would feel electrified as in a thunderstorm, and bits of paper and straw would jump about. Too often, these effects would presage a major rock collapse.

Although long a part of mining lore, these emissions have only recently been studied in the laboratory. Reporting in the May 29 NATURE, Brian T. Brady and Glen A. Rowell of the Bureau of Mines in Denver suggest that as rocks fracture, they eject electrons, which in turn excite surrounding air molecules to produce light.



Brady & Rowell

Left: A sample of granite, about 2 inches tall and 1 inch in diameter, during breakup. Right: Light emission from a fracturing granite sample.

"This is the first laboratory investigation of this problem," says Brady. The experiments provide a possible explanation for light and electrical emissions associated with rock fracture not only in mines but also during earthquakes. Reports of "earthquake lights" have a long history, and scientists have proposed several hypotheses to account for this effect (SN: 6/5/82, p. 375).

In their experiments, Brady and Rowell compress cylindrical samples of granite, basalt, coal, marble and other rocks. When the pressure is high enough, the rock samples fracture explosively. Within milliseconds, a dust cloud of fine rock particles is ejected and light flashes appear. In general, however, only an observer in darkness with night-adapted vision can see this light.

By fracturing samples in diffrent atmospheres and by examining the spectra of emitted light, the researchers found that the light comes not from the rocks but from the ambient gas. Moreover, the spectra show distinct lines rather than a continuous range of wavelengths. A continuous spectrum would be seen if the effect were due to heat generated by friction within the rock.

Even more surprising is the finding that when the tests are done in water, the water glows and hydrogen is produced. The ejected electrons appear to have enough energy to cause the dissociation of water, says Brady. Thus, the fracturing process, in the presence of water, could promote a variety of chemical reactions.

"We believe that insufficient consideration has been given to the role of rock fracture in fluid- and gas-saturated rock masses in promoting molecular dissociations," the researchers say, "and the role of this process in initiating chemical reactions of geological and biological interest." That may include reactions contributing to the formation of natural-gas deposits or to the origin of life on earth.

Brady and Rowell are now studying the details of these effects. They speculate, for instance, that electron emission within fracturing coal masses may cause the dissociation of methane, leaving pockets of potentially explosive hydrogen gas.

This research also provides the first plausible explanation for the observation of earthquake lights at sea. Previously, says John S. Derr of the U.S. Geological Survey in Denver, "it was not possible to explain earthquake lights at sea, except by invoking the help of legions of excited, phosphorescent plankton."

And, says Derr, the overall results show that under the right conditions, even the smallest earthquakes can produce light. This fits Derr's own observations of luminous phenomena that seem to be associated with very small quakes (SN: 12/24 & 31/83, p. 412).

However, there is a great difference in scale between a laboratory sample and a major earthquake. Although the work of Brady and Rowell is a significant step toward finding one possible geological mechanism for light production, Derr says, ". . . investigations in other areas are still required because we may be looking at several phenomena which sometimes share a common appearance and name."

Also not settled, says electrical engineer Stuart A. Hoenig of the University of Arizona in Tucson, is the question of how the breakup of rock generates free electrons. "Why does the rock give off electrons when it breaks?" he asks. "How do the electrons escape?"

Nevertheless, the fact that electrons are emitted is quite certain, says Hoenig. This electrical activity and its related chemical effects — possibly causing changes in the air's ion concentration — may account for the unusual behavior of some animals before an earthquake, he says.

Says Derr, "A new, challenging area of geophysics is just opening."

— *I. Peterson*