# The Challenger Disaster: Assessing the Implications

*The explosion has shaken the U.S. space program to its foundations; have we become too dependent on the space shuttle?*

WHEN the space shuttle Challenger exploded in the blue Florida sky last week, killing all seven crew members, it underscored not only the fragility of human life but the vulnerability of human technology. Thus, as the nation paid tribute to the Challenger astronauts, and as officials of the National Aeronautics and Space Administration (NASA) pursued their investigation into the cause of the disaster, policy-makers back in Washington were moving toward a careful reassessment of the nation's near total dependence on the shuttle for access to space.

Obviously, the most urgent priority is to find out what happened; until NASA officials know that they have no way of knowing how long the rest of the shuttle fleet will be grounded, nor can they say how long it will take and how much it will cost to fix the problem.

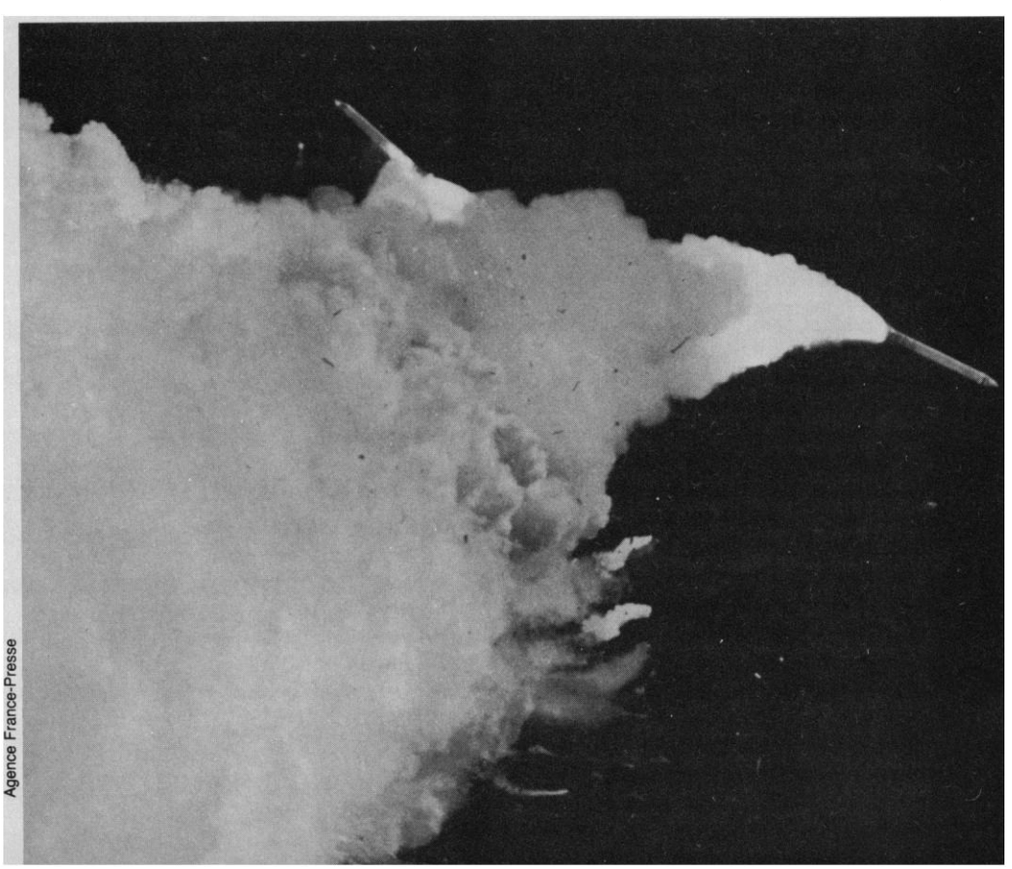
As *Science* went to press, agency officials were still refusing to speculate as to the cause of the explosion. However, on Saturday, 1 February, at a meeting with members and staffers of the congressional space committees at NASA headquarters in Washington, acting administrator William Graham showed previously unreleased photographs that revealed an abnormal white spot of light—Graham declined to call it a flame—appearing on the right-hand solid rocket booster about 10 seconds before the explosion and about one-third of the way from the bottom of the booster. The light continued to spread along the right side until the instant of detonation, at which point the liquid hydrogen and liquid oxygen fuel stored in the external tank exploded and consumed both Challenger and its crew.

These new images lend credence to the theory that the booster casing, which is actually a stack of separate cylinders bolted one on top of the other, somehow ruptured at one of the joints and squirted flame onto the side of the external tank, thereby melting a hole and igniting the liquid hydrogen inside. Unfortunately, the boosters themselves continued on their own fiery paths after the explosion and had to be destroyed by the Air Force range safety officer some 20 seconds after the explosion lest they fly into populated areas. Thus, any direct evidence for the ruptured booster theory was scattered across a wide area of the Atlantic. The manufacturer of the booster, Morton Thiokol of Brigham City, Utah, has joined in the investigation. Officials there are refusing all comment.

Whether the culprit proves to have been the right-hand booster rocket or something else, the critical question is whether the failure was due to a single bad component, or whether it stemmed from a fundamental design flaw. If it was the former, then the remaining three orbiters should be back in service relatively quickly after NASA pinpoints the problem and takes whatever steps are necessary to ensure that such an accident does not happen again. But if it was the latter, then the recovery will be long, arduous, and expensive. The agency will have to undertake an extensive redesign of the flawed system, followed by a painstaking regimen of testing and recertification. Early speculation was that the program could then be set back a year or more. After a launch-pad fire that killed three Apollo astronauts in January 1967, the hiatus lasted 18 months.

A final possibility, which will doubtless cause a good deal of soul-searching at NASA, is that the agency's push to increase the flight rate to 24 flights per year by 1988 may have somehow caused people to cut corners on safety and quality control, perhaps even unconsciously.

Whatever the answer, there seems little doubt that NASA will continue with manned spaceflight in general and the shuttle program in particular. The outpouring of public support and confidence in the agency has been remarkable, with some 80 per cent of the respondents in a poll taken by the *New*



Agence France-Presse

**Moments after the explosion**

*The two solid-fuel booster rockets continued to burn until they were destroyed by a signal from the ground controllers.*

*York Times* saying that the shuttle flights should continue. "Man will continue his conquest of space, to reach out for new goals and ever greater achievements," said President Reagan at memorial service for the astronauts who died in the explosion: "That is the way we shall commemorate our seven Challenger heroes."

Sentiment aside, however, the fact is that the country has little choice but to continue with the shuttle program. There is a long line of scientific, military, and commercial payloads waiting to get into space, and in the near term neither NASA nor anyone else has any alternative way to launch them. Indeed, fiscal year 1986 was to be NASA's most ambitious year yet, with 15 shuttle flights planned. The loss of Challenger and the unknown delay in the program have now thrown that schedule into chaos, and have likewise cast the nation's dependency on the shuttle into stark relief.

The most immediately affected are three time-critical science missions:

■ Astro-1, a battery of astronomical instruments, was scheduled for launch on 6 March to observe Halley's comet as it emerged from its closest approach to the sun; Halley's comet, of course, only comes around once every 76 years.

■ Ulysses, formerly known as the International Solar Polar Mission, was scheduled for launch—aboard Challenger—on 15 May. In this case the timing is critical because the spacecraft must first travel to Jupiter, where the giant planet's gravity will fling it up over the sun's unexplored polar regions; the proper alignment of Earth and Jupiter occurs only once every 13 months, which means that the next launch opportunity will not come around again until June 1987.

■ Galileo, which was scheduled for launch 5 days after Ulysses on 20 May, would have followed a similar path to Jupiter. Once there it would have dropped a probe into the Jovian atmosphere and taken up orbit around the planet. Missing the launch opportunity in May will thus result in a similar delay of 13 months. Moreover, given a May launch, Galileo's trajectory would have taken it by the asteroid Amphitrite in December 1986, thereby providing scientists with their first close-up view of an asteroid. The Amphitrite encounter will obviously be ruled out if the launch has to be delayed until 1987, although it may prove possible to fly by some other asteroid.

A fourth science mission, the Hubble Space Telescope, is scheduled for launch on 27 October. Since it will remain in Earth orbit, however, it has considerably more flexibility in terms of launch timing.

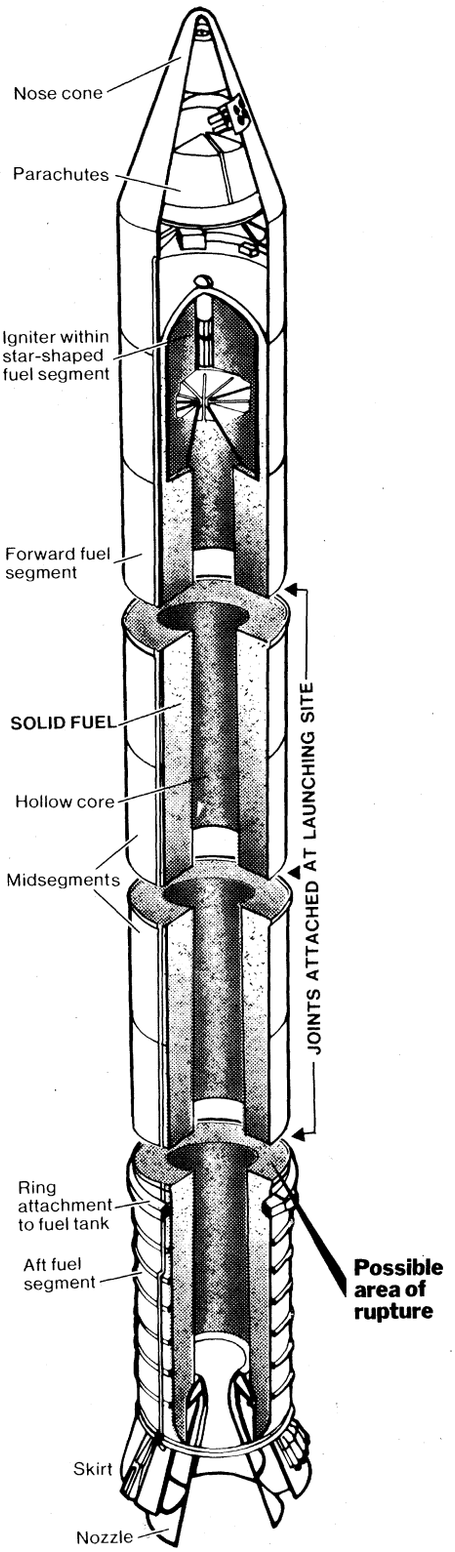
At week's end, NASA had not officially postponed any of these flights and the mission teams were continuing to prepare for launch on schedule. However, it seems almost inconceivable that the agency will complete its investigations into the Challenger disaster and be ready to launch the Astro mission by March. Moreover, it seems extremely unlikely that the agency would be ready to fly Galileo and Ulysses by May. Quite the contrary, one can expect agency officials to be exceedingly cautious about resuming the shuttle flights, since NASA could hardly afford another major accident.

Beyond the science missions the shuttle system is committed to a heavy schedule of Defense Department payloads and commercial communications satellites. Many of these payloads could be launched on conventional unmanned rockets, and in fact, the Air Force is planning to launch two of its satellites per year on Titan rockets starting in October 1988. However, even a conventional rocket takes some 3 years to build. For the interim the Air Force has no alternative but the shuttle.

Much the same story holds for the commercial satellites: the major alternative at the moment is the European-built Ariane launcher, which is booked up until 1988. Other alternatives include General Dynamics and the start-up firm Transpace Carriers, Inc., which have been trying without success to commercialize, respectively, the Atlas-Centaur and Delta launch vehicles that NASA abandoned in favor of the shuttle. However, these firms cannot respond much more quickly than Ariane, and in any case it is not clear they could handle all the shuttle's traffic. Moreover, moving a payload from the shuttle to an unmanned rocket requires certain modifications to the payload, and is not something to be undertaken lightly.

Thus, when the shuttle fleet does start flying again, NASA is going to find itself with a lot of commitments to meet and only three shuttle orbiters to meet them with. Agency officials will then have to face the delicate question of how to juggle the priorities.

Under normal conditions, urgent military payloads in the "national interest" take top priority, followed by time-critical science missions such as Galileo and Ulysses, and then the commercial payloads for which NASA has a contractual obligation. Non–time-critical NASA science and engineering payloads come last. Since payloads are usually scheduled years in advance, these priorities have never created much of a problem in practice. However, these are clearly not normal conditions. By week's end, officials in the White House were setting up an interagency mechanism for resolving these launch priority questions, possibly through




**The culprit?**

*Attention is focusing on a possible problem with the right-hand booster rocket as a cause of the explosion. An unusual plume from the rocket seconds before the disaster may have been caused by flames from the solid fuel emerging from a rupture or faulty seam in the rocket casing. If so, the skin of the external fuel tank may have been breached and its hydrogen ignited.* [*Credit: NYT Pictures*]

the existing Senior Interagency Group on Space. This panel will also look at the longer-term policy implications of the Challenger disaster, a topic that is very much on people's minds in Washington.

It is clear that a decision has to be made quickly whether or not to replace Challenger, since the process will take some some $2 billion and 3 to 4 years. That decision is obviously complicated by the current deficit crisis and the pressure being placed on the federal budget by the Gramm-Rudman-Hollings amendment. On the other hand, it is equally clear that the decision will have important long-term implications for U.S. space policy, and no one wants to stumble into it for short-term budgetary or political reasons.

There is a broad consensus in Washington that the shuttle has an important role to play as a manned platform—as a hands-on, zero-gravity laboratory, for example, or as a mobile dry-dock for the maintenance and repair of facilities such as the Space Telescope. However, one can expect to hear some tough questions about the nation's long-standing commitment to the shuttle as its primary launch vehicle. As one Capitol Hill staffer pointed out, "It's difficult in a political process to get people to presuppose a catastrophe that severely impacts your ability to do the program. It's like fantasizing that one fourth the planes in the Air Force are suddenly wiped out one morning. People can't deal with it." The demise of Challenger, however, has focused their attention.

The commitment was a presidential-level decision first made in the 1970's and reaffirmed by every administration since then, including Reagan's. Not surprisingly, NASA has preferred to interpret the phrase "primary launch vehicle" as meaning that the shuttle should be the nation's *only* launch vehicle. Indeed, to justify the $10.2-billion cost of developing the shuttle (in 1982 dollars), the agency has tried to make the system be all things to all people. In particular, NASA has emphasized the shuttle's role as a launch vehicle for military and commercial satellites, when in fact many of those spacecraft could just as easily be launched by conventional rockets. Furthermore, since the shuttle has never been the low-cost pathway to space that the agency originally promised, having the extra payloads has also been seen as a way to amortize the fixed costs of the shuttle launch facilities and thereby minimize the cost per flight.

However, with what now seems remarkable prescience, others have argued that this all-eggs-in-one-basket approach is dangerous and inflexible. That has always been one of the major arguments used by the people trying to develop commercial launch services, and it is also one of the principal reasons behind the Pentagon's insistence on reviving its own independent launch capability (page 666).

It is in this context that policy-makers will have to grapple with the question of a new orbiter. If the decision is made to go ahead, work could begin fairly quickly: NASA has been accumulating the major components of an orbiter's wings, tail, and fuselage since 1983, with exactly this contingency in mind. These "structural spares," as they are called, already represent an investment of several hundred million dollars towards a new orbiter. On the other hand, given the gruesome example of Challenger, NASA will presumably want to replace the spares also. The cost of a new orbiter will thus remain about $2 billion spread over 3 to 4 years. The question, of course, is where this money is going to come from in the era of Gramm-Rudman-Hollings. If NASA is told to replace the orbiter with money from its other programs, then everything from space science to aeronautics is going to be devastated. Such a result seems unlikely, since these programs have a lot of support on Capitol Hill. But still—$2 billion?

An alternative would be for NASA to make do with three orbiters while giving up its effort to have the shuttle do everything. In other words, the Air Force could fly more Titans and the commercial customers could be encouraged to move to Ariane and to any

***If the space shuttle is a means to an end, what is the end?***

private U.S. launch companies. However, not everything can fly on conventional rockets. With NASA committed to building a space station in the 1990's—a commitment that Reagan vigorously reiterated after the explosion—and the Pentagon wanting to conduct any number of its own experiments on the shuttle, it seems clear that a three-shuttle fleet would be stretched to the limit. Moreover, it would leave NASA with no flexibility whatsoever should another shuttle be lost or damaged and the fleet reduced to two orbiters.

Still another alternative, suggested by some staffers on Capitol Hill, would be to put even more emphasis on the shuttle while building not only a fourth orbiter but a fifth orbiter. The fifth orbiter would actually be somewhat cheaper than the fourth, since the production lines would already be up and running. Nonetheless, it is going to be hard enough to find money to replace Challenger. Moreover, the question of a fifth orbiter has been debated many times before, and the need for it has never been convincingly demonstrated.

Complicating the issue is the fact that NASA and the Defense Department have already begun to think about a second-generation shuttle for the late 1990's, presumably one that would be cheaper and simpler to operate than the current one. Thus, one option in the aftermath of the Challenger disaster would be to make do with three orbiters for the time being while accelerating the development of the new generation. However, one can argue that a premature rush to start work on an advanced shuttle might well lead to the same kind of development problems that plagued the current one. NASA got itself into serious trouble in the 1970's when it tried to develop three new technologies—the shuttle airframe, the shuttle main engines, and the tiles of the thermal protection system—simultaneously. A joint NASA–Air Force study of new launch technologies is due out in May.

In summary, there is no shortage of options for where to go with the shuttle program. However, it is important to realize that it makes no sense to argue over how many shuttles are needed until one grapples with a more fundamental question: If the space shuttle is a means to an end, what is the end? What is the United States is trying to accomplish in space?

While there are many potential answers to that question, there has been no clear national consensus on the answer since the end of the Apollo program. Indeed, thoughtful observers of the space program have long maintained that a national debate on the issue is overdue. It may well be that the Challenger disaster will provide the impetus for such a debate. And in that context, it is perhaps significant that the presidentially appointed National Commission on Space, which has spent the last year hammering out a long-term national agenda for space exploration, is scheduled to present its report to President Reagan on 11 April, right in the midst of the Challenger inquiry. ■

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## Federal Budget

The President's budget for fiscal year 1987 was released as this issue of *Science* went to press. A detailed analysis of the implications for science and technology will appear in next week's issue.