The Shuttle Record: Risks, Achievements

There is nothing new about the shuttle having propulsion system failures; but this time the consequences were grave

FROM its inception, the shuttle program has operated under great pressure. It has been pushed to meet tight budgets, to chase ever-receding deadlines, to boost rocket power, to shave the weight of structural elements, and to do all these things safely. In the early years, NASA managed well enough. But by 1977 funds were running short and large problems remained unsolved. NASA took money-saving steps in this period that came to haunt the shuttle later. For example, the agency decided not to test the main engine components individually, but in whole engine units. This came to light in 1978 and 1979, when the engines ran into technical trouble and Congress unexpectedly got a request to provide extra funds.

One area where NASA kept its promise was in maintaining a good safety record. True, two technicians died of asphyxiation and two were injured in a test just before the first shuttle launch in 1981, but aside from this there were no major mishaps until the terrible explosion of 28 January. However, the shuttle was not able to achieve the 60,000 pounds of payload lift capacity promised in 1971 to military supporters who helped NASA win authorization for the program. Nor has it come near the once-a-week flight schedule promised for 1985. The price tag, originally expected to be $5.2 billion (1971 dollars), is now over $10 billion. For 8 years, program leaders have downplayed problems and promised better results just around the corner. This management posture has been criticized since the 1970's (*Science*, 23 November 1979, p. 910).

Whatever its flaws, the shuttle did not lack technical clearances. Early in 1979, a National Academy of Engineering panel headed by Eugene Covert of MIT looked into serious problems with the shuttle's main engines. It warned against rushing them into use. Covert said in a recent interview that, in the end, his group was satisifed that NASA took the advice to heart. A major Carter Administration review of the program later in 1979 found many faults, but judged the program to be fundamentally sound. And John Brizendine, former president of Douglas Aircraft and now chairman of NASA's independent Aerospace Safety Advisory Panel, says that in the latest review of the shuttle, his group found "no crucial safety issues." About a year ago the panel issued some tartly worded advice, saying NASA ought not to encourage people to think that the shuttle had reached a routine or "operational" status, when in fact it is still emerging from the R&D phase. The panel thought NASA's statements exaggerated the shuttle's robustness and worried that this could lead to relaxed workplace standards.

Yet Brizendine also stressed in a telephone interview that the shuttle program is "remarkable" for its accomplishments. Indeed, it is. Some of the milestones in that record are given here:

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- On 20 July 1969, American astronauts walked on the moon, taking the Apollo program through its final paces. The logical next step, NASA said, was to build a space station, and its support vehicle—the shuttle—would come first.
- In 1970, early plans called for a complex double shuttle with a planelike orbiter on top and a piloted, reusable launch vehicle beneath.
- In 1971, the White House gave NASA the bad news that its budget would not grow much. NASA decided the new space vehicle would fly better in Congress if it had military support. After long negotiations, NASA agreed to Air Force specifications for a huge payload bay 15 by 60 feet, 60,000 pounds of lift capacity, and the ability to land on either the West or East Coast.
- President Richard Nixon officially endorsed the big shuttle on 5 January 1972, although the launch system was still undefined.
- In March 1972, the technical debate on the propulsion system ended. The piloted launcher was dropped; it would have been difficult to certify two vehicles. In a compromise, it was agreed that the propulsion would be part solid and part liquid, part recoverable and part throwaway. (The liquid hydrogen–oxygen system that has proved so troublesome and hazardous was included because it permitted greater specific impulse at lift-off and greater pilot control. Liquid motors can be throttled down; solid ones cannot.)
- In July 1972, Rockwell International won the shuttle design contract. The design was ready in May 1973 and construction began in June 1974. The Enterprise, an unpowered flight test vehicle, rolled out in September 1976.
- The flight test program ran smoothly through 1977.
- The years 1978 and 1979 were the season of engine fires. No one had built throttled liquid rockets of this size before, and the problems of pressurizing, heating, and containing the explosive fuel were (and still are) formidable. Leaks, fires, and turbopump failures occurred repeatedly—once during tests in September 1977, twice in December of 1978, and again in May, July, and November 1979. The first successful, full-duration firing of all three engines occurred in December 1979.
- In February 1979, the Covert report pointed out that there were "significant" differences between the engines being tested and those to be put on the shuttle. It warned that key components may not have been tested long enough and urged that more time be taken for flight certification.
- Robert Frosh, chief of NASA, in October 1979 released a broad review of the shuttle program, finding it "fundamentally technically healthy." But independent analysts saw it as having narrower safety margins than the Apollo program. General Electric executive and former astronaut William Anders wrote that the high risks should "be brought to the attention of the President for his review."
- In November 1979, Rocketdyne announced that many shuttle engine welds were too weak because its workers unknowingly used the wrong welding wire. As a remedy, suspect welds were nickel-plated.
- In January 1980, Frosh told Congress the first launch of the shuttle would have to be put off another year, until early 1981. The original launch date was March 1978. Work on the insulating tiles and the engines continued.
- On 12 April 1981, the first shuttle, Columbia, made a successful launch and orbited for 2 days with John Young and Robert Crippen at the helm. Sixteen insulating tiles were lost.

■ The Columbia made a second 2-day flight on 12 November 1981. The launch was delayed by a nitrogen tetroxide spill, a low reading on the oxygen tank, and overpressure in the hydraulic system.

■ In 1982 the Columbia made three successful flights and the crew carried out a number of biological spaceflight tests. There were problems with the auxiliary power unit; 36 insulating tiles were lost; two recoverable booster rockets sank in the ocean.

■ In July 1982, a new, lighter fuel tank (to help increase payload lift) was readied for use.

■ A flight with the new vehicle Challenger scheduled for 18 December 1982 was scrubbed when hydrogen from the fuel system was found leaking in the engine area. Further checking revealed that all three main engines had a fuel or oxygen line leak.

■ In February 1983, NASA ordered a broad review of quality control, to be directed by Air Force Lieutenant General James Abrahamson. He noted that the oxygen leak could have created a "blow torch" in the engine area, had it not been detected fortuitously. "If it had gone undetected," *Science* reported (11 March 1983, p. 1195), "the leak could have resulted in a devastating explosion between 1 and 2 minutes after the Challenger had lifted off."

■ In 1983, Columbia and Challenger made four trips. Sally Ride became the first U.S. woman to travel in space. Several satellites were launched. One was recovered from space for the first time and another (TDRS) limped to orbit when its booster failed. Spacelab experiments were begun, and other "firsts" occurred.

■ In August 1983, more powerful solid rockets were used for the first time. "Inhibitor material" was removed from some of the rocket fuel to allow it to burn faster—another attempt to increase payload lift.

■ In October 1983, NASA detected a flaw in the type of material used as insulation in the nozzle of the solid rocket boosters and postponed a launch for one month to replace the nozzle. Had it not been replaced, rocket flames could have burned through the metal, possibly leading to an explosion or sending the craft into a lethal spin.

■ Discovery and Challenger made five flights in 1984, including the first to deploy three satellites on one trip.

■ In February 1984 NASA announced that the wings of the new vehicles Atlantis and Discovery—made lighter to increase lift capacity—would have to be reinforced with cross straps for extra stength. Wind-tunnel data had been miscalculated. In the interest of losing weight, the casings of the solid rocket boosters also were being changed to

Europe Assesses Its Options

Last week's shuttle disaster has come at a critical time for Europe's space community. It is currently locked in an intense internal debate over the detailed future of its own space programs and, in particular, the relative weight to be given to manned and unmanned space technologies.

The shuttle experience will inevitably strengthen the hand of those who argue the continued need for a European family of expendable launch vehicles, based on the Ariane rocket. But it also poses both technical and political questions to those promoting a greatly expanded European manned-space effort, such as French proposals for the minishuttle Hermès (*Science*, 17 January, p. 209).

In the short term, the delays and/or cancellation of shuttle flights will have an immediate impact on several space research programs. One of the first casualties, for example, will be the Ulysses mission of the European Space Agency (previously known as the International Solar Polar Mission) which was due to have been launched in May. This has already suffered from NASA's previous withdrawal from what was to have been a dual-spacecraft mission.

ESA is also a major contributor to the Space Telescope, for which it has provided 15 percent of the funding, and was scheduled to conduct the Earth Observation Mission with its own astronaut from the Spacelab in August. In addition, several individual countries—in particular West Germany—are participating in the Galileo mission to Jupiter and other scientific projects currently threatened with significant delays.

Conversely, the shuttle disaster has raised speculation that it could boost the commercial prospects for ESA's own launcher, Ariane. French officials, for example, are optimistic that it will raise their chances of persuading the British Ministry of Defense to allow Ariane to launch its Skynet 4c military communications satellite planned for 1988, since the shuttle launches of Skynet 4a and 4b satellites, due this June and next January, respectively, are among those likely to be put back.

Ariane, however, is not without its own problems. The launch of the French remote-sensing satellite SPOT has already been postponed several times (it is now planned for 20 February) because of remedial action needed after the failure of the last Ariane launch in September, and also the discovery last month of leaks in the rocket's fuel system. These delays also mean that there is little slack in the Ariane launch schedule to absorb customers who might want to switch from the shuttle.

Further down the road, the disaster is expected to confront Europe with many of the same questions as those being faced in the United States. In particular, some countries, principally Germany and France, which have argued for priority for a strong manned presence in space, remain confronted by others, such as Britain (and large sectors of Europe's scientific community), which continue to argue for the greater cost-effectiveness of unmanned space efforts.

A compromise between different national perspectives appeared to have been reached at a ministerial meeting in Rome last January (*Science*, 4 January 1985, p. 39). However, it has since become clear that the full range of projects endorsed by the meeting (including those that will constitute Europe's contribution to NASA's space station) cannot be achieved within the budget ceiling that was then agreed to. Some further compromises will have to be made.

ESA said in a statement last week that, while the agency was "deeply shocked" by the loss of the shuttle and the death of its crew, it continued to have "full confidence in the shuttle program and is convinced of its necessity," adding that "manned space flight is an indispensable part of the overall conquest of space."

At the same time, however, Frédéric d'Allest, the director general of France's National Center for Space Studies, has admitted that the catastrophe is going to be "a test for Europe," warning that some may use it as a "pretext" for holding back Hermès, which France has said it would like to see launched in 1995.

Space officials from ESA member states are meeting informally in London this week to try to reach a new balance between their different priorities. Escalating cost estimates, as well as budgetary and timing uncertainties about NASA's space station plans (and the U.S. agency's recent rejection of Europe's proposed hardware contribution) have already complicated their discussion. Last week's events have not made it any easier. ■ DAVID DICKSON replace some of the steel with a tough wound filament of plastic and graphite.

■ On 26 June 1984, the main fuel valve failed to open on engine number one after the liquid propulsion system ignited for Discovery's maiden flight. The takeoff was aborted 4 seconds before the unquenchable solid rockets were to ignite, and a vulcanizing material in Discovery's rear caught fire. There was concern that the sudden, aborted drawdown of hydrogen and oxygen from the fuel tank would cause a pressure instability and explosion. Launch controllers relieved the pressure gradually by manipulating a series of valves and extinguishing the fire. For 40 hair-raising minutes, the astronauts sat immobile in their cabin.

■ In 1984 NASA began to get the new designs it solicited for making the troublesome shuttle engines more durable and reliable. The agency said it would spend $1 billion fixing them over 10 years. One of the leading contractors, Pratt & Whitney, said it was submitting a refurbished 13-year-old design.

■ The year 1985 was by far the best for the program, with three shuttle orbiters in use and nine successful flights. The first classified mission was flown by Atlantis on 3 October.

■ A near accident occurred with Challenger on 29 July 1985 when a sensor indicated that a turbopump was overheating, making a computer shut down one of three main engines 6 minutes into an 8-minute lift-off. The shuttle barely made it into orbit, flying at an initial altitude of 122 miles rather than 400. Had the engine cut out sooner, a NASA official said, the craft would have landed near Greece. Observers noted that a landing on water might well kill the crew.

■ On 12 January 1986, Columbia began a successful 6-day flight after seven non-starts, making this the most-delayed launch on record. The delays were caused by bad weather.

■ On 28 January 1986, Challenger exploded 74 seconds after lift-off, and a technical inquiry focused on a "burn-through" in a solid rocket casing. ■ ELIOT MARSHALL

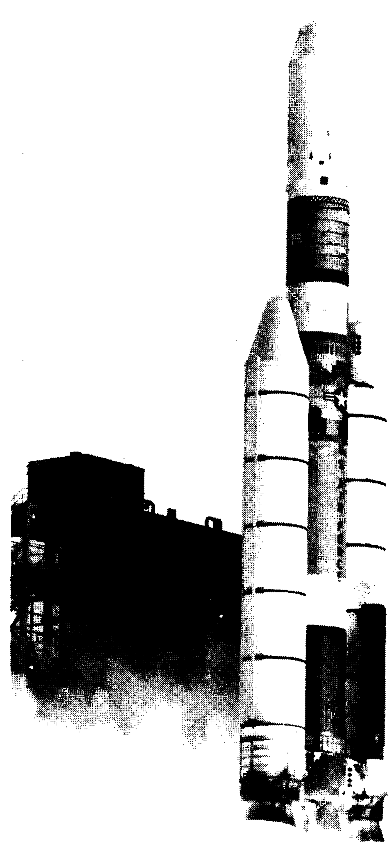
A Crimp in the Pentagon's Space Plans

By launching some payloads on expendable rockets, DOD may mitigate long-term impacts of the shuttle disaster

Two years ago, after watching the space shuttle experience a series of false starts and minor mishaps, Secretary of Defense Caspar Weinberger concluded that it was simply not fit to transport the most important military payloads into space. Over the National Aeronautics and Space Administration's bitter opposition, he sought and obtained congressional permission to construct some new, expendable rockets, each capable of carrying payloads of the same size and weight as the shuttle.

Weinberger's foresight will help protect the military from any long-term adverse effects of the recent shuttle calamity. But none of the rockets may be available before 1988 and in the meantime, the Pentagon will have a tough time getting its vital experiments and satellites into space on schedule.

This bind is not created by the destruction of the Challenger itself. Although it was a tragic loss for the civilian space program, it will not seriously disrupt the Department of Defense plans. Only 3 of the 11 DOD shuttle missions scheduled for the next 2 years were to have used the Challenger, and none of them would have deployed critical intelligence satellites. Still, DOD technically has the right—under a policy set by the President in 1982—to bump civilian payloads on the remaining orbiters so that it can fly the missions approximately on schedule.



The military's workhorse

The Pentagon is maintaining an independent launch capability with a successor to the Titan for launching some military payloads.

There is little the Pentagon can do if all shuttle flights remain suspended, due either to uncertainty about the explosion's cause or to a need to modify the orbiters. Even a slight additional delay is apt to affect the next three military flights, now scheduled for July, August, and December. The first is to conduct a key "Star Wars" experiment and deploy an experimental sensor designed to track military aircraft. The second is also believed to be related to "Star Wars," while the third will apparently deploy a sophisticated new photoreconnaissance satellite.

Two of these are to be launched from a new $3-billion complex at Vandenberg Air Force Base in California, which stands as a potent symbol of the Pentagon's tie to the shuttle's fortune. A more modern and compact version of the existing shuttle launch site in Florida, the Vandenberg site was constructed so that the shuttle could ferry a series of military satellites into polar orbits, which are optimum for intelligence gathering. Although the military presently launches several expendable rockets from Vandenberg—the Atlas and the Titan 34D—neither is capable of ferrying payloads as big or as heavy as the shuttle can, and both are being phased out. Thus, any lengthy delay in shuttle operations could have substantial national security implications.

At present, six military shuttle flights are scheduled for launch from Vandenberg by