NASA Wrestles with New Shuttle Troubles

The shuttle's vexatious engines are resisting some heroic troubleshooting

For the last several weeks, it has been a multimillion dollar mystery. Just 4 seconds before the last scheduled launch of the space shuttle, a crucial fuel valve in one of its engines malfunctioned, causing the launch to be scrubbed. Once again, a last-minute glitch subverted the careful preparations of the National Aeronautic and Space Administration (NASA), disrupting the plans of its customers, and throwing its launch schedule into turmoil.

With no clue as to the cause of the engine malfunction, Jesse Moore, the acting shuttle program director, decided on 9 July simply to cancel the shuttle flight. This decision was thought to be less cumbersome than simply putting the flight off, but it would nonetheless set in motion a domino-like series of shifts in the shuttle's manifest.

Specifically, two payloads intended for launch on the canceled flight—a naval communications satellite and a drug manufacturing experiment—would be moved to the next shuttle, now scheduled for launch on 29 August. In order to create the requisite space, two payloads from that flight—a second naval communications satellite and a unique large format camera intended for use in mapmaking, environmental studies, and oil exploration—would be flown instead in October and November. In turn, several scientific payloads from these flights, including an X-ray telescope developed by the Naval Research Laboratory and a collection of furnaces for the processing of various materials in zero gravity, might have to be moved to flights scheduled for next spring. And so on for a year or so.

On 10 July, however, final agency approval of this plan was delayed by the discovery of a new, unrelated problem involving the shuttle's payload assist module, which propels small satellites from the shuttle's payload bay into a higher orbit in space. Twice during a shuttle flight in February, the module's own engine malfunctioned, with the result that two communications satellites were sent tumbling into space. McDonnell–Douglas, the module's manufacturer, has been working to correct the problem so that it could be ready to deploy two new satellites on the 29 August flight. Shortly before NASA was to announce its new flight plan, however, a new module engine component also failed to operate in tests.

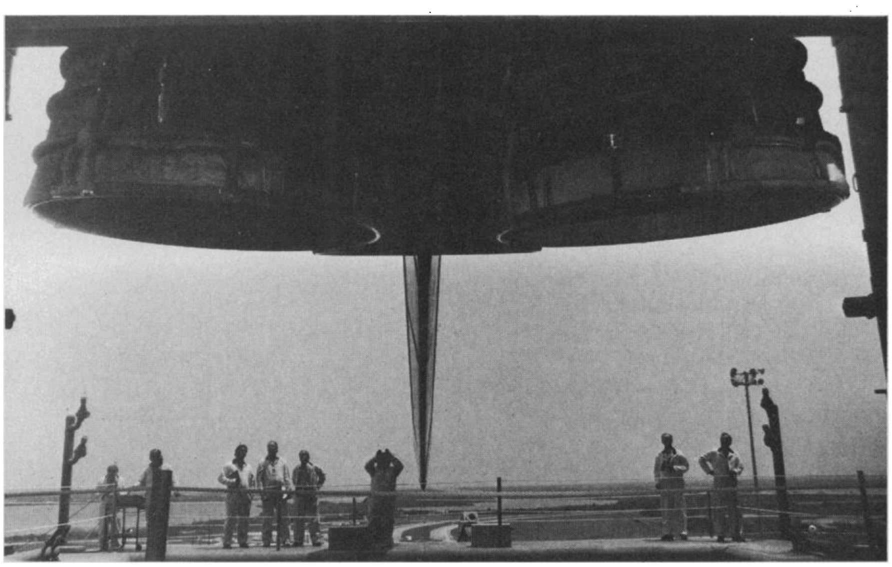
As a result, the agency began to reconsider flying the original payloads later in July. Even this brief delay would have long-term schedule implications, necessitating the delay of a handful of flights and the juggling of numerous payloads so that the agency's most pressing commitments can be met.

NASA officials are uncertain if immediate engine modifications will be required. "Any formal conclusions must await additional tests," says William Taylor, an engineer who is directing the investigation at NASA's Marshall Space Flight Center. Ironically, the best the agency might hope for is a clear sign that the failure was due to simple negligence and therefore easily correctable; at worst, it may uncover serious defects in highly complicated electrical or mechanical valve controllers, requiring laborious and time-consuming repair, replacement, or redesign.

Perhaps the most worrisome aspect of the shuttle's latest engine troubles is that the malfunction occurred without warning at a highly inconvenient moment. After opening and closing countless times in rigorous prelaunch tests, the errant valve failed to open properly 6 seconds before lift-off. This temporarily halted the flow of fuel to the first of three engines, which normally start approximately 120 milliseconds apart. By the time the launch computer learned of the malfunction and interrupted the firing sequence, the second engine had already ignited. In the process of shutting both engines down, some highly volatile hydrogen was emitted, and a small fire erupted at the base of the orbiter. Fortunately, it was rapidly extinguished by water sprays and only an ablative material on the shuttle's body flap was scorched. "This was a phenomenon we haven't seen before," Taylor says.

At first, agency officials believed that the malfunction was due—in Rube Goldberg fashion—to problems that began on 25 June, when a transistor in one of the shuttle's main computers failed for unknown reasons shortly before the scheduled launch. Replacement of the computer caused a 1-day launch postponement, which in turn required that a large engine pipe be drained and then later refilled with hydrogen fuel cooled to −423°F. The stress on the pipe caused by this rapid temperature shift apparently led to detachment of a small piece of its insulation. Shortly before the rescheduled launch, gaseous nitrogen was used to purge oxygen from the area surrounding the engines, as a precaution against fire. When this nitrogen came into direct contact with the supercold pipe at the point of loosened insulation, NASA officials hypothesized, it liquefied and dripped onto the critical fuel valve, causing it to bind up.

The difficulty with the theory was that



A team of specialists peers up at the space shuttle main engines shortly after the failure of a valve forced the cancellation of a launch.

this sequence of events could not be repeated when the faulty engine was tested at NASA's laboratory in Bay St. Louis, Mississippi. In one test, supercold propellants were piped in and a bag of nitrogen gas was placed around the insulation tear, but no substantial drip developed. In another test, frustrated investigators ripped a bigger hole in the insulation, pumped in extra nitrogen, and used a deflector to direct the resultant drip onto the valve. Still, the stubborn valve operated flawlessly, time after time. "Although the drip could have been a contributor, we clearly don't have strong evidence to substantiate its role," says Melvin McIlwain, the engine program chief at NASA's headquarters.

As this is written, three shuttle contractors in Florida and California are closely inspecting the valve and its associated mechanical and electrical equipment for previously undetected defects. One of these components, a compact, highly sophisticated computer, alone has 41,709 parts. Because of the difficulties involved in replicating every potential malfunction, McIlwain cautions that the ultimate cause might never be pinpointed. He is uncertain if the next shuttle flight will be delayed in the event that no clear explanation for the malfunction emerges.

The accident points up the delicacy of the engines, which cost $36 million each. On one previous occasion, several engines were removed from the shuttle for repairs shortly before lift-off, causing a 2-month delay to repair a series of potentially dangerous oxygen and hydrogen leaks. Willis Hawkins, a former Lockheed Company executive who recently served as chairman of NASA's Aerospace Safety Advisory Panel, says that problems are to be expected during the development of such a highly complex piece of machinery. But he believes that the agency should have worked a lot harder than it did to correct them early on. "They've finally got a good program," he says. "It's just late."

Specifically, he says, the agency should have gone to work long ago on the engine's weakest and most vulnerable part: its turbomachinery. Although the engines were ostensibly designed for use in 55 flights without significant refurbishment, shuttle managers have been forced to remove each one after only three flights, primarily to inspect and repair the turbine blades inside high-pressure oxygen and hydrogen pumps. Prior to engine ignition, the blades are chilled to −300°F. They are subsequently heated, in less than 5 seconds, to 1500°F and spin at 37,000 revolutions per

Labs Favored Over Research

Congress has directed the Department of Energy (DOE) to provide a $7-million down payment for a supercomputer center at Florida State University, a $2.3-million planning grant for a science facility at the University of Oregon, $8.9 million to complete a vitreous state lab at Catholic University, and $3 million to continue construction of new chemistry facilities at Columbia University. Although DOE did not request any of these funds, they have been included in the department's basic energy sciences budget, largely as the result of pressure from key legislators.

At the same time, Congress has cut some $16 million from the budgets of a variety of other basic science programs supported by DOE. Although congressional staff members insist that no direct trade-off was involved, as one DOE official ruefully notes, the effect is "a transfer of funds from people to bricks and mortar."

These funding decisions are contained in a DOE appropriations bill, which was approved by Congress on 27 June and is currently awaiting President Reagan's signature.

Florida State will get its supercomputer center largely thanks to support from Representative Don Fuqua (D–Fla.), the chairman of the House Science and Technology Committee, in whose district the university is located (*Science*, 8 June, p. 1075). Fuqua's interest was sufficient to ensure that the House included $7 million for the project in its version of the DOE appropriations bill.

The Senate's version of the bill did not contain any funds for Florida State's center, but it did include money for a science facility at the University of Oregon. This project has the backing of Senator Mark Hatfield (R–Ore.), the chairman of the Senate Appropriations Committee. Although no proposal has been submitted to DOE, the Senate bill directed the department to divert $2.3 million from its research budget to a planning grant to the university for a science facility that will include "chemical physics, materials science, computer science, high-energy physics, geothermal energy research, laser technology, and biotechnology."

When a House-Senate conference committee ironed out differences between the two versions of the bill, it ended up approving both projects. It agreed to the full $7 million voted by the House for Florida State, and directed DOE not only to provide the planning grant to the University of Oregon but also to include funds for construction in next year's budget request.

Funds for the Catholic and Columbia facilities were added to last year's budget through pork-barrel amendments first proposed on the floor of the House. DOE did not request additional funds for fiscal year 1985, however, because it had not received proposals from the two universities by the time the budget was put together. The House and Senate decided to provide the money anyway. The $8.9 million approved for Catholic University should be enough to complete the facility; some $12 million more will be needed to finish Columbia's center.

In contrast to the generous treatment of these university projects, Congress has cut $9 million from the $49.7 million budget proposed for basic research in nuclear science and $7 million from the $141 million proposed for materials science. DOE officials are currently deciding where the cuts will be made, but some university labs are bracing for hard times.

For example, the Stanford Synchrotron Radiation Laboratory, which was planning for .a 20 percent increase in operating funds, from $7.5 to $9 million, could end up with a cut of $1.1 million, according to a memorandum written by lab director Arthur Bienenstock.

In addition to shifting funds around in basic energy sciences, the bill also slashes $43 million from the budget requested for fusion research. This cut, which amounts to almost 10 percent, will require some rethinking of the program (*Science*, 22 June, p. 1322). Indeed, the congressional report accompanying the budget bill directs DOE to seek international collaboration and financial participation in future large-scale research devices and demands that a new management plan be drawn up.—**COLIN NORMAN** minute. Not surprisingly, many develop cracks, which if left untended would lead to rupture or freezing of the pumps, which in turn could result in engine overheating or cause a substantial hydrogen leak. Although a new set of turbine blades costs only $12,000, engine removals and launch delays consume thousands, perhaps millions, of dollars more.

"The agency has essentially reached so far into the state of the art that the engines have very narrow margins," Hawkins concludes. Jerry Johnson, vice president for flight engines at the Rocketdyne Division of Rockwell International, agrees. "We all worry ourselves to death when we fly at [the standard rated power level]. It's a lot like flying at the emergency power level in a jet. You don't want to run a 20-year program with that margin."

In the program's defense, Johnson notes that the shuttle's engines are by far the most complex ever constructed. Similarly, McIlwain points out that the need to work with high-pressure hydrogen in extremely high temperatures forced the agency to invent a lot of new machinery. An additional hurdle was created by use of a unique staged-combustion cycle, in which the fuel is, in effect, burned a second time for improved efficiency. In an article published last year, McIlwain and Walter Dankhoff, NASA's director of shuttle propulsion, called it "the greatest challenge ever imposed on rocket-engine designers." It has taken roughly a thousand people up to 2 years to produce each of the 27 engines completed thus far.

Judged by its overall budget, the engine research and development program stands merely at its midpoint. Since 197X, it has cost $919 million. Between 1984 and 1989, it will cost another $900 million. Roughly a quarter of its 70,000 parts have been substantially modified to date. The agency's primary focus at present is on the turbomachinery. One goal is to reduce its operating temperature; another is to toughen several key components. By 1986, Johnson says, turbine blade replacement will be required every ten flights; by 1990, every 40 flights. Although annual maintenance costs will double over the next 4 years, to $97 million, they are then expected to decline.

Ultimately, additional engine components will be redesigned to boost power by roughly 5 percent. "The number of problems we've encountered is not unusual," Johnson says. "Some of them have simply proven harder to solve than we anticipated."—**R. Jeffrey Smith**

The Secret Recipe of GE's Reactor Safety Study

Risk estimates, like elixirs, are often brewed in obscurity and sold without labeling of the ingredients. Studies that find very high or very low risks are particularly suspect if they are put forward by the promoter of a special cause or a moneymaking venture. For this reason, Susan Niemczayk, a physicist at the Union of Concerned Scientists, would like to have the General Electric (GE) Company publish the details of a risk analysis that makes GE's latest nuclear reactor look like the safest ever conceived.

GE turned down Niemczayk's request. Instead, it labeled a probabilistic risk assessment of the "Mark III" boiling water reactor confidential, putting it off limits to the public. The study indicates that the new reactor would run a tiny risk of having a core melt accident—something like one chance in 5 million per year of reactor operation. On the basis of this and other GE assertions, Niemczayk claims, federal regulators are whisking the new design through an accelerated safety review, aiming for completion this August. The goal is to award a formal seal of approval by autumn to aid GE in marketing the plant abroad.

This review is important as the first use of new rules at the Nuclear Regulatory Commission (NRC) that encourage standardized plant design. The NRC is to use its "rule-making" authority to examine new designs, certify them as safe, and protect them from technical challenge for 10 years. This is supposed to speed up paperwork and discourage nit-picking. The public is meant to have a chance to comment on the design once, during the rule-making, but not afterward. Subsequent hearings will deal with construction licenses at specific sites.

The GE reactor will be the first to go through this new system, making this a groundbreaking case. However, Niemczayk argues that the NRC may be setting a bad precedent, for it is backing GE's claim that the risk analysis should be kept private. She says she knows of no other risk assessment that has been kept confidential, and finds it irksome in this case because the study plays an important part in NRC decision-making. For example, it may be used to help the NRC decide whether or not over 80 staff-recommended design changes are necessary. Having read an unauthorized copy of the risk study, Niemczayk says it is "not a state-of-the-art analysis." She worked on such studies herself in her former job at the Oak Ridge National Laboratory. Some of the calculations are in error, she believes.

GE official Joseph Quirk disagrees and explains that his company wants to keep the study secret because "there is a lot of competition for [probabilistic risk] analysis." If GE's raw data were published, he argues, another company could steal it and provide the same service to purchasers of the GE reactor at a cheaper rate.

GE has published a nonproprietary version that "includes the bottom line on the core melt probability and the consequences," Quirk says. "Because of that, we believe we are not withholding information that is crucial to the public. The actual methods and data to support that have been withheld because of the commercial value."—**Eliot Marshall**

Baby Doe Compromise Imminent

A resolution of the long-running Baby Doe controversy may be close at hand in the form of an amendment to the Child Abuse Prevention and Treatment Act, which is up for reauthorization this year.

The measure was crafted by six senators, including right-to-life advocate Orrin G. Hatch (R–Utah), after intensive consultation with interested parties. It is a meticulously worded statement which appears to satisfy everyone while at the same time affirming prevailing medical and ethical practices.

It would redefine child abuse to include "withholding of medically indicated treatment from disabled infants with life-threatening conditions." Such treatment, however, is not required where it would be "virtually futile" in prolonging an infant's life, or when it