Shuttle Problems Compromise Space Program

With the shuttle earth-bound, political troubles and cost overruns take off

In a large hangar at the Kennedy Space Center in Cape Canaveral, Florida, still encased in a cocoon of metal pipes and walkways, sits the space shuttle Columbia, the most advanced hybrid airplane-space capsule ever developed. Amid a high-pitched yowl from huge fans, several hundred workers imported from California hustle to and from the Columbia, each carrying small boxes containing a single tile to be fixed to its hull. Others gaze at intricate, checkered maps of the shuttle's skin, tacked onto long rows of portable corkboard. Still others tinker with wires and small parts within the shuttle's belly, beneath a lighted sign that blazes, "Vehicle Powered." Men and women carrying clipboards rush about, watching small groups of people either affixing tiles or attempting to pull them off with small arrays of vacuum pumps.

The $8.5 billion space shuttle is behind schedule. As a result, a host of related civilian and military space projects may be postponed or canceled. The shuttle's first launch, initially scheduled for March 1978, has been moved back eight times. At present, the National Aeronautics and Space Administration (NASA) predicts lift-off in late fall of next year. But some officials there talk internally of further slippage into the first or second quarter of 1981. This delay will add millions of dollars to the shuttle's cost, which is well over budget already.

More importantly, the delay plays havoc with the carefully drawn plans of federal agencies, private businesses, and foreign governments counting on the shuttle to carry their satellites into space—satellites needed for communication, national defense, and scientific experimentation. Because of the delay, private firms such as RCA and Comsat that have contracted for shuttle launches may be forced to launch with more costly conventional rocket systems. Scientists will have to postpone for years or even cancel missions such as the Galileo orbiter of Jupiter or the dual orbiters of the sun's polar regions. Bruce Murray, director of the Jet Propulsion Laboratory in Pasadena (JPL), also notes that because of the cost overruns, "all of NASA's other divisions are supplying the contingency money" needed to finish the shuttle. Space scientists have been unable to find friends in Congress or the White House for new space projects, such as a flyby of Halley's comet or an imaging radar probe of Venus. Gerald Wasserburg, a planetary scientist at Caltech and a former member of the National Academy of Sciences' space science board, is worried that problems brought on by the shuttle could damage the entire U.S. civilian space program.

The military is affected, too. Because of the shuttle's unavailability, the intelligence community will lose spy satellite data needed for verification of the SALT II treaty, assuming ratification. Air Force Secretary Hans Mark told *Science* this will force the United States to rely on more costly backup intelligence.

So far, the only item in the shuttle program to skyrocket is cost. When the shuttle was first authorized in 1971, with its promise of inexpensive and routine space flight, total development costs were estimated at $5.15 billion. Actual development costs are expected to top $8.4 billion. Included in this figure is NASA's anticipated request to Congress for an extra $700 million for fiscal years 1980 and 1981, which comes to added expenditures of $6.7 million each week. Even taking inflation into account, the anticipated cost of a single shuttle launch has roughly doubled from the initial estimate of $10 million.

The agency is not only spending more but getting less. The shuttle's three main engines fall considerably below specifications, and the shuttle vehicle itself is 8000 pounds overweight. As a result, its lifting capacity is limited to only 50,000 pounds, some 15,000 pounds below its rated capacity, and well below the requirements of certain scientific and intelligence missions.

NASA is so far behind in its development work it has decided to put off wrestling with these and other problems until the Columbia is successfully launched. President Carter, meanwhile, has taken a personal interest in the project and expects to be briefed this week by science adviser Frank Press and NASA administrator Robert Frosch.

The agency has long been aware of the shuttle's problems, both budgetary and technical. The agency has therefore tried to give the program as low a political profile as possible. This has meant controlling costs and keeping to within a strict budget. The first 6 years of the shuttle's life, the strategy worked, but at a price. The project was kept within budget, but the severe technical problems that developed were merely postponed to be dealt with in future years. Having sown the wind, NASA is now reaping the whirlwind in the form of engines that don't work and tiles that don't stick.

The key to NASA's approach is "success-oriented management," a strategy which is simply the inverse of Murphy's law; it assumes that everything will go right. As one official put it, "it means you design everything to cost and then pray."

The intention of the strategy, a special committee of the National Academy of Engineering later commented, was to "eliminate parallel and possibly redundant development and test hardware," keeping expenses to an absolute minimum. But in NASA's hands, success-oriented management has led to wholesale deferrals of difficult work, embarrassing accidents, expensive redesigns, erratic staffing, weakening of specifications, and the illusion that everything was running well. In the end, overruns and schedule slippages were not particularly diminished, just concealed, largely by deferring them until the "next year."

The approach has recently been criticized. Noel Hinners, recently NASA's top scientist and now director of the National Air and Space Museum, says that for NASA "to take on a technological challenge with penny-pinching as the major goal was just plain stupid; if you're going to break technical ground, you can't design to cost." According to an internal NASA report, "The net effect of this management approach has been an absence of realistic plans, inadequate understanding of the status of the program, and the accumulation of schedule and cost deficit without adequate visibility."

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No one has determined if costs would have been higher under a more typical management approach. Myron S. Malkin, a former director of defense missile programs and currently manager of the shuttle operation, insists that "the current strategy *is* cheaper. And a 30 percent cost overrun, while politically terrible, is not historically terrible." But he acknowledges that it could have been done better. And four recent studies of the program recommended an immediate shift to an alternative strategy, one in which more testing is done and financial reserves are set aside.

Lacking the reserves, managers of the shuttle development work decided to reduce testing. The risks accompanying this strategy are immense. Nowhere have they been more obvious than in the invention of the shuttle's three main engines. Each is designed to deliver 375,000 pounds of thrust for 8 minutes during lift-off, by burning liquid oxygen and hydrogen to produce superheated steam; they are considered to be the lightest and most efficient liquid propellant rocket engines ever developed. Each costs $25 million. Rather than cautiously—and expensively—test each engine component separately, NASA's main contractor, Rockwell International, merely constructed everything to novel design, bolted it all together, and—with fingers crossed—turned on the power. At least five major fires resulted, the most recent on 4 November, in a simultaneous test of all three engines at NASA's laboratory in Bay St. Louis, Mississippi. Nine seconds into an 8-minute test, a problem developed and NASA had to shut them down; in so doing, a hydrogen-carrying engine nozzle broke, immolating the engine's interior. Previous fires have severely damaged a fuel pump, the engines themselves, the test orbiters to which they were attached, the insulation on an external fuel tank, and the test stand in which the engines sat. Concomitant with a strategy that predicts success is a decision not to build spare parts. The engine testing program was delayed for months while the test stand was rebuilt. Malfunctions have been laboriously traced to flaws that might have been detected individually. Instead, every time a part failed, an entire engine was jeopardized.

There were other surprises, too, such as the accidental drop from 10 feet of a 300,000 pound segment of the motor that drives one of the shuttle's two reusable boosters. Confronted consistently with such problems, NASA officials took the only action they felt they could: they deferred until the next fiscal year all work on the technical surprises and got on with production of the Columbia. The money simply was not available to do anything else. Also, it was thought at the time, that revelation of these problems might bring the entire program tumbling down, judged for all time as having had an insurmountably weak scientific foundation.

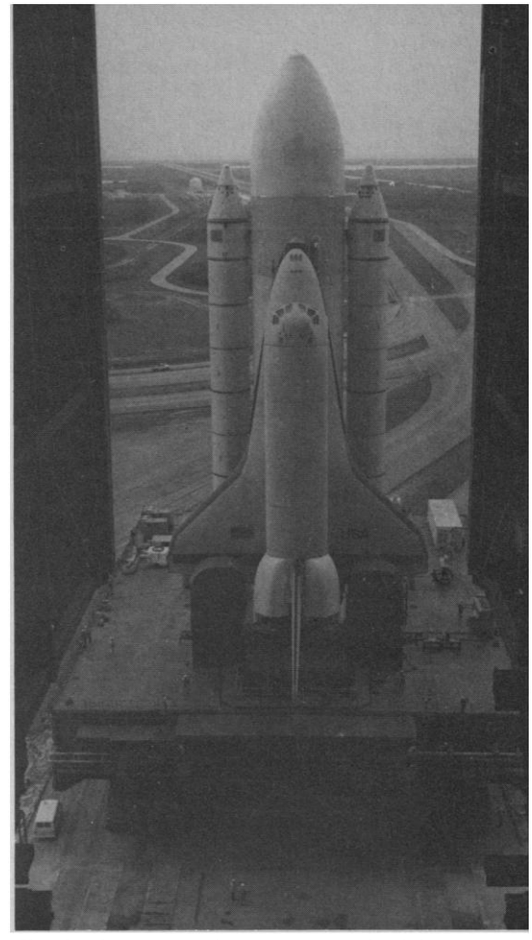
So the agency plunged ahead, effecting a jumble of activity occurring in unusual sequence at NASA's centers and at various shuttle contractors scattered throughout the United States. Last March, for example, the Columbia was moved to the Kennedy Space Center from the West Coast, where employees of Rockwell International had been struggling for 2 years to complete installation of its outer skin of protective tiles. The tiles, made of silica fiber and glass, are delicate enough to be broken with a hard punch, yet resistant enough to withstand temperatures of up to 3000 degrees (F.) when the shuttle reenters the earth's atmosphere. Because of their delicacy, the tiles are each no larger than a square foot; because of the need to insulate completely the shuttle's underside, each must be separately installed in a time-consuming process that involves installing two tiles and then designing a third to fit the gap between them (it takes one person 3 weeks to install four tiles). Fully one-third of the shuttle's 31,000 tiles had not yet been installed when the Columbia was moved to Florida.

Still, it was thought that work would proceed faster there, because preliminary testing and final production could be done at the same time. Hence, 2000 employees of Rockwell International, specially trained in tile installation, moved along with the shuttle from the West Coast to the East. They had to complete installation of the one-third, as well as re-install 7500 that were damaged in transit because of the unplugged tile gaps. There are presently 3000 tiles requiring installation. When two are installed, the workers carefully measure space for the third and send out to Sunnyvale, California, where the tiles are machined, for a design to specifications that must then be shipped to Florida.

That is only part of the tile problem. As a result of NASA's management decision, bonding of the tiles onto the Columbia was begun before vibration and temperature tests in a wind tunnel were complete. The tests revealed many of the bonds were inadequate, and this is why half of Rockwell's crew in Florida is applying tiles and the other half is attempting to pull them off.

As problems of this nature have multiplied, the shuttle's specifications were shaved. The number of orbital flight tests was reduced from seven to four. The concept of a reusable tug—to ferry satellites into unusual orbits once they were in space—was dropped in place of a less costly, but nonreusable upper stage rocket. A proposal to build a subscale shuttle, in order to test its design under hypersonic, supersonic, and transonic conditions, was dropped as too costly, with the result being that the first shuttle astronauts will pilot a craft whose structure and design will have been examined only on paper.

The result is a shuttle that many feel will be the most risky spacecraft ever launched. In February 1978, for example, Herbert Grier, chairman of NASA's safety advisory board, told a congressional committee that "we feel one of the important safety considerations is the effect of the schedule driving technical people to make 'fixes' rather than engineer a solution to the problem." The same concern was voiced by ex-Apollo astronaut William Anders,



The shuttle consists of a squat, ungainly glider powered by three aft engines and two reusable rockets, attached to a fuel tank (center) that is junked after each launch. This mockup is the only shuttlecraft to visit the launch pad so far.

who was asked by President Carter to look into shuttle overruns and delays. "I would worry more about it than I did for Apollo Eight due to narrower safety margins (e.g. fallout from reduced hardware qualifications and unmanned flight testing)," Anders wrote. "I believe that this narrower-than-Apollo-margins situation should be brought to the attention of the President for his review of any national and international political/policy implications."

Under the influence of success-oriented management, NASA officials perhaps began to confuse prediction with reality. NASA suffered from a "technological hubris," says a Senate aide. Managers became overconfident that technological breakthroughs would materialize to save the situation. NASA officials outside the shuttle program were caught unprepared. "There was no appreciation at the center directors' meetings that the problems would be anything this bad," says Bruce Murray of JPL. John Casani, director of the Galileo project to orbit and probe Jupiter, notes that the availability of the shuttle was taken for granted during all mission planning. "We were originally scheduled to be taken up on the 26th launch, and then schedule slippages moved us up to the seventh," he says. "We sure thought we had enough padding." Now, delays and problems with the shuttle's weight-lifting capability have forced the agency to defer the launch until 1984, when the Jupiter orbiter and an atmospheric probe have to be launched separately, costing millions of dollars more. The solar polar orbiters, designed to peer at heretofore unexamined parts of the sun, are in similar straits, facing additional expense and a 13-month delay.

As problems of this variety loomed on the horizon, NASA decided in 1978 to ask for more money. By this time, enough had been spent on the program to minimize the chance of its being canceled. The Senate subcommittee on science, technology, and space then asked the National Academy of Engineering to look into the shuttle's engine problems. The academy found that because the Columbia's engines had been installed before the development work was complete the engines that NASA intended to certify as fit for flight—in a separate testing program—were "significantly different" from the engines that NASA would actually be flying. Alarmed, the academy committee asked for, and got changes: the testing program was revised. In return, NASA got the academy to drop a statement in its report that there would be at least a 1-year delay past the mid-1979 launch date, a statement that would have brought about more political troubles. "The folks at NASA nearly fainted," says a congressional aide. The academy reported nonetheless that NASA's optimism about the launch date was not likely to be realized in practice.

At the urging of Defense Secretary Harold Brown, who was concerned about the shuttle's availability for conducting intelligence missions, President Jimmy Carter eventually got into the act. In October 1978, Carter had stood on the shuttle landing field and said he sincerely hoped the first flight would be before his next birthday, 1 October 1979. "I have every assurance from those involved that there will be no slippage in the present schedule as it now stands" (Applause). When his birthday—but no launch—was fast approaching, Carter asked NASA administrator Robert Frosch and several consultants for a special report on the shuttle and its problems, which the White House is presently mulling over. The consultants were generally critical of NASA's management approach, and one wrote, "Care should be taken to insure [sic] that excessive optimism is weeded out and that adequate contingency reserves—[in] cost and schedule—are now provided." In other words, the success-oriented approach should be scrapped immediately. "If NASA has a credibility problem," the consultant went on, "I believe it is more due to a tendency to overly accommodate to budget pressure for the sake of preserving a national commitment [to the shuttle] rather than to a lack of candor."

NASA officials respond to such criticism by embracing the accusation that the agency fudged in 1971 about how much the shuttle would cost. Their original proposals called for an even more complicated shuttle, with an expected cost of $8 billion. The Nixon White House slashed the request and the program down to a cost of $5.15 billion, entailing fewer technological challenges. Rather than admit this was an illusory estimate, NASA assented. Officials now say there was no other way that the shuttle would have got through a skeptical Congress and a barrage of criticism that it was not cost-effective.

Some of the critics' original accusations appear to be justified. Although costs are still hard to predict, it is not clear that the shuttle will be cheaper than conventional rockets. The European Space Agency is billing its proposed customers less to use its rocket Ariane than

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Ex-President Disputes Election

Audiences at scientific conferences in pre-Watergate days would sometimes be electrified to hear a voice declaring, "I am President Nixon. . . ." Heads would turn, and then the other shoe dropped: ". . . of the American Chemical Society." Alan C. Nixon is now an ex-president, in retirement in California, and trying to get back into the political limelight.

He has recently brought suit against the American Chemical Society, claiming the October 1978 election for the ACS director from Region VI was unfairly conducted, and that in a fair election he would have been successful.

During his presidency in 1973, Nixon posed an interesting challenge to the traditional character of the ACS as a learned society. A write-in candidate, he tried to make the ACS more interested in professional issues such as conditions of employment.

In the disputed election to the ACS's board of directors, Nixon lost to another candidate by a vote of 1913 to 1916. He claims that about 3000 members in the region received no ballots or got them too late because they were sent by third-class mail.

The ACS is contending the suit. At its meeting in April in Honolulu, the Council Policy Committee voted by 12 to nil, with one abstention, that the election should not be rerun.

CO_2 in Climate: Gloomsday Predictions Have No Fault

A group of experts has told the President's science adviser that they can find no flaw in a central argument of several recent climatic studies, that an increase in the CO_2 content of the atmosphere will lead to a global warming and significant climatic changes.

The group, convened by the National Academy of Sciences, says that the basic model relating CO_2 to global warming is correct, so far as they can see. "We have tried but have been unable to find any overlooked or underestimated physical effects that

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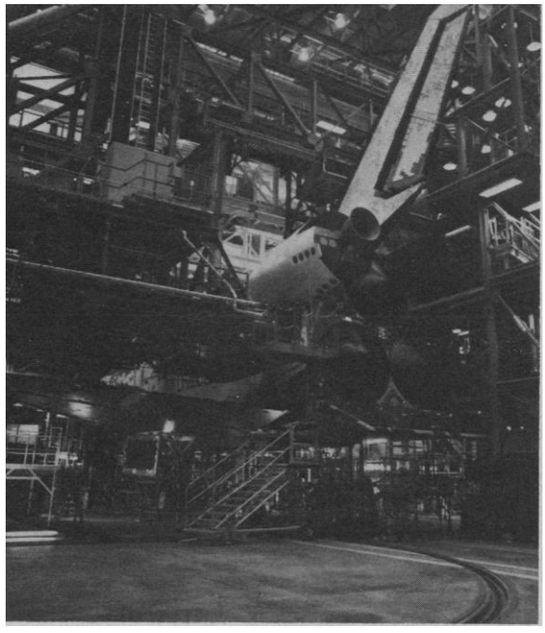

The space shuttle Columbia remains camouflaged by tiers of work platforms in its hangar at the Kennedy Space Center.

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NASA is charging for a shuttle launch. Both forms of space transport are heavily subsidized, so cost comparison is difficult, but the shuttle is nevertheless facing competition of a kind. Critics also derided the estimates that 60 shuttle launches a year would be required; projected demand is now down to 40 flights a year and even this modest schedule seems wildly optimistic.

The much vaunted capabilities of the shuttle for manufacturing in space have yet to interest many firms; perhaps this is due to a June 1978 report of the National Research Council that "economically justifiable processes for producing materials in space" have yet to be discovered. Even the European-built Spacelab, which will be orbited from the shuttle in seven launches, has excited only mild interest in the scientific community. A worldwide call for experiments elicited only 200 replies, from which 40 investigators were chosen; many of the investigators work for NASA. To use up vacant shuttle space, NASA sales officials devised what they call a "Getaway Special," which permits small pallets to be flown into space for a fee of several thousand dollars. Among those who have purchased the special are Steven Spielberg, a popular film producer; the science editor of *Quest* magazine; various Rotary clubs and civic groups; an occasional investigator; and more than a few small-time promoters and entrepreneurs.

The agency anticipates better business once the flights are under way, but the foremost shuttle customer is obviously going to be the federal government, with the Department of Defense assuming the largest role. Wasserburg of Caltech is troubled by this prospect. "The Air Force is now the real user of the shuttle, and the rest of the program is about to be scuttled, terminating the civil space program in the United States," he claims. Senator Lowell Weicker (R-Conn.) has also expressed concern. "Before, when I justified the space program in my state, I could always differentiate that program from the military," he told a Washington newspaper.

Initially, the shuttle was conceived as a civilian project, consistent with the division of military and civilian space work mandated by NASA's enabling act. In order to attract support and expand its mission model, however, NASA in 1971 offered to redesign the shuttle to accommodate military payloads and activities; so badly did the agency want Air Force support that it agreed to build two shuttlecraft entirely at its own expense, to be converted upon completion to almost exclusively military use. The Air Force in return forswore its diffidence and told Congress it needed the shuttles for 20 flights a year, a number that current Air Force Secretary Hans Mark characterizes as "all flaky. Some lieutenant colonel pulled that number out of a hat, realizing that the shuttle was ten years away and he'd have retired by then." Mark now estimates the Air Force needs as half that much, although he is vague about specific missions. "The most important near-term impact is to have mission specialists and pilots who get into space in a routine way," says Mark. Presumably, in addition to launching and servicing satellites, Air Force crews could sidle up to Soviet satellites and snap photographs; the shuttle could also be launched for direct observation during a crisis or localized war. "This is one of the few fields where we will for the next decade be clearly ahead of the Russians," Mark says.

Several of the intelligence satellites essential for monitoring future Soviet missile deployment are too big for launch by any existing conventional rocket. "Although the backup things are there for verification of SALT II," Mark says, "SALT III would be macroscopically changed without the shuttle." The Air Force need for the shuttle will soon become acute, as the military's supply of backup rockets will be depleted within 2 years. The issue is not so much when the first shuttle flies as when its development has been concluded, and NASA gets on with production of the shuttlecraft allocated to the military.

This is why DOD, which carries much more clout than NASA, has recently been lobbying the White House and Congress to give the program sufficient funds for it to overcome technical obstacles and forego further schedule slips. It is also why technicians and engineers are bustling around the Columbia for what the manager of the work, Kenneth Kleinknect, swears is 169 hours a week. Despite the effort exerted to date, the chance of additional delay is considered strong: the schedule is still oriented to the expectation of success. The three main engines have already been installed, even though engine development will not be complete until next summer. The shuttle's subsystem components—such as the inside cooling mechanism and the computer system—are also in place, even though they have not been fully tested. The structural analysis of ascent and descent loads is not complete—and may not be complete before all of the tiles are in place. So NASA is attempting to build a tiny remote television camera satellite that can scoot around the shuttle once it's in space, to search for loose or missing tiles; if even one is lost, in the wrong place, the shuttle could burn up on reentry, from the hole outward. John Naugle, formerly NASA's top scientist and presently an agency consultant, notes that both the tiles and the engines continue to push the state of the art. He calls it a "sporting proposition" that everything will work itself out. Richard Smith, newly appointed director of the Kennedy center, says that even if it does, the transition from test to operational flights will be more arduous than many people think. "We'll have to stop brute-forcing the shuttles off and begin to finesse them; once they return, we'll be able to make only minor repairs."

The President is meeting with Frosch this week.

Everyone breathes a sigh of relief that the Defense Department and the White House have—now that national security is at stake—finally gotten on board, just when the criticism was beginning to fly fast and thick, with timing that couldn't have been more perfect if it had been planned. And then, after a quick uptake, everyone continues to predict the shuttle will be launched next year.

—R. JEFFREY SMITH