Space Telescope in Trouble

The project has a history of technical excellence and managerial sloppiness; overruns now threaten the rest of space science

The ironies abound. The National Aeronautics and Space Administration's (NASA's) Space Telescope (ST) is a technological masterpiece, its 2.4-meter mirror easily ranking as the finest ever made. Within NASA it has a priority second only to the space shuttle itself. In fact, it will be the first demonstration of the shuttle's much-vaunted ability to repair, maintain, and upgrade a permanent facility in orbit.

And yet, NASA has saddled ST with a management system that virtually guarantees foul-ups and misunderstandings. It now appears that the $600-million telescope, until recently scheduled for launch in 1985, will face overruns of $100 million to $250 million and delays of 1 to 2 years. That money will almost certainly have to come out of the agency's other scientific missions; the crown jewel of NASA astrophysics thus threatens disaster to a space science program that had only just begun to recover from the stringencies of the shuttle era.

ST's problems have been festering for years, but the communications within the program are such that NASA headquarters was only told of their full extent in January. Agency administrator James M. Beggs was not amused. He immediately notified Congress and White House Office of Management and Budget (OMB) of the situation, launched a top-to-bottom review of the ST program, and started restructuring the ST management at all levels. "We should have been able to see this coming," he grimly told Representative Edward P. Boland (D–Mass.) during appropriations hearings on 22 March. "Good management would have sniffed it out."

The problems are the legacy of the 1970's, the same era that saw massive cost overruns in the shuttle, Landsat D, and other major NASA programs. In the case of ST, it is now apparent that no one was ever really put in charge. When the telescope was approved for a new start in 1977, responsibility for scientific instrument development and post-launch operations was given to NASA's Goddard Space Flight Center in Greenbelt, Maryland, while responsibility for spacecraft engineering was given to the Marshall Space Flight Center in Huntsville, Alabama. Marshall then parceled out the work to two separate but equal "associate contractors": Perkin-Elmer would fabricate the main mirror and the rest of the optical assembly in Danbury, Connecticut, while Lockheed would build the spacecraft itself and then integrate all the components in Sunnyvale, California.

"Byzantine," says Andrew J. Stofan, director of NASA's Lewis Research Center in Cleveland and formerly the acting head of space sciences at agency headquarters. "This is the way absolutely *not* to set it up." The split between the engineering at Marshall and the science at arch-rival Goddard meant that no one was doing end-to-end systems integration. The split between Lockheed and Perkin-Elmer meant that no one was even doing a proper job of hardware integration. "You needed a committee to solve every interface problem," says Stofan. "ST is an extremely difficult challenge technologically. And then to lay on a system like this . . . !"

The communications, apparently, have been nothing short of horrible. Quite aside from intercenter rivalries, the Office of Space Sciences at headquarters has had five directors in 6 years, with a similar turnover of project managers at Marshall. As Beggs points out, "A large part of the communications breakdown was that people didn't know each other and didn't know how to ask the right questions."

Oddly enough, no one contacted by *Science* could recall just whose idea it was to do things this way. The official explanation for the Marshall/Goddard split is that both centers had been involved in the early planning and that each had unique skills to contribute. Cynics wonder about intra-agency pork-barreling. The Lockheed/Perkin-Elmer split is even more mysterious, since NASA has almost invariably managed projects with a single prime contractor. Beggs, however, did tell Boland that the reasons "could not be discussed in the open." This gives credence to a rumor that at the time the contracts were put out to bid, the Pentagon was afraid that an overly intimate contractor/subcontractor relationship between certain companies might compromise sensitive optical technologies.

If the management problems were bad at the NASA level, however, they were worse within Perkin-Elmer. In 1977, on the basis of a low bid and a high technical rating, Perkin-Elmer beat out its competitor, Eastman Kodak, for the right to take on the project's greatest technological challenge: the Optical Telescope Assembly. The assembly is really the essence of ST. Exploiting the airless clarity of space requires a mirror accurate to less than a millionth of a centimeter over its entire 2.4-meter expanse. The associated optics have to be held rigid to a similar accuracy despite the stresses of launch and wide swings in temperature. And for long exposures of faint objects, fine guidance sensors have to keep ST aligned within 0.007 arc second for up to 24 hours—a precision that would let a laser in Washington pierce a dime in Boston.

There has never been any doubt about Perkin-Elmer's ability to meet the technical challenge. The company's products are widely hailed as superb. The problem is getting the hardware out the door.

"Their ST program is probably the most poorly managed thing I have ever seen in any company," says Stofan. "Nobody knew how to do internal scheduling. They used to come in every 6 months or so with new schedules, new milestones, and new costs. We had no way of knowing where we were."

The most extensive changes came in 1980, as Perkin-Elmer was engaged in fine-polishing the primary mirror. Although Marshall was very happy with the company's technical work, it was becoming apparent to everyone that the telescope would never be ready in time for its scheduled launch in late 1983. Thus, in December 1980, after an extensive review that supposedly pinpointed and fixed the management problems, NASA revised the project cost estimates upward and slipped the launch date to early 1985.

The polishing and silvering of the mirror took another year. NASA and the anxiously waiting astronomy community were ecstatic with the results—the mirror actually exceeded specifications; Stofan calls it "the finest ever made by man"—but that did not change the fact that Perkin-Elmer was continuing to fall behind schedule at the rate of about 1 week per month. In early 1982, as the slippage was starting to become obvious

at headquarters, Beggs demanded a full report from Marshall. The answer came back in April: ST, said Marshall, was "Basically OK."

But it was not OK. In the summer of 1982 came another 3-month slip; the program was now falling behind schedule at the rate of one month per month. "We weren't making any progress at all," says Beggs. With his fiscal year 1984 budget proposal soon due at the White House, he demanded another investigation. Marshall reported back in November: "Yes, there are difficulties, but things are not so bad that we need to rework the budget." On that basis, then, Beggs and the OMB drew up the 1984 figures.

Meanwhile, however, under pressure from Marshall, Perkin-Elmer had reorganized its entire ST program and brought in a new manager: Donald Fordyce, formerly of Goddard. He arrived in October. Shortly before Christmas, after he had taken a fresh look at the situation, he contacted Fred A. Speer, ST project manager at Marshall. On 14 January, they brought the news to Samuel W. Keller, deputy associate administrator for Space Science and Application: "We can't get there from here."

With Beggs scheduled to defend his budget before the House authorization subcommittee in less than 3 weeks, Keller went to Danbury himself. "It became apparent that the problem was real," he recalls. It was a combination of the kind of technical glitches one expects in any advanced development project and severe failings of management. "Perkin-Elmer's manpower was not compatible with the schedule," he says, "and they could not fully analyze what they needed to do."

Specifically:

- It was not yet clear how Perkin-Elmer would get the nearly 1-tonne primary mirror into its support ring in a strain-free condition, so that mechanical stresses would not distort the perfect optical surface.
- The latches that would hold the scientific instruments in position turned out to have a surface coating that might gall during launch, making it difficult or impossible for astronauts to change the instruments in orbit.
- There was some concern about dust accumulating on the primary mirror. It was in a clean room and covered, but it had been sitting there for 15 months. Some contamination was already visible.
- Most serious of all, it was not clear that the fine guidance sensors would work according to specifications.

The fine guidance sensors are the most challenging single components of ST. There will be four of them (three plus a backup), each using interferometric techniques to lock the telescope in position relative to guide stars at the edge of its field of view. There appears to be no question that the sensors will work with guide stars brighter than about 13th magnitude (roughly 600 times fainter than can be seen with the naked eye). But not every portion of the sky has stars that bright. If ST is to have full sky coverage, the fine guidance sensors must be able to use guide stars of magnitude 14.5, four times fainter still.

Unfortunately, Perkin-Elmer does not know whether the sensors will work that well or not, because at the moment it cannot test them. The sensor electronics are produced by a subcontractor, Harris Electronics of Melbourne, Florida. In early 1982 the project's cost overruns forced a cutback in Harris's effort, and the personnel dispersed. When Harris finally got the go-ahead, it had to bring in a new and inexperienced team. The first set of electronics should be delivered next month, and testing will finally begin.

Keller reported all of this back to Beggs, who took it directly to Congress and OMB: "We have a severe problem," he said, "and we don't yet know the magnitude." He ordered Keller to organize a "Tiger Team" to independently review the whole program—which was just as well, since Boland put his own staff to work on the same thing shortly thereafter—and he set off on visits to Perkin-Elmer, Harris, and Lockheed himself.

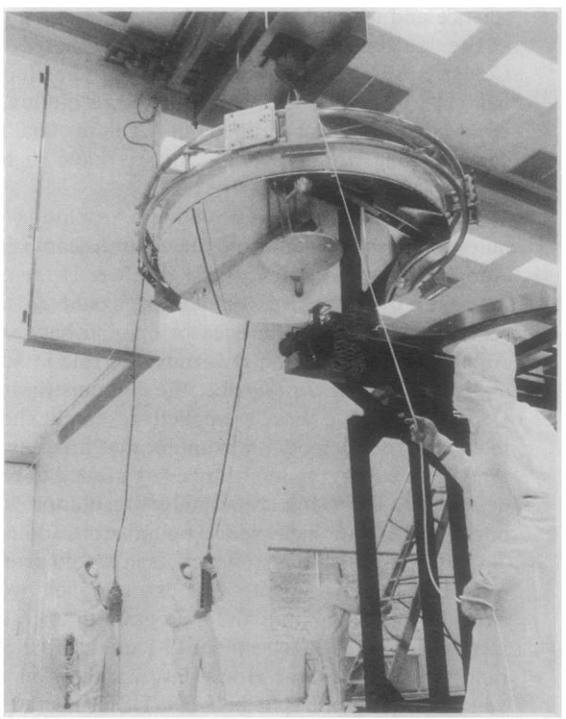
NASA's investigations culminated in a series of project-wide meetings at headquarters in mid-March. "It was evident that the whole program had become far too success-oriented," says Keller. As overruns ate into the budget, NASA had tried to save money by cutting back on things like spare parts and special test equipment. Worse, in 1980 NASA dropped the development of alternate approaches to the fine guidance sensor, leaving the program totally dependent on the success of the primary approach.

Acutely embarrassing was the fact that, just prior to the revelations of last fall, Marshall had paid Perkin-Elmer a special $2 million "award" fee on the basis of its good work on the mirror.

On 22 March, Beggs made a full report to Boland, who by then had his own staff's analysis in hand. "It's a disturbing report," said Boland. "NASA's management, particularly at Marshall, broke down totally." Beggs did not disagree.

The question now is what NASA is going to do about it. Apparently it is too late to change the Marshall/Goddard/Lockheed/Perkin-Elmer structure in any fundamental way. Nonetheless, in an effort to streamline communications, Marshall has already beefed up its oversight team at Perkin-Elmer, and Beggs is reorganizing Marshall. He is also looking for "a mean, tough program type" to stay on top of things at headquarters.

Next, how much is it going to cost, and who is going to get hurt? The one



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A technological masterpiece

In December 1981, Perkin-Elmer technicians lifted the Space Telescope's primary mirror from a specially designed vacuum chamber, where it had just been coated with a 650-angstrom reflective layer of aluminum and a 275-angstrom protective layer of magnesium fluoride. Subsequent testing showed that the surface was virtually perfect.

Democrats Boost R & D

Democrats and Republicans are engaged in a bidding war to determine which party should be regarded as the patron of science and technology. President Reagan opened in January with a budget that would provide large increases in selected areas of R & D. Now the Democrats have raised the stakes with a budget resolution—approved by the House on 23 March—that would increase Reagan's request for nondefense R & D by $1.25 billion.

The House passed the resolution the day before the annual AAAS colloquium on R & D and the federal budget, a fact that led AAAS president Margaret Burbidge to remark that "the political climate today is reminiscent of that in the late 1950's and 1960's with science and technology hot political items."

As a guide to what will actually be spent, the Democrats' resolution is no more reliable than Reagan's budget, which was cast aside by Congress almost before the ink had dried. But the two proposals together indicate that R & D is definitely back in political favor, with both parties looking toward science and technology as a key to economic growth.

The budget resolution, it should be noted, is only the first step in Congress's Byzantine budget process. The Republican-controlled Senate has yet to produce its version of the resolution, and differences with the House then have to be ironed out. Even the final resolution's figures are not cast in stone, for individual budgets have to be approved by the usual appropriations process.

Nevertheless, the House budget resolution is an important political milestone, as is evident from the vigorous campaign mounted by the Reagan Administration to defeat it. In the R & D area, about half the proposed increases over the Reagan budget would go to energy programs. This represents a major difference of opinion between the Democrats and the Administration over the government's role in supporting applied research and development. In essence, the Administration argues that much of the Department of Energy's applied research should be done by private industry. The Democrats maintain that in areas such as conservation and renewable energy, federal support is needed to ensure that technologies are developed. The Democratic budget resolution would also provide a major boost to the National Science Foundation, adding some $250 million to the Administration's request, which itself would provide an 18 percent increase over this year's budget. The extra money would be used for science education ($150 million) and a program to upgrade instruments in universities and colleges ($100 million). The extra helping for science education reflects passage by the House last month of major legislation for a science education program split between NSF and the Department of Education (*Science*, 11 March, p. 1198).

The resolution also includes an extra $150 million for NASA's civilian science programs, an amount that includes funds "to initiate the acquisition process for a fifth shuttle orbiter," according to the House Budget Committee report on the resolution.

As for the National Institutes of Health (NIH), the resolution would add $200 million to Reagan's request. The Administration proposed virtually no increase for NIH, a fact that has caused a good deal of concern in the scientific community over the Administration's apparent bias toward the physical sciences. In fact, the White House Office of Science and Technology Policy was pushing for an increase in NIH and thought that the Office of Management and Budget had agreed. At the last moment, however, OMB decided to hold NIH constant, partly because it expected Congress to increase the budget anyway. Its expectation seems to have been borne out.

Although the Administration's budget request was fast being rendered obsolete by congressional action, it was given a detailed examination at the colloquium and in a background paper prepared by the AAAS and its member societies. Most participants seemed to agree with the chief author of the background paper, Willis Shapley, that the budget "has some rough edges but is a good one for science." The Democrats' budget resolution was considered even better.—**COLIN NORMAN**

solution that Beggs will not countenance is a degradation in ST's performance. "Tell me now," he has consistently told his ST team, "what do you have to have to make this program well?"

At this writing the answer is still not clear; to some extent it will be a trade-off of money versus time. The overruns could range from $100 million to $250 million or more, and the delays could range from 1 to 2 years. Beggs told Boland that he could probably handle the costs in fiscal 1983. But next year, because he was not told the truth last October when the fiscal 1984 budget was being devised, he will have to carve out some $20 million to $40 million from the rest of NASA's space science.

Solar Optical Telescope has already been cut back to the bare bones. The prime contractor is none other than Perkin-Elmer, and Beggs wants that company's attention focused in one direction only. The Advanced X-ray Astronomical Facility (AXAF), ST's counterpart in x-ray astronomy, will almost certainly be slipped for the simple reason that NASA cannot credibly ask for another space telescope while the first one is in such disarray. For the remainder, Beggs intends to work his way through the rest of the Office of Space Science and Applications, picking up a million dollars here and there as he can.

Boland asked about "pillage." (Scientists have bitterly referred to "The Slaughter of the Innocents.") "There's no question that it is going to hurt," replied Beggs, "but it's the only place I've got to go for money." At this time there are no plans to ask for a budget amendment, he added, although Boland appeared to leave the door open. OMB has certainly made it clear as a general policy that new money will be very hard to come by.

Ironically, ST is one of the few programs in NASA that OMB has never stinted; the agency has always gotten pretty much what it asked for. The problem is that no one on the project knew how to forecast what they really needed.

It is hardly a situation unique to ST. "We've been working on the edge," Beggs told Boland, referring to NASA's overall performance in the last decade. "We've been pushing the state of the art with insufficient reserves to handle contingencies and inadequate backup on critical technologies." He pointed to a stinging in-house critique of NASA management produced in 1981 (the "Hearth" report): "Its message is to get back to the fundamentals of sound management. We still don't do enough of that."

—**M. MITCHELL WALDROP**