A Crisis in Space Research

Almost by accident, NASA's science and applications programs are undergoing a massive transformation—with no money to pay for it

On the surface, at least, the National Aeronautics and Space Administration (NASA) approaches the first anniversary of the Challenger disaster of 28 January 1986 in relatively good shape. The agency has won permission to build a replacement orbiter, together with $2.1 billion to pay for it. President Reagan is asking Congress for a substantial increase in the agency's budget for fiscal year 1988. NASA engineers are well along with their redesign of the solid rocket boosters. The agency has taken steps to implement all the recommendations of the Presidential Commission on the Challenger Accident. It has completed a shake-up of top management. And it has announced a new schedule for the resumption of shuttle flights. None of these actions is without controversy. Yet morale within the agency is rising, and the recovery seems well under way.

On the surface.

At a deeper level, however, the prospects are not so rosy. In conversations with the people involved in space science, space applications, and technology development—the things NASA is actually supposed to be doing with all that hardware—one finds a pervasive sense of foreboding. Moreover, the reasons go well beyond the crisis precipitated by Challenger and the Gramm-Rudman-Hollings deficit exercise, although these are obviously the most immediate concerns. The fundamental problem lies with space research itself: after two decades of ever-increasing ambition and maturity, NASA's science and applications programs have outgrown the available resources. Taking even the most obvious next steps will require a major escalation in the space program as a whole—an escalation that no one really anticipated, and that now, in the current fiscal climate, seems utterly infeasible. Thus, outside researchers and NASA managers alike have begun to wonder which disciplines they will have to abandon.

This situation has been addressed by a variety of studies in the year since Challenger, with perhaps the most notable being "The Crisis in Space and Earth Science," an 80-page report released by NASA's Space and Earth Science Advisory Committee (SESAC) in November 1986 after 2 years of preparation. In all the analyses, however, certain themes stand out:

■ *The lack of access to space.* The bitterest complaint that space researchers have about the manned spaceflight program is not that shuttle cost overruns have eaten into the science budget, although that is often how the problem is stated. Space science and applications funding has actually stayed relatively constant at about 15 to 20% of the agency's budget for more than a decade; it currently stands at $1.5 billion, which is roughly equal to the budget of the entire National Science Foundation. The scientists' real complaint is that they have been forced to use the shuttle, whether their payloads really needed the manned capabilities or not.

"It simply is not acceptable for this country to give up preeminence in space science."

"[NASA's] commitment to the shuttle as the single launch vehicle introduced human safety as a crucial consideration into the program even for those missions where less risky alternatives should have been available," says the SESAC report. The cost of "man-rating" research payloads has thus become a significant part of overall mission costs. Even worse, however, has been the cost of delay: the all-eggs-in-one-basket approach has meant that every delay in the shuttle launch schedule—of which there have been many—has forced a slippage in the science schedule as well. By the mid-1980s people were talking about a "bow wave" of deferred missions being pushed forward indefinitely into the future. As SESAC puts it, "Much of the time of creative scientists is wasted as launch dates change, including the time which must then be devoted to analyzing and reanalyzing revised mission scenarios, in budgeting and rebudgeting exercises, and in planning and replanning research programs for students, colleagues, and themselves."

The Galileo orbiter/probe mission to Jupiter, for example, was begun in 1977 with an estimated cost of $379 million and a target launch date of 1982. As the launch date slipped to 1986 because of shuttle schedule delays and booster problems, the total mission cost likewise climbed to an estimated $843 million. The additional slip because of Challenger will raise the costs even further. Moreover, Galileo will now not get to Jupiter until 1995—half a research career after it was initially funded.

In the aftermath of Challenger, the space science community has thus become adamant about the need for a "mixed fleet," in which conventional expendable launch vehicles would be used in addition to the shuttle. Indeed, Challenger made the fragility of NASA's all-shuttle approach so obvious that the mixed fleet concept has now become official Reagan Administration policy. Unfortunately, however, the bill for those extra expendables could total as much as $1 billion, just to fly off the backlog of currently planned science missions. And no one has yet determined how NASA is supposed to pay that bill. At the moment, the guessing is that the money will have to come out of the agency's science and applications budget.

■ *The trend toward "Big Science" in space.* The shuttle is hardly the only reason for the increasing cost of space research. The fact is that most of the pioneering missions have already been done. Taking the next step—higher resolution, greater sensitivity, more sophistication—almost invariably means spending more money. NASA planners now talk about "facility-class" missions, a phrase that is roughly synonymous with a cost of $1 billion.

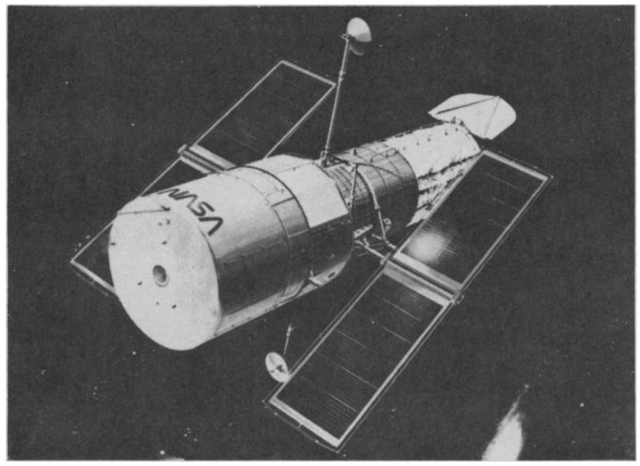
The astronomers, for example, have identified four such facility-class missions—"the Great Observatories"—as top priorities for the 1980s and 1990s. In addition to the $1.4-billion Hubble Space Telescope, these include the $1-billion Advanced X-Ray Astrophysics Facility, which is considered the logical next step after the $300-million Einstein x-ray satellite that flew in 1979; the $500-million Gamma Ray Observatory, which follows the $250-million HEAO-3 satellite of 1979; and the $500-million Space Infrared Telescope Facility, which follows the $200-million Infrared Astronomy Satellite of 1983. (All costs are expressed in 1987 dollars.)

Meanwhile, the earth scientists are calling for their own multibillion-dollar facility-class mission to follow up on earlier spacecraft such as Landsat and Seasat. Known as the Earth Observing System, it would be a comprehensive battery of remote-sensing instruments mounted on a permanent platform in polar orbit, and serviced by astronauts from the space shuttle. In much the same vein, the solar-terrestrial community is looking forward to another platform full of instruments dedicated to studying the sun. And NASA's Solar System Exploration Committee recently gave top priority to a multibillion-dollar Mars Sample Return mission.

In sum, the space sciences are in much the same situation as disciplines such as particle physics, where the logical next step seems to be a $4-billion, 20-trillion-electron-volt superconducting supercollider—or even molecular genetics, where some visionaries have called for a $1-billion project to sequence the entire human genome. Just as in these fields, the space scientists are insistent about the importance of small- and medium-scale experiments as a way of testing out new ideas and getting students involved. And yet, just as in these fields, cutting-edge research requires cutting-edge instrumentation. And that is very, very expensive.

■ *The new era of "operations."* Not only is space science becoming bigger science than ever, it has extended its time scale enormously. Until now, satellites have invariably been one-shot missions that expire after a few years at most. Once they were launched there was essentially no way to get at them for repair or refueling. In the shuttle era, however, the new facility-class missions are being designed to operate more like ground-based research laboratories, in the sense that they will be maintained, upgraded, and utilized for decades. The prototype is the Hubble Space Telescope, which is the first spacecraft designed to be serviced by astronauts in space suits, and which has a design lifetime of 20 years.

The long lifetimes presumably mean that these big-ticket missions will yield a lot of science and applications per dollar, which is certainly desirable. And yet, long lifetimes also mean that NASA's research budget will increasingly be devoted to long-term operating costs, as opposed to funding new missions. The cost for maintaining, refurbishing, operating, and periodically upgrading Space Telescope has been estimated at $150 million per year. In other words, some 10% of NASA's current space science and applications budget would be spent on just this one instrument. Add in similar figures for the other facility-class missions, and it seems clear that very little money would be left over. "This is a major issue that's not well appreciated in the science community," says SESAC chairman Louis Lanzerotti of Bell Laboratories. "Large facilities imply long-term commitments—and if you aren't careful, that means no new initiatives."



The Hubble Space Telescope

The prototypical example of a long-lifetime, facility-class mission.

■ *The need for "infrastructure."* Research in space does not live by spacecraft alone; the missions also depend upon a vast array of support facilities. As an example, consider Space Telescope again. It will be taken into orbit aboard the shuttle, which itself depends upon a massive launch complex at Cape Canaveral and a standing army of some 6000 people worldwide for each flight. Once in orbit it will be controlled from a special facility at the Goddard Space Flight Center in Greenbelt, Maryland, according to a scientific agenda developed at the Space Telescope Science Institute in Baltimore. And it will remain in continuous contact with the ground through a $2.8-billion system of Tracking and Data Relay Satellites.

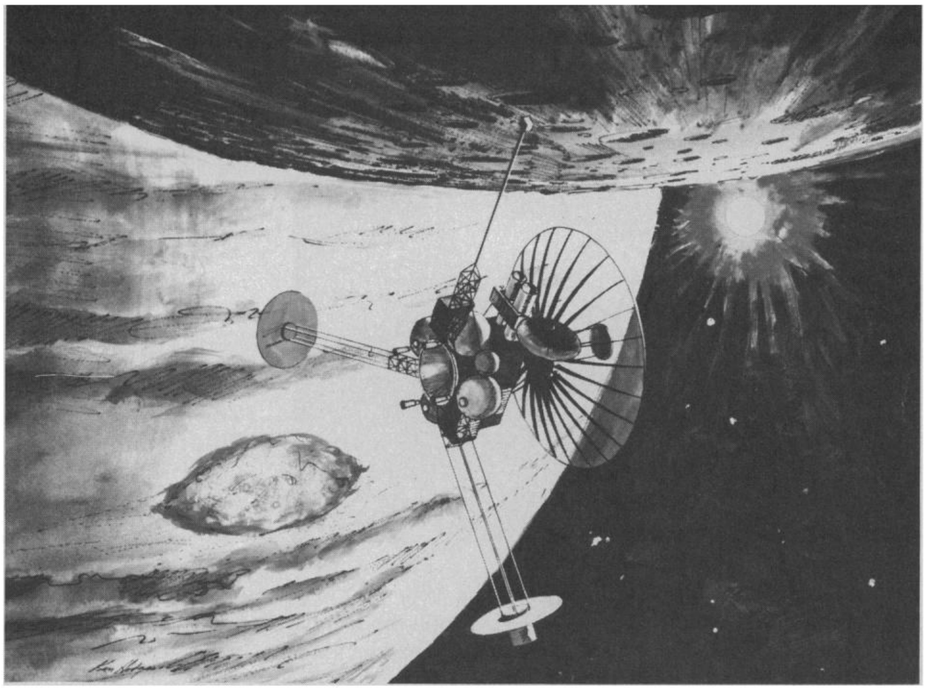
Many of these facilities will be used to support other space activities in addition to Space Telescope. And many of them, such as the shuttle launch complex, have largely been paid for. Nonetheless, the actual cost to NASA of doing Space Telescope—or any other such mission—will be considerably higher than the budget figures explicitly allocated to it.

Nor will the support costs necessarily stop there. Assuming that the agency does go ahead with the Great Observatories and its other facility-class missions, it will eventually need to supplement its ground-based infrastructure with on-orbit infrastructure such as a space-going spare parts depot, a floating drydock for maintenance and repair, an Orbital Maneuvering Vehicle for servicing satellites by remote control, or an assembly facility for putting together large radio dishes and complex interplanetary spacecraft. (A Mars Sample Return mission would almost certainly be too big to be launched in one piece.) The alternative—having the shuttle carry specialized equipment up and down every time—would be cumbersome in the extreme. NASA's current plan is to base these on-orbit facilities on the space station, which is scheduled for construction in the early 1990s. But wherever they are based, they will cost still more billions.

Looking back over all this, one can draw several conclusions. First, NASA's space science and applications programs are undergoing a major transition, both in scale and in operating style. Traditional dichotomies such as "operations" versus "R&D," or "manned" versus "unmanned" spaceflight, are increasingly irrelevant when it comes to missions of the caliber of Space Telescope and its brethren. These missions will have to operate within a larger framework that includes the shuttle, the astronauts, all the various support facilities, and eventually, some kind of space station.

Second, this transition has been taking place more by accident than as a result of conscious policy. Decisions to go with this mission or that mission have been made in relative isolation, and until recently, no one seems to have come to grips with the long-term implications. As SESAC chairman Lanzerotti points out, the committee's report is as much a message to the research community as to NASA itself.

And finally, NASA's budget of roughly $7.5 billion per year is grossly inadequate to support this transition. Indeed, this was becoming obvious long before the Challenger accident. The authors of the SESAC report calculate that NASA's Office of Space Science and Applications would have needed an extra $300 million to $400 million per year—roughly one quarter of its current $1.5-billion budget—just to accommodate the missions already proposed by the major space science disciplines. Furthermore, that figure does not include any increases for emerging fields such as life sciences or materials processing, nor does it include research into robotics and automation, advanced propulsion technology, advanced materials, or the aerospace plane and other new gener-



Galileo. *The cost of orbiter/probe mission to Jupiter is more than double its original estimate, in large measure because of launch delays.*

ation launch vehicles. Nor does it include the cost of launching the missions, or the cost of the various platforms and support facilities associated with the space station. Overall, the pre-Challenger wish list for space research could have easily soaked up another several billion dollars per year.

After Challenger, of course, what was once a chronic fiscal problem became a crisis. Instead of being the much-heralded "Year of Science," when the shuttle would finally start delivering on its long-delayed promises as a research platform, 1986 more closely resembled a collapsing house of cards. In quick succession came such events as the cancellation of the Centaur booster that was to have launched Galileo and Ulysses out of the shuttle payload bay, cancellation of over half the planned Spacelab flights, and delays of 2, 3, and 4 years even on the missions that were left. Meanwhile, the fiscal shortfall has been aggravated by the cost of the recovery. Space Telescope's storage costs are running $7 million a month; under the current schedule, which calls for launch of the facility in November 1988, this item alone will take another $160 million out of the agency's space science budget. One NASA official estimates that the total cost to space science of the Challenger delay will come to roughly $1.5 billion.

Thus the sense of foreboding among space researchers: it is all too easy to look at this situation and see fiscal disaster. And thus the urgent question: is there any way to avoid such a disaster?

Maybe. For example, one approach might be for NASA to buck the political currents in Washington and ask for more money. And in fact, NASA Administrator James C. Fletcher has persuaded the White House to approve a handsome increase for the agency in its fiscal year 1988 budget request. Along with extra funding to support the shuttle recovery effort, the proposal includes funding for the new Civilian Space Technology Initiative, which is designed to sharpen up NASA's cutting-edge efforts in areas such as propulsion, power, and robotics. It also includes funding for one new start in space science: U.S. participation in the International Solar-Terrestrial Physics program, which is a multi-spacecraft mission to monitor the earth's magnetosphere in unprecedented detail.

However, the new budget proposal is *not* an explicit policy document. It offers no commitment from the Administration to support a multibillion-dollar expansion of the space program. It does not even explain when expendable launchers will be available for research payloads, or how they will be paid for. And in any case, it still has to win the approval of Congress, which is hardly a foregone conclusion in the era of massive federal deficits. In short, the new budget represents an encouraging upward trend—but, as pointed out by Bernard F. Burke of the Massachusetts Institute of Technology, president of the American Astronomical Society, "It doesn't show a solution for any of our fundamental problems."

Thus, given the dubious prospects for major increases in NASA's funding overall, one comes to a second approach: shift around priorities—and money—within the agency. Fletcher, for his part, has consistently pledged that NASA's future activities will include a heavy emphasis on science, exploration, and aeronautics technology. On the other hand, he has never said that space research will be NASA's only priority. Nor could he arbitrarily cut back on other programs, even if he wanted to. Consider the most obvious tactic: stretching out the development timetable for the $8-billion space station and moving the money into more immediate research activities. A great many space scientists would support such a move. However, the space station has already won the endorsement of Ronald Reagan. He likes it, and sees it as a centerpiece of his space program. NASA itself sees the station as symbolic of its future—and in any case, needs the project to keep its engineering teams together and its centers busy. Outside NASA, the station has attracted strong support from both the U.S. aerospace industry and NASA's international partners in Europe, Canada, and Japan, all of whom have made substantial investments in the project. And finally, the station has begun to win some belated support within the science community itself, particularly among researchers interested in doing hands-on materials science and life science experiments.

In sum, it seems unlikely that any significant new money will be diverted into science from the space station; the project already has too big a constituency. Thus, one has to consider a third approach to the crisis: get the mission costs under control and do more with the money that is available. In fact, the SESAC report points to a number of things that can be done, even leaving aside the issue of launch delays. In a mission's design and development phase, for example, keep the scientific objectives of each mission sharply focused, and avoid the temptation to load instruments on the spacecraft until it resembles a kind of high-tech Christmas tree. Use similar spacecraft for a variety of missions instead of developing each one from scratch; this keeps the development costs low and allows the agency to save money by buying the spacecraft components in bulk. And most important, maintain stability in program definition and funding levels. The cost of not doing this has received widespread attention of late, and not just within NASA. A recent Defense Department study on weapons cost overruns found that stability in weapons requirements and in funding levels would save some 30%. In the case of NASA's Solar Optical Telescope, 3 years of delay because of tight budgets led to an estimated cost increase of $73 million—which in turn led Congress to cancel the project. "Increasing the costs of a program by delaying it and then canceling it because of those increases does not appear to be a particularly effective way to manage a program," notes the SESAC report.

The problem with SESAC's recommendations, however, is that they are not new. NASA's Solar System Exploration Committee proposed all of them a few years ago in its widely praised plan for cost-effective exploration of the planets. Its work was held up by then-presidential science adviser George A. Keyworth, among others, as a paradigm of how scientific planning should proceed. And yet, even before Challenger, the committee's plan was rapidly becoming a shambles. Most notably, NASA's decision in late 1985 to postpone the Comet Rendezvous/Asteroid Flyby mission for budgetary reasons greatly undermined the concept of program stability.

The lesson is clear: "efficiency" in space science is not just a matter of building cheaper hardware. Nor, for that matter, are NASA's overall budget levels and internal priorities simply a matter of administrative fiat. They depend far more on institutional imperatives, year-to-year budgetary upheavals, and politics—factors that no one has yet been able to control.

Thus, one comes to a fourth approach to resolving the crisis: abandon certain areas of space science outright. Leave them to the Europeans, the Japanese, and the Soviets.

Obviously, no one is actually advocating this. Thomas M. Donahue of the University of Michigan, chairman of the National Academy of Sciences' Space Science Board, echoed a palpable sense of anguish in the community when he recently told *Science*, "It simply is not acceptable for this country to give up preeminence in space science." To abandon whole disciplines at this point would be to penalize NASA and the affected research communities for their vigor and success. Furthermore, no one has the slightest idea how to choose which fields to eliminate.

And yet, barring any unexpected upheavals in the budgetary landscape, some kind of drastic action seems inevitable. The alternative of simply muddling through—always the preferred course for a bureaucracy—seems to guarantee stagnation, frustration, and mediocrity for everyone.

"Clearly," write the SESAC panelists, "the decision between these alternative paths [increased funding for space research and sharp reductions] cannot and should not be decided by NASA or by the scientific community alone. It also should not happen by accident. It is a national decision requiring a consensus of the American people, and thus of their representatives in the Executive and Legislative branches of government."

In short, if the choices must be made, then so be it—but *choose*, deliberately and explicitly. ■

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Science Sections in U.S. Newspapers Increase Dramatically in Past 2 Years

The recent demise of two prominent science magazines, the AAAS's *Science 86* and the Hearst Corporation's *Science Digest*, has raised questions about the public's interest in news about science and technology. The question is made harder to answer because daily newspapers have been starting special science sections just at the time when all popular, general circulation science magazines were suffering substantial financial losses because of a dramatic drop in advertising revenue.

A recent survey conducted by the nonprofit Scientists' Institute for Public Information* (SIPI) reveals that between 1984 and 1986, 47 daily newspapers began weekly science sections (defined as at least a page-and-a-half that appears on the same day every week), bringing the total number of science sections to 66. In addition, SIPI reports, 81 daily newspapers now have a weekly science page. The *New York Times*, which was the first with a science section when it launched "Science Times" in 1978, also has the largest circulation at 776,000 readers. The Lewiston, Maine, *Journal*, which started its science section last March, is the smallest with 12,000 readers.

Fred Jerome of SIPI observes that "When so many papers introduce science sections in so short a time, somebody other than university professors and researchers must be interested in reading about science." Indeed, newspapers consistently find a high interest in science and medicine (particularly medicine) when they poll readers about their special interests.

For instance, in an interview in *SIPIscope*, William Randolph Hearst III, publisher of the *San Francisco Examiner*, which recently started a science section called "Spectra," reports that "We knew science, health, technology, and the environment were high-interest areas with readers. They told us every time we asked. Not every reader shares those interests, of course, but those who do have a real passion." Hearst sees the reader who has a real passion as key to newspapers in the future. "In an era when reading is becoming an endangered skill and TV can deliver a truly mass audience, newspapers have to talk about who is reading the paper, not just how many," he says.

Although the majority of the newspapers' sections cover science, technology, and medicine, a significant number focus exclusively on medicine. According to SIPI survey data, in 1984, five or 18% of 28 sections reported exclusively on medicine and health, which veers into articles on fitness. By 1986, 21 of 66 (32%) science sections were really sections on medicine. Carol Krucoff, former editor of the *Washington Post's* weekly magazine "Health," told *SIPIscope* she thinks the existence of the section has "enhanced and increased" coverage of medical stories in the main news sections of the paper. "That's partly because its focus has brought to the fore the great reader interest in health, so it's increased our awareness of all the health news that's out there."

But enthusiasm for science or medicine sections is not universal, according to SIPI. Some journalists think that the special sections inadvertently "ghettoize" science and end up reinforcing the idea that the subject is special, arcane, apart from real daily news. Lewis Cope of the *Minneapolis Star and Tribune* says "I've been here for 20 years, and one of the things I try to do in a newspaper as a journalist is to make the science news part of the routine, treat it like any other news. I think there's a risk of ghettoizing science coverage with a section. There's a real advantage of having people expect science in the paper every day."

With the exception of the big dailies such as the *New York Times*, which has a dozen writers, the science sections tend to have small staffs of two or three reporters and modest budgets, consistent with the fact that, like science magazines, most of the newspaper sections are more attractive to readers than to advertisers, who remain to be convinced that science pages are the best place to spend advertising dollars.

How science sections will fare in the long run will depend both on reader response and advertising. Although they require advertising support, their expenses come nowhere near those of the popular science magazines with large staffs, four-color art, and substantial promotional costs. (A large mailing of brochures to potential subscribers can run in the millions of dollars for magazines like the late *Science 86* or Time, Inc.'s *Discover*, which has had losses totalling some $50 million since it began.)

Since the SIPI survey was completed, at least two newspapers (the *Albuquerque Tribune* and the *Chicago Tribune*) have folded their science sections and will run science news elsewhere in the paper. Whether this is the beginning of a new and opposite trend is anybody's guess. ■

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