News & Comment

Great Telescope, Bad Service Plan

Space Telescope should be as scientifically productive as NASA promised—but only part time; moreover, having the astronauts take care of it in orbit could be a nightmare

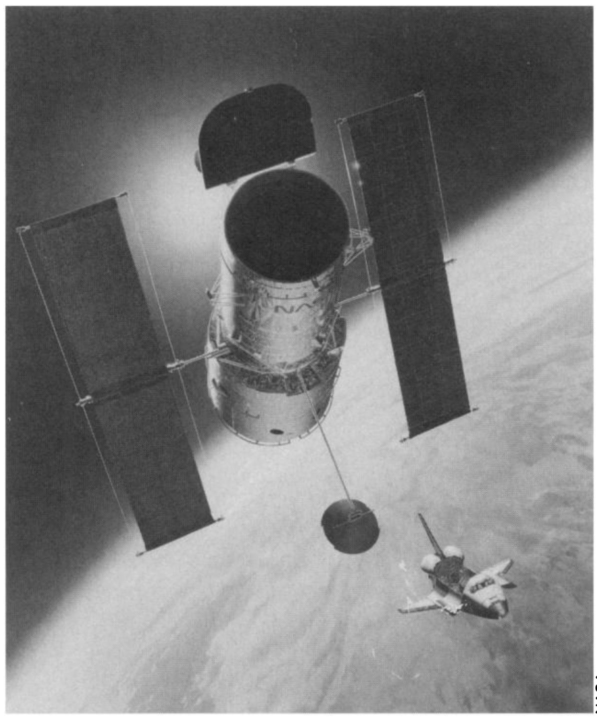
BACK IN THE GOOD OLD DAYS of the mid-1970s, when the Hubble Space Telescope was supposed to cost less than $300 million and the space shuttle was supposed to fly once a week, the union of these two technologies seemed like a marriage made in the heavens.

The shuttle, for its part, would not only launch the telescope, but would keep it alive for 15 years or more by bringing the astronauts back again and again to make repairs and upgrade the instruments. Space Telescope, in turn, would serve as the vanguard of a whole new generation of long-lived space observatories—the perfect justification for having humans in space and for building the shuttles to fly them.

Alas, that was then and this is now. With launch of the telescope now set for 26 March, many scientists feel that this whole concept of shuttle servicing has become a fiasco. As currently conceived it will cost the Space Telescope project as much as $100 million per year, exclusive of launch costs. Worse, the bitter experience of the Challenger disaster makes it all too clear that servicing will tie the telescope in perpetuity to a fragile and hugely expensive shuttle system. "We've built a telescope that's totally reliant on servicing," says a former chief scientist on the project, Robert Brown of the Space Telescope Science Institute. "And yet the whole concept of rapid repair requires a much greater investment in money and space shuttles than we have—or that is planned."

But perhaps worst of all, the requirement that the telescope occupy a low, 600-kilometer orbit that can be reached by the shuttle will cost the astronomers as much as two-thirds of their observing time.

"The idea that we commit to this kind of effort for each and every Great Observatory just boggles the mind," says science institute director Riccardo Giacconi. While it is far too late to change the Space Telescope, he says, NASA could get a lot more science for the money in the future if it just forgot about servicing and instead replaced its aging space science satellites with new ones.


NASA

Hubble and friend. *A marriage gone sour?*

In fairness to NASA, however, no one was talking this way back in the mid-1970s when the Space Telescope was being designed. The scientists themselves were big fans of servicing. "The idea was that servicing would be done in the context of this very robust shuttle infrastructure," Brown says. Shuttle flights were supposed to be cheap and easy, and having the astronauts drop by to fix a broken widget just did not seem like much of a problem.

NASA accordingly drew up a maintenance schedule that called for regular visits by the astronauts every 2 years, plus a return of the telescope to Earth every 4 years for a top-to-bottom refurbishment. The engineers, meanwhile, designed Space Telescope so that the instruments, the electronic black boxes, and virtually everything else but the optical system itself could be removed and replaced by astronauts wearing space suits.

No one fooled themselves that designing the telescope this way would be easy—the hand-operated latches that hold the instruments in place turned out to be particularly tricky, for example—but no one doubted it would be worthwhile, either. Once the telescope was safely above Earth's murky atmosphere, it promised to send back scientific goodies by the carload: Voyager-like images of the planets; a ten times better view of distant quasars; new insights into the origin and evolution of the galaxies; a much improved measure of the true scale of the universe; perhaps even a detection of other planets around other suns.

But then, as the shuttles began to fly in 1981 and as the telescope progressed toward its planned mid-1980s launch date, people began to realize what servicing was actually going to involve. The idea of bringing the telescope back to the ground was abandoned in 1984: The image of a shuttle trying to land 10,000 kilograms of exquisitely aligned optics brought a cold sweat to engineers and astronomers alike. Once it's up, they said, do everything you need to do in orbit—but leave it up.

Unfortunately, the shuttle astronauts had already discovered that working in spacesuits was clumsy, slow, and exhausting at best: The occupant constantly had to fight against the pressure in the suit and the bulk of the thick-fingered gloves. Add in the risk to the telescope itself—among other things, exhaust from an approaching shuttle's hydrazine jets could fog the telescope's mirrors—and servicing started to look less like a routine event and more like a last resort. One thing for sure, says NASA's astronomy chief Charles J. Pellerin, Jr., "We're not going to service for fun."

Back on the ground, meanwhile, Space Telescope project managers were calculating what it would cost to maintain a stockpile of spare parts, not to mention operating a test facility, and retaining a cadre of people who remember how Space Telescope works. Depending on exactly what gets included in the total, says David Pines, the deputy director of NASA's observatory servicing facilities, the servicing bill will come to some $50 million to $100 million per year—or as much as twice the $50-million budget for all of Space Telescope's science and data archiving activities.

Of course, as Brown points out, even $100 million per year could be called a bargain if it protects the $2 billion or so already invested in Space Telescope. But that leaves out one brutal reality, he says: the fragility of the space shuttle itself.

The vision of frequent, routine shuttle flights exploded for good on the frosty morning of 28 January 1986. "What Challenger brought home was that the shuttle isn't going to be available to deal with unexpected glitches," Brown says. NASA's caution level on the shuttle is way up—with good reason—and the planned flight rate is way down: Current projections call for only one flight per month or so.

In fact, one satellite, the Solar Maximum Mission, has already fallen victim to the scarcity of shuttle flights. None was available to push it into higher orbit during the current sunspot cycle, which warmed Earth's upper atmosphere, increased the drag on the low-flying satellite, and sent it to a fiery death on 2 December.

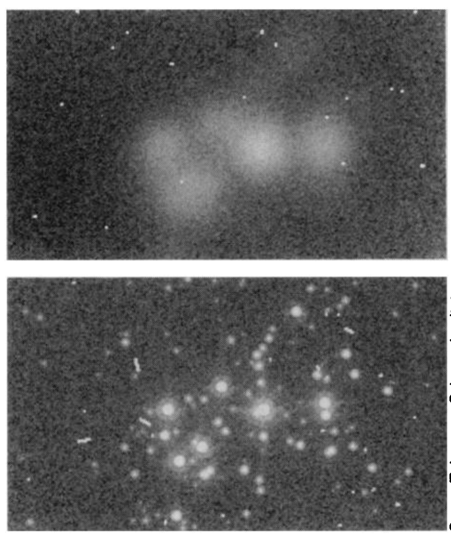
Agency officials insist that they have no intention of letting Space Telescope fall. Quite the opposite: They are already developing elaborate contingency plans for reboosting the telescope during the next solar cycle, which is due to peak in the year 2001 or 2002. But the lesson is that servicing missions are going to be very hard to come by in the post-Challenger era. Says Pines, "We're assuming 5-year reflights—*if* nothing breaks."

And if something does break? "If there's a problem that really threatens the telescope," says Pines, "we go to the administrator [of NASA] and ask for a shuttle as soon as possible." However, soon does not mean tomorrow. "We'll want to understand the problem before we go up," he says, "which means troubleshooting it on the ground to make sure it's not a generic problem and we're replacing a bad part with a bad part. Then we have to get a shuttle ready, get the equipment ready, train the astronauts on the specific black box, make contingency plans—we have a commitment from Johnson [Space Center] to have a flight in 12 months."

No one has been more acutely aware of these post-Challenger constraints than the shuttle mission planners at NASA. Until recently, however, they could offer up a ready solution: the space station. Whenever Space Telescope (or any other satellite) needed servicing, went the argument, the space station crew would send out a remotely piloted spacecraft known as the Orbiting Maneuvering Vehicle (OMV) to bring it in. Once back at the station the OMV would maneuver the telescope into a pressurized "garage," and the astronauts could work on it in a shirtsleeves environment.

Unfortunately, however, this scenario has also developed a few little problems. First, assuming that it's built at all, the station's completion date has slipped until 1999—which is already two-thirds of the way through Space Telescope's planned lifetime. Second, budgetary pressures have long since forced NASA's designers to defer the station's servicing garage until a nebulous "Phase 2," sometime in the next century. And finally, the OMV, which could also be operated from the shuttle and which would still allow the astronauts to service Space Telescope remotely without having to struggle with the space suits, is rumored to be a target of this year's Gramm-Rudman budget cuts.

So for the foreseeable future and consid-



Space Telescope Science Institute

New views of the heavens. *This computer simulation shows a distant star cluster as seen through a ground-based telescope (top), and through Space Telescope (bottom).*

erably beyond, satellite servicing is going to be done by space-suited astronauts working from the shuttle—which immediately raises the specter of another accident. As the congressional Office of Technology Assessment recently pointed out, even a highly optimistic success rate—say, 99%—makes a shuttle accident of some sort better than even money by the end of the 1990s (*Science*, 18 August 1989, p. 697). "What happens then if there's another 3-year hold?" Giacconi asks. "That's what I worry about at night."

And so, in the end, he asks, given all the costs of servicing and given how hard it is going to be for any space telescope to reap the benefits—why bother?

As Giacconi and Brown have both pointed out on numerous occasions, that question becomes particularly acute when you consider what living in a 600-kilometer, shuttle-compatible orbit is going to cost Space Telescope in scientific terms.

To begin with, they say, the astronomers' observing time on the telescope will tend to be highly fragmented. Not only will the Earth block out half the telescope's sky, but it will constantly be blocking out a *different* part of the sky as the telescope circles around and around every 90 minutes. So any given target may be in the clear for as little as 40 minutes at a stretch—not very long for studying a faint, distant galaxy or quasar. Moreover, this constantly changing celestial geometry translates into a scheduling nightmare for the telescope—one that even the computers will have a tough time handling (*Science*, 17 March 1989, p. 1437).

Meanwhile, the telescope will lose about 15% of its data-taking time to the South Atlantic Anomaly, a region east of Brazil where Earth's radiation belts dip low enough to send a flood of spurious signals through the telescope's electronic detectors. And finally, even when the telescope is free to take data, its communications back to the ground will have to pass through NASA's system of Tracking and Data Relay Satellites—which means that those communications will have to be coordinated with priority traffic from the space shuttle and classified Pentagon operations.

Now factor in such engineering details as the telescope's own molasses-like slowness as it moves from one target to the next, and the average fraction of time that the telescope will actually spend looking at something works out to just 35%, *maximum*. That's no better than a ground-based observatory that has to contend with daylight, moonlight, and clouds.

For comparison, the International Ultraviolet Explorer (IUE), which has been operating since 1978 in the 35,900-kilometer geostationary orbit used by communications satellites, is on target roughly 90% of the time. A 35% efficiency seemed like a tolerable price to pay back when servicing seemed to offer big benefits. But not now, Brown and Giacconi maintain.

NASA needs to consider better alternatives for future missions, they say. Studies done for the agency's upcoming Advanced X-Ray Astrophysics Facility (AXAF) suggest that by leaving out all the explicit and hidden costs of servicing, the agency could buy two telescopes for the cost of one. With savings like that, Brown says, you can imagine a whole different concept for long-lived space observatories: "*No* servicing after launch—but with the same amount of science done by a series of expendable telescopes to cover the same 20-year span." Each telescope could go into a scientifically optimal orbit—geostationary or higher—thereby doubling or even tripling its productivity. And each replacement would serve as a backup for the telescope before it. As Giacconi points out, "Right now, ST is a single point failure—if it should fail early, we have no backup."

Brown and Giacconi's message is definitely being heard in the astronomical community. This past spring, for example, the science working group for another upcoming telescope mission, the Space Infrared Telescope Facility (SIRTF), strongly recommended that the agency forget about servicing the spacecraft and instead place it in a very high orbit some 100,000 kilometers out. NASA space science director Lennard Fisk accepted the recommendation immediately.

However, NASA is by no means ready to give up on servicing entirely. The AXAF x-ray satellite, for example, is being designed from scratch to be as robust as possible, so that it can last out its 15-year life with an absolute minimum of servicing. But it is still going to go into that 600-kilometer shuttle-compatable orbit.

"I think servicing gets a bad rap," declares astrophysics chief Pellerin. Servicing Space Telescope, he maintains, is worth it because the astronauts will not just repair the thing. They will upgrade the instruments. "I see the life of Hubble as three 5-year epochs," he says—the first featuring its current suite of optical and ultraviolet instruments; the second featuring a new set of powerful infrared cameras; and the third featuring a new generation of ultraviolet imaging arrays. "You couldn't even think of doing that without servicing," says Pellerin.

Pellerin also has little patience with Brown and Giacconi's vision of expendable telescopes. "I wonder if people would have even done Hubble without servicing," he says. "Would they have invested in that superb optical system, just to throw it away?"

And indeed, Giacconi is the first to admit that the main argument against their idea of disposable telescopes is political. "Congress' reaction is 'Look, we just *bought* you a telescope. Why do you want another one?'—even though the two may cost the same as one!"

The answer, Giacconi says, is that each telescope would build on the one that went before. So instead of spending money on sterile upkeep, says Giacconi, you could spend it on improving the instrumentation, advancing the technology, and getting new generations of students involved in the discipline—"the activities that provide a better benefit to the nation."

■ M. MITCHELL WALDROP

Plea to Bromley: Save Our Neutrons

Presidential science adviser Allan Bromley and a dozen other government officials got a sharp message this week from researchers who do neutron scattering experiments. A petition signed by about 100 scientists warns that U.S. research in materials science, which many see as a key to continued economic growth in the 1990s, could be seriously hampered unless a commitment is made to increase funding for the nation's handful of aging neutron scattering facilities.

Neutron scattering is becoming an increasingly important technique in areas vital to the U.S. technological future. In the study of high-temperature superconductors, for instance, neutron scattering has provided vital information on structure and magnetic properties. Because neutrons are more sensitive to light elements than x-rays, they are able to pinpoint the exact locations of the all-important oxygen atoms in crystals of the copper-oxide superconductors, whereas x-ray diffraction cannot. And because neutrons have a spin, or magnetic moment, they can probe superconductors' magnetic properties, which many scientists feel hold the key to why these materials become superconducting at such high temperatures.

Moreover, neutrons can see deeper into an object than can x-rays, and they are nondestructive, which makes them ideal for such tasks as checking residual stress in cast metal parts. Residual stress is an internal stress left over from the manufacturing process, and it can cause a part—a turbine blade in a jet engine, for example—to fail under applied stresses much less than it was engineered to withstand.

"There isn't any competition [to neutron analysis] if you want a nondestructive method of looking at industrial parts," says John Hayter, a solid-state physicist at Oak Ridge National Laboratory. But researchers like Hayter are becoming increasingly frustrated with delays and outdated equipment at U.S. neutron scattering facilities.

The immediate problem, says Stephen Shapiro of Brookhaven National Laboratory, is that safety concerns have shut down the two most powerful research reactors in this country, putting much of the neutron work on hold. Brookhaven's High Beam Flux Reactor was closed in April for a safety review, and the High Flux Isotope Reactor at Oak Ridge has been out of commission since November 1986. The latter reactor was originally shut down because routine testing revealed possible radiation damage to its pressure vessel. Although that problem was resolved in August 1987, the restart was delayed while various committees studied safety procedures with an eye toward guaranteeing that no possible accident could cause a release of radioactivity.

The shutdowns have forced researchers such as Brookhaven's John Tranquada, who uses neutrons to study high-temperature superconductors, to "try to get time at other facilities outside the country," he says. That has slowed his research considerably, he notes.

Tranquada and his colleagues are looking forward to the new year when both reactors are expected to be restarted. But they're still worried about the future. "The bigger problem is the perception that there's no support [for neutron scattering] in the long term," Hayter says. Few young researchers in the United States are going into the field at this point, he says, because they worry they will not have the necessary facilities to do their work.

Hayter echoes sentiments expressed in the petition, which was passed around at a neutron scattering session at the fall meeting of the Materials Research Society, held in Boston from 27 November to 2 December. The petition points out that many of the nation's neutron facilities are 20 to 25 years old, and increased safety costs have reduced the money available for both upgrading them and doing research. It adds that safety concerns have "seriously impeded the design of the Advanced Neutron Source," a planned state-of-the-art research reactor that researchers hope will be available by the turn of the century. "It becomes costlier and costlier to run [reactors] when these things are included," says Simon Moss, a physicist at the University of Houston. "Then you have safety for something that you can't [afford to] run."

Safety is less of an issue at pulsed neutron facilities, which employ a particle accelerator instead of a nuclear reactor to produce neutrons. But even there, funds have not kept pace with the increasing operating costs, such as electricity bills. The result is that the two major pulsed neutron facilities are kept open for less time now than 2 years ago.

■ ROBERT POOL