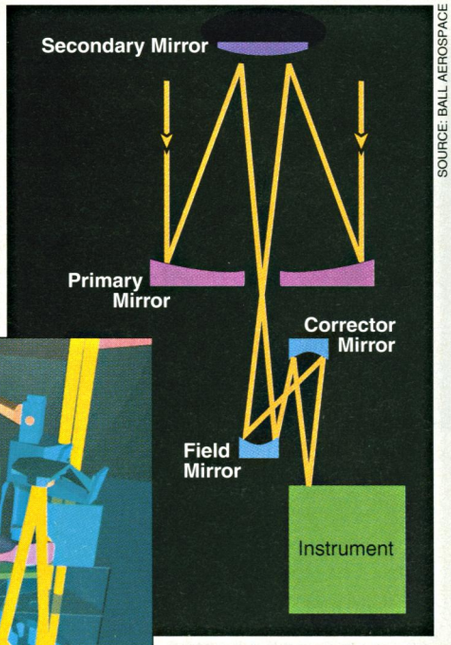
SPACE SCIENCE

NASA Stakes Its Reputation On Fix for Hubble Telescope

An opening scene in the comedy film *Naked Gun 2 1/2* features a dark lounge with a depressing atmosphere, downbeat music, and walls lined with pictures showing historically horrible disasters. There, between a picture of the Hindenburg and a half-sunk Titanic, is the Hubble Space Telescope. That's an exaggeration of the space telescope's plight, but it's a symptom of the reputation that the instrument has gained, in spite of the National Aeronautics and Space Administration's (NASA) best public-relations efforts. Although many of the telescope's discoveries have made it into front page headlines, the astronomy community considers the $1.5 billion instrument a profound disappointment: Its misshapen mirror has blurred the bird's eye view of the heavens they dreamed of. This December, however, the agency will mount a high-stakes, $550 million-plus effort to fix the troubled telescope.



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DANA BERRY

Look sharp. A set of corrective mirrors *(blue)* will sharpen light going to each instrument *(above)*. A frame called COSTAR will position the corrective optics *(left)*.

Much of the groundwork for this drama of redemption has already been laid at instrument builders, aerospace companies, and astronaut training centers. At Ball Aerospace company in Boulder, Colorado, workers are testing a precisely aligned array of quarter-sized mirrors that will intercept and sharpen the fuzzy images as they travel to three of the telescope's scientific instruments. At the Jet Propulsion Laboratory (JPL), engineers are checking out a just-completed, corrected replacement for the fourth, primary instrument, the Wide Field Planetary Camera (WFPC). And in clean rooms and water-filled tanks in NASA centers, astronauts are rehearsing the delicate surgery they will have to perform when they step from the Space Shuttle 10 months from now to install these prosthetic parts.

But blood pressures are rising as the date for this difficult task nears. If it works, astronomers and engineers expect a telescope virtually as powerful as the one they originally dreamed of. But if it doesn't, NASA managers and project engineers fear that another high-profile failure would destroy the agency's credibility with Congress and the public and kill support for further missions. "Most of us feel the reputation of the agency rides on getting this right," says NASA optics expert John Wood.

Engineers and administrators at NASA are taking steps to avoid a titanic failure. No longer are they taking it for granted that their contractors will do the job right, as managers admit having done with the fateful mirror. Now they are testing everything thoroughly and repeatedly before the new equipment goes up into space. But NASA management remains so jumpy, according to project scientist Edward Cheng, that the agency has subjected the repair project to dozens of reviews and oversight panels.

Just last week, an alarm swept through the project when the latest engineering review panel, called by NASA administrator Daniel Goldin and headed by Massachusetts Institute of Technology engineer Joseph Shea, revived a long-closed issue: whether to fly the telescope back to Earth and do the repairs on the ground instead of in space. Engineers on the project don't expect the suggestion to go anywhere: Retrieving and relaunching the delicate instrument would be far too expensive and might destroy the telescope, they say. But NASA's move to call in a panel and open such fundamental questions at this late date suggests that the agency is suffering a severe case of nerves.

Astronomers, too, are aware of the high stakes. "If astronomy is going to have a future at NASA, this repair mission is going to have to go well," says Arizona State University astronomer J. Jeff Hester. But Hester and his colleagues are willing to run the risk, in hopes that the space telescope will finally live up to its potential.

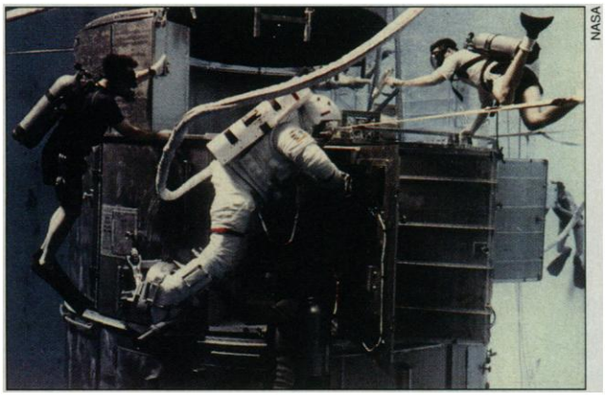
Lost in a fog. Astronomers had counted on the space telescope to show them planets around other stars and galaxies at the edge of the universe, but those dreams shattered soon after Hubble's 1990 launch. The images of distant stars and galaxies were blurred because of a tiny warp in the 2.4-meter main mirror. Although the contracting company that made the mirror, Perkin-Elmer in Danbury, Connecticut (now Hughes-Danbury), had spent many years making sure the shape was perfect, a faulty measuring device had thrown it off by 2.34 microns—no more than "the amount a human hair grows in an hour," says Frank Cepollina, who manages the repair project at the NASA-Goddard Space Flight Center in Greenbelt, Maryland.

Small as that sounds, all of the telescope's instruments are crippled by the fuzziness of images coming from the main mirror. "It's really bad," says astronomer Jon Holtzman of the Lowell Observatory in Flagstaff, Arizona. The two cameras—the Faint Object Camera and the WFPC—are hurt more than the spectrometers, and certain types of studies are hampered more than others. Worst off are observations of faint, distant objects—galaxies so far out in distance and time that they appear as they looked when the universe was just one-tenth its present age. Holtzman had to defer his plans "to see details in [galaxy] structure when they were young, when they were forming." Precise brightness measurements of individual stars—vital in efforts to use them as "standard candles" in calibrating cosmic distances—also suffered because the blur prevents Hubble instruments from measuring individual stars. "If you want to measure how bright a star is to 1% or 2% accuracy, you really can't do it," Holtzman says.

Less crippled are studies of bright objects, such as closer galaxies whose central stars are packed so tightly that astronomers believe they are clustered around massive black holes. Space telescope portraits of some of these ob-jects have made it onto newspaper front pages, but the dazzling images hide some disappointments, says Holtzman. With the current telescope, "it's always a black hole candidate," never a sure thing. The reason: Definitive evidence of the presence of a black hole would come from spectral measurements of the innermost stars. If those galaxies really do have central black holes, the stars should be whirling in a maelstrom, their high veloci-

ties evident in Doppler shifts in their spectra. But because of the telescope's faulty optics, such measurements are out of reach of the spectrometers.

Soon after these disappointments came to light, hope sprang from the prospect of repair. Luckily, the telescope was designed to be serviced. It's built to lock right into the cargo bay of the Space Shuttle while the astronauts go about replacing parts. The plan all along was to service the telescope in 1993, and again around 1997. Indeed, the telescope would be due for repairs by now even if its optics were perfect: Since its launch it has suffered from gyroscope and magnetometer failures, wobbly solar panels, and a handful of other ailments, all of which the astronauts will attend to in December.



Practice makes perfect? Astronauts rehearse the Hubble repair in a tank at the Johnson Space Flight Center in Houston.

In another saving grace, tests done before the scope was launched pinpoint the mirror's flaw, says astronomer Chris Burrows of the Space Telescope Science Institute. Through a complex series of errors, people who saw the results interpreted them as a problem with the test apparatus and ignored them, Burrows says. Now, however, they are coming in handy for making the right prescription for Hubble's correction.

The notion of correcting Hubble's vision by fitting it with eyeglasses came from a "strategy panel" of 17 scientists and engineers from inside and outside NASA assembled in 1990, soon after NASA realized with horror that its prize telescope was badly flawed. They examined a range of other possibilities—from heating and warping the mirror in space, to hauling the telescope back to Earth for repairs, to leaving it as it was. In the end, the panel decided on a set of 10 quarter-sized corrective mirrors—four each for the Faint Object Camera and Faint Object Spectrometer and two for the High Resolution Spectrometer. "There was general agreement that this was desirable but hard from an engineering point of view," says panel member Lyman Spitzer of Princeton University, the astronomer who first proposed a space telescope more than a quarter-century ago.

Installing and aligning the mirrors posed a special challenge, until one of the panel's engineers came up with the idea of packing them into a phone booth-sized apparatus dubbed COSTAR—for Corrective Optics Space Telescope Axial Replacement—and making room for it by taking away one of the scientific instruments. Fitted to the instrument chamber of the telescope, where light emerges from the main mirror (see diagram), COSTAR will hold each mirror in just the right position to capture and correct light on the way to three of the instruments. The fourth and primary instrument, the WFPC (the source of most of the pictures featured so far in the media), will be replaced. NASA had planned to build a backup for the camera anyway, so engineers came up with a plan for grinding a corrective prescription into the new camera's internal mirrors.

Work on COSTAR began in July 1991, when NASA farmed out the mirror grinding to an 80-person company known as Tinsley Labs. The completed mirrors—ground to strange shapes known as anamorphic aspheres—then went to Ball Aerospace, which mounted them in COSTAR's labyrinth of adjustable, motorized hinges and joints. The complex mechanism will keep the corrective mirrors stowed until COSTAR is installed, then pop them into position.

Breaking an incestuous cycle. To succeed at those technical fixes, NASA officials say they needed some organizational fixes as well—strategies for overcoming what NASA engineer Robert Lilly calls "the kind of incestuous cycle that got us in trouble before with contractors." NASA is still relying on contractors, but this time around, say project scientists, there will be no lack of oversight. Says Wood, "We've learned a lot out of this whole, horrible process—This time we're doing sanity checks—double sanity checks."

The makers of the corrective instruments, JPL and Ball Aerospace, are now doing their own testing, using light sources that imitate the fuzzy light coming from the telescope's faulty mirror to check that the corrective mirrors sharpen it properly. But NASA won't stop there. In June, the instruments will be tested on a life-sized mockup of key parts of the telescope, now painstakingly taking shape in the clean room at NASA-Goddard. "We have to locate the latches within four-thousandths of an inch—it's a bear," says Lilly, who heads up work on part of the simulation.

In June, the new wide-field camera and COSTAR will be installed in the mockup, and tests of their ability to work together with other parts of the telescope will begin. Engineers will check that both devices properly feed off the main mirror's light and search for stray light introduced by all these new mirrors. This kind of testing will continue for the months leading up to launch, says Lilly. "This gives us an independent way to make sure everything fits together in orbit," he says.

Come December, though, the engineers and scientists will have to step back and leave the risky business of installation to the astronauts, who will carry the prostheses into space aboard the Space Shuttle Endeavor. They will snag the telescope, lock it into the shuttle's open cargo bay, and, in 3 to 6 days of spacewalking, install the corrective optics along with new solar panels, gyros, and the various other replacement parts.

With luck, the corrective optics will slide smoothly into place like well-fitted dresser drawers. But if they jam, the outcome could be disastrous. If the guide rails that line the opening for the wide-field camera get bent, for example, the astronauts might not be able to put in the new camera. They'll be left with a "gaping hole," says Wood, which they will have to cover with a thermal blanket. There are potential pitfalls in other parts of the mission as well—the replacement of the solar panels, for example. "There is always a risk of damage," says Burrows of the Space Telescope Science Institute. And since the panels supply power to the Hubble, "in the worst possible case you could lose the telescope entirely."

The entire operation, says NASA-Goddard senior project scientist David Leckrone, is "like delicate surgery." And like a team of surgeons getting ready for an unprecedented operation, the 7-person crew is doing some intensive preparation. To simulate the weightlessness of space, crew members are training in swimming pools at NASA centers in Houston and Huntsville, Alabama, ferrying around duplicates of the heavy instruments and installing them in Hubble mockups. But in spite of all the precautions, crew member Story Musgrave says he expects the unexpected. "It will not go according to plan," he says. "I know that because I've been an astronaut for 26 years." Still, he says he's confident that they can pull it off.

Even if the mission itself goes smoothly, astronomers won't get their dreamed-of view of the heavens immediately. Working by remote control, NASA engineers will refine the optics by fiddling with the position and angle of the mirrors. "It will take several months before we get things lined up," says Wood. "This will not be an instant gratification thing."

And gratification, when it finally comes, won't be complete. NASA is attempting to absorb the $80 million cost of correcting the bad mirror—including COSTAR and the corrective elements in the new camera—within the budget for operations and main-

tenance of the telescope, says project scientist Ed Weiler of NASA headquarters. As a result, "people have made sacrifices" to get ends to meet, says Burrows. For example, he says, the new wide-field camera will span a field just three-quarters the size of the old one. There are other science losses, too; to fit COSTAR onto the scope, the astronauts will have to remove the high-speed photometer—a device useful for monitoring rapid brightness changes, such as pulsar pulses, nova explosions, and other stellar outbursts.

Despite the inevitable losses and the risk of still greater ones, most astronomers strongly favor the repair mission as planned. The risks of bringing the telescope back to Earth are even greater, they say. If a drop of oil spills on the main mirror somewhere in transit, for instance, it would be blinded, says Space Telescope Science Institute astronomer Tod Lauer—unable to reflect ultraviolet light. "When we [astronomers] think of taking the telescope down we get the same gut-level feeling that we get about pointing it at the sun," says Weiler. "It means death to the program either way." Weiler and other scientists say they believe they've convinced the panel not to pull their telescope back to Earth. "People will realize that we're doing this right," he says. "I'd be extremely surprised if they decided to take it back down."

–Faye Flam

PROPRIETARY RIGHTS

Scripps-Sandoz Deal Comes Under Fire

Just 2 months after the Scripps Research Institute signed a contract with Sandoz Pharma that would give the Swiss pharmaceutical company first rights to all Scripps technology in return for a total of $300 million in research support, the deal has come under investigation by federal authorities. In response to an angry letter from Congress, the National Institutes of Health (NIH) last week agreed to look into the propriety of the arrangement and the reasons why NIH had not been informed about the deal before it became final.

The Sandoz deal came under scrutiny after a 19 January editorial in the *San Diego Union Tribune* criticized the arrangement because it will give Sandoz rights to the fruits of federally funded research. When the contract takes effect in 1997, Sandoz will have right of first refusal to all Scripps technology over the following decade, including any technologies developed under NIH research grants (*Science*, 4 December 1992, p. 1570). Scripps currently gets about $100 million a year from NIH, which would add up to at least $1 billion over the 10-year period covered by the Sandoz deal. The deal, the *Union Tribune* charged, would allow Sandoz to achieve a "leveraged buyout of a $1 billion federal research effort."

"We're in full legal compliance with everything NIH requires."
–Richard Lerner

Scripps president Richard Lerner acknowledges that Sandoz is indeed getting the rights to federally funded results, but he points out that the Sandoz deal is similar to several others around the country. He notes that in 1991, for example, the Dana-Farber Cancer Institute struck a similar deal with Sandoz to exchange intellectual property rights for research funds, and in 1990 another Swiss drug company, CIBA-GEIGY, agreed to set up a new arthritis research program at the University of California, San Diego, in exchange for exclusive licenses. In both those examples, however, the drug companies have exclusive access only to the research they sponsor, but Lerner argues that his approach avoids situations in which drug companies "cherry pick" and steer their support toward the most applied research at the institutions. At Scripps, he says, researchers will continue to pursue whatever topics they see fit.

The *Union Tribune* editorial got the attention of Representative Ron Wyden (D–OR). In a 2 February letter to NIH Director Bernadine Healy, Wyden charged that when the agreement takes effect, "in essence, Scripps becomes a [federally subsidized] Sandoz laboratory." What is "most troubling about this deal" he wrote, was that NIH had not reviewed, nor, apparently, had an opportunity to review the deal before it was signed. He asked NIH to investigate the arrangement and to respond to a list of questions about it.

NIH spokeswoman Johanna Schneider says Healy "shares Congressman Wyden's concerns about the entire arrangement....It's troubling. We want to look into it immediately." In particular, she says, NIH's general counsel will examine whether any mechanisms exist for a federally funded institution such as Scripps to notify NIH of planned ties with industry and, if none is found, will investigate the possibility of creating such a mechanism. "We're in full legal compliance with everything NIH requires," Lerner responds. Scripps had not informed NIH about the arrangements, he says, because "we wouldn't have even known who to inform." NIH is expected to finish its review of the case later this month.

–Christopher Anderson

AIDS RESEARCH

Shalala Backs Reorganization

Testifying at her first congressional hearing since being appointed, Secretary of Health and Human Services (HHS) Donna Shalala last week put the Clinton Administration prominently on record in support of a proposal to revamp the National Institutes of Health's (NIH) Office of AIDS Research (OAR). The proposal, contained in legislation now before the Senate, has drawn fire from some scientists and NIH officials who contend that it would add another layer of bureaucracy to AIDS research (*Science*, 5 February, p. 753).

Slipped into the bulging NIH reauthorization bill, the Senate proposal aims to improve planning and coordination of AIDS research at the 21 NIH institutes by strengthening OAR's authority over NIH's AIDS budget and establishing a discretionary fund for the OAR director to use as he or she sees fit. (The House has yet to introduce a similar amendment.)

Opponents of the Senate bill include the NIH directors, who on 22 January sent a memo to NIH Director Bernadine Healy spelling out their fears that the budget process would be "severely disrupted" by the proposed changes, which "may inadvertently be detrimental" to AIDS and non-AIDS research. Healy sent the memo along to Shalala. Both NIH and HHS had held this memo close to the vest, but Shalala quickly agreed to release it when members of the House subcommittee on health and the environment asked her about it during her 3 February testimony.

Shalala told the subcommittee, which is chaired by Representative Henry Waxman (D–CA), that while she doesn't believe that "a reorganization alone will yield improvements in science necessarily," HHS supports the bill because it hopes that a fortified OAR will provide "a clearer view of where we're going." And Shalala stressed that if the move backfires and impedes AIDS research, "we will be the first ones back here at this table to tell you that we have a structure that doesn't work."

Prominent scientists outside NIH have lined up on both sides of the issue, offering Congress impassioned testimonies of their own, but a staffer for Waxman believes a bill can be hammered out that will be acceptable to both sides. "Most parties don't seem that far apart," he says. The staffer says Waxman likely will introduce a more concrete plan for restructuring OAR when the House subcommittee marks up the NIH reauthorization bill during the week of 15 February. The Senate is expected to vote on its version of the bill during the same week.

–Jon Cohen