NASA Facts

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Corrective Optics Space Telescope Axial Replacement (COSTAR)

Background

When the spherical aberration was discovered in the primary mirror of the Hubble Space Telescope (HST), NASA established a panel consisting of astronomers, engineers, opticians and astronauts from U.S. and European institutions and selected for their experience in optics, HST systems, space operations and large optical telescopes. The panel evaluated dozens of proposals on how to "fix" the mirror error and selected COSTAR (Corrective Optics Space Telescope Axial Replacement). The corrector system in COSTAR was based on a proposal by the late Dr. Murk Bottema, of Ball Aerospace, Boulder, Colo. The panel of experts made its recommendations to NASA in December 1990. In January 1991, NASA selected Ball Aerospace as the prime contractor. Ball was selected, according to NASA officials, because it had been involved with HST for more than 15 years and had firsthand experience with the scientific, technical and programmatic demands of the project. Ball was given only 26 months to complete the project.

Description

The idea of COSTAR can best be described as placing eyeglasses in front of each of the instruments, except COSTAR uses mirrors rather than lenses. The aberration in HST causes light from different parts of the primary mirror to come to focus at different places. Much as eyeglasses correct the aberration of the lens of the eye, COSTAR optics, or mirrors, correct for the optical errors of the primary mirror. HST was designed to provide for installation of new science instruments over its 15-year life by a series of servicing missions. The COSTAR package, about the size of a telephone booth, will replace the High Speed Photometer (HSP) on Hubble. The HSP measures rapid brightness variations in stars. HSP was the least used instrument on HST and the logical choice for sacrifice, officials explained. Once COSTAR is installed, a tower will emerge from the COSTAR enclosure upon ground command from the Goddard Space Flight Center's Space Telescope Operations Control Center (STOCC) in Greenbelt, Md. This tower, called the Deployable Optical Bench (DOB), contains mechanical arms designed to place and align the "eyeglasses" precisely for each of the three scientific instruments COSTAR will support—the Faint Object Spectrograph (FOS), Faint Object Camera (FOC) and the Goddard High Resolution Spectrograph (GHRS). The mirrors range in size from about the size of a dime for the FOS to the size of a quarter for the FOC.

With the exception of the GHRS, each of the instruments to be corrected by COSTAR has two apertures for two channels and requires two mirrors each, one a simple spherical shape and one a little more complex shaped with the corrective prescription. Because GHRS has only one aperture for both channels, a single pair of mirrors is able to correct both channels. As a result, 10 corrective mirrors are required to deliver high-quality images to the six channels of the three scientific instruments.

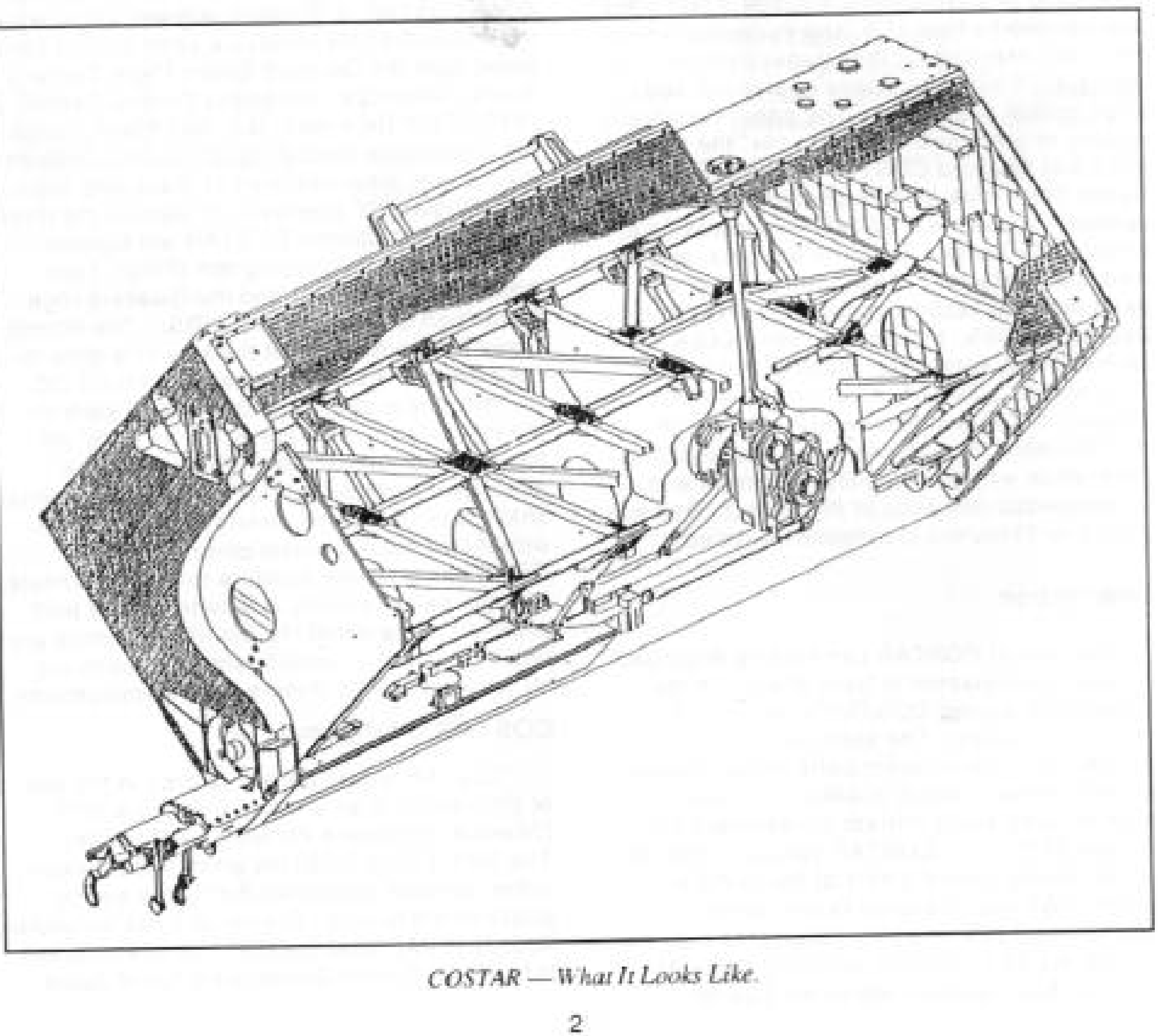
COSTAR Changeout

COSTAR will be carried to orbit in the bay of Endeavour in an enclosure called a SIPE (Science Instrument Protective Enclosure). The SIPE keeps COSTAR warm and provides some vibration protection during the ascent phase of the launch. During an Extra Vehicular Activity (EVA), after the HST has been docked to the Flight Support System in the bay of Space

Shuttle Endeavour, astronauts in space suits will open the aft bay access door on HST, disconnect the electrical connectors on the HSP and, using a ratchet tool, disengage the latches that hold the HSP in position. The astronauts slide the HSP out and place it in a temporary holding fixture while COSTAR is removed from the SIPE. COSTAR then is moved toward the HST by an astronaut riding on the robot arm. Once at the aft bay, a protective cover will be removed, and COSTAR will be inserted into the HST using guide rails. The power ratchet tool is used to engage the latches and electrical connections on COSTAR. Before the aft bay door is closed, Goddard ground controllers will verify that the electrical connections are fully mated. A more complete series of tests will be run overnight during the crew sleep period. The HSP will be returned to the COSTAR SIPE and then be returned to Earth.

How Do We Know It Will Fit?

The assurance that COSTAR could be placed into HST was a key factor in its selection as the method for correcting the telescope's spherical aberration. This assurance rests on the fact that the HST science instruments were designed from the beginning to be replaced by instruments with more advanced technology over the 15-year life-span of HST. Thus, the mechanical and electrical connections were designed to be changed out in orbit. Key pieces of hardware, the ASIS (Axial Science Instrument Simulator) and the ABS (Axial Bay Simulator), were used to verify the instruments currently on HST and likewise were used to verify COSTAR. In addition, a replica of the aft end of the telescope, known as the High Fidelity Mechanical Simulator, has been constructed at Goddard. The simulator will hold both the



COSTAR — What It Looks Like.

COSTAR and the second-generation Wide Field/Planetary Camera, also to be installed in the HST, and both will be given final fit checks in that simulator simultaneously.

How Do We Know We Got The Prescription Right This Time?

The assurance rests with NASA's knowledge of what the actual aberration in the HST mirror is. Experts have determined this error in two independent ways. First, the tooling for the HST mirror was still in place at the mirror's manufacturer. Measurements of the setup confirmed that an error had been made in the setup and provided a precise value of the error. An independent group of scientists and engineers calculated the error by evaluation of actual images taken by HST in orbit. When these two values were compared, they showed excellent agreement. To further ensure accuracy, these data were distributed to several independent groups using different methods to determine the optical prescription.

This knowledge of what prescription is required, however, is only the first step. Each of the new optical elements was subjected to two different and independent tests to verify the correct prescription while still at the manufacturers. After the optics were installed, COSTAR was placed in a device called the CAS (COSTAR Alignment System). That system was used to ensure that the mirrors were in the correct place and had the proper shape. Had there been an error in the CAS, there also could be an error in COSTAR that would go undetected. To eliminate this possibility, a device called HOMS (Hubble Opto-Mechanical Simulator) was constructed. This device simulated the aberrated HST optical system. The COSTAR was latched into the HOMS exactly as it will be latched into the HST on orbit. The HOMS has been checked and cross-checked to ensure the optical prescription matches the HST and to ensure the COSTAR is held exactly like it will be held on orbit. The HOMS first was verified by Ball Aerospace using an image analyzer and interferometer. Later, an independent team from Goddard using an ABA (Aberrated Beam Analyzer) confirmed the Ball measurements. As a second independent check, the European Space Agency (ESA) provided an engineering model of the Faint Object Camera. This exact copy of the instrument permitted optical experts to view the optics just as they would be in the flight FOC. After evaluation, these images match the aberrated on-orbit images. The COSTAR then was placed in the HOMS, and the corrected images demonstrated that COSTAR has the proper correction and alignment.

Challenges

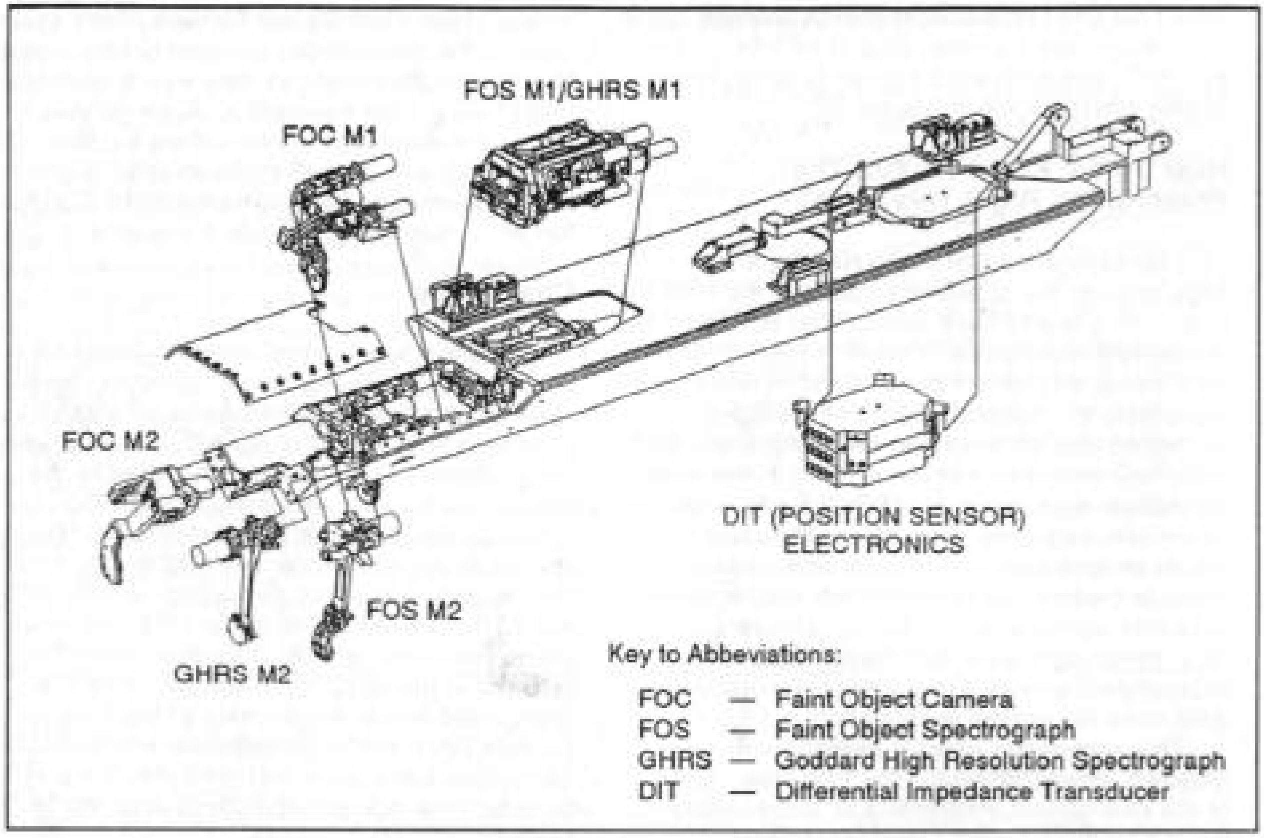
The most challenging areas of COSTAR development were the optics, the short development schedule and the small packaging volume available for the optics. The short development cycle, 26 months, included the design, production, assembly and testing. The schedule was extremely demanding but necessary to support the schedule for the first servicing mission. The small packaging volume was due to the limited space in the HST hub area, where the correctors must be deployed. This resulted in the need for miniature motors to deploy and adjust the position of each mirror. To date (May 1993), all technical and schedule milestones have been met, and officials are confident the mission objectives also will be met.

Cost

The total cost of COSTAR development will be $50 million. This represents a small percentage (3%) of the cost to build HST. The mission to fix HST already was planned as one of the routine servicing missions to keep HST operational during its 15-year lifespan. No additional funds were requested to fund COSTAR development. The necessary funds were obtained by rearranging HST program priorities and instrument development efforts within the planned budget.

Life Expectancy

COSTAR is designed to last as long as the expected life of the instruments it is to correct. The current plan is to replace two of these in the 1997 mission and another instrument on the 1999 servicing mission. The new instruments will have a WF/PC II-type correction built into their optical systems.



COSTAR Deployable Optical Bench Assembly.