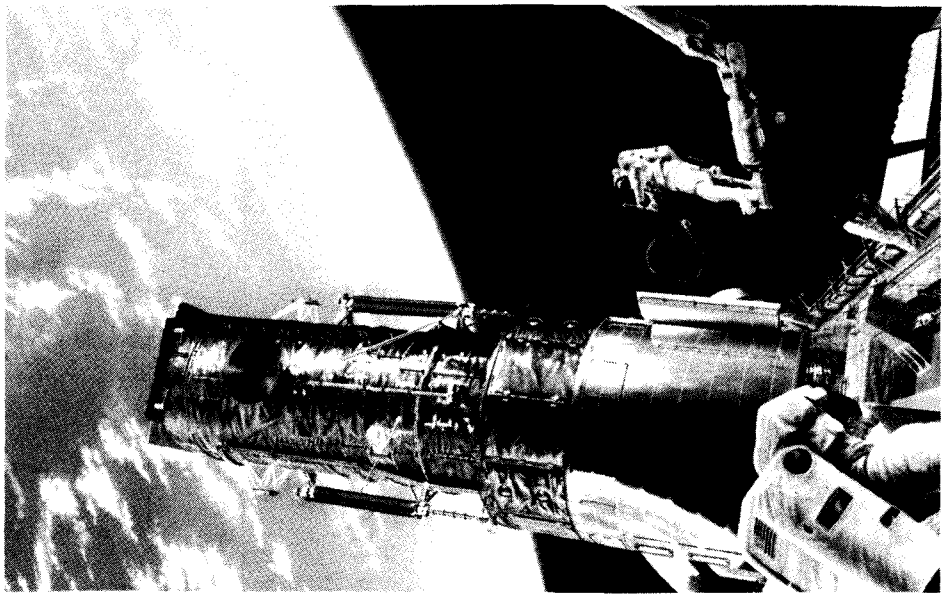
Special Edition

NASA
National Aeronautics and Space Administration
Goddard Space Flight Center

Goddard News

Greenbelt, Maryland / Wallops Island, Virginia HST 1993

NASA embarks on historic Hubble First Servicing Mission



This artist conception shows STS-61 astronauts installing the Corrective Optics Space Telescope during the first Hubble Space Telescope (HST) Servicing mission.

Goddard employees take part in history making mission

The launch of the Hubble Space Telescope on April 24, 1990, was an historic event — the biggest and best observatory of its kind ever launched into orbit. Goddard and the many employees who have worked on the project will rub shoulders with history once more with the First Servicing Mission scheduled for December 1993.

The record-setting STS-61 mission will cover 12 days, including five days of astronaut spacewalks to service the space telescope on orbit. It will be the most complex and challenging mission ever undertaken by NASA. This Special Issue of the Goddard News is dedicated to that enterprise, and to the men and women who have devoted themselves to it.

The Hubble Space Telescope (HST) servicing mission is the most difficult and challenging satellite servicing mission NASA has ever attempted. It includes more spacewalks than ever before planned for a mission of this type. In addition, many of the servicing tasks are complex and all must be performed in a limited amount of time.

The primary objective of the Hubble Space Telescope (HST) First Servicing Mission is to correct for the spherical aberration in HST's primary mirror and replace faulty solar arrays. While NASA views this mission as difficult, it must be remembered that Hubble was designed for servicing in space. NASA expects the preplanned servicing tools and techniques to result in a smoother running operation.

The major constraint on NASA's ability to service the space telescope on this mission is the amount of work that can be completed during the planned space shuttle flight. The current plan calls for at least five days of Extra Vehicular Activity (EVA) servicing, a day to redeploy HST and another day to assure the safe return of the space shuttle. This amount of on-orbit work time provides for two optical fixes—the Wide Field Planetary Camera II (WF/PC II) and the Corrective Optics Space Telescope Axial Replacement (COSTAR), and replacement of the solar arrays, two gyros, two magnetometers, one solar array drive electronics box and the installation of a co-processor on the flight computer.

The Hubble Space Telescope First Servicing Mission is scheduled to begin in early December with the early morning launch of the Space Shuttle Endeavour. The orbiter will rendezvous with Hubble on the third day of the mission. At that point, HST will be captured and secured in an upright position in the shuttle's cargo bay for servicing. Working in pairs, on alternating days, STS-61 EVA crew members are expected to spend at least five 6-hour spacewalks performing repairs.

Mission Objectives and Success

The three objectives of the first Hubble servicing are to restore planned scientific capabilities of the telescope, reestablish reliability of the HST systems and subsystems and to validate that the concept of on-orbit servicing of the space telescope is viable.

The top priorities are installation of the replacement Solar Arrays, two Rate Sensor Units, Wide Field/Planetary Camera II (WF/PC II); Corrective Optics Space Telescope Axial Replacement (COSTAR), at least one new Magnetic Sensing System and a new Solar Array Drive Electronics (SADE) unit.

The minimum criteria for mission success are to leave HST with three reliable gyroscopes and either an operational WF/PC or COSTAR.

Planning for the first servicing mission has emphasized being

Continued on page 2

Hubble Space Telescope designed for on-orbit servicing

Launched on April 24, 1990, NASA's Hubble Space Telescope (HST) was designed to be the most powerful astronomical observatory ever built. HST also was designed for on-orbit servicing and built to last 15 years.

And, indeed, HST far surpasses the capabilities of ground-based optical telescopes for many types of research. The keys to Hubble's power are its operation in space, far above the interference the Earth's atmosphere, and to the unique instruments it carries as it orbits the planet.

But while the launch on the Space Shuttle Discovery more than three years ago was flawless, Hubble was not. Two months after HST was deployed into orbit 370 miles (595 kilometers) high, Hubble produced a disquieting discovery not about space, but about itself: the curvature of its primary mirror was slightly—but significantly—incorrect. Near the edge, the mirror is too flat by an amount equal to 1/50th the width of a human hair.

A NASA investigative board later determined that the flaw was caused by the incorrect adjustment of a testing device used by the contractor that built the mirror. The device, called a "null corrector," was used to check the mirror curvature during manufacture. The NASA board determined that the defect was known by the contractor but discounted as a flaw in the test rather than in the mirror, and the space agency was not told about it.

The result is a focusing defect, or spherical aberration. Instead of being focused into a sharp point, light collected by the mirror is spread over a larger area in a fuzzy halo. Images of extended objects, such as stars, planets and galaxies, are blurred.

NASA has been coping with Hubble's fuzzy vision with computer processing to sharpen images. For bright objects, this technique has yielded breathtaking detail never seen from the ground. NASA also has been concentrating on the analysis of ultraviolet light, which ground-based telescopes cannot see because of the Earth's intervening atmosphere.

To realize the full potential of HST, however, the spacecraft must be serviced. The telescope mirror itself cannot be fixed or changed. But corrective optics can be applied to the HST instruments to compensate for the aberration, much the same as glasses or contact lenses correct human sight. The new optics should allow Hubble to focus about 60 percent of the light it collects compared to the 15 percent it now focuses. The original design had called for focusing 70 percent.

The mission, though, will accomplish much more than improved vision. Hubble was designed to spend 15 years in space. Even before the spherical aberration was known, several servicing missions, including one in 1993, had been planned so that—like on a car—failed parts could be replaced and others improved with newer and better technology. This mission will perform that type of servicing in addition to installing corrective optics.

Endeavour will carry some 16,000 pounds (7,300 kilograms) of servicing hardware into space. During nearly two weeks in orbit around the Earth, astronauts will use the shuttle as a kind of orbiting service station from which they will venture to work on the 12.5-ton (11.35-metric ton) telescope as it hurtles around the planet at 18,000 miles (29,000 kilometers) an hour. The crew will spend some 30 hours in space during at least five separate spacewalk periods, undertaking a series of tasks more complex than any ever attempted in orbit, to ensure that Hubble remains a viable and productive national resource throughout its planned 15-year lifetime.

Goddard's STOCC: Hubble's operational nerve center

Goddard's Space Telescope Operations Control Center (STOCC) is the nerve center of the Hubble Space Telescope (HST). Even though the telescope will be berthed to the Space Shuttle Endeavour during the servicing mission, the STOCC will be a very busy place — all commanding of the HST during STS-61 will originate from Greenbelt, Md., in this facility.

The heart of HST's ground system is the Mission Operations Room, which is located within the STOCC. From this room, space telescope project managers and engineers control the orbiting observatory and maintain an around-the-clock vigil from an array of consoles.

In addition to issuing all commands to the HST, data gathered by the spacecraft arrive in the STOCC first. The commands to HST from the STOCC STS-61 will include:

- configuring the space telescope for retrieval by the space shuttle.
- integrating commands with crew activities during Extravehicular Activities (EVAs) to configure various spacecraft hardware and perform hardware checkouts.
- configuring HST for deployment from the orbiter.

First Servicing Mission

Continued from page 1

prepared for both the expected and unexpected. The STS-61 spacewalk teams underwent the most extensive Extra Vehicular Activity (EVA) training ever in both water tanks and simulators, including the first virtual-reality simulator at the Johnson Space Center, Houston, Texas, rehearsing both scheduled tasks and potential contingencies. Lessons learned from spacewalks conducted on three shuttle flights earlier this year were incorporated into the mission planning.

To further emphasize flexibility and adaptability, the STS-61 EVA tasks are arranged in a modular fashion and can be reworked as necessary during the mission. One day of the mission can be used anywhere in the flight plan, and there are opportunities for three additional EVAs if required, two for Hubble servicing and one for a shuttle contingency.

Goddard manages HST for NASA's Office of Space Science. At Goddard, Joe Rothenberg, Code 440, is the HST associate director; Dr. David Leckrone, Code 600, is the HST senior scientist; and Frank Cepollina, Code 442, is the project manager for HST flight systems and servicing.

Hubble Space Telescope Science Accomplishments

Despite the flaw in the primary mirror, the Hubble Space Telescope still has been able to gather a wealth of scientific data, most of which would have been impossible to collect if the telescope did not exist. In the last three years, HST has conducted a variety of scientific investigations that have rapidly expanded our knowledge of what lies beyond the Earth, from the relatively nearby planets in our own solar system to the most distant reaches of the universe.

Hubble's studies have ranged from our neighbor Mars, to the evolution of stars from birth to death, to the characteristics of galaxies beyond our own, and finally, to a field known as cosmology, which probes the fundamental nature of the universe itself.

The following is a small sampler of some of Hubble's discoveries and work in progress:

THE PLANETS

Prior to the servicing mission, Hubble was conducting long-term observations of global weather changes on Mars. It was observing the development of a rare, planet-wide storm on Saturn. The telescope also resolved, as two distinct objects, the most distant planet in the solar system, Pluto, and its moon, Charon. Previously, no telescope had been able to separate the two bodies.

HST also has been studying long-term weather changes on Jupiter and its auroral activity. Hubble has been measuring the extent of the atmosphere of the Jovian moon Io and also has looked for changes in the satelliteís surface.

STELLAR EVOLUTION

Hubble uncovered the strongest evidence yet that many stars form planetary systems. This evidence was the discovery of disks of dust around 15 newly-formed stars in the Orion Nebula, a starbirth region 1,500 light-years away. Such disks are considered a prerequisite for the formation of solar systems like our own. The HST images confirm more than two centuries of speculation, conjecture and theory about the genesis of a solar system.

STAR CLUSTERS

HST discovered young globular star clusters at the core of a peculiar galaxy. The discovery of these stars early in their evolution was the equivalent of finding a "Jurassic Park" in space, according to astronomers.

The space telescope found "blue straggler" stars in the core of globular cluster 47 Tucanae, providing evidence that some stars "capture" others and merge with them.

GALAXIES

HST uncovered circumstantial evidence for the presence of a massive black hole in the core of the neighboring galaxy M32 as well as the giant elliptical galaxy M87. Both galaxies have a central concentration of starlight that probably is shaped by the gravitational field of the black hole. This implies that massive black holes may be quite common among "normal" galaxies, perhaps even our own.

Hubble yielded direct evidence for galaxy evolution by resolving the shapes of galaxies that existed long ago. HST revealed that many ancient spiral galaxies have since disappeared, possibly through fading, or collisions and mergers with other galaxies.

COSMOLOGY

The Hubble Space Telescope allowed astronomers to take a major first step in redetermining the rate at which the universe is expanding. HST detected 27 stars called Cepheid variables; these stars are "standard candles" for estimating distances to galaxies. The expansion rate, known as the Hubble Constant, is one of two critical numbers needed for making a precise determination of the size and age of the universe.

HST discovered boron, the fifth lightest element, in a very ancient star. This star would have been one of the earliest formed after the Big Bang explosion that most scientists believe began our universe. If boron was produced in the first few minutes of the birth of the universe, it implies that the Big Bang was not a uniform explosion.

Hubble precisely determined the ratio of deuterium to hydrogen in interstellar gas clouds. This value shows that the universe has only 6 percent of the matter required to prevent itself from expanding forever.

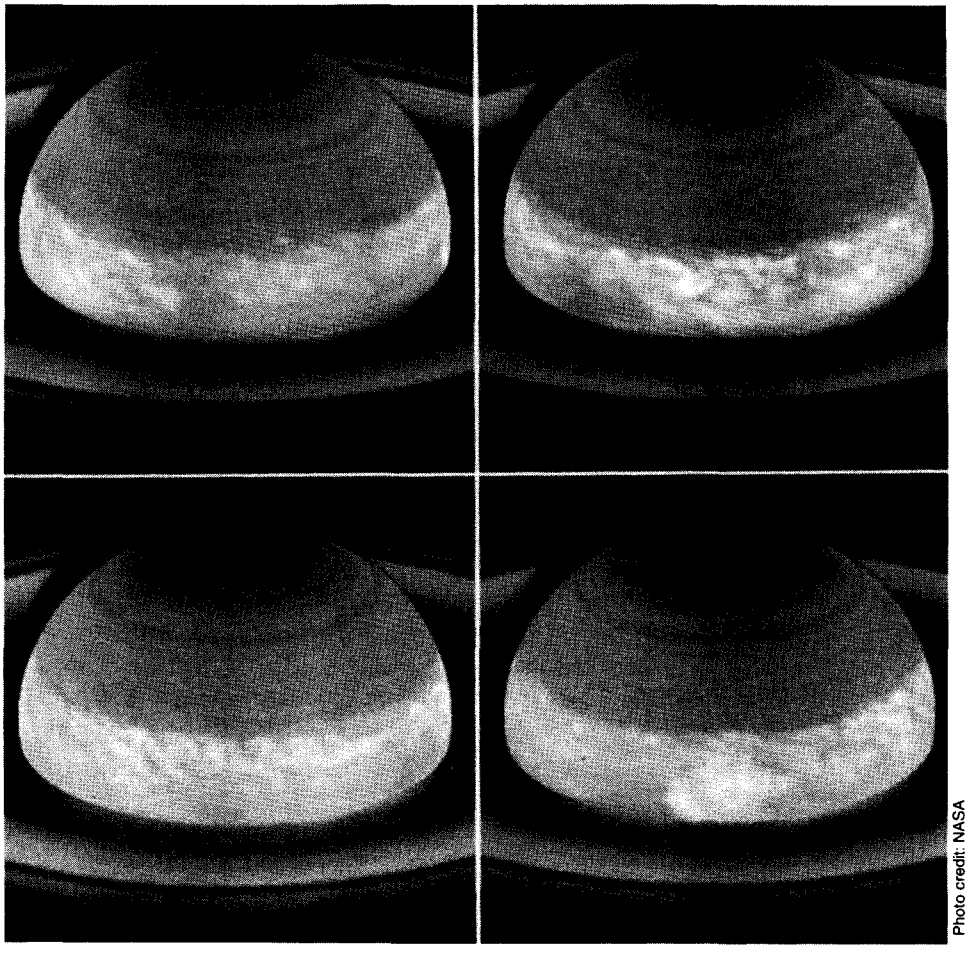


Photo credit: NASA

Saturn Storm

These images are part of a 24 frame sequence taken by the Hubble Space Telescope. The images were taken with the Wide Field/Planetary Camera (WF/PC).

Hubble: First S

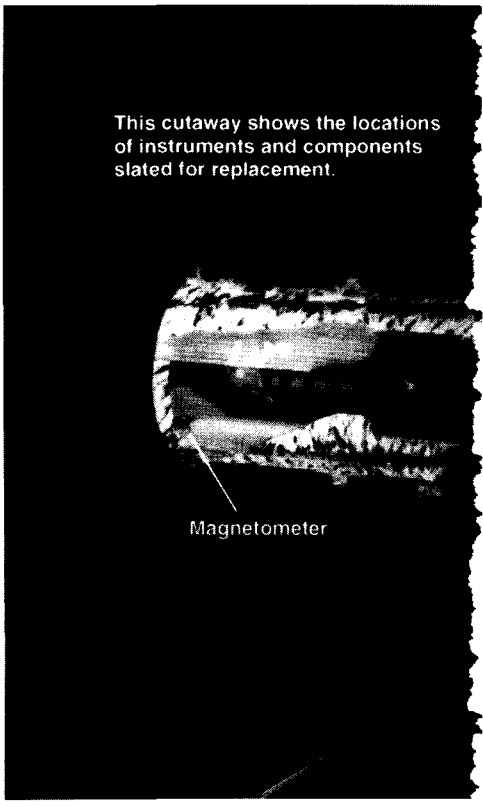
NASA

Payload commander F. Story Musgrave practices with the Goddard Power Wrench. This tool may be used in the manual and power modes. Power will automatically shut off if the motor is over heated.

Interesting facts about the Hubble Space Telescope

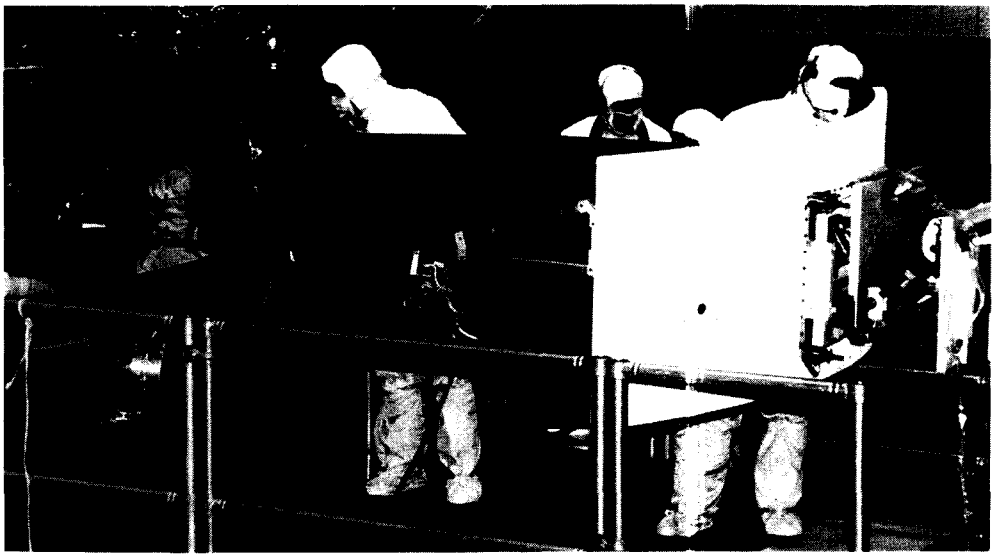
DID YOU KNOW...

- The spherical abberation of the primary mirror is only 1/50th the width of a human hair.
- The 12.5-ton (11.35-metric ton) spacecraft is one of the heaviest civilian satellites ever deployed by a shuttle. The heaviest was the 17-ton (15.42 metric ton) Compton Gamma-Ray Observatory, launched in April 1991.
- To aid in servicing missions, some 16,000 pre-launch photos were taken of Hubble.
- To prepare for their spacewalks, astronauts spent 400 hours practicing the servicing mission underwater.
- The spacecraft carries 16,000 pounds (7,300 kilograms) of hardware.
- Astronauts will have more than 200 crew aids and tools with them in space to work on Hubble.
- Each instrument installed or replaced on the spacecraft will be put into place to within 1/6,000th of an inch of specifications.
- STS-61 will be one of the two highest shuttle missions ever flown — 380 miles (611.55 kilometers). The other high-flying mission was the one to deploy Hubble in 1990 — 377 miles (607 kilometers).
- Hubble has some 225 feet (68 meters) of handrails and tether points for astronauts to use.
- If an emergency, such as a cabin pressure leak, developed during an EVA, the astronauts have 20 minutes to clear the payload bay and start their decent back to earth.



BDM

Hubble Spa

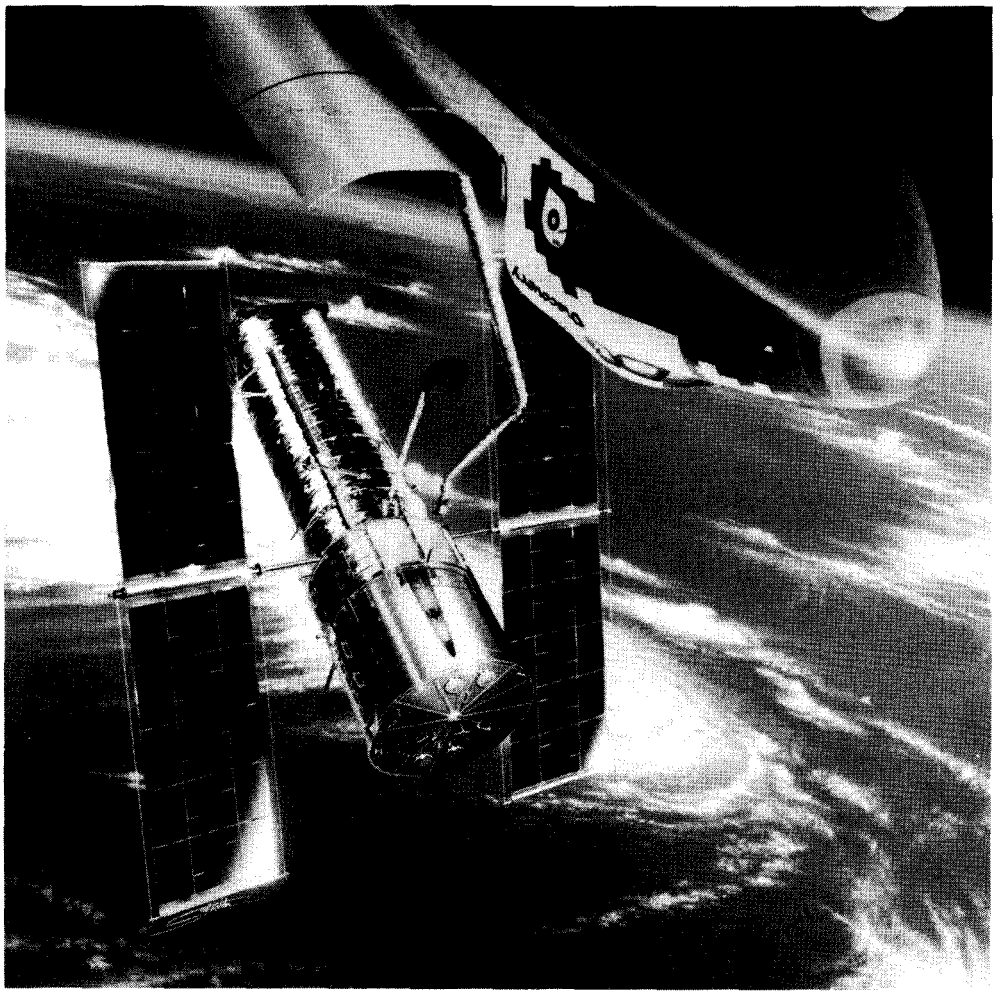


NASA

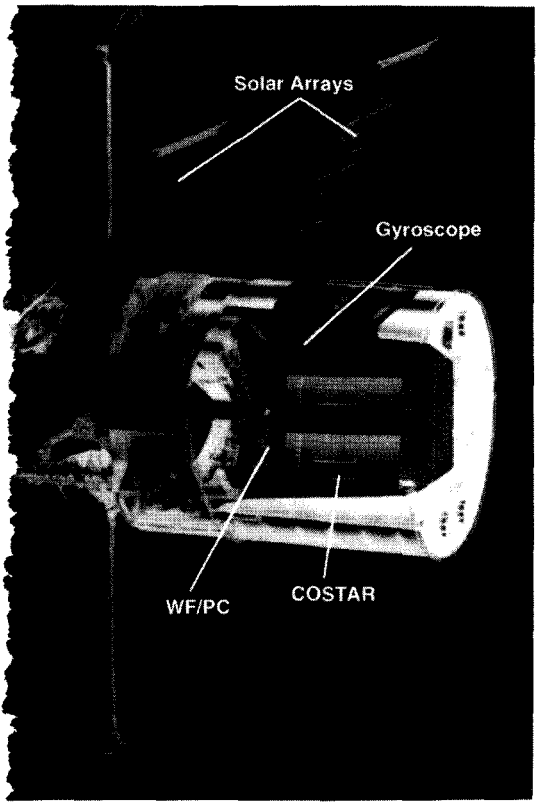
Technicians install the Wide Field/Planetary Camera II in a High Fidelity Mechanical Simulator in the Building 29 cleanroom at Goddard.

ervicing Mission

The Hubble Space Telescope being launched from the cargo bay of Space Shuttle Discovery in April 1990.



Ball Corporation

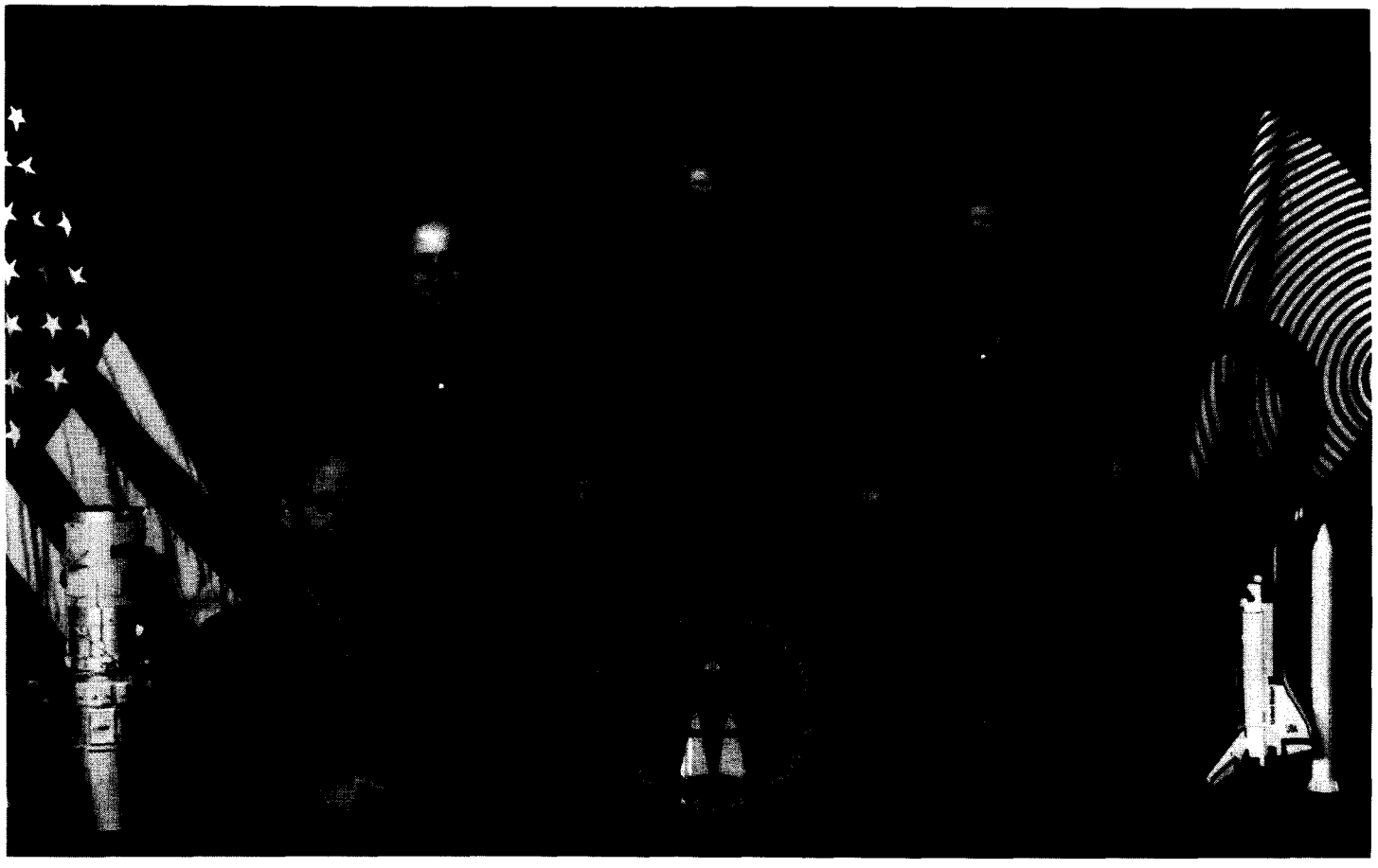


ace Telescope

BDM

This artist rendering shows STS-61 astronauts installing the new Wide Field Planetary Camera (WF/PC II) during the Hubble Space Telescope First Servicing Mission.

STS-61 Crew "hand-picked" for mission



Crew of STS-61

Standing from left to right are mission commander Richard Covey and mission specialists Jeffrey Hoffman and Thomas Akers. Seated left to right are pilot Kenneth D. Bowersox, mission specialist Kathryn Thornton, payload commander F. Story Musgrave and mission specialist, Swiss scientist Claude Nicollier.

The seven-member crew for STS-61 has been carefully selected by NASA officials for the experience and skills they can bring to bear on the Hubble mission. All have flown on previous missions that involved either extensive spacewalking activities or the capture and deployment of various types of spacecraft.

Mission Commander is Richard O. Covey (Col., USAF). In his three previous flights, Covey participated in the on-orbit rendezvous and repair of the SYNCOM IV-3 satellite (51-I), return-to-flight (STS-26) and the first orbiter landing at Kennedy Space Center, Fla., since 1985 (STS-38).

Pilot Kenneth D. Bowersox (Cmdr., USN) flew on Mission STS-50, which at the time was the longest shuttle flight. **Payload Commander is F. Story Musgrave (M.D.),** making a record fifth flight aboard the shuttle. He was one of the first astronauts to perform an Extra Vehicular Activity (EVA) from the shuttle, and helped plan EVA activities during the STS-49/INTELSAT rescue mission in 1992.

Musgrave and **Mission Specialist Jeffrey Hoffman (Ph.D.)** make up one of the two EVA teams. Like Musgrave, Hoffman is well-versed in extravehicular activity. On his first shuttle flight (51-D), he made the first contingency spacewalk in the shuttle program. STS-61 will be his fourth spaceflight.

Making his second trip into space is **Mission Specialist Claude Nicollier** of the European Space Agency. He will work extensively throughout the mission with both EVA teams, as it is his responsibility to operate the orbiter's Remote Manipulator System arm. The robot arm will be used to snare and berth Hubble, to support the astronauts during the EVAs and release the telescope once servicing is complete. In the event the arm becomes unavailable, the crew has been trained to perform all HST servicing tasks without it.

The second EVA team members, **Mission Specialists Tom Akers (Lt. Col., USAF) and Kathryn C. Thornton (Ph.D),** flew together on Mission STS-49, during which they performed a space walk together. Both are making their third trip into space. Thornton also has flown with Musgrave, while Nicollier and Hoffman are former crew mates.

Astronauts will conduct five EVAs during servicing mission

NASA

STS-61 astronaut inspects a solar array on the Hubble Space Telescope mockup in the Neutral Buoyancy Simulator at the Marhall Space Flight Center, Huntsville, Ala.

Some of the most spectacular sights during STS-61 will be had during the five spacewalks planned for the servicing mission. The astronauts trained for more than 400 hours under water to prepare for these events. Depending on the launch date, the Extra Vehicular Activities (EVAs) will begin between 10 p.m. and midnight EST and are expected to last at least six hours each.

The EVA teams, composed of two astronauts, will rotate EVA assignments, with each team taking one day. Astronauts Story Musgrave and Jeffrey Hoffman make up one of the two EVA teams. The second EVA team members, Mission Specialists Tom Akers and Kathryn Thornton, flew together on Mission STS-49, during which they performed a spacewalk together.

Plans call for Endeavour to rendezvous with Hubble on flight day three. Once the bus-sized telescope has been grappled by the Remote Manipulator System (RMS) arm and berthed upright on the Flight Servicing Structure (FSS), it will be transferred to orbiter power while its batteries are charged. The targeted EVA sequence, subject to adjustment, is as follows:

EVA #1, Flight Day 4, Musgrave and Hoffman. Replace two Rate Sensor Units (RSUs), each housing a pair of gyroscopes; prepare the Solar Array Carrier for the next day; replace the RSU Electronic Control Units (ECUs), and install new electrical fuse plugs.

EVA #2, Flight Day 5, Thornton and Akers. Remove and replace the original solar arrays with a redesigned pair of spares. The design of the originals does not adequately accommodate thermal contraction and expansion resulting from moving in and out of daylight, creating an unwanted jitter. The spares, redesigned by the European Space Agency, will reduce the jitter to an acceptable level.

EVA #3, Flight Day 6, Musgrave and Hoffman. Remove and replace the Wide Field/Planetary Camera (WF/FC) with WF/PC II, a second generation version of the original which was already being developed when HST was launched. Corrective optics were added to compensate for the spherical aberration in the Hubble primary mirror. Designed to be installed like a giant, wedge-shaped drawer, WF/PC II has three wide field cameras for imaging wide swaths of the universe, and one planetary camera able to capture in a single exposure the entire face of a planet. Two Magnetic Sensing Systems also will be replaced.

EVA #4, Flight Day 7, Thornton and Akers. Install the Corrective Optics Space Telescope Axial Replacement (COSTAR). COSTAR will replace the High Speed Photometer, which does proportionately less observations than any of the other four Hubble instruments. COSTAR employs a series of 10 corrective mirrors to compensate for the primary flaw in light entering the remaining three of Hubble's observing instruments: the Faint Object Camera (FOC), the Faint Object Spectrograph (FOS) and the Goddard High Resolution Spectrograph (GHRS). With the corrective optics, the FOC will be able to image very faint objects, and the FOS will be able to produce spectra of extremely faint astronomical sources. The GHRS will be able to record ultraviolet spectra with even greater sensitivity, picking out individual stars in crowded fields. A co-processor to augment the computer memory and speed of some operations on the Hubble DF-224 computer also is scheduled to be installed during this EVA.

EVA #5, Flight Day 8, Musgrave and Hoffman. Replace one Solar Array Drive Electronics (SADE) unit, install the GRS redundancy kit; and deploy the new solar arrays.

When the Akers-Thornton team is performing an EVA, Musgrave will serve as the Intra Vehicular (IV) astronaut, directing the EVA team from inside Endeavour. Tom Akers will perform the IV function for the Musgrave-Hoffman EVA team. Each EVA is scheduled to last about six hours.

On Flight Day 10, Hubble will be redeployed. A landing at Kennedy Space Center, Fla., is targeted for Flight Day 12. Some seven to nine weeks of checkout, calibration and alignment must be performed on the Hubble Spacecraft and instruments before the first corrected images can be produced.

All in a days work: Astronaut training includes more than 100 tools

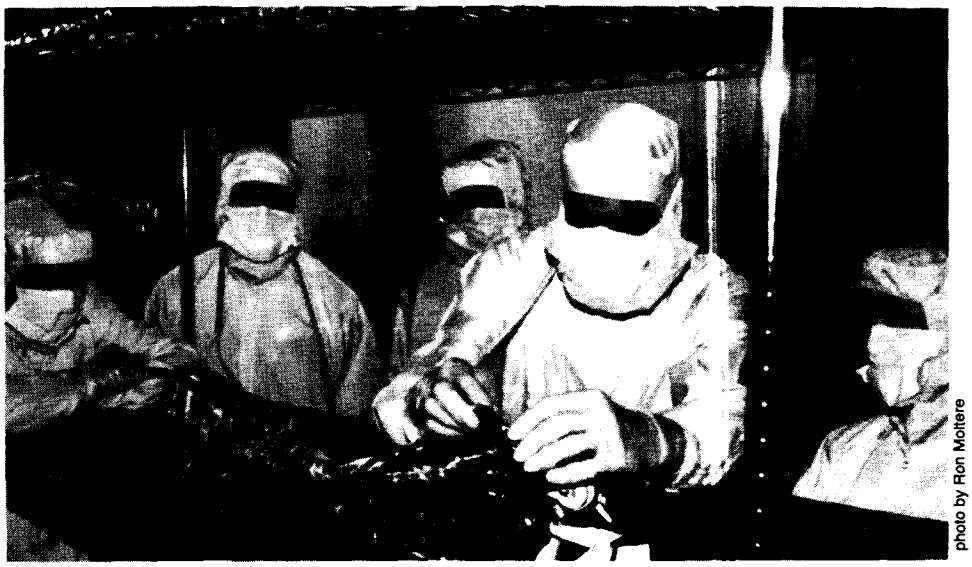


photo by Ron Mottere

Here STS-61 crew members (from left) Story Musgrave, Tom Akers, Greg Harbaugh and Kathy Thornton (far right) look on as Jeff Hoffman works on the Goddard High Resolution Spectrometer repair kit.

Crew preparation for the Hubble Space Telescope servicing mission has been intense as the astronauts selected for STS-61 underwent training at Goddard and other NASA centers.

The astronauts began their training in March 1992 at Johnson Space Center's Weightless Environment Training Facility (WETF) and Marshall Space Flight Center's Neutral Buoyancy Simulator (NBS). They also have been at GSFC several times in 1993 to learn how to use tools developed by Goddard for the servicing mission. Goddard is responsible for the components that will be serviced or replaced on HST.

The crew spent hundreds of hours learning to use more than 100 different Hubble-specific tools and rehearsing their specific tasks in simulators and deep-water tanks that feign the weightlessness of space. In just the tanks alone, the four spacewalking astronauts logged nearly 400 hours, a 50 percent increase in the amount of time normally spent training in those facilities. They spent another approximately 150 hours in training at Goddard.

Tools and crew aids

The crew of STS-61 will take more than 200 tools and crew aids with them for the servicing of the Hubble Space Telescope. The tools and crew aids, known as Space Support Equipment (SSE) hardware, range from a simple bag for carrying some of the smaller tools to sophisticated, battery operated power equipment. These tools will be used by the Extra Vehicular Activity (EVA) crew members servicing the spacecraft.

Crew aids

Crew aids are defined as those that are fixed in place, and those that are portable equipment items but not hand tools, used to assist crew members in accomplishing servicing mission tasks. SSE equipment crew aids permit the crew members to maneuver safely or to restrain themselves, transfer Orbital Replacement Units (ORUs) and other portable items, protect equipment and crew during changeout activities and temporarily stow or tether equipment during EVAs.

Examples of crew aids are handrails, handholds, translation devices, transfer equipment, protective covers, tethering devices, grapple fixtures, foot restraint sockets and stowage and parking fixtures.

Tools

Tools are hand-operated or manipulated devices that allow the EVA astronauts to increase the efficiency of performing intricate, labor-intensive tasks. Tools permit access to equipment, removal and replacement of replacement units and the work site restraint of crew members, tools and hardware using platforms, caddies or equipment tethers.

Uses

Tools and crew aids considered "general," with a wide variety of uses, include the Power Ratchet Tool (PRT), Multi-setting Torque Limiter (MTL), adjustable extension with 7/16th-inch sockets, ingress aids, portable work-light receptacle and a locking connector tool. More specific general items are a low-gain antenna (LGA) cover, umbilical connector covers, a flight support system (FSS) berthing and positioning system (BAPS) support post and a multi-layer insulation (MLI) repair kit.

Special Edition
NASA National Aeronautics and Space Administration Goddard Space Flight Center
Goddard News

The GODDARD NEWS Staff is:
Executive Editor: Randee Exler
Chief Editor: Jim Elliott
Managing Editor: Fred Brown
Contributing Editors: Michael Finnerran, Tammy Jones, W. Allen Kenitzer, Keith Koehler
Production Assistants: William Brown, Michelle Mangum, Tony May