A new day dawns for **Hubble**

Shuttle astronauts installed two new instruments, fixed two older ones, and upgraded the space telescope's gyroscopes and batteries. **by Richard Talcott**

On the afternoon of May 11, space shuttle Atlantis roared off Launch Pad 39A at Florida's Kennedy Space Center. At the time, the Hubble Space Telescope was passing overhead. Yet it would take Atlantis 2 days to catch up with the orbiting observatory and get down to the important work of Servicing Mission 4. The goal: upgrade Hubble by installing new instruments, repairing old ones, and replacing worn-out parts. The result: a resounding success.

After 19 years in the harsh environment of low Earth orbit, Hubble was showing its age. Two of its four science instruments — the Space Telescope Imaging Spectrograph (STIS) and the Advanced Camera for Surveys (ACS) — had suffered devastating power failures. STIS no longer worked. And ACS, which still operated on one of its three channels, had lost its ability to take beautiful images.

To compound the troubles, three of Hubble's six gyroscopes had failed, and two of three Fine Guidance Sensors were ailing. The telescope needs at least two gyros and two sensors to point accurately, so it was facing a possible crisis in the not-too-distant future.

To top it off, the telescope's main Science Instrument Command and Data Handling unit failed September 27, 2008. This unit provides all the electronics needed to operate the science instruments from the ground and send science and engineering data from Hubble back to Earth.

The craft has two such units — one active and an unpowered backup. Although NASA had switched to the backup, it did not want to leave the orbiting observatory without a spare. The space agency had postponed the servicing mission from its scheduled October 2008 launch until engineers could test and deliver a backup system to Kennedy Space Center.

Rocketing into space from Cape Canaveral May 11, space shuttle Atlantis and its seven astronauts set off to repair the Hubble Space Telescope.

^ **Repairing** the Space Telescope Imaging Spectrograph (STIS) occupied nearly all of the fourth spacewalk, in part because of a balky handrail. Here, Michael Good (on the shuttle's robotic arm) and Michael Massimino (just to his right) work on STIS inside Hubble. All images by NASA

> **Wide Field Camera 3** finds its new home inside Hubble, as astronauts John Grunsfeld (left) and Andrew Feustel wrap up the camera's installation during the first spacewalk.

Hubble stands tall in the cargo bay of Atlantis. The crew captured this scene after Mission Specialist Megan McArthur grabbed the telescope with the shuttle's robotic arm.

Atlantis crew members pose the day after they released Hubble. Sitting in the front row (left to right) are Gregory Johnson, Scott Altman, and Megan McArthur. Behind them (left to right) are Michael Good, Michael Massimino, John Grunsfeld, and Andrew Feustel.

The fifth spacewalk included several maintenance tasks. In this scene, John Grunsfeld (left) and Andrew Feustel prepare to install new thermal blankets on the space telescope.

Rendezvous with destiny

Science operations aboard Hubble continued until launch. At that point, mission controllers at NASA's Goddard Space Flight Center in Greenbelt, Maryland, began to shut the telescope down. They put its science instruments into standby mode, closed the aperture door, and retracted the two large high-gain-antenna masts.

This was the Hubble that awaited Atlantis and its astronauts as they approached May 13. Commander Scott Altman and Pilot Gregory Johnson brought Atlantis up next to the telescope. Mission Specialist Megan McArthur then grappled Hubble with the shuttle's robotic arm, brought it into the payload bay, and locked it down. This would be Hubble's home for the next 6 days.

During five spacewalks lasting a total of 36 hours and 56 minutes, two teams of mission specialists repaired the ailing craft. John Grunsfeld and Andrew Feustel worked days 1, 3, and 5, while Michael Massimino and Michael Good donned their spacesuits on days 2 and 4. The teams accomplished all of NASA's goals for the mission. But — as always seems to happen when working in space — there were a few glitches.

One problem came during the first spacewalk and threatened the installation of what will become Hubble's primary camera. To install the Wide Field Camera 3 (WFC3), Grunsfeld and Feustel first had to remove the Wide Field and Planetary Camera 2 (WFPC2). After more than 15 years on Hubble, however, WFPC2 didn't want to leave.

The astronauts had a difficult time removing a bolt that held the camera in place. They tried a variety of tools and even applied extra force to the bolt, all to no avail. If the bolt had broken, they wouldn't have been able to remove the old camera and install the new one. The pair eventually retrieved a ratchet tool, reconfigured it, and managed to remove the bolt. The rest of the removal and WFC3's installation went perfectly.

New views of the heavens

Hubble scientists have high hopes for the new camera. WFC3 will observe the universe at ultraviolet, visible, and near-infrared wavelengths simultaneously. With this capability, the camera can view a galaxy and see its hot young stars (which radiate mostly in the ultraviolet) and cool old stars (which glow in the red and near-infrared) at the same time. With its heightened sensitivity and wide field of view, WFC3 will far outclass any of Hubble's previous cameras.

During its lifetime, WFPC2 took a few hundred thousand images of the cosmos. Among them were some of Hubble's most iconic, including the "pillars of creation" in the Eagle Nebula and the Hubble Deep Field. Atlantis brought the camera back to Earth, where it will go on permanent display in the Smithsonian Institution's National Air and Space Museum in Washington, D.C.

Astronauts installed Hubble's other new science instrument — the Cosmic Origins Spectrograph (COS) — on the third spacewalk. It replaces the Corrective Optics Space Telescope Axial Replacement — the "glasses" installed during the first servicing mission to compensate for the telescope's misshapen primary mirror.

COS breaks down incoming light into its component colors, revealing an object's temperature, composition, density, and velocity. Astronomers will use COS' ultraviolet sensitivity to explore distant galaxies and quasars. Researchers expect that the results will give them a keener insight into the universe's structure and evolution.

The third spacewalk also saw astronauts install new electronics in the ACS. The electronics worked, but they restored only the camera's wide-field channel. The high-resolution channel remains inoperable. Fortunately, scientists use the wide-field channel more than any other. Since astronauts installed ACS in 2002, the wide-field channel garnered 70 percent of the observation time.

The most complex repair took place on the fourth spacewalk when Massimino and Good fixed STIS. NASA did not design the spectrograph for repair. The task required the astronauts to painstakingly remove 111 screws after affixing a "capture plate" over the instrument's access panel to prevent any screws from floating free. Oddly enough, this part of the repair went smoothly, but the astronauts had trouble removing a handrail to attach the capture plate. In the end, Massimino simply yanked the handrail off.

Ready for the long haul

The astronauts encountered only one other significant problem during the repairs, while replacing the gyroscopes. The gyros are packed in pairs inside boxes called Rate Sensor Units. Atlantis brought along three replacement units, but one refused to fit into its slot. The astronauts managed to place a spare unit into the slot, so the telescope now has six working gyros.

The other key upgrades went well. Hubble now sports a new Science Instrument Command and Data Handling unit, a new Fine Guidance Sensor, two new batteries, and three new thermal blankets.

The astronauts also attached the Soft Capture Mechanism to Hubble's back end. This allows a next-generation vehicle to capture the spacecraft and send it on a controlled reentry into Earth's atmosphere. But this fate lies at least 5 years in the future. No one was thinking about that day when McArthur released Hubble back into space May 19.

Atlantis touched down at Edwards Air Force Base in California May 24, 2 days later and a continent away from its scheduled landing. Persistent tropical rains in Florida had kept the shuttle in space overtime. Still, NASA couldn't be happier. Atlantis' 5.3-million-mile (8.5 million kilometers) journey accomplished all of the tasks NASA set out to achieve. And Hubble is now back in the peak of health, ready to push the frontiers of astronomical observation even deeper.

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Hubble drifts away after Atlantis' crew finished servicing it. The space telescope should be set for at least 5 more years of discoveries.