Hubble's Mr. Fix-It

Astronomer and astronaut John Grunsfeld '80 helped give the Hubble Space Telescope its final makeover—but the adventure isn't over for either stargazer.

By ANNE-MARIE CORLEY, SM '09

When most astronomers want to fix their telescopes, they tinker with parts, run tests, readjust, go home, and try again the next day. When John Grunsfeld '80 had to fix his, he suited up and rocketed into space.

The final Hubble Space Telescope servicing mission in May 2009 was "a special mission in lots of ways," says Grunsfeld, a five-time spaceflight veteran. It was the last time humans would visit the telescope, and the first time its components would be repaired on the spot instead of simply being replaced.

The mission was special for another reason, too: it almost didn't happen. Originally scheduled for 2004, the flight was scrubbed after the space shuttle *Columbia* broke apart over Texas in 2003. In the aftermath, NASA officials decided that all future shuttle missions should be capable of scurrying to the International Space Station in case of emergency—an impossible task from Hubble's higher and less steeply inclined orbit. So a Hubble mission was deemed "too risky," says Grunsfeld, who was then in Washington, DC, as NASA's chief scientist. "There's no place to hide out if something goes wrong."

Having visited Hubble twice before, Grunsfeld says he felt like he'd been hit with a two-by-four when he heard the announcement in a meeting. Without a mission to replace its batteries and limping gyroscopes, the telescope would have just two to four years left. And as chief scientist, he would have to explain the decision to the public. "People love Hubble," he says. "A lot of people think it's the one thing [from the space program] giving value."

So Grunsfeld set about trying to save the telescope, first thinking to service it by other means. He came up with plans for a robotic mission and even designed T-shirts and stickers with a "Robots to the Rescue" logo. (Another senior leader decided that this "cheapened the mission," though, so you can't find the shirts in your local spaceflight apparel store—and the robotic mission never flew.) He and others also challenged Goddard Spaceflight Center and the Space Telescope Science Institute, which operate the telescope, to extend Hubble's battery life and run fewer gyros at a time until a mission could be scheduled to upgrade the systems.

By October 2006, once shuttles had started flying again after a two-and-a-half-year hiatus, a visit to Hubble was back on the roster. Grunsfeld himself was tapped to lead the spacewalking service team. "John was instrumental in bringing back the mission," former astronaut Jeffrey Hoffman, a professor of the practice of aeronautics, told MIT students when Grunsfeld returned to his alma mater last November. "So it's just that he got a starring role in it."

A crew of seven trained for two years in NASA's simulators and in telescope mock-ups underwater. Still, the real Hubble wasn't ready for them: on the eve of the scheduled shuttle launch in October 2008, a computer failure on the telescope meant another repair had to be planned and trained for, scrapping the mission again until February 2009. Further delays pushed it to May. But the day the space shuttle *Atlantis* finally went up, with Grunsfeld strapped into seat 5, it went right on time.

HUBBLE HUGGERS

An astronaut since 1992, Grunsfeld has served on a mission to the Russian *Mir* space station and one to carry out astronomical observations with ultraviolet telescopes, in addition to his three servicing trips to Hubble.

But as an astronomer by passion and education, he started staring at stars long before the telescope did. After earning three physics degrees (a bachelor's from MIT and a master's and PhD from the University of Chicago), Grunsfeld became a senior research fellow at Caltech, where he studied gamma-ray bursts—jets of high-energy radiation spewed our way by distant, rapidly spinning stars—before joining the astronaut corps. Following the first Hubble rescue

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mission, in 1993—when astronauts installed "contact lenses" to correct an error in the mirror's curvature—Grunsfeld's astronomical work relied on results from the telescope itself. So his own first Hubble visit, in 1999, was "a magical moment" that began a whole new relationship with the telescope, as he wrote in the journal he kept "on orbit," posted online as the John Grunsfeld Reports.

Now Grunsfeld is a Hubble pro, and as leader of the spacewalking team on the final mission, he gave his team more than a few tips and hints. That included a top 10 list—with "about 35 items," he says, laughing. The main one, he recalls, was "Don't break the telescope!"

Upgrades on this mission included installing a wide-field camera that sees from the ultraviolet all the way into the near infrared—a new capability for the telescope—and adding a state-of-the-art ultraviolet spectrograph that will sniff out the chemical content of nearby stars and galaxies while helping scientists study how dark matter has molded the shape of the universe.

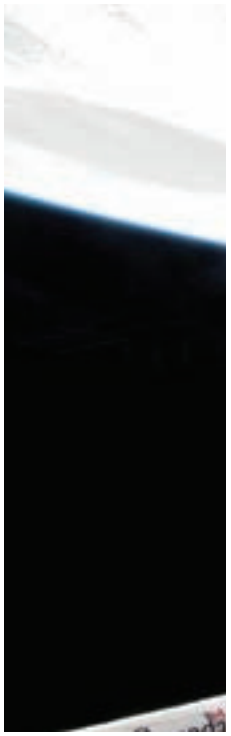
The team also replaced one of two computers, to ensure redundancy after the 2008 failure, and installed a docking system to help bring the telescope down when it finally peters out. Other fixes included replacing the 19-year-old nickel-hydrogen batteries and adding six new gyroscopes, which let the telescope "stare" at one spot for a long time. A new fine-guidance sensor was also added, to complement the only one of three original sensors still functioning.

In addition to replacing parts, the astronauts completed Hubble's first-ever in-flight repairs. They fixed the advanced camera for surveys, which yielded the classic galactic snapshots associated with the telescope before failing in 2007, and the electronics board for Hubble's older imaging spectrograph, which failed in 2004.

"Everyone said [repairs] wouldn't work," Grunsfeld says. The naysayers pointed out that it would be nearly impossible to keep track of lots of tiny screws in zero gravity (and any that got loose could damage Hubble's sensitive instruments), and that astronauts would have to reach into parts of the telescope that were never meant for humans to access in space. But after hundreds of practice go-rounds on Earth and multiple hours of space walks, he and his team proved them wrong. Using special tools designed to remove the screws and trap them inside a clear casing during repair, the astronauts brought both instruments back online.

After his tense space walk with astronaut Andrew Feustel to finish fixing the survey camera, Grunsfeld was elated—and exhausted. "I slept sounder than ever in my life," he recalls. "I slept through the wake-up call and the wake-up music [the next morning]." He was so sound asleep, in fact, that crew member K. Megan McArthur asked, "Is John dead?"

www See more photos of the Hubble repair mission: **technologyreview.com/Hubble**



EXPLORER SANS FRONTIERS

Space isn't the only backdrop for Grunsfeld's adventures. He also climbs mountains, flies planes, cycles, and sails. "I thrive with high-performance challenges in front of me," he says. An avid mountaineer, he was anxious to return to technical climbing after his mission. But a bum shoulder from a preflight training injury kept him in rehab for months, and he had to put his plans on hold.

Undaunted, the explorer still hopes to pay a few visits to the mountains, including Mt. Lucania, a 5,226-meter peak along the Alaska-Canada border: you can "count on one or two hands" the number of people who've scaled it. The late Bradford Washburn—a friend and fellow mountaineer who founded the Boston Museum of Science—was the first to do so, in 1937. To honor that climb and his friend's exploring spirit, Grunsfeld took Washburn's expedition camera, a 1929 Zeiss Maximar B, for a ride in space. He used it to take pictures of Hubble and of Earth's mountains.

Grunsfeld dreams of using the camera one more time: to take pictures at Mt. Lucania of the same spots Washburn photographed, which could reveal how the area has been affected by climate change. There's a "reasonable possibility that you'd see significant changes," he says.

Like mountain climbing, spaceflight is sometimes pure fun for him. On the final Hubble repair mission, Grunsfeld got to kick back during the last two days, when bad weather over Florida, the primary shuttle landing site, temporarily stranded the crew in space. He took the opportunity to do "all the stupid astronaut tricks" he'd never gotten to do on past missions, he says. He and Feustel particularly enjoyed "fluid-physics experiments" (playing with water and juice balls in zero gravity), and he and fellow MIT graduate Mike Massimino, SM '88, MEng '90, PhD '92, had fun studying the "stability of rotating systems and conservation of angular momentum" (doing somersaults). They joked about sending their videos back to MIT to be used in basic mechanics courses.

SERVICE CALL At left, John Grunsfeld uses a power tool on the mid deck of the space shuttle *Atlantis* on May 13, 2009. Above, Grunsfeld is positioned on a foot restraint on the end of *Atlantis*'s remote manipulator system as he and his colleague Andrew Feustel (bottom center) participate in the mission's fifth and final space walk. At right, Grunsfeld works on the Hubble Space Telescope during the first STS-125 space walk, during which Wide Field Planetary Camera 2 was removed and Wide Field Camera 3 was installed.

Grunsfeld also posed with MIT paraphernalia, including a pennant that he presented to the MIT athletics department in November. (His picture from a previous mission also hangs in the MIT sailing pavilion.) He spent much of his free time looking down at Earth and taking pictures.

BON VOYAGE

Before the mission launched, Grunsfeld says, he was often asked how it would feel to say good-bye to Hubble.

When the time came, he gave the telescope one last pat, a salute, and a mumbled farewell. "I said something subaudible, which is how I wanted it," he says. "Something like, 'Good-bye, Mr. Hubble—have happy voyages.'"

After the crew released the telescope from the shuttle's cargo bay (using an egg timer for the countdown), it flew past the windows on its way to its own orbit. "I've done this three times now," Grunsfeld says with a laugh. "And every time Hubble goes by the overhead windows, everybody ducks."

Then the astronauts watched as Hubble literally disappeared into the sunset.

"I actually was not particularly sad," Grunsfeld recalls. Once they finished everything on their checklist, he adds, "there wasn't anything more we could do for Hubble." Still, his tone is wistful as he recalls thinking, "That may be the last time human eyeballs look at Hubble ... the last time people will ever crawl around with the telescope."

The team's repairs and additions should keep the telescope going until at least 2014, with more capability and sensitivity than ever. Hubble can now directly image planets in other solar systems, and thanks to its increased range in the infrared, it can see through cosmic dust to peek at stars being born. It has already produced spectacular images of the most distant sections of the universe ever seen—galaxies as they appeared just 600 million to 800 million years after the Big Bang. In a universe estimated to be 13.7 billion years old, that's almost the first generation of galaxies, Grunsfeld says.

"These are the things we never expected Hubble to be able to do," he told MIT students. "[It's] a fun time to be in science and to have these great tools."

In January, Grunsfeld left NASA to become deputy director of the Space Telescope Science Institute, a job he got after e-mailing his résumé from space with the message "I am holding Hubble hostage until you read my application." There he will help keep Hubble's science operations on track and gear up for the launch of the next-generation James Webb Space Telescope, planned for 2014. He will also continue his astronomical work with Hubble, this time using the telescope's new capability in the ultraviolet spectrum to study cratering effects on the moon. Just as excited about science and the stars as when he began, Grunsfeld shows no signs of slowing down.

Nor, with its brand-new equipment, does the Hubble Space Telescope. "We've reinvented the Hubble with what we did on orbit," Grunsfeld says. "The Hubble story is really just beginning." ■

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