

Laser Vision Helps Hubble, Package Shippers See Clearly

NASA Technology

For more than 25 years, the Hubble Space Telescope has provided stunning photos of the universe unequalled in their depth, detail, and distinction. Hubble imagery has been used for calendars, T-shirts, coffee mugs, computer decals, and countless other products, but, more importantly, also for groundbreaking scientific research both in our galaxy and across the observable universe. NASA hopes to continue using the tool for as long as possible, even as it prepares to launch the high-powered James Webb Space Telescope (JWST) in 2018.

However, in its early days, Hubble wasn't capable of sending back such breathtaking photos. Within weeks of launch, it became apparent that something was wrong, as the images beamed back to Earth were fuzzy and out of focus. It was determined by analysts that Hubble's

primary mirror had been ground to the wrong shape and was too flat by 2.2 micrometers—or one-fiftieth the thickness of a human hair—causing reflected light from the edge of the mirror to be focused on a different point than light coming from near the center. A commission led by the Jet Propulsion Laboratory determined that the device used to create the precisely shaped but nonspherical mirror had been incorrectly assembled and that the mirror's manufacturer had failed to notice the problem before Hubble was launched.

NASA decided on a two-step approach to address the problem. During the first repair mission to Hubble, astronauts would replace the Wide Field Planetary Camera (WFPC) with an improved version featuring advanced detectors and more accurate contamination control along with built-in corrective optics, known as WFPC 2. Secondly, the astronauts would replace one of Hubble's

original components, the High-Speed Photometer, with the Corrective Optics Space Telescope Axial Replacement (COSTAR), which would work like a pair of eyeglasses to better focus the telescope's view of the universe.

But first, the Agency wanted to make sure the repairs going up into space would indeed improve Hubble's ability to capture images and not suffer from any undiscovered flaws.

Technology Transfer

NASA put out a call for optics companies to prove they could verify the shape of a mirror hidden from view and detect any defects, however slight. Along with other companies, AOA Xinetics, now a Cambridge, Massachusetts-based subsidiary of Northrup Grumman, made the trek to Goddard Space Flight Center with its aberrated beam analyzer (ABA), which it built to meet NASA's specific requirements.

"The only thing worse than spending \$1 billion to launch a space telescope with the wrong mirror would be to send a second billion-dollar mission to fix it and still



A misshapen mirror aboard the Hubble Space Telescope caused the first images beamed back to Earth to be fuzzy and out of focus. After the installation of new optics, tested by an aberrated beam analyzer invented by AOA Xinetics to ensure the new lenses would work perfectly, Hubble began sending back crystal-clear, vivid images from across the observable universe.

have the wrong mirror,” says Cameron Dryden, director of AOA’s systems and service business. The challenge, nicknamed the “Sense-Off,” consisted of a series of five mirrors for the companies to measure, each a slightly different shape and one purposely shaped to match the defective mirror on Hubble. AOA needed to use its analyzer to determine both the mirror’s flaw and how to compensate for the fuzzy image using a static corrector.

“Before this challenge, we didn’t have a piece of optical test equipment capable of solving this problem,” Dryden recalls. Prior to creating the ABA, he says, AOA had experience in measuring the way the atmosphere bends and distorts light, a process that requires split-second measurements but not high levels of accuracy relative to the measurements NASA needed. For the “Sense-Off,” accuracy was paramount, but the company could take all the time it needed.

The team decided to illuminate the mirror using flat wave-fronts of light from a laser, knowing that the waves bouncing back could allow the ABA to detect the unseen mirror’s shape, right down to microscopic divots and bumps.

Within 30 days, a team from AOA designed and created the new tool and drove down to Goddard with the ABA in the back of a station wagon. The instrument not only detected the mirror’s shape accurately but did so to within three-thousandths of a wavelength of light, something that had never been done before. AOA’s analyzer was selected by NASA as the tool used to verify both COSTAR and WFPC 2 were perfect before being sent into space. Thanks in part to AOA’s work, Hubble has been sending captivating images back ever since.

Benefits

After developing the ABA, “There was a complete shift of mentality” at AOA, Dryden says, leading the company to consider three-dimensional imaging when presented with a new problem. “From then, it just opened up a whole suite of applications with an overarching goal of making images better and more useful,” he says.

Shortly after the work on Hubble, AOA used the ABA to create the Mass Scanning and Dimensioning System, originally used by FedEx to quickly and accurately create



Utilizing the improved optics capabilities it developed for NASA, AOA Xinetics has worked with Kroger grocery stores on a scanning system that better and more rapidly identifies products, allowing customers with large orders to take advantage of self-checkout aisles.

3D images of the packages that would need to be sorted and shipped in a given day.

The scanning system “creates a contour map of parcels as they travel down a conveyor belt past a laser ranging imager,” Dryden says. “Height contours are subsequently analyzed to determine the location of each parcel and its dimensions,” which helps to identify packages that might require additional charges due to size or weight. Previously, someone would have to manually pull items off conveyor belts and use a tape measure to single out packages.

This imaging system, which has since been adopted by all major shipping services, including the U.S. Postal Service, has been utilized by “hundreds of machines running millions, if not billions, of hours for 20 years,” he adds.

Building on the FedEx work, AOA partnered with Kroger grocery stores to develop the Scan Tunnel to ease checkout at its stores. Customers put their products on a conveyor belt, which then travels through an upright tunnel with laser scanners on three sides, capturing product information from brand name to bar code for

identification and pricing. This allows customers with larger orders to take advantage of self-checkout aisles. Scan Tunnel uses 14 scanning cameras and 2 types of dimensioners, an improvement over the 7 cameras and 1 dimensioner used in FedEx’s system, Dryden says. The Scan Tunnel was named Retail Innovation of the Year in 2010 by *Planet Retail* magazine, after the first machines debuted, and AOA is working with Kroger to install additional machines throughout the country.

Both products have roots in the initial work to save Hubble from obsolescence. “Some companies we work with introduce us as the people who fixed the Hubble telescope, and that might be a little overstating it, but it certainly has helped us make inroads with a number of commercial companies,” Dryden says.

Now, after 25 years, Hubble continues to provide breathtaking images of the galaxy, long exceeding the optimistic predictions that it would send back views of the heavens for only 15 years. While JWST will eventually replace and outshine Hubble, there’s every reason to think Hubble will continue to dazzle for at least another 5–10 years. ❖

