Inner Workings: Hubble's quarter century in orbit has opened a universe of possibilities

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When the Hubble Space Telescope was deployed from Space Shuttle *Discovery* on April 25, 1990, few knew just how far-reaching its impact would be on astronomy, cosmology, and public appreciation of the universe. "It has given us views of the universe that we have never seen before and provided a wealth of data for astronomers around the world to ponder," says Ken Sembach, head of the Hubble Mission Office at the Space Telescope Science Institute. Hubble also laid the foundation for a new generation of space telescopes.

But such lofty achievements took plenty of study and political will. The telescope had a troubled beginning because of repeated questions about its price tag and mission, not to mention a faulty mirror.

Hubble's origins stretch back nearly three decades before its launch. In 1962, a National Academy of Sciences report recommended the creation of a large space-telescope study program to complement its orbiting astronomical observatories program: "Consideration should be given to the desirability of a large space telescope, and the technical problems associated with it, as the next step beyond the present orbiting astronomical observatories program" (1). This new breed of telescope would have a much larger aperture than existing orbiting astronomical observatories and be capable of "stellar and nebular studies through the entire spectral range from soft X rays to infrared." However, the budgets and the technological capabilities of the time presented challenges for a large-aperture space telescope.

Recommendations at the Academy's 1965 Space Science Board added some specifics: "We conclude that a space telescope of very large diameter, with a resolution corresponding to an aperture of at least 120 inches, detecting radiation between 800 Å and 1 mm, and requiring the capability of man in space, is becoming technically feasible, and will be uniquely important to the solution of the central astronomical problems of our era" (2) (Figs. 1 and 2). This led to the Large Space Telescope program, later to be known as the Hubble Space Telescope, named for Edwin Hubble, discoverer of the relationship between distance and velocity for receding galaxies (3).

By 1970, Congress still balked at the price tag and didn't pay much attention. But after advocates, including astronomers John Bahcall and Lyman Spitzer, in 1974 obtained a letter from the National Research Council's decadal survey of astronomy committee saying that an updated 1970 survey would rank the project higher. That gave them the leverage they needed to convince Congress.

The initial proposed launch date was 1983. But technical delays, budget problems, and the 1986 Space Shuttle *Challenger* disaster pushed the launch to 1990. Then came a series of difficult servicing missions beginning in 1993 to install corrective optics for the incorrectly ground main mirror and upgrade various components. Hubble was designed to be serviceable, but these weren't easy fixes. Nevertheless, astronauts made the repairs and boosted the telescope to a higher orbit to compensate for the atmospheric drag that had gradually brought it closer to Earth. "There are moments you look back on, and see that they are pivotal moments that made the mission what it is," says Sembach.

Science Mission

Soon after, Hubble was launched with three key projects planned. It observed 37 quasars with the faint object spectrograph instrument and created a database of information for investigating the properties of the intergalactic medium (4). Its medium deep survey, using the wide-field camera, revealed some of the most distant galaxies observed at that time, as well as embryonic galaxies (5). And the telescope measured Hubble's constant, which quantifies the rate of expansion of the universe, to about 10% precision (6).

But the space telescope was far from done. Hubble went on to help refine the age of the universe (using the more precise Hubble constant), advance astronomers' understanding of the accelerating expansion of the universe and dark energy through the observation of Type Ia supernovae, demonstrate the unexpected frequency of black holes at the center of galaxies, and offer up evidence for extrasolar planets. In all, more than 12,700 papers have been published using data from the Hubble Space Telescope.

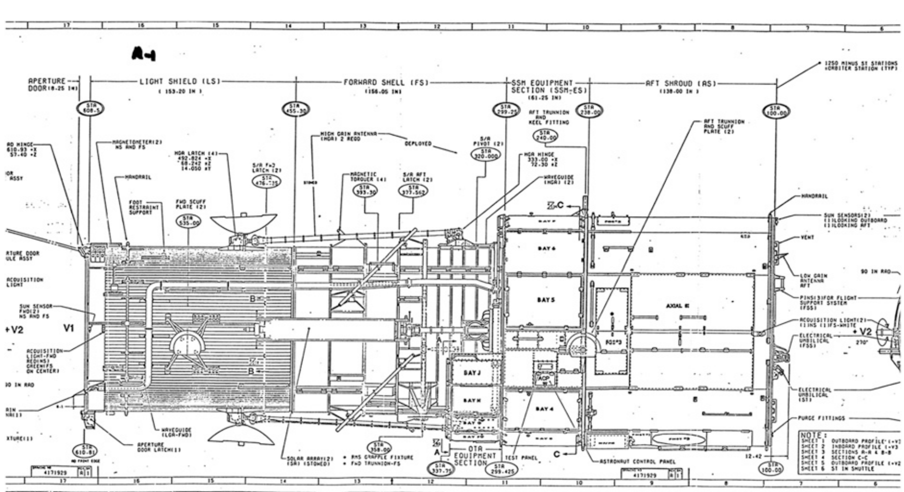

Fig. 1. Detail of Hubble Space Telescope schematic showing the main mirror and solar array. Lockheed Missiles and Space Company, Inc. prepared it for NASA in 1985. Full version available in *Supporting Information*. Image courtesy of STScI/NASA.

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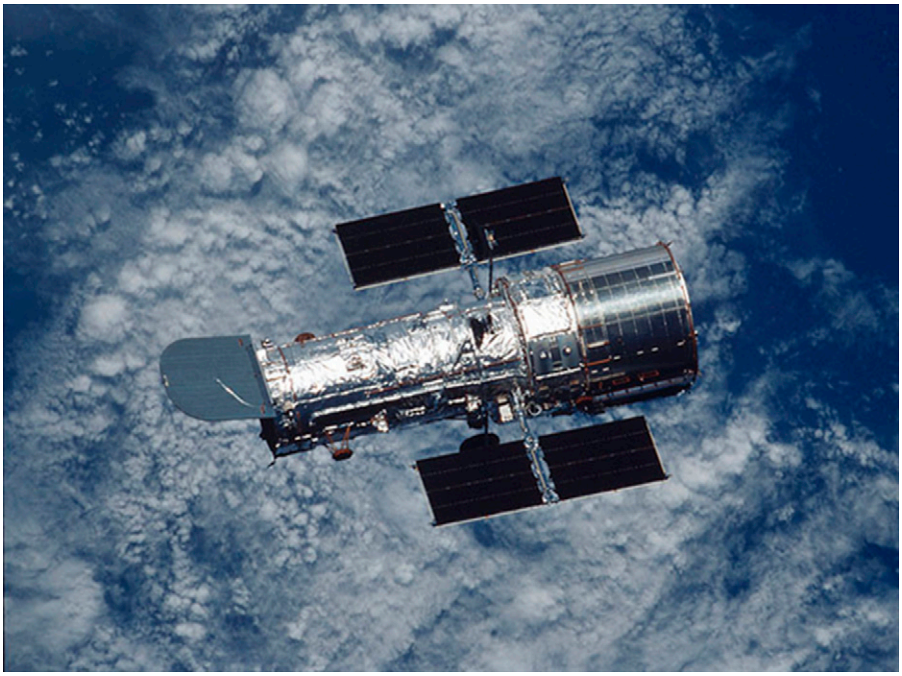

Fig. 2. The Hubble Telescope in orbit in 2009. Image courtesy of NASA.

In the public eye, some of the greatest achievements have been the high-resolution multicolor images captured. “Through the images secured by Hubble,” says science historian Robert Smith of the University of Alberta, “there has been a major shift in the way many members of the public, as well as astronomers, perceive the universe.” Although the telescope was almost decommissioned in 2005 because of a presidential budget request, Congress and NASA intervened after an upwelling of public support, including children sending in piggybanks of pennies to help keep Hubble going. Congress approved the funds for a final critical servicing mission that would extend Hubble’s life. The telescope could be operable as late as 2020.

Beyond Hubble

Other space telescopes have already followed. The latest is the James Webb Space Telescope (JWST), scheduled to launch in October 2018. Hubble’s lessons-learned have informed the JWST, from how to stage a large, expensive science project to how to secure Congressional approval and funding. Team members have routinely shared tools, infrastructure, and feedback. The telescopes have followed a similar trajectory, says Sembach. “Early on, people think it’ll be too ambitious, too costly, too difficult, take too long,” he says. “You have to convince the stakeholders that you mean what you say and you can do what you say.”

JWST will be situated much farther from Earth, near the stable L2 Lagrange point, which means it can orbit the Sun and the Earth using just one sun shield. This will keep the telescope sufficiently cool to perform infrared observations.

Although Hubble primarily observes optical wavelengths, the JWST will focus mostly on infrared light, which passes through gas and dust that can otherwise obscure distant objects. The JWST will be able to look to a farther distance, further back in time, and see some of the dimmest and coolest objects in the sky.

JWST promises to advance astronomy, astrophysics, and cosmology, just as Hubble has already done. “Hubble has shown us what is possible,” Sembach says, “but has also motivated us to reach even further into the depths of the universe to reveal what remains hidden. I think that’s something the public will want.”

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