



## Hubble Space Telescope – An Overview

NASA's Hubble Space Telescope was the first astronomical observatory to be placed into orbit around Earth with the ability to record images in wavelengths of light spanning from ultraviolet to near-infrared. Launched on April 24, 1990 aboard the Space Shuttle Discovery, Hubble is currently located about 340 miles above Earth's surface where it completes 15 orbits per day — approximately one every 95 minutes. The satellite moves at the speed of about five miles (8 km) per second, fast enough to travel across the United States in about 10 minutes.

### The Telescope

Hubble is classified as a Cassegrain reflector, named after a 15th century French cleric who was among the first to suggest this basic optical design. Light hitting the telescope's main, or primary mirror is reflected to a smaller, secondary mirror suspended above the primary. The secondary, in turn, reflects the light back through a hole in the primary where it enters Hubble's instruments (cameras and spectrographs) for final focus before it hits their detectors.

Hubble's primary mirror is not only exquisitely

polished, but at 94.5 inches (2.4 m) in diameter, collects an immense amount of light. Hubble can detect objects that are 10 billion times fainter than the unaided eye can see. High above the blurring effects of Earth's atmosphere, Hubble also gets a much clearer view of the cosmos than do telescopes located on the ground. The space telescope can distinguish astronomical objects with an angular diameter of a mere 0.05 arc seconds — the equivalent to discerning the width of a dime from a distance of 86 miles. This resolution is about 10 times better than the best typically attained by even larger, ground based telescopes. High resolution enables Hubble to locate such objects as dust discs around stars or the glowing nuclei of extremely distant galaxies.

Also because it circles above the atmosphere, Hubble can view astronomical objects across a wider range of the electromagnetic spectrum than ground-based telescopes which are limited by atmospheric absorption at various wavelengths. This gives astronomers using Hubble a fuller view into the energetic processes that create the radiation seen and measured.

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Finally, Hubble's observations are predictably consistent. The telescope's seeing conditions do not change from day to day or even orbit to orbit. Astronomers can revisit targets with the expectation that they will be imaged at the same high quality each time. This optical stability is critical for detecting tiny motions or other small variations in celestial objects. Such is not the case for ground-based observatories, where observing conditions vary with weather and directly affect the quality of the images acquired.

### The Spacecraft

Hubble is 43.5 feet long and 14 feet wide at the back, where the scientific instruments are housed. Weighing nearly 25,000 pounds, the telescope is approximately the same size and weight as a school bus. The observatory is powered by two solar arrays that convert sunlight into electrical energy that is stored in six large batteries. The batteries allow the observatory to operate during the shadowed portions of Hubble's orbit when Earth blocks the satellite's view of the Sun.

In the middle of the spacecraft, near its center of gravity, are four 100-pound reaction wheels used to reorient the observatory. Based upon Sir Isaac Newton's Third Law of Motion — for every action there is an equal and opposite reaction — turning a reaction wheel in one direction causes Hubble to react by turning the opposite way. The satellite knows where and when it should turn based on a target schedule uploaded from the control center. Hubble's main computer then calculates which wheels should slow and which ones spin faster to most efficiently maneuver the spacecraft to the new target.

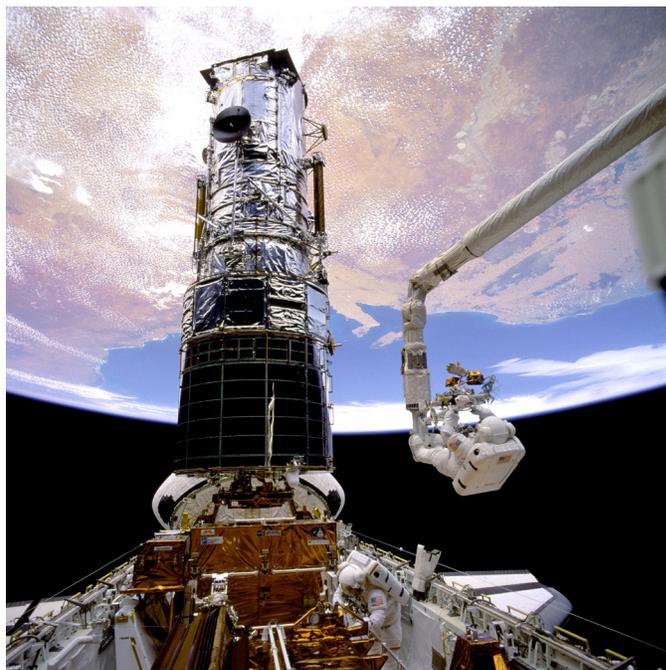
The observatory uses high-precision gyroscopes (gyros) to detect its rate and direction of motion. Hubble's typical operating mode uses three gyros, but it has six from which to choose. The others serve as backups, as gyros eventually wear out and fail. One of the six, in fact, failed in March 2014. Backup operating modes also exist that enable Hubble to continue collecting science data with only one gyro, if necessary, but with slightly less efficiency.

In addition to gyros, Hubble has three Fine Guidance Sensors (FGS) that act within the spacecraft's overall pointing and control system to keep the telescope virtually motionless while observing. Hubble jitters less than 7 milliarcseconds in a 24-hour period when locked

on its target. This is equivalent to shining a laser on a dime 200 miles away for this period.

Commands and data are transmitted between the spacecraft and the control center through two high-gain antennas that communicate through NASA's Tracking Data and Relay Satellite System that are in geosynchronous orbit. The science data is then forwarded from the control center to the Space Telescope Science Institute via a wide-area network for processing, dissemination, and archiving.

NASA has conducted five astronaut-servicing missions to repair and upgrade Hubble. These refurbishments, along with the redundancies originally designed into the observatory's critical subsystems, should keep Hubble running for years to come. Based on formal reliability studies, engineers believe that there is a high probability that Hubble's instruments and primary spacecraft subsystems (gyros, reaction wheels, solar arrays, batteries, etc.) will continue to operate until at least the year 2020. NASA's goal is to operate Hubble concurrently with the James Webb Space Telescope, the agency's new and most capable infrared observatory, planned for launch in 2018.



*Astronauts F. Story Musgrave (anchored on the end of the Remote Manipulator System arm) and Jeffrey A. Hoffman (bottom of frame) work on Hubble during the first servicing mission in December 1993.*

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