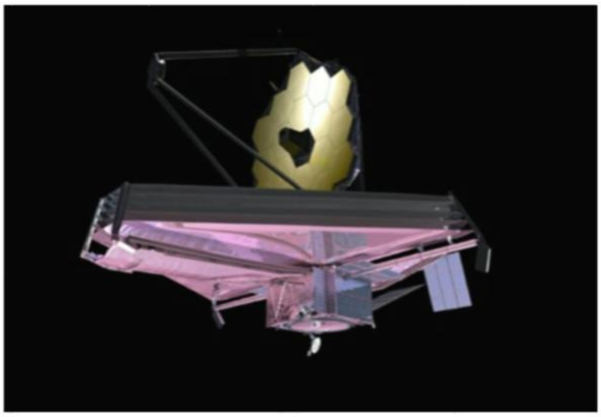

Beyond Hubble_

Future Space Observatories

Space Technology Students' Society
Indian Institute of Technology (Kharagpur)

Few researchers could have predicted the diversity of the Hubble Space Telescope's workload when the iconic observatory launched into orbit over a quarter-century ago. The Hubble Space Telescope (HST) is a space telescope that was launched into low Earth orbit in 1990 and remains in operation. Although not the first space telescope, Hubble is one of the largest and most versatile, and is well known as both a vital research tool and a public relations boon for astronomy. The HST is named after the astronomer Edwin Hubble, and is one of NASA's Great Observatories, along with the Compton Gamma Ray Observatory, the Chandra X-ray Observatory, and the Spitzer Space Telescope.

With a 2.4-meter mirror, Hubble's four main instruments observe in the near ultraviolet, visible, and near infrared spectra. Hubble's orbit outside the distortion of Earth's atmosphere allows it to take extremely high-resolution images, with substantially lower background light than ground-based telescopes. Hubble has recorded some of the most detailed visible light images ever, allowing a deep view into space and time. Many Hubble observations have led to breakthroughs in astrophysics, such as accurately determining the rate of expansion of the universe and also in the discoveries of exoplanets.

What's next for space telescopes, from a tech perspective? Marc Postman said that, ideally, all such scopes would be serviceable, although the ones planned for the near future won't be. But the big observatories expected to reach space in the near future will carry a legacy from Hubble's quarter-century (and counting) of successful operations, he added.

James Webb Space Telescope

The JWST originated in 1996 as the Next Generation Space Telescope (NGST). In 2002 it was renamed after NASA's second administrator James E. Webb , noted for playing a key role in the Apollo program and establishing scientific research as a core NASA activity. The JWST is a project of the National Aeronautics and Space Administration, the United States space agency, with international collaboration from the European Space Agency and the Canadian Space Agency.

The telescope has an expected mass about half of Hubble Space Telescope's, but its primary mirror (a 6.5 meter diameter gold-coated beryllium reflector) will have a collecting area about five times as large. The JWST is oriented toward near-infrared astronomy, but can also see orange and red visible light, as well as the mid-infrared region, depending on the instrument. The design emphasizes the near to mid-infrared for three main reasons: High-redshift objects have their visible emissions shifted into the infrared, cold objects such as debris disks and planets emit most strongly in the infrared, and this band is difficult to study from the ground or by existing space telescopes such as Hubble. Ground based telescopes must look through the atmosphere, which is opaque in many infrared bands. Even where the atmosphere is transparent, many of the target chemical compounds, such as water, carbon dioxide, and methane, also exist in the Earth's atmosphere, vastly complicating analysis. Existing space telescopes such as Hubble cannot study these bands since their mirrors are not cool enough (the Hubble mirror is maintained at about 15 degrees C) and hence the telescope itself radiates strongly in the IR bands.

The JWST will operate near the Earth-Sun L2 (Lagrange) point, approximately 930,000 miles beyond Earth's orbit. By way of comparison, Hubble orbits 340 miles above Earth's surface, and the Moon is roughly 250,000 miles from Earth. This distance makes post-launch repair or upgrade of the JWST hardware virtually impossible. Objects near this point can orbit the Sun in synchrony with the Earth, allowing the telescope to remain at a roughly constant distance and use a single sunshield to block heat and light from the Sun and Earth. This will keep the temperature of the spacecraft below 50 K, necessary for infrared observations. The prime contractor is Northrop Grumman.

Wide Field Infrared Survey Telescope

The original design of WFIRST, featured a 1.3 m diameter unobstructed three-mirror anastigmat telescope. It contained a single instrument, a visible to near-infrared imager/slitless prism spectrometer. In 2012, another possibility emerged: NASA could use a second-hand National Reconnaissance Office telescope made by Harris Corporation to accomplish a mission like the one planned for WFIRST. NRO offered to donate two telescopes, the same size as the Hubble Space Telescope but with a shorter focal length and hence a wider field of view. This provided important political momentum to the project, even though the telescope represents only a modest fraction of the cost of the mission and the boundary conditions from the NRO design may push the total cost over that of a fresh design. This mission concept, called WFIRST-AFTA (Astrophysics Focused Telescope Assets), was matured by a scientific and technical team; this mission is now the only present NASA plan for the use of the NRO telescopes. The WFIRST baseline design includes a coronagraph to enable the direct imaging of exoplanets.

WFIRST has had a number of different implementations studied. In the most recent report, WFIRST was considered for both geosynchronous and L2 orbits. Appendix C documents the disadvantage of L2 vs. geosynchronous in the data rate and propellant, but the advantages for improved observing constraints, better thermal stability, and more benign radiation environment at L2. Some science cases (such as exoplanet microlensing parallax) are improved at L2, and the possibility of robotic servicing at either of the locations requires further study.

Event Horizon Telescope

The Event Horizon Telescope (EHT) is a project to create a large telescope array consisting of a global network of radio telescopes and combining data from several very-long-baseline interferometry (VLBI) stations around the Earth. The aim is to observe the immediate environment of the Milky Way's supermassive black hole Sagittarius A*, as well as the even larger black hole in Messier 87, with angular resolution comparable to the black hole's event horizon.

The EHT is composed of many radio observatories or radio telescope facilities around the world to produce a high-sensitivity, high-angular-resolution telescope. Through the technique of very-long-baseline interferometry (VLBI), many independent radio antennae separated by hundreds or thousands of miles can be used in concert to create a "virtual" telescope with an effective diameter of the entire planet. The effort includes development and deployment of submillimeter dual polarization receivers, highly stable frequency standards to enable very-long-baseline interferometry at 230–450 GHz, higher-bandwidth VLBI back ends and recorders, as well as commissioning of new submillimeter VLBI sites.

Each year since its first data capture in 2006, the EHT array has moved to add more observatories to its global network of radio telescopes. The first image of the Milky Way's supermassive black hole, Sagittarius A*, was thought to be produced in April 2017, but due to the South Pole Telescope being closed during winter (April to October) the data shipment delayed the processing to December 2017, when the shipment arrived. A date for the release of the image has not yet been announced. The image will also test Einstein's general relativity at the extreme.

Data collected on hard drives must be transported by jet airliner (a so-called sneakernet) from the various telescopes to the MIT Haystack Observatory in Massachusetts, USA, and the Max Planck Institute for Radio Astronomy, Bonn, Germany, where the data are cross-correlated and analyzed on a grid computer made from about 800 CPUs all connected through a 40 Gbit/s network.