The James Webb Space Telescope's Near Infrared Spectrograph (NIRSpec) separates light in a spectrum. NIRSpec's components are sensative to infrared light and will help study galaxies.

CHRIS GUNN/NASA

Unraveling the History of the Universe

The James Webb Space Telescope will peer further back in time

By Joseph Bennington-Castro

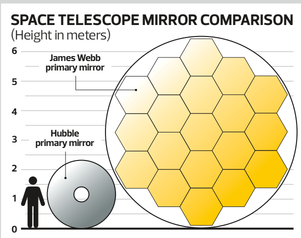
SET TO LAUNCH in October 2018, the James Webb Space Telescope (JWST), will be Earth's largest and most-expensive space observatory to date.

The $8.8 billion telescope represents an international collaboration involving more than 100 people from 17 nations. NASA, the European Space Agency and the Canadian Space Agency are the largest contributors, supporting the project with funds, technology and personnel.

"It's a strong collaboration throughout the entire process," said John Mather, JWST senior project scientist and an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Md.

The JWST is the successor to the still-operational Hubble Space Telescope, which launched in 1990. But unlike Hubble, which primarily sees the visible and ultraviolet portions of the electromagnetic spectrum, Webb operates mainly in infrared. And compared with Hubble's 2.4-meter-diameter (7.9 feet) primary mirror, JWST has a primary mirror 6.5 meters (21.3 feet) in diameter.

"Webb has seven times the light-collecting area of Hubble, but half the mass," Mather said. This allows the telescope to peer further back in time by collecting



NASA

THE GREAT AGE OF SPACE TELESCOPES

Electromagnetic radiation comes in many forms, such as visible light, radio waves and microwaves. Objects in space give off different types of radiation, but observing these signals from Earth is difficult because the atmosphere absorbs gamma rays, X-rays, ultraviolet light and most of the infrared spectrum. It also can blur or otherwise distort images from the Earth's surface.

The solution to this problem: space telescopes. When the James Webb Space Telescope launches in 2018, it will join a host of other active space observatories.

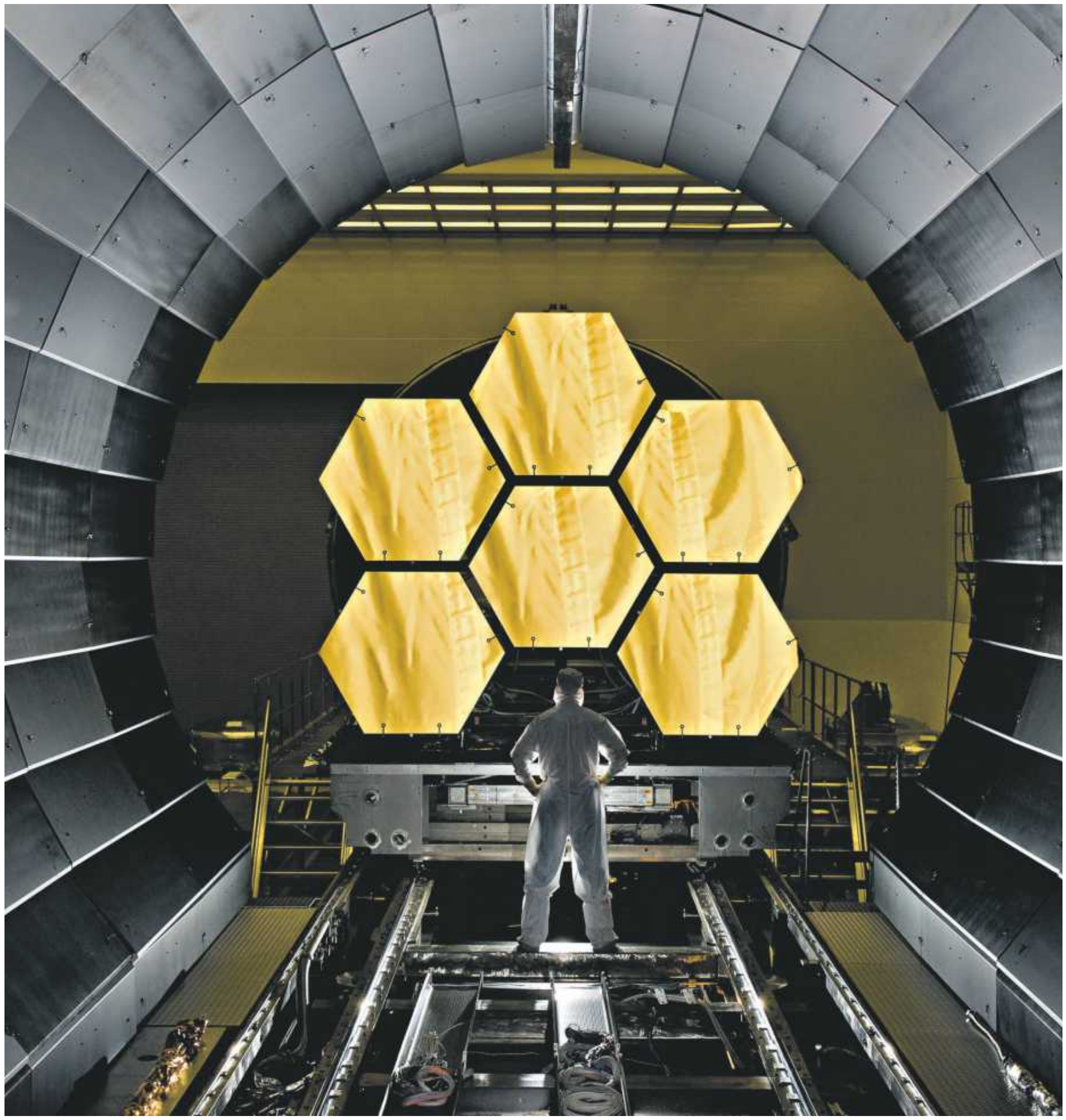
Launched in 1990, the **Hubble Space Telescope** is the most well-known space observatory. It observes near-infrared, ultraviolet and visible light, and has numerous successes, including discovering two new moons of Pluto, finding evidence of ancient dark energy and measuring the atmospheres of extra-solar planets.

The **Kepler Observatory** is the only space telescope dedicated solely to hunting for extra-solar planets, especially those that may have the water necessary for life as we know it. Kepler monitors light from more than 100,000 stars at once, looking for the telltale dip in brightness caused by a planet passing in front of its star. Since a 2009 launch, Kepler has discovered nearly 1,000 exoplanets, including one that's only 10 percent larger than Earth and orbits around its star in a region where liquid water could exist, and more than 3,000 potential planets.

Chandra X-Ray Observatory, launched in 1999, is the world's most powerful X-ray telescope. It set out to unravel some of the biggest mysteries, such as where dark matter lingers and what drives the explosive activity in distant galaxies. Chandra has helped map the distribution of dark matter in massive galaxies and discovered a new class of black holes, among other successes.

In 2008, NASA launched the **Fermi Gamma-Ray Space Telescope** into low-Earth orbit. Its job: to study the most energetic objects, including supernovas and black hole-powered galaxies, and identify other sources of gamma rays. And in 2009, the European Space Agency launched the microwave-detecting Planck Observatory, which studies the cosmic microwave background, an echo of radiation from the Big Bang.

— Joseph Bennington-Castro



DAVID HIGGINBOTHAM/MSFC/NASA

The first six flight-ready primary mirror segments on the James Webb Space Telescope are prepped to begin final cryogenic testing at NASA's Marshall Space Flight Center. NASA engineer Ernie Wright looks on.

> "Webb has seven times the light-collecting area of Hubble, but half the mass."
>
> **— John Mather, Goddard Space Flight Center**

more light from dim, distant objects in the universe. In fact, JWST's task will be to study the entire history of the universe, including objects that formed shortly after the Big Bang, the prevailing scientific theory for the birth and early evolution of the universe. (Despite its name, the Big Bang was not an explosion.)

The JWST's own history began several years after Hubble launched.

Even in its infancy, Hubble was wildly successful — it confirmed the existence of super-massive black holes in the hearts of galaxies and provided the best images of comet Shoemaker-Levy 9's collision with Jupiter in 1994, among other things.

But "after it launched, people saw it was never going to answer all of our questions," Mather said. So an 18-member committee of experts gathered to discuss what NASA's next steps should be. In 1996, the experts gave their answer: NASA needs to build

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NASA LEADER

JAMES WEBB: VISIONARY

James Webb was NASA's second administrator. He ran the nascent space agency — formally established in 1958 — from February 1961 to October 1968.

Webb, who was 85 when he died in 1992, enjoyed a long career in public service in Washington, D.C., before taking over NASA. Considering Webb's lack of a science background, NASA scientists were initially uneasy about his running the space agency. He quickly calmed those fears.

During his tenure, Webb gave scientists greater control over NASA's science mission selections. He also created the NASA University Program, which provided financial support for space research, university laboratories and graduate students. This program also encouraged university administrators to publicly support NASA's endeavors.

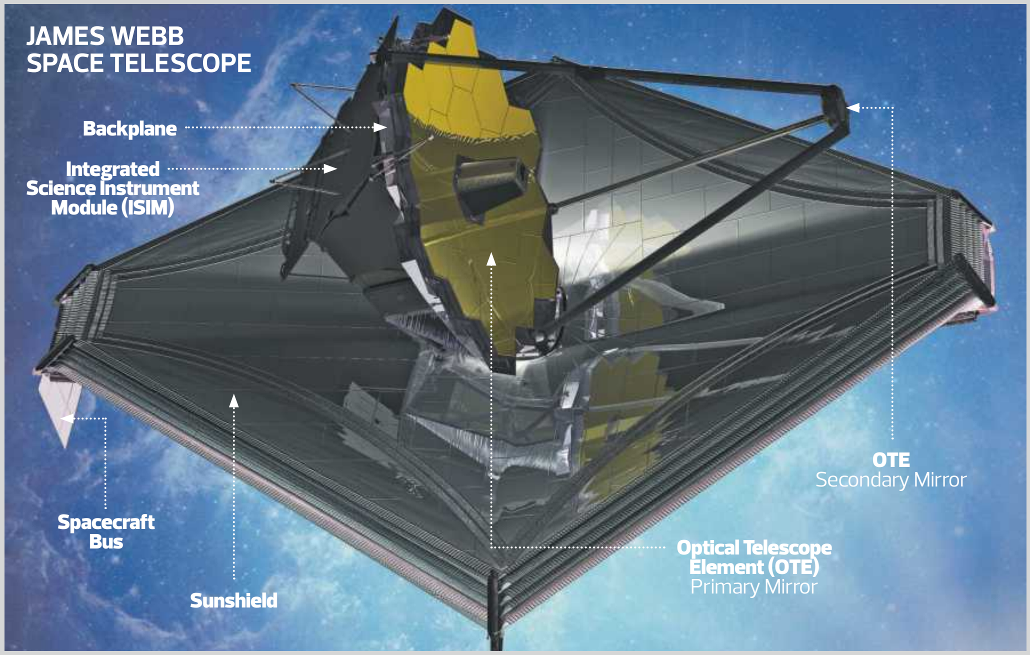
Under Webb's guidance, NASA explored the moon with robotic spacecraft in preparation for manned missions and sent scientific probes to Mars and Venus. In all, he supervised more than 75 space science missions. He also advocated for the construction of a major space observatory, known then as the Large Space Telescope — this project would later become the Hubble Space Telescope.

Webb retired not long before the historic mission he helped NASA prepare: the Apollo 11 moon landing in July 1969.

— James Bennington-Castro

NASA

NASA Administrator James Webb is seated in the Gemini rendezvous and docking simulator during an Aug. 7, 1965, visit to the Manned Spacecraft Center (renamed the Johnson Space Center in 1973).



NASA

WHY STUDY INFRARED LIGHT?

Infrared is a form of electromagnetic radiation with wavelengths larger than visible light but smaller than microwaves. It's divided into three categories: Near-infrared is the portion of the infrared spectrum closest to visible light, far-infrared is closest to microwaves and mid-infrared sits between these two extremes.

The James Webb Space Telescope (JWST) has sensitive instruments that detect near- and mid-infrared light, which are suited to study galaxy, star and planet formation.

The universe is expanding, with objects farther away from us moving away at faster rates. This movement causes the visible and ultraviolet light from these objects to redshift, or move into "redder" (longer) wavelengths, particularly near- and mid-infrared.

JWST will allow scientists to study the oldest galaxies in the universe, or those farthest away. What's more, visible light from newborn stars cannot penetrate the cloud of gas and dust that surrounds them — but near-infrared can. Also, Earth-temperature objects emit mostly mid-infrared radiation, and the material surrounding newly forming stars (and possibly planets) also shines brightly in the mid-infrared.

— James Bennington-Castro

the so-called Next Generation Space Telescope, which was renamed in 2002 to honor NASA's second administrator, James Webb.

Development of JWST's science instruments and 18-segment primary mirror commenced in 2004. Construction kicked into high gear in 2007.

Unfortunately, technical and financial issues have plagued JWST throughout its construction, delaying its launch (at one point, 2014 was its planned launch date). But it's now on track for a 2018 launch, according to NASA.

NASA and its collaborators already completed building the telescope's most difficult and important components, including its scientific instruments, mirrors and sunshield, which will unfold in space to keep the observatory's sensitive infrared instruments at the necessary operating temperature of -388 degrees Fahrenheit (-233 degree Celsius).

> NASA needed to build the so-called Next Generation Space Telescope, which was renamed in 2002 to honor NASA's second administrator, James Webb.

"There's still some fabrication to do," Mather said. "We delayed the easiest parts for the end."

In the next few years, scientists will carefully piece the telescope together and then rigorously test it to make sure everything works properly.

Once operational, JWST will have four main goals, which will ultimately help scientists better understand how we all got here. It will identify the first luminous objects that formed after the Big Bang; understand how galaxies evolved; watch the birth of new stars and proto-planetary systems (planetary systems in the process of forming); and study other planetary systems and determine their potential for life.

Along the way, the observatory also may make some startling and unexpected finds, such as the discovery of a new kind of galaxy or planet, Mather said. "The hope we all have is that there is some big surprise."