IV. Science and Technology

James Webb Space Telescope: The Universe Like We've Never Seen It Before

by Janet G. West

Oct. 24—Try to research "James Webb Space Telescope" casually, and the media will serve up the pablum of the "many years" it's taken to assemble and prepare the telescope for launch, as well as the "cost overruns." You will even find credence given to the ridiculous idea that the name should be changed because "James Webb wasn't 'woke' enough."

Turns out, *you should believe the hype*, and not the "mainstream media" hyenas doing what they do best—crapping on beautiful ideas to demoralize and weaken the population. The reality of this dazzling mission is like the unfolding of a rare and marvelous flower.

NASA/Chris Gunn

Fully assembled and tested, NASA's James Webb Space Telescope is here being prepared for shipment to its launch site in French Guiana. It will be fitted into an Ariane 5 rocket and launched on December 18.

The journey of the James Webb Space Telescope (JWST) from a mere idea in 1989, to now being only weeks away from launch in December 2021, has developed like Beethoven's *Grosse Fuge* or his master choral work, the *Missa Solemnis*. Even before the Hubble Space Telescope was launched in 1990, astronomers, scientists, and engineers began to wonder, "What if…?" What if we could develop and build a 10-meter, passively cooled, near-infrared telescope in a high-Earth orbit to study galaxies at high redshift (great distance from our Milky Way galaxy)?

Scientists and astronomers began to organize around the idea for such a space-based telescope, and in 1996, an 18-member committee formally recommended to NASA to develop such a project. The ability of such a telescope to view the heavens in infrared light was crucial, as this allows astronomers to see through the immense dust and gas clouds that shroud much of the galaxy and beyond, extending mankind's vision further into space, as well as back in time.

In 1997, NASA began to fund additional studies to determine the technical and financial requirements to build such a telescope, and in 2004, work finally began. At that time, the project was formally named the James Webb Space Telescope, after the NASA administrator who led the development of the Apollo program.

James Webb (1906–1992) was the second appointed administrator for NASA, from 1961-1968 (from the Kennedy through to the end of the Johnson Administration). Many consider that he "did more for science than perhaps any other government official," in part because—even though he was tasked by JFK to ensure America put a man on the moon in the time allotted by JFK—he also strongly believed that there had to be a balance between human space flight, and science for its own sake. He felt that keeping a broad focus on exploration of space would strengthen America's universities and high schools, and catalyze a rapid pace of advance in the aerospace industry.

A 'Universal' Cup of Coffee

In the 1970s, the American economist and statesman Lyndon H. LaRouche developed an analogy as a way to understand physical economics, which took the concept of the "bill of materials" for a cup of coffee, and extended it to include all the components from all over the world—the beans, the person who picked the beans, the transport of the beans to a factory, etc.—in order to deliver it to your table, and called it "the worldwide cup of coffee."

In a similar way, the components for the JWST weren't developed in just one place, and many of the technologies had to be invented. Although Northrup Grumman was the managing contractor, and did build many of the parts of the telescope, the golden mirror—made up of 18 hexagonal component mirrors—was subcontracted to Ball Aerospace & Technologies, which in turn further subcontracted the components.

NASA/ASU/Jeff Hester & Paul Sowen

The Pillars of Creation, in the Eagle Nebula (M16), as imaged by the Hubble Space Telescope in 1995.

The JWST is an international collaboration among NASA, the European Space Agency (ESA), and the Canadian Space Agency (CSA). NASA's Goddard Space Flight Center in Greenbelt, Maryland is managing the development team.

In total, the number of institutions that have worked on some part(s) of, or contributed to the JWST mission are a jaw-dropping 306! In America, this includes CDA InterCorp (Florida), Genesis Engineering Corp. (Maryland), and Quantum Coating (New Jersey); in Canada, Honeywell Aerospace (Ottawa) and National Optics Institute (Quebec); and in Europe, Airbus Defence and Space (Spain), ArianeGroup, GmbH (Germany), and the Danish Space Board (Denmark), among many others. Now, imagine the logistics and supply-chain expertise required to bring all of these components together into one unit.

NASA has taken the overall responsibility for the Webb mission; the ESA has provided the Near Infrared Spectrograph (NIRSpec), the Mid-Infrared Instrument (MIRI) Optics Assembly, and the Ariane Launch Vehicle; and the CSA took responsibility for the Fine Guidance Sensor/Near Infrared Imager and Slitless Spectrograph. After launch, the Space Telescope Science Institute (a subsidiary of NASA) will *operate* the JWST.

As the NASA JWST site explains, the components of the JWST—

> include a primary mirror made of 18 separate segments that unfold and adjust to shape after launch. The mirrors are made of ultra-lightweight beryllium. Webb's biggest feature is a tennis court-sized, five-layer sunshield that attenuates heat from the Sun more than a million times. The telescope's four instruments—cameras and spectrometers—have detectors that are able to record extremely faint signals. One instrument (NIRSpec) has programmable micro-shutters, which enable observation of up to 100 objects simultaneously. Webb also has a cryo-cooler for cooling the mid-infrared detectors of another instrument (MIRI) to a very cold 7 kelvin (minus 447 Fahrenheit) so they can work.

Even if other nations of the world didn't participate, the spirit of this endeavor is to transmit new discoveries "of profound and passionate nature" to all of humanity, for the benefit of all mankind.

'First Light'

The JWST will be about one hundred times more powerful than the Hubble Space Telescope, not only because of the size of its mirror (6.5 meters to Hubble's 2.4), but because of the wavelength at which it will primarily "see," that of the infrared part of the spectrum.

The electro-magnetic spectrum is a continuum of wavelengths, from the very long (think of radio waves, which can be 100 kilometers and more in length) to the very small (such as visible light, measured in billionths of a meter, nanometers). We humans see a very narrow range of this spectrum (about 400-700 nanometers) which we call visible light. Anything much past either side of that is invisible to us.

For example, if you've ever glanced at a black light (UV range: about 10-400 nanometers), you may notice that it's difficult to focus on it and will appear "fuzzy" (and you shouldn't try to focus if you don't want to fry your retina)—this is because the wavelength is too small for our lenses to focus upon. And, on the other extreme, deep red light is at the other, long wavelength end of the visible spectrum, and for that reason is used on submarines and other conditions of near darkness, because the wavelength makes it easier for the human eye to adjust from darkness to the red-lit instrument panel. Night-vision infrared optics also use the heat signature of a person, animal or object to be able to detect it.

Seeing in the infrared range allows the JWST to do a number of things that Hubble can't—it allows it to pierce the gas and dust clouds that normally hide whole fields of stars; and due to the redshift, it allows the telescope to see further back in time.

Einstein's General Relativity theory comes into play, in terms of how the telescope "sees." It tells us that the expansion of the universe means it is the space between objects that actually stretches, causing objects (galaxies) to move away from each other. Right now, that means that all of the galaxies around us are moving away from us, so the wavelengths get stretched and move further into the infrared range. This is very much like the experience when a fire engine's siren approaches you, the sound waves bunch up, so the sound is higher-pitched, and then as the vehicle moves past you, the sound waves are lengthened and sound lower in pitch.

It also means that a telescope can peer back in time, to over 13.5 billion years ago, to see the first stars and galaxies take shape out of the darkness of the early Universe.

By comparison, Earth is estimated to be a little over 4.5 billion years old.

The further out one looks out into space, galaxies are harder to see—this is not only due to the distance, but the "stretching out" of the wavelength. Hubble sees in the ultraviolet and visible light range, so these faraway galaxies become more difficult to detect. And, usually a telescope is pointed in the direction where astronomers want to see more detail of an object of interest. However, in 1995, they pointed Hubble in the direction of seemingly dark, empty space—and returned stunning images of billions of galaxies (the Deep Field studies). Current estimates are that there are at least three trillion galaxies—imagine what new horizons will reveal when the JWST probes into deep space with its infrared capabilities.

This may have been the inspiration for Sarah bint Yousif Al Amiri, UAE Minister of State for Advanced Sciences, who spoke of how one could point upwards in any direction into the sky, and one would be able to see billions of galaxies. This was during the UAE's Hope Probe mission that successfully entered Mars' orbit in February 2021.

Using another aspect of its capabilities, JWST will study the atmospheres of exoplanets, that is, planets orbiting suns other than our own. This is done through spectroscopy, the measurement of the intensity of light emitted by an object at different wavelengths. The graphical representations of these measurements are called spectra, and they are the key to unlocking the composition of exoplanet atmospheres.

When a planet crosses in front of its sun, the light from the sun passes through the planet's atmosphere. Using spectroscopy, we can see an "absorption line" in the place in the spectrum where one would expect to see an element's "signature." For example, the presence of sodium in an atmosphere will present as a black line in a particular portion of the spectrum. This is because different elements absorb light at particular energies. In this way, we can investigate far-away planets that might have an atmosphere which could support life.

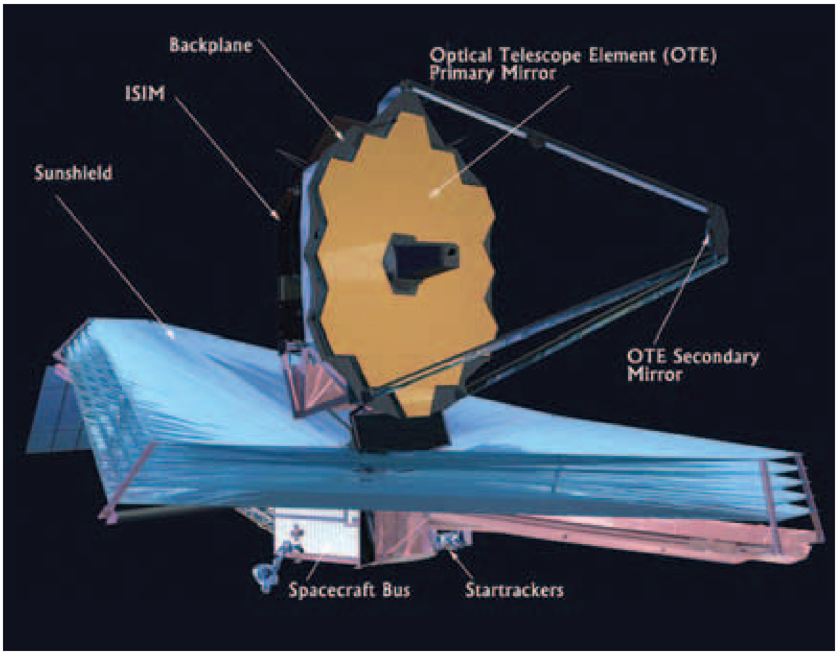
The JWST will also augment our current exploration of our own solar system, by examining the atmospheres of the planets, and even very sparse atmospheres of their moons.

Precious Instruments and the Golden Mirror

The instruments which do all of the fine measurements are located within the Integrated Science Instrument Module (ISIM) which in turn, is one of three major elements that make up the JWST Observatory flight system. The second is the Optical Telescope Element (OTE), and the third, the Spacecraft Element, which comprises the Spacecraft Bus and the Sunshield.

The ISIM includes the cryogenic instrument module. Here, various detectors must be brought down to extreme temperatures—in the range of 39 kelvin—so that the sensitive instruments will pick up interstellar light, and not an accidental infrared "selfie."

The four main instruments within the ISIM are these:



Public domain

Configuration of the James Webb Space Telescope, showing the major components, as of September 2009.

• Near-Infrared Camera (NIRCam), provided by the University of Arizona

• Near-Infrared Spectrograph (NIRSpec), provided by the ESA, with components provided by NASA/Goddard Flight Space Center

• Mid-Infrared Instrument (MIRI), provided by the consortium of the ESA and the NASA Jet Propulsion Laboratory (JPL)

• Fine Guidance Sensor/Near Infrared Imager and Slitless Spectrograph (FGS/NIRISS), provided by the CSA.

The NIRSpec, in particular, possesses a unique capability:

> One unique technology in the NIRSpec that enables it to obtain those 100 simultaneous spectra is a micro-electromechanical system called a "microshutter array." NIRSpec's microshutter cells, each approximately as wide as a human hair, have lids that open and close when a magnetic field is applied. Each cell can be controlled individually, allowing it to be opened or closed to view or block a portion of the sky.
>
> It is this adjustability that allows the instrument to do spectroscopy on so many objects simultaneously. Because the objects NIRSpec will be looking at are so far away and so faint, the instrument needs a way to block out the light of nearer bright objects. Microshutters operate similarly to people squinting to focus on an object by blocking out interfering light.

The "eye" of the telescope is the Optical Telescope Element (OTE), which comprises a number of elements:

• The 6.5 meter (over 21 feet) diameter primary mirror, which in turn is made up of 18 hexagonal mirrors, which each can be independently maneuvered for fine-tuning

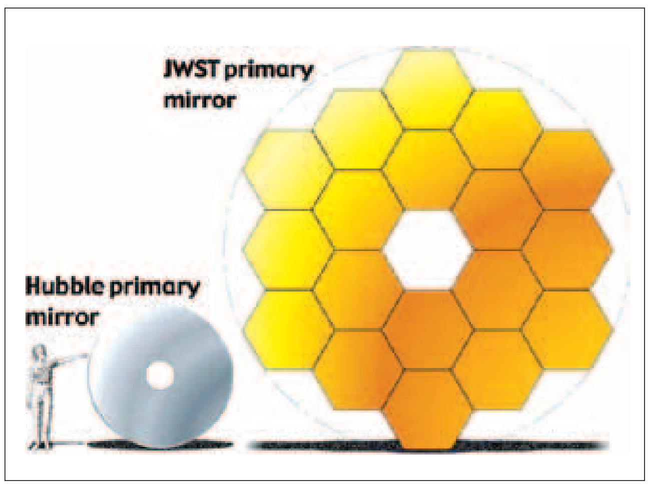
• The round, 0.74 meter (2.4 feet) secondary mirror

• The tertiary mirror, and the Fine Steering Mirror, all of which are part of the Aft Optics Subsystem

• Telescope structure (which includes the primary mirror backplane assembly, the main backplane support fixture (BSF), the secondary mirror support structure, and the deployable tower array). The BSF will house the instrument module.

• Thermal Management Subsystem
• Aft Deployable ISIM Radiator (ADIR)
• Wavefront sensing and control.

The primary mirror had to be large in order to capture as much light as possible from distant objects. Each

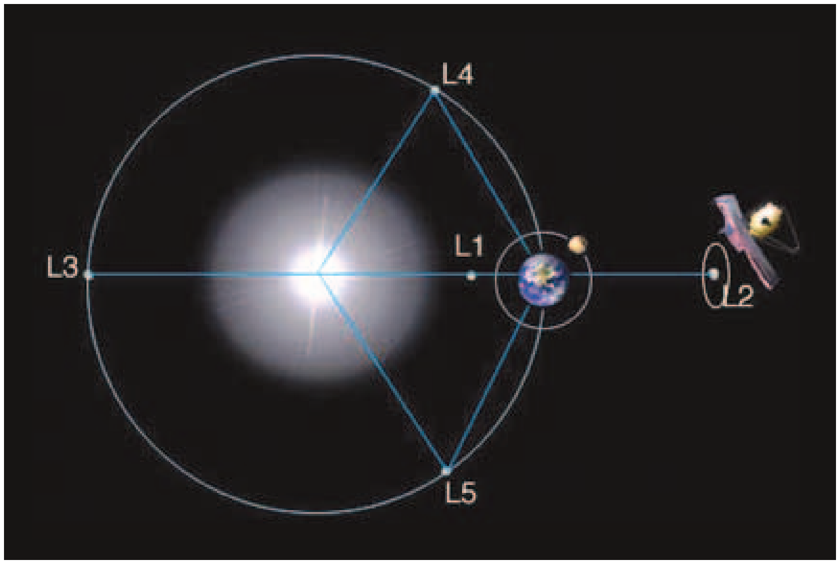


NASA

JWST's 6.5-meter diameter primary mirror, compared with Hubble's mirror.

individual mirror is made of ultra-lightweight beryllium and coated with an ultra-thin layer of gold—which improves the mirror's reflection of infrared light. A mirror this size has never before been launched into space! It also had to be capable of being folded, much like a chrysalis, in order to fit within the Ariane rocket. It is programmed to unfurl in space at precise points in the mission, and at precise speeds, in order not to create motion in the opposite direction.

As Johannes Kepler (1571-1630) discussed in his delightful book, *On the Six-Cornered Snowflake*, the hexagon is the most perfect shape for such a telescope, because a hexagon is the most stable structure that demonstrates a "high filling factor." This means that all of the smaller hexagons fit together without any space between, and can approximate a circular curved surface, which will focus the incoming light into the most compact region for the detectors.



NASA

JWST will orbit around Lagrange Point 2, about 1.5 million kilometers directly behind the Earth as viewed from the Sun, where the gravitational forces of the Sun and Earth on the spacecraft balance the centrifugal force on it.

Another challenge is to keep the mirror cold enough in space to be able to detect far-flung stars and galaxies, and it has been put through rigorous tests to ensure that it would function normally (and its structures wouldn't deform) in the deep reaches of space. The main means of keeping the mirror cool is the sunshield, protecting it from the heat of the Sun and the Earth.

The Sunshield

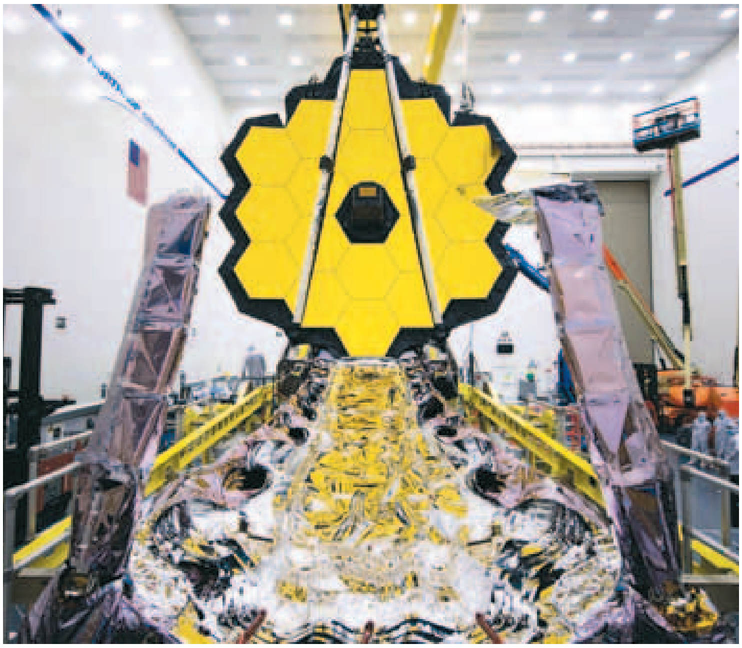
The means by which the mirror and other instruments will be kept cool is a 5-layer, tennis court–sized sunshield that will act like a parasol providing shade. (Actual dimensions: 21.197 × 14.162 m [69.5 × 46.5 ft])

The sunshield will always be between the Sun/Earth/Moon and the telescope. It's able to be positioned this way because JWST will be orbiting the Sun 1.5 million kilometers (932,000 miles) away from—but approximately in line with—the Earth. The telescope will be orbiting around a "balance point" in space, the Lagrange Point 2 (L2), nearly 1.6 million kilometers (1 million miles) from Earth. The telescope will essentially be orbiting L2 in a plane perpendicular to the plane of Earth's solar orbit.

By having five layers of a specialized material called Kapton, heat is dissipated in the spaces between the layers. The shiny silver material of the five-layer sunshield is a complex and innovative feat of materials science and engineering. Each layer is made from this unique composite material, each has a specific thickness and size, and the layers must be precisely separated in space. There are even special seams and reinforcements to limit meteorite damage (i.e., "ripstop" capabilities on a very small scale).

As the James Web Space Telescope website explains:

> The sunshield layers are also coated with aluminum and doped-silicon for their optical properties and longevity in the space environment. Doping is a process where a small amount of another material is mixed in during the silicon coating process so that the coating is electrically conductive. The coating needs to be electrically conductive so that the membranes can be electrically grounded to the rest of JWST and will not build up a static electric charge across their surfaces. Silicon has a high emissivity, which means it emits the most heat and light and acts to block the sun's heat from reaching the infrared instruments that will be located underneath it. The highly-reflective aluminum surfaces also bounce the remaining energy out of the gaps at the sunshield layers' edges.



NASA

The JWST with its primary mirror deployed. Its folded sunshield is also visible.

James Cooper, James Webb Space Telescope Sunshield Manager at NASA's Goddard Space Flight Center in Greenbelt, Maryland, explains as follows (https://www.jwst.nasa.gov/content/observatory/sunshield.html):

> The shape and design also direct heat out the sides, around the perimeter, between the layers. Heat generated by the Spacecraft bus at the "core," or center, is forced out between the membrane layers so that it cannot heat up the optics.
>
> The five layers are needed to block and redirect enough heat to get the telescope down to required temperatures, with margin. The fifth layer is mostly for margin against imperfections, micro-meteoroid holes, etc. The gap between the layers provides an additional insulating effect.
>
> Each layer of the sunshield is incredibly thin. Layer 1 will face the sun and is only 0.05 millimeters (0.002 inches) thick, while the other four layers are 0.025 mm (0.001 inches). The thickness of the aluminum and silicon coatings are even smaller. The silicon coating is ~50 nanometers (nm) (1.9 microinches) thick, while the aluminum coating is ~100 nm (3.93 microinches) thick.

What Lies Ahead?

All of these magnificent technologies and instruments must be folded up, origami-style, to fit into the nose cone of the Ariane-5 rocket, which will lift the entire 6,500 kilogram (14,300 pound) structure into orbit. The total endeavor is truly an awesome feat—from a mere idea, to a machine of such wondrous capabilities.

As of October 12, 2021, the telescope had arrived in French Guiana, just north of Brazil, after a 16-day ocean voyage that covered 9,300 kilometers (5,800 miles). It is now being prepared for launch on December 18, 2021. It is launching from French Guiana because that's where the Ariane rocket launch site is—near the equator; the spin of the Earth at the equator gives an additional push to the launch, as the surface of the Earth is moving fastest there, at 1,670 km/hr (about 1,037 mph). Thousands of astronomers and scientists around the world will be riveted to the news coverage on launch day.

As awesome as this achievement is, one can't help but wonder, "If mankind can do *this* with just a few thousand devoted personnel, what *can't we accomplish* with a similar dedication?" Or, as Robert Kennedy once said, "Some men see things as they are, and ask, 'Why?' I dream things that never were, and ask, 'Why not?' "

One can't help but notice the irony of this glittering machine launching from a country that has only 10 people per square mile! Haiti—2,668 kilometers (1,650 miles) to the northwest—has a population of 1,072 per square mile.

If a few thousand enthusiastic scientists and engineers can do all of this, what then is holding back the world from rebuilding Haiti and Afghanistan, as Helga Zepp-LaRouche and the Schiller Institute have advocated? Where is the political will, and the morality, for nations to work in concert to uplift millions from poverty? Couldn't the science and technology of the advanced sector help these nations to "leapfrog" into the 21st Century?

If such a spark of dedication from a few thousand people burns so brightly for humanity, how bright then would be the flame of millions devoted to a just cause?