



MEDIA KIT



WEBB
SPACE TELESCOPE

www.nasa.gov



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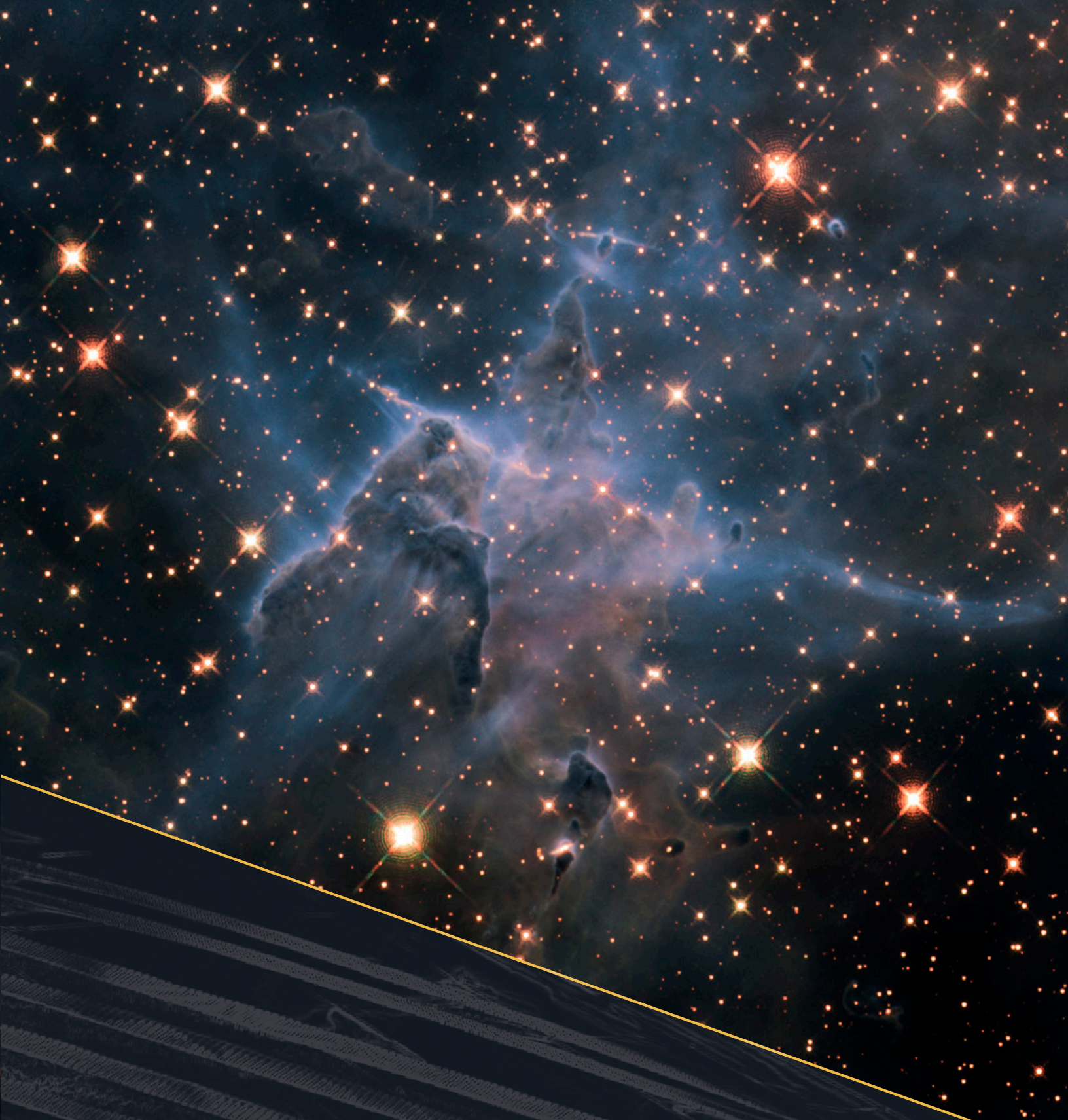
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INTRODUCTION

The Webb Story: Unfolding Our Cosmic History

Where did we come from?

The greatest origin story of all unfolds with the James Webb Space Telescope. Webb is NASA's newest premier space science observatory – destined to be a household name, like its predecessor, Hubble. This is an Apollo moment for NASA science: Webb will fundamentally alter our understanding of the universe. It can observe all of the cosmos, from planets to stars to nebulae to galaxies and beyond – helping scientists uncover secrets of the distant universe as well as exoplanets closer to home. Webb can explore our own solar system's residents with exquisite new detail and search for faint signals from the first galaxies ever made. From new forming stars to devouring black holes, Webb will reveal all this and more.

Webb is engineered to build upon the groundbreaking discoveries of other spacecraft, such as the Hubble Space Telescope and the Spitzer Space Telescope. While Hubble views the universe in visible and ultraviolet light, Webb focuses on infrared, a wavelength important for peering through gas and dust to see distant objects. After Spitzer blazed trails in the infrared, Webb will take us farther by virtue of a primary mirror that is nearly 60 times larger in area. Finally, Webb's mirror gives us Hubble's incredible resolution with even greater sensitivity, and it is fully adjustable in space.

Webb's large mirror and advanced suite of instruments are protected by a five-layer sunshield, built to unfurl until it reaches the size of a tennis court. The entire observatory is folded up to fit inside the launch vehicle and will unfold in space. This complex deployment sequence has never been attempted for a space telescope, and the amazing engineering that enabled Webb includes many innovations that push the boundaries of technology.

Webb is a feat of human ingenuity. The mission has been developed over two decades, with contributions from thousands of scientists, engineers, and other professionals from more than 14 countries and 29 U.S. states.

Webb's launch is a pivotal moment that exemplifies the dedication, innovation, and ambition behind NASA and its partners, the European Space Agency (ESA) and Canadian Space Agency (CSA), but it is only the beginning. The observatory's six months of commissioning in space is an exciting but harrowing time, during which thousands of parts and sequences all have to work correctly together, almost a million miles from Earth. This period culminates when the telescope begins to take data – a truly momentous celebration for the mission, NASA, the United States, and the world.

Fundamental astronomy questions propelled Webb's unique design, cutting-edge capabilities, and unparalleled infrared sensitivity – all geared to provide a new view of the universe and capture our imagination with extraordinary science discoveries. It's a giant leap forward in our quest to understand humanity's place in the great cosmic expanse.

MEDIA SERVICES



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Products and Events

News Releases and Features

Mission news, updates, and feature stories about the James Webb Space Telescope are available below:

[NASA News Releases](#)

[Scientific News Releases](#)

[Resources in Spanish/Recursos en Español](#)

The latest information about launch and commissioning activities can be found here at the [Webb Launch Toolkit](#).

Multimedia Resources

Webb's image and video galleries include:

[NASA B-roll and Animations Gallery](#)

[NASA Flickr gallery](#)

[Space Telescope Science Institute Resource Gallery](#)

[Webb Science Writer's Guide](#)

The NASA image use policy can be found [here](#).

The Space Telescope Science Institute's image use policy can be found [here](#).

Web Resources

Official NASA Sites

[General](#) / [Technical](#)

Official Partner Sites

Canadian Space Agency

[English](#) / [French](#)

European Space Agency

<https://esa.int/webb>

Space Telescope Science Institute

<https://webbtelescope.org>

Media Events

The most up-to-date information about the James Webb Space Telescope's media events and where they may be viewed can be found on the [Webb Launch Toolkit](#). More information on NASA Television and streaming channels can be found below in the Watch Online section.

How to Watch

News briefings and landing commentary are streamed on [NASA TV](#), [NASA.gov/live](#), and [YouTube.com/NASA](#). (On-demand recordings will also be available after the live events have finished on YouTube.) Any additional feeds or streams will be listed in the Watch Online section of the Webb Launch Toolkit.

Follow Webb on Social Media

HASHTAGS

[#UnfoldTheUniverse](#)

[#NASAWebb](#)



WEBB AT A GLANCE



6 Sides to the James Webb Space Telescope

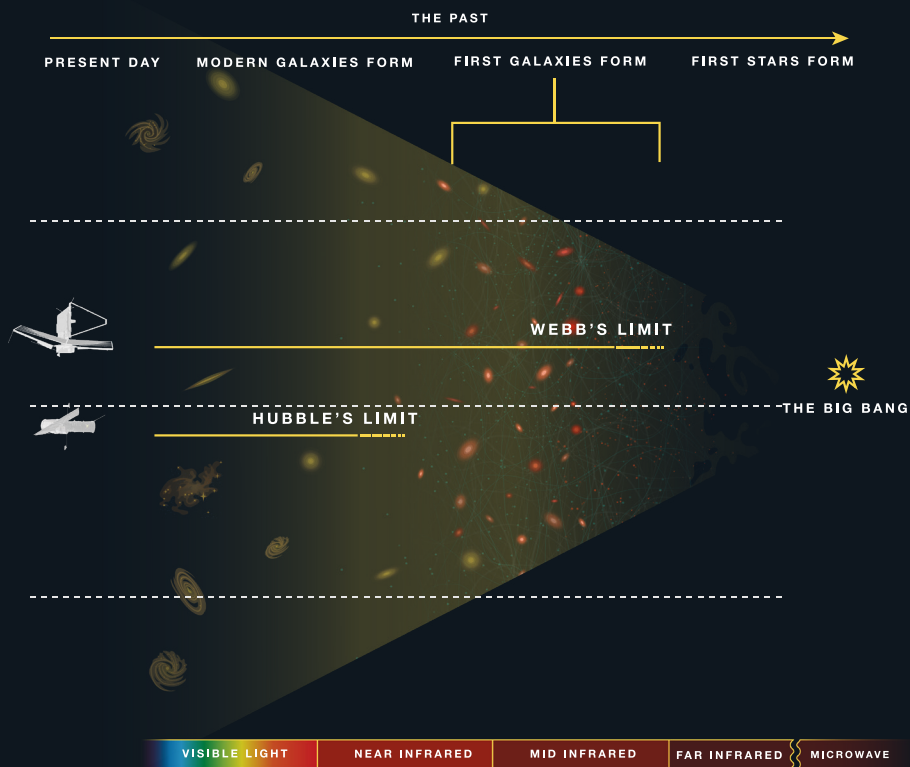
The James Webb Space Telescope is the largest and most powerful space science telescope ever built.

It will unfold the universe, transforming how we think about the night sky and our place in the cosmos. The telescope lets us look back to see a period of cosmic history never before observed. Webb can peer into the past because telescopes show us how things were – not how they are right now. It can also explore distant galaxies, farther away than any we've seen before.

Here's what you should know about this one-of-a-kind marvel of engineering:

1 The James Webb Space Telescope studies every phase of cosmic history

The Webb telescope is the scientific successor to the iconic Hubble and Spitzer space telescopes, built to complement and further the discoveries of Hubble, Spitzer, and other NASA missions by accessing the near-infrared and mid-infrared wavelengths with unprecedented resolution. Webb's revolutionary technology will allow scientists to explore every phase of cosmic history – from within our solar system to the most distant observable galaxies in the early universe, and everything in between. Webb will reveal new and unexpected discoveries and help humankind understand the origins of the universe, as well as our place in it.



2 The Webb observatory is so large it must fold up for launch and then unfold in space, like giant high-tech origami

Webb's science objectives require the observatory to be very large – so large that, when expanded to full size, it can't fit into the nose cone (i.e., fairing) of any available launch vehicle in its operational configuration.

One of Webb's main components is the sunshield, a diamond-shaped structure roughly the area of a tennis court. It was carefully folded and packed to fit inside Webb's launch vehicle, the Ariane 5 rocket. In space, the sunshield will expand, tension, and separate into its five distinct layers.

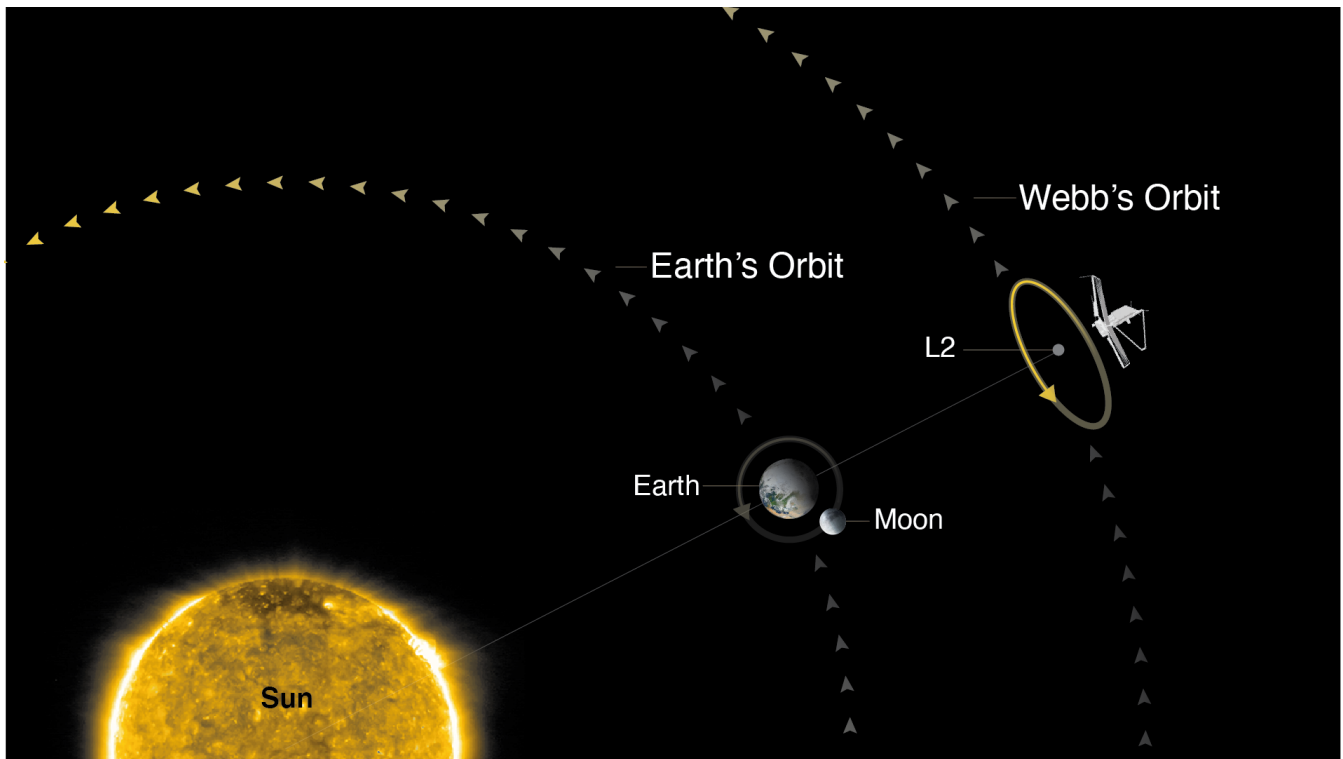
At over 21 feet (6.5 meters) in diameter and about 270 square feet (25 square meters) in area, Webb's primary mirror is also too wide to fit into the Ariane 5 fairing in one piece, so it is segmented into 18 hexagonal pieces on a hinged structure so it can fold up for launch and unfold in space. It will be the largest mirror ever flown into space.

More details of Webb's complex two-week unfolding process are outlined below.



3 Webb has a million-mile journey to reach its destination, where it can orbit the Sun in line with Earth

This special orbit allows one side of Webb's sunshield to always face the Sun, Earth, and Moon, blocking their heat and light from reaching the telescope's heat-sensitive optics. Webb's month-long journey takes it to the second Lagrange (L2) point, one of five positions in space where the gravitational pull of the Sun and Earth balances the centripetal force required for a spacecraft to move with them. This makes Lagrange points particularly useful for reducing the fuel required for a spacecraft to remain in position. The location also enables continuous communications with Webb through the Deep Space Network, an international array of giant antennas managed by NASA's Jet Propulsion Laboratory (JPL).



4 Webb's state-of-the-art scientific instruments are engineered to produce a treasure trove of awe-inspiring imagery and data

The instruments primarily have two functions: 1) imaging, or taking images of scientific targets; and 2) spectroscopy, or breaking down light into separate wavelengths – like raindrops create a rainbow – to determine the physical and chemical properties of various forms of cosmic matter. Learn more in the [Instruments section](#).

Webb's Science Instruments

The diagram illustrates the internal layout of the James Webb Space Telescope's science instruments. On the left, a white wireframe shows the telescope's primary mirror and secondary mirror assembly. A yellow box highlights the instrument bay. On the right, a 3D cutaway view shows the internal instrument bay with four instruments labeled: NIRSpec (top left), FGS/NIRISS (top right), NIRCам (bottom left), and MIRI (bottom right). Each instrument label is accompanied by icons representing its capabilities: a camera for imaging, a rainbow for spectroscopy, and a star for coronagraphy.

What's inside?

- CAMERAS** take pictures of astronomical objects.
- SPECTROGRAPHS** break light into colors for analysis.
- CORONAGRAPHS** block starlight, allowing observation of planets orbiting nearby.

NIRSpec

FGS/NIRISS

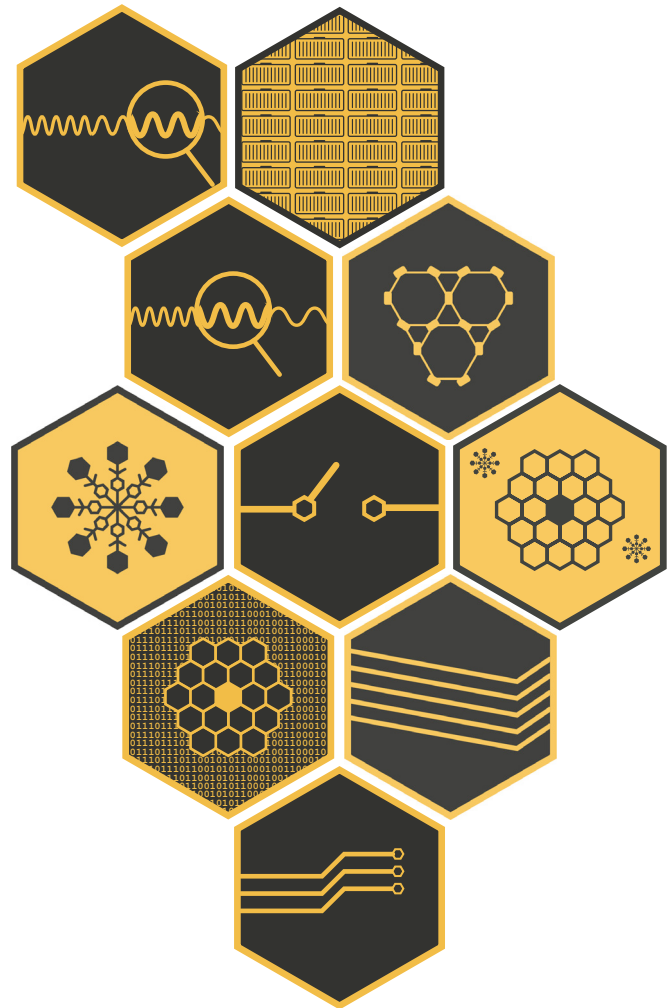
NIRCам

MIRI

5 Several new technologies were developed during the building of the Webb telescope, including innovative spinoffs that have already improved life here on Earth

In designing Webb, engineers had to imagine a telescope unlike any that has ever been built before. Technological advances, and even new inventions, were necessary to make the mission feasible: Breakthrough lightweight deployable mirrors and advanced composite structures that align to millionths of millimeters and work at super-cold temperatures. Large, ultra-sensitive infrared light detectors. A “microshutter” device with thousands of tiny windows, each the width of a human hair and programmable to be open or closed, to enable spectroscopic measurement of hundreds of individual objects simultaneously. A cryocooler that chills the mid-infrared detectors to the necessary temperature of only a handful of degrees above absolute zero.

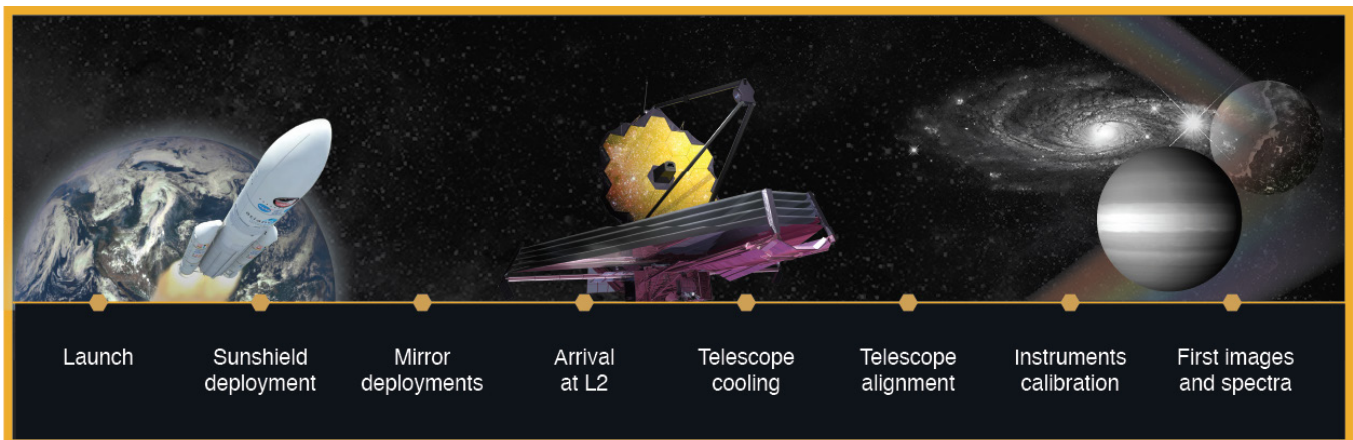
Some Webb developments have had serendipitous spin-off benefits. One example assists surgeons performing LASIK eye surgery: Engineers developed a technique for precisely and rapidly measuring the mirrors to guide their grinding and polishing. This technology has since been adapted to creating high-definition maps of patients’ eyes for improved surgical precision.



6 The James Webb Space Telescope's very first science images are worth the wait

Webb begins gathering its first set of scientific observations after its commissioning process is complete, roughly six months after launch. The initial few weeks of commissioning includes Webb's unfolding process, which occurs as Webb is on its month-long, million-mile journey to its operational orbit. The observatory then gradually cools down to its cryogenic operating temperatures before we can safely operate the science instruments (about 40 kelvins, or less than -380 degrees Fahrenheit), and the commissioning team aligns all of its mirrors and calibrates its scientific instruments. In order for Webb's primary mirror segments to act as a single optic, each of the 18 segments must be aligned to within a fraction of a wavelength of near-infrared light, i.e., mere nanometers, or about 1/10,000th the thickness of a human hair!

Keep up with Webb's journey and look out for Webb's upcoming, stunning images on social media via [@NASAWebb](#) on [Twitter](#), [Instagram](#) and [Facebook](#), as well as the hashtag [#UnfoldTheUniverse](#).



Quick Facts

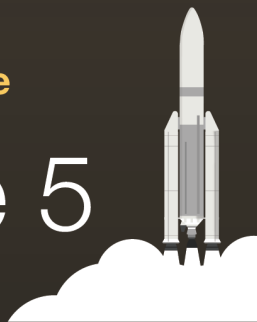


Launch and Orbit

Launch Vehicle

Ariane 5

ECA Rocket



Launch Site

Guiana Space Center

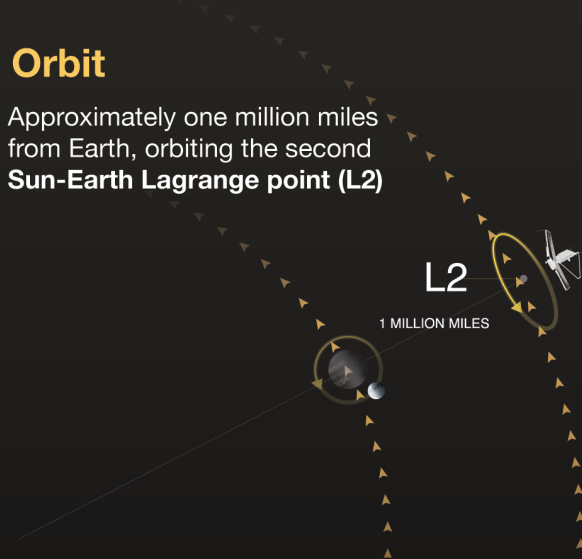
Kourou,

French Guiana



Orbit

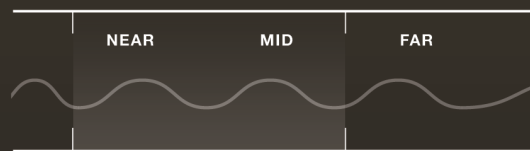
Approximately one million miles from Earth, orbiting the second Sun-Earth Lagrange point (L2)



Observatory

Wavelength Coverage

Infrared / 0.6-28.5 microns



Optical Resolution

About 0.1 arc-seconds

Mass

Approximately

13,700 lbs

Roughly the mass of a full-size school bus



Mission Duration

5 YEARS

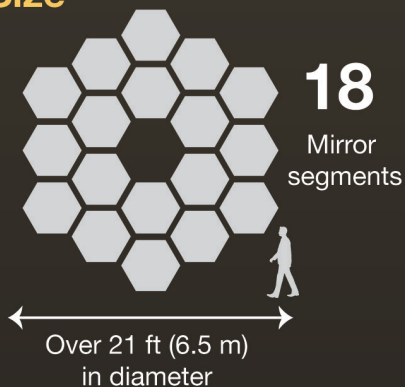
UP TO 10 YEARS

Quick Facts



Primary Mirror

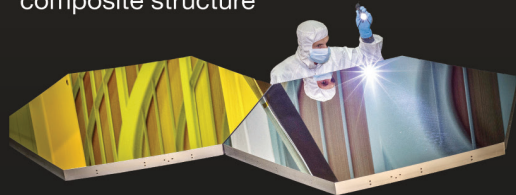
Size



Materials

Beryllium

coated with a microscopically thin layer of gold only about 700 atoms thick, and carried on a specially formulated graphite-epoxy composite structure



Operating Temperature

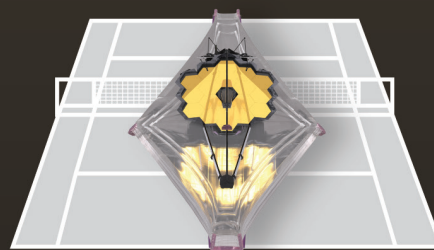
below 60 K (-370° F)



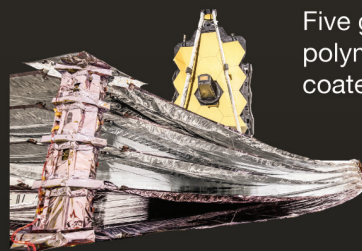
Sunshield

Size

about 69.5 ft x 46.5 ft (about 21 m x 14 m) – comparable to a tennis court



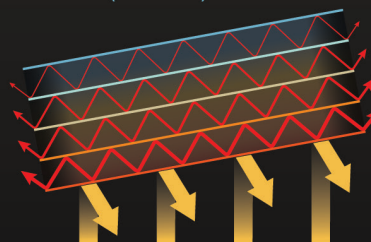
Materials



Five gossamer polymer membranes coated with aluminum

Temperature Range

minimum temperature (inner layer)
-235° C (-390° F)



maximum temperature (outer layer)
125° C (260° F)

Quick Facts



People



40 MILLION
TOTAL HOURS
SPENT BUILDING WEBB

An international team from government, academia, and the private sector

Thousands of
scientists,
engineers,
and technicians

14 Countries

29 U.S. states and
Washington D.C.

Fun Facts

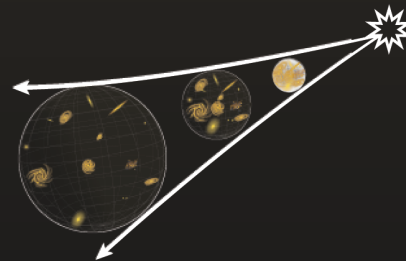


The sunshield protects the observatory, essentially providing an equivalent Sun Protection Factor, or SPF, of a million.



Webb is so sensitive it could theoretically detect the heat signature of a bumblebee at the distance of the Moon.

BIG BANG



Webb will peer back in time to when the universe was young - over 13.5 billion years ago, a few hundred million years after the big bang - to search for the first galaxies in the universe.



THE MISSION

History

Since the late 1980s, Webb has evolved from just an idea – “What’s next?” – to a premier flagship mission in 2021.

In 1989, the Space Telescope Science Institute (STScI) in Baltimore, Maryland, and NASA co-hosted the Next Generation Space Telescope Workshop at STScI, where engineers and astronomers debated the science and technical capabilities of an observatory that would follow the Hubble Space Telescope. Discussions from that workshop led to the formal recommendation in 1996 that the telescope should operate in infrared wavelengths and be equipped with a mirror larger than 4 meters.

By 2002, NASA had selected the teams to build the instruments and the group of astronomers who would provide construction guidance.

Construction on Webb began in 2004. In 2005, the European Space Agency’s Centre Spatial Guyanais (CSG) spaceport in French Guiana was chosen as the launch site and an Ariane 5 rocket as the launch vehicle. By 2011, all 18 mirror segments were finished and proven through testing to meet required specifications.

Between 2012 and 2013, Webb’s individual pieces, constructed in a variety of locations, began to arrive at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. In 2013, construction of the sunshield layers began. From 2013 to 2016, Webb’s science instruments were packaged together and subjected to numerous tests of extreme temperature and vibration. From late 2015 to early 2016, the telescope optics and structures were assembled, featuring installation of all 18 of Webb’s individual mirrors on the telescope’s backplane structure to assemble the 21-foot (6.5-meter) mirror.

In 2017, the telescope assembly and the package of science instruments were integrated into one unit and subjected to mechanical integrity vibration testing at Goddard, then shipped to NASA’s Johnson Space Center in Houston, Texas, for end-to-end optical performance testing in a giant cryogenic temperature vacuum chamber.

In 2018, the performance-verified telescope plus instrument assembly was delivered to Northrop Grumman in Redondo Beach, California, where the spacecraft bus plus sunshield assembly was being built and tested, and the following year, these two halves of Webb were connected.

Final environmental, electrical, functional, and communications testing continued until Webb was folded and stowed for the final time in 2021.



An early concept for the James Webb Space Telescope – known at the time as the Next Generation Space Telescope – was designed by a Goddard Space Flight Center-led team. It already incorporated a segmented mirror, an “open” design, and a large deployable sunshield.

International Collaboration

Webb is an international collaboration between NASA, the [European Space Agency](#) (ESA), and the [Canadian Space Agency](#) (CSA).

NASA is responsible for the overall Webb mission. [NASA Headquarters](#) oversees the program for the Science Mission Directorate. [NASA's Goddard Space Flight Center](#) manages the entire Webb project, leads its overall engineering, and also produced components for the Integrated Science Instrument Module (ISIM). NASA's [Jet Propulsion Laboratory](#) (JPL) managed the Mid-Infrared Instrument (MIRI), including the cryocooler. NASA's [Ames Research Center](#) developed detector technology for the mission, while NASA's [Marshall Space Flight Center](#) developed mirror technology and provided environmental research. NASA's [Johnson Space Center](#) provided observatory test facilities. Lastly, NASA's [Glenn Research Center](#) was involved in cryogenic component development.

ESA has provided the Near-Infrared Spectrograph (NIRSpec) instrument, as well as about half of the MIRI instrument through special funding from the [ESA Member States](#). In addition, ESA is providing the launch vehicle — the Ariane 5 ECA rocket — and all launch services at Europe's Spaceport in Kourou, French Guiana. In return, ESA scientists have a minimum share of 15% of the total observing time on the Webb telescope. ESA scientists will support mission operations at the [Space Telescope Science Institute](#), and European scientists are also represented on all advisory bodies of the project.

CSA is contributing the Fine Guidance Sensor (FGS) and Near-Infrared Imager and Slitless Spectrograph (NIRISS) instrument. In exchange, Canadian Webb scientists will receive a guaranteed 450 hours of observing time in the first few years of the mission. About 5% of the General Observations program is also reserved for Canada. CSA scientists will support mission operations at the Space Telescope Science Institute, and Canadian scientists are also represented on all advisory bodies of the project.

A Telescope for the World

Thousands of scientists, engineers, and technicians from 14 countries, 29 U.S. states, and Washington, D.C., contributed to building, testing, and integrating Webb. Scientists from 41 countries, 42 U.S. states, and Washington, D.C., have been awarded observing time during Webb's first year of science operations.

Northrop Grumman is the main industrial partner for the Webb mission, under contract to NASA's Goddard Space Flight Center. The company designed and built Webb's sunshield and spacecraft bus, and integrated and environmentally tested the full observatory. Ball Aerospace was responsible for designing and building Webb's optical technology and lightweight mirror system; L3Harris led the assembly of components made by various NASA partners to assemble Webb's optical telescope element and integrate it with the instruments.

The Space Telescope Science Institute (part of the Association of Universities in Research and Astronomy, or AURA) is the Science and Operations Center for the Webb observatory. STScI staff are responsible for the development of Webb's ground system, including flight operations and the software the astronomical community will use to plan, execute, and analyze Webb observations. STScI will also host Webb data in the Mikulski Archive for Space Telescopes (MAST).

The Near-Infrared Camera (NIRCam) instrument was designed by the University of Arizona in conjunction with Lockheed Martin, who built and tested NIRCam for the University of Arizona and NASA. Teams led by professors

at the University of Arizona helped develop NIRCam’s focal plane and additionally contributed to the MIRI instrument.

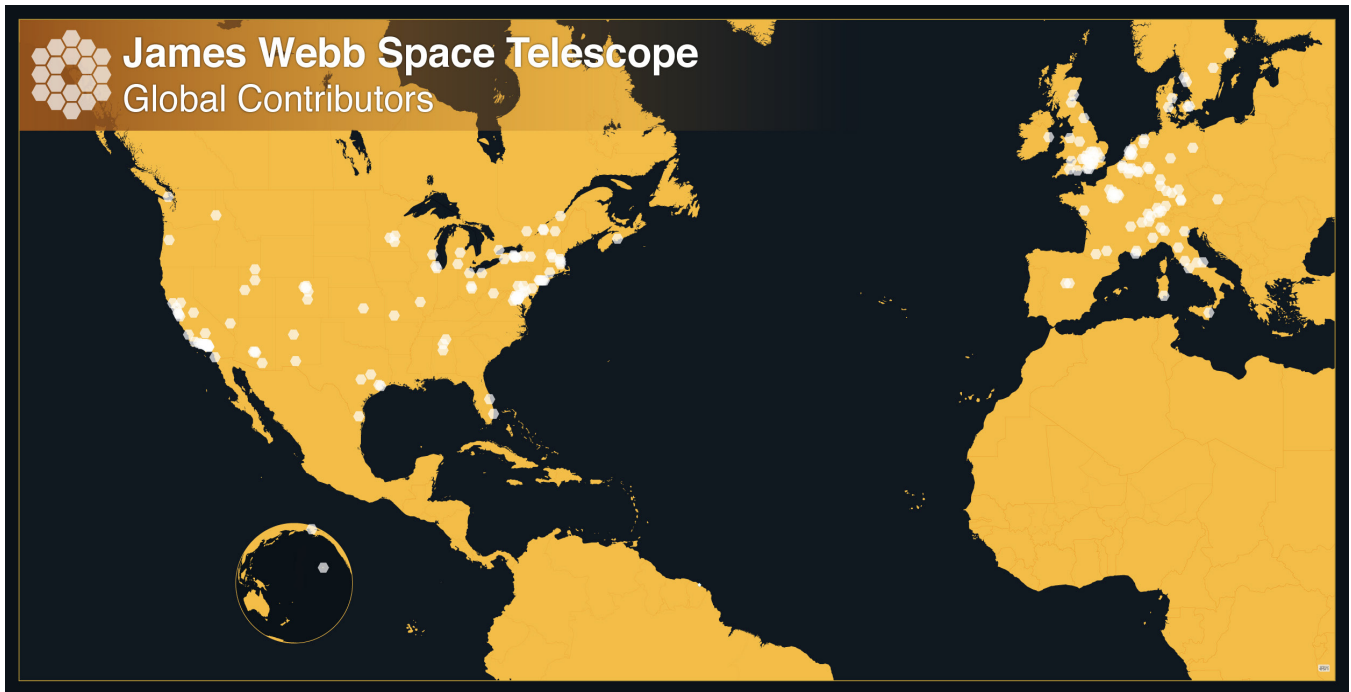
A group of European companies, led by Airbus Defence and Space (ADS), built the NIRSpec instrument for ESA, with NASA’s Goddard Space Flight Center contributing the detectors and micro-shutters.

ESA, a nationally funded European Consortium (EC) consisting of scientists and engineers across multiple European countries, NASA’s JPL and NASA’s Goddard Space Flight Center worked together to develop the Mid-Infrared Instrument (MIRI). Besides managing the instrument, JPL was responsible for the focal plane system and the flight software. The consortium was responsible for the optics and optical bench, as well as the assembly, integration, and testing of MIRI.

The Fine Guidance Sensor and Near Infrared Imager and Slitless Spectrograph was built and tested by Honeywell with help from the Canadian Space Agency, Université de Montréal, NASA, and the Space Telescope Science Institute.

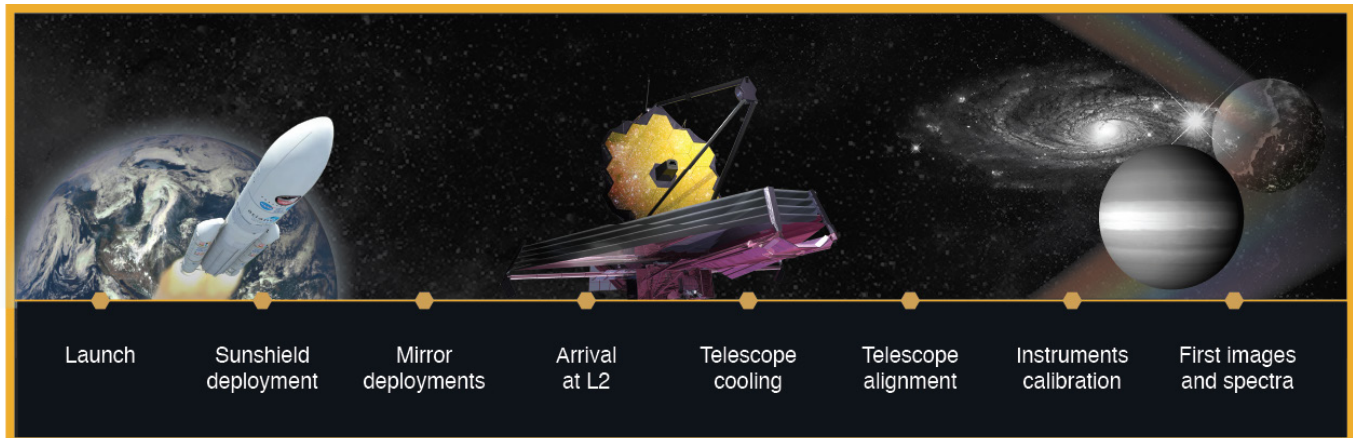
NASA’s partnerships reflect that science is made possible by a worldwide community. Effective teamwork across partners and contractors from multiple nations required extensive coordination, such as careful defining of engineering requirements and interfaces. Team members also had to navigate varying laws and regulations regarding information sharing. Despite these challenges, Webb’s successful integration and testing stand as a testament to the benefits of global cooperation. Just as Webb was created as a collective effort, the telescope will provide an incredible trove of data that will serve the entire world.

A full list of global contributors to the Webb mission can be [found here](#).



[Interactive map \(online version\)](#)

Launch and Commissioning Timeline



Launch

Launch Vehicle

The launch vehicle for the James Webb Space Telescope is an Ariane 5 rocket.

With over 100 successful missions to orbit, the Ariane 5 is one of the world's most reliable heavy lift vehicles capable of delivering Webb to its destination in space.

The European Space Agency (ESA) is providing the launcher and associated launch services as part of its contribution to the Webb mission. These launch services have been tailored to accommodate all the specific requirements of the Webb mission.

ROCKET: The Ariane 5 is a multistage rocket that uses combination solid and cryogenic liquid propellant. It has an industry-standard 16-foot diameter (5-meter diameter) nose cone, or fairing. Total powered flight time is nearly 27 minutes.

LOWER COMPOSITE STAGE: The lower composite stage is composed of two boosters and a cryogenic-liquid, single-engine core stage. The core stage ignites



7 seconds prior to liftoff and operates for 540 seconds, delivering about 300 thousand pounds (136 tonnes) of thrust and burning 385 thousand pounds (175 tonnes) of its liquid oxygen and liquid hydrogen propellants. The two strap-on solid-propellant boosters, each weighing 529 thousand pounds (240 tonnes) at liftoff, fire next. Together they deliver about 2.6 million pounds (1,200 tonnes) of thrust for 135 seconds, providing just over 90% of the total thrust of the launcher at liftoff.

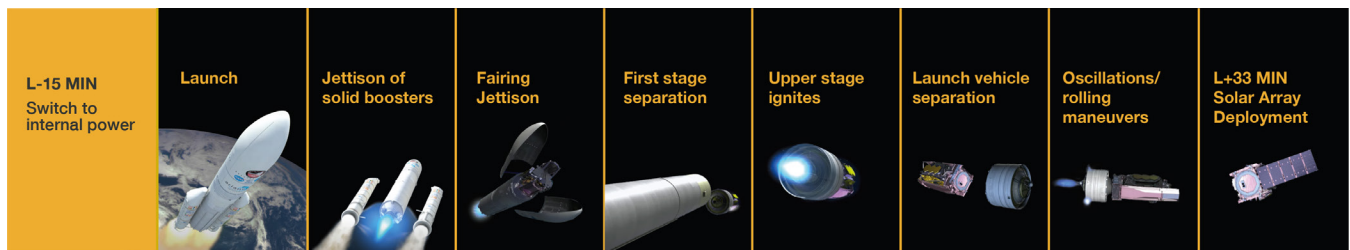
UPPER STAGE: Another cryogenic-liquid, single-engine stage that runs on liquid oxygen and liquid hydrogen, the upper stage operates for 945 seconds, delivering about 15 thousand pounds (6.5 tonnes) of thrust.

PAYLOAD ADAPTER: This mechanically and electrically connects Webb to the top of the Ariane rocket upper stage and contains the release mechanism that separates Webb from the launch vehicle.

PAYLOAD FAIRING: Ariane 5's "nose cone," or fairing, serves to protect Webb from atmospheric drag and heating during ascent. Its outer dimensions are about 18 feet (5.4 meters) in diameter and 56 feet (17 meters) in height, but payloads must fit in a space that is only about 15 feet (4.57 meters) in diameter and 53 feet (16.19 meters) in height. In its stowed condition, all folded up, Webb fits neatly inside the fairing, with just enough clearance to accommodate the relative motions expected during launch.

Made of an aluminum honeycomb core covered with graphite-epoxy composite, the fairing is comprised of two thin half-shells riveted together for launch. Lightweight for its size, the fairing's role is to make the launcher aerodynamic and protect Webb on ascent through the atmosphere.

After 206 seconds of flight, at an altitude of about 75 miles (120 kilometers), the atmosphere is extremely thin and no longer presents a significant force. The fairing is jettisoned to lighten the upper stage by 5,900 pounds (2.7 tonnes) and improve rocket performance. At jettison, the two halves of the fairing are separated by a dual pyrotechnic system, with springs pushing them away from the launcher's trajectory.



Launch Site

Webb's launch site is Arianespace's ELA-3 launch complex at the Centre Spatial Guyanais (CSG), or Guiana Space Center. The center is located near the town of Kourou in French Guiana, an overseas department of France on the northeastern coast of South America. Rockets launching from there benefit from a slingshot effect of being so close to the equator, where the rotational speed of Earth at the surface is greatest. CSG is also referred to as Europe's Spaceport, and many commercial payloads are launched from there on a variety of vehicles.

Preparation for Webb's launch in French Guiana lasts 55 days, from the observatory's arrival by ship to the day of launch (not including shipment of some support equipment and supplies and some preparatory setup ahead of time). After shipment, engineers run a final, abbreviated set of electrical and functional tests and check

the stowed mechanical configuration. A trained crew in special hazmat suits then loads the spacecraft with propellant. Next, Webb moves to the vehicle integration building and is lifted and mounted on top of the Ariane rocket “stack.” The final few remove-before-flight (“red-tag”) items are taken off, and the few add-before-flight (“green-tag”) items are installed, and the fairing is lifted and lowered over top.

As a fully integrated launch vehicle with payload, the Ariane rocket rolls out to the launch pad on its launch table a few days before launch. Engineers monitor the rocket via electrical connections running from the payload control room to the launch pad through an umbilical attachment to the vehicle that separates at liftoff. A few hours before launch, the Ariane is loaded with liquid hydrogen fuel and liquid oxygen oxidizer. About a half hour before launch, engineers in the payload control room switch the spacecraft from CSG-provided electrical power to the spacecraft’s on-board battery. Launch is controlled from CSG’s “Jupiter 2” mission control room, based on status reports on the ground systems and the observatory from the payload control room at CSG as well as Mission Control Center at the Space Telescope Science Institute in Baltimore, Maryland.

Launch Day

Starting at liftoff, the Ariane rocket provides thrust for about 27 minutes. Webb begins to transmit telemetry data (measurements of the observatory’s performance) after payload fairing separation, almost 3 and a half minutes after launch. Webb separates from the Ariane 5 launch vehicle a half hour after launch, and the solar array deploys automatically moments afterward.

Two hours after launch, the high gain antenna deploys. Twelve hours after launch, there is the first trajectory correction maneuver by small rocket engines aboard Webb itself. This is the first of three critical course corrections to ensure the observatory achieves a successful orbit.

Critical Course Corrections

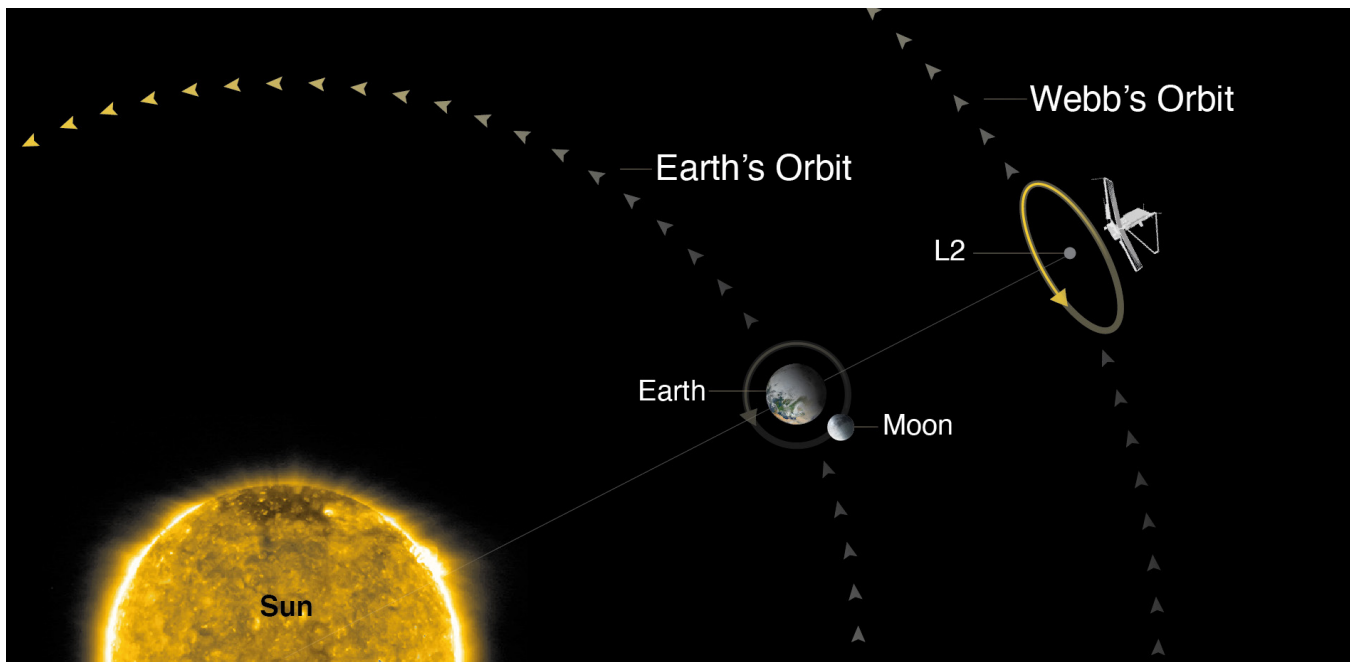
The James Webb Space Telescope is launched on a direct path to an orbit around the second Sun-Earth Lagrange Point (L2), but it needs to make its own mid-course thrust correction maneuvers to get there. This is by design, because if Webb gets too much thrust from the Ariane rocket, it can’t turn around to thrust back toward Earth because that would directly expose its telescope optics and structure to the Sun, overheating them and aborting the science mission before it can even begin. Therefore, Webb gets an intentional slight under-burn from the Ariane and uses its own small thrusters and on-board propellant to make up the difference.

There will be three mid-course correction (MCC) maneuvers: MCC-1a, MCC-1b, and MCC-2. The first burn, MCC-1a, is the most important and the only other time-critical operation aside from solar array deployment during Webb’s commissioning period. MCC-1a should occur between 12.5 hours and approximately 20 hours after launch, and is a continuous burn lasting up to a few hours. The second maneuver, MCC-1b, is a shorter burn performed approximately 2.5 days after launch, right before sunshield deployment is scheduled to start. The final maneuver, MCC-2, performed 29 days after launch, is designed to insert Webb into the optimum orbit around L2.

Orbit

From launch to its final destination at the second Lagrange point (L2), the James Webb Space Telescope's journey spans about a month. Once there, Webb's orbit follows a special path around L2 that allows it to stay on Earth's night side and track along with Earth while moving around the Sun.

Located about a million miles (1.5 million kilometers) directly "behind" the Earth as viewed from the Sun, the second Lagrange point is an ideal location for astronomy and has been home to previous missions such as WMAP, Planck, and Herschel. There are five Lagrange points in the Sun-Earth system: positions in space where the gravity of the Sun and Earth balances the centripetal force required for a spacecraft to move with them. This makes Lagrange points useful for reducing the amount of fuel it takes for a spacecraft to remain in orbit. Webb's orbit is actually a halo orbit around the L2 location.



As an infrared observatory, Webb must be protected from all bright, hot sources in order to see the faint heat signals of distant objects in the universe. Because Webb will always stay on Earth's night side as it moves around the Sun, its orbit ensures that one side of its sunshield will continuously face the Sun, Earth, and Moon to block their view from the telescope's optics.

Another advantage of this orbit is that Webb will always be at the same general location relative to Earth. Consequently, it is always close enough to continuously stay in contact through the Deep Space Network, an international array of giant antennas supporting NASA's deep space missions.

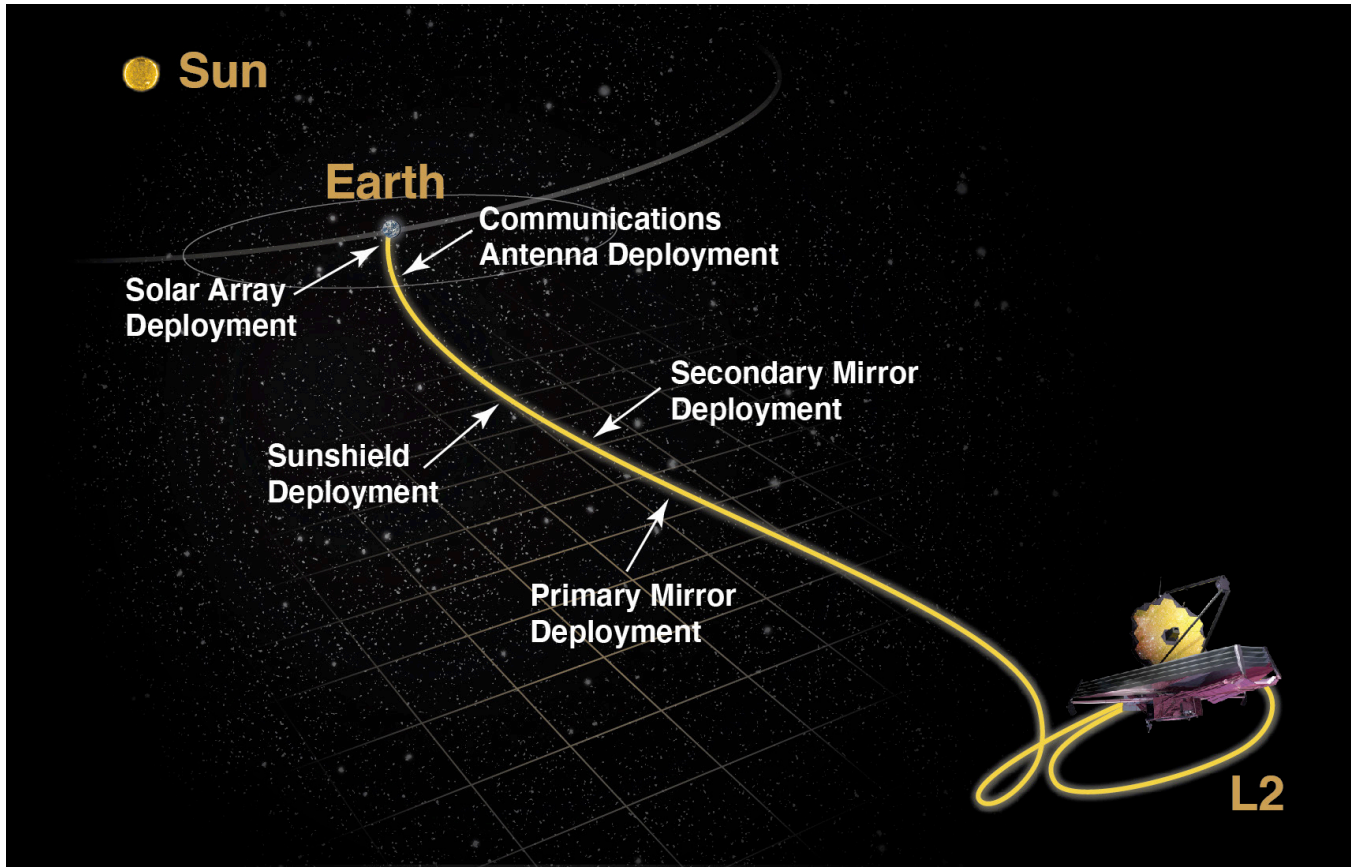
Finally, orbiting L2 allows Webb to be perpetually bathed in sunshine to generate power via the solar array on the Sun-facing side of the spacecraft, while providing an unobstructed view of deep space. The orbital path that Webb takes ensures that it stays out of the shadows of both Earth and the Moon.

As Webb is orbiting L2, it is also moving around the Sun. Given that Webb can only point to roughly half the sky at any given moment because it can't look in the direction of Earth and the Sun, this affords Webb access to the entire sky over the course of a year.

Commissioning

Once launched, Webb undergoes an action-packed six-month commissioning period, during which it fully deploys, cools down to operating temperatures, aligns its mirrors, and calibrates its instruments.

Major Deployments



Webb's [deployment sequence](#) is an intricately choreographed and thoroughly tested series of movements.

After a second trajectory correction maneuver about 2.5 days after launch, the first week of deployments starts with bringing down the two sunshield pallets, which are support structures for the sunshield. Afterward, the observatory's [Deployable Tower Assembly](#), which separates the upper and lower halves of Webb, extends. This is necessary to provide clearance to allow the rest of the sunshield to deploy. The rest of the week is devoted to finishing sunshield deployment – extending the sunshield's telescoping booms and unfolding and tensioning each of Webb's [five sunshield layers](#).

Webb's second week of deployments focuses on the telescope. The tripod holding the [secondary mirror](#) unfolds and extends the secondary mirror ahead of the [primary mirror](#). This is followed by unfolding the mirror segment wings on the sides of the primary mirror, revealing all 18 mirror segments in space.

Million-Mile Journey

Webb deploys as it travels to its destination of L2, a million miles away from Earth. About one month after launch, a mid-course correction places Webb into its final orbit around L2. More about L2 can be found in the [Orbit section](#).

Cooldown

Webb begins to cool during the deployment process itself: Following the sunshield deployment, the mirrors and instruments quickly start to cool in the shade of the sunshield. After Webb achieves its L2 orbit, the observatory takes about a week to cool down to a point where its NIRCам instrument can start operating to support telescope alignment. It takes roughly three additional weeks to get the shaded portion of the observatory down to its extremely cold operating temperatures of less than -380 degrees Fahrenheit (around 40 kelvins).

Because Webb’s MIRI instrument uses a cryocooler to reach its significantly lower operating temperatures of -447 degrees Fahrenheit (7 kelvins), it independently takes much longer to achieve its full cooldown – just under 100 days after launch.

Telescope Alignment

Once Webb is sufficiently cool, Webb’s NIRCам instrument is able to help determine that light is correctly following its path through the mirrors and instruments. Next is the process of adjusting each of the individual primary mirror segments.

Through a process called wavefront sensing and control, the NIRCам instrument measures any imperfections in the alignment of the mirror segments that prevent them from working as a single mirror. The mirror segments are aligned to within a fraction of a wavelength of near-infrared light, or mere nanometers.

[Telescope alignment](#) of both the primary and secondary mirror is completed about four months after launch.

Instrument Calibrations and Check Out

In the final months of commissioning, Webb points at a variety of representative science targets to test, characterize, and begin to calibrate all of the instrument capabilities. Data is collected using each observing mode of each instrument and then run through data reduction pipelines to ensure accuracy and precision. Further calibration programs happen during the first year of science, to understand the limits and sensitivities of the various modes and capabilities.

Science Operations

Routine science operations begin after about six months of commissioning, when all mirrors have been aligned and all instruments have been calibrated.

Science Operations

Science Programs and Execution

The Space Telescope Science Institute (STScI) oversees the science operations behind the James Webb Space Telescope. STScI provides researchers with the tools needed to plan and execute operations and organizes proposal reviews and investigation selection, all completed through a dual-anonymous review system to reduce bias in the selection process. Science operations will begin following the telescope's six-month commissioning period, kicked off with the first incredible images and spectra.

There are several key categories of science programs that account for Webb's observation time:

General Observer: Through this program, any astronomer in the world can apply for time and funding to use Webb for a specific investigation. These programs are selected by a dual-anonymous peer-review process, similar to other Great Observatories. The Cycle 1 General Observer programs have been selected and include 280 programs, submitted by 2264 investigators from 41 countries and 43 U.S. states.

Guaranteed Time Observations: These programs are designed by members of the instrument and telescope science teams, as well as a number of interdisciplinary scientists who supplied knowledge to help develop the observatory.

Director's Discretionary Early Release Science: These observations are designed to demonstrate Webb's capabilities and provide preliminary datasets for use by the global scientific community. They will be completed in the first several months of science operations and include 13 programs with 253 investigators from 18 countries and 22 U.S. states.

Early Release Science observations take place within the first few months of science operations, while Guaranteed Time Observation programs are scheduled within the first few years of the observatory's lifetime. General Observer programs take place over the mission lifetime, with the call for proposals taking place yearly.

Mikulski Archive for Space Telescopes (MAST)

All Webb data will be stored at the Mikulski Archive for Space Telescopes (MAST) at STScI. STScI provides secure storage and reliable retrieval services for observational data, creates user-friendly and scientifically useful search tools, develops fully processed data products that are ready for scientific analysis, and offers support services to the astronomical community. Data in MAST is accessible online to the scientific community and the general public. MAST hosts data from over a dozen missions like Hubble, Kepler, and TESS, with a primary focus on scientifically related datasets in the optical, ultraviolet, and near-infrared parts of the spectrum.



THE SCIENCE

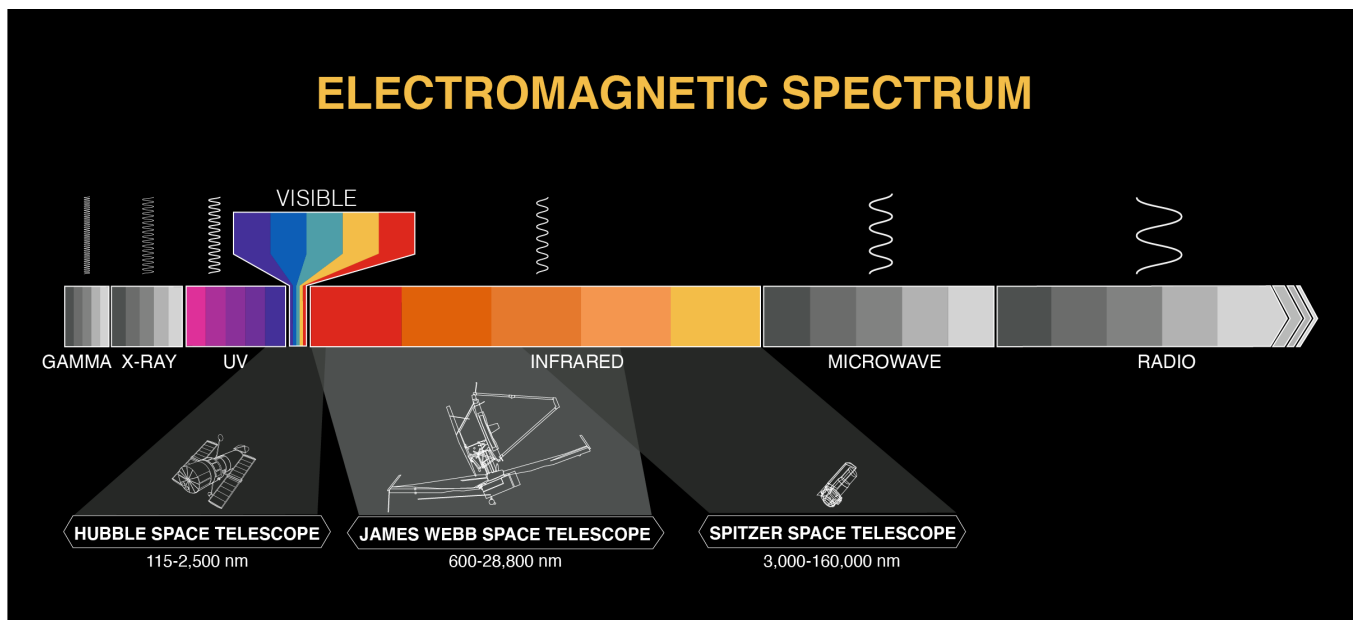
Overview

The James Webb Space Telescope represents a giant leap forward in our quest to understand the universe and our origins. How did the universe begin? Are we alone in the cosmos? Webb will help us answer scientifically significant questions about the early universe, the formation and evolution of galaxies, the birth of stars and protoplanetary systems, and the properties of planets within and outside our solar system. Webb is the first observatory capable of observing the very earliest galaxies, and perhaps even some of the first exploding stars.

Webb detects light outside the visible range to show us otherwise hidden regions of space at the near-infrared and mid-infrared wavelengths. With its longer wavelengths, infrared radiation can penetrate dense molecular clouds, whose dust blocks most of the light detectable by the Hubble Space Telescope's instruments.

Why Infrared?

Webb will study infrared light from celestial objects with much greater clarity and sensitivity than ever before. Unlike the short, tight wavelengths of visible light, longer wavelengths of infrared light slip past dust more easily. Therefore, the universe of star and planet formation “hidden” behind clouds of dust comes into clear view for Webb’s infrared instruments.



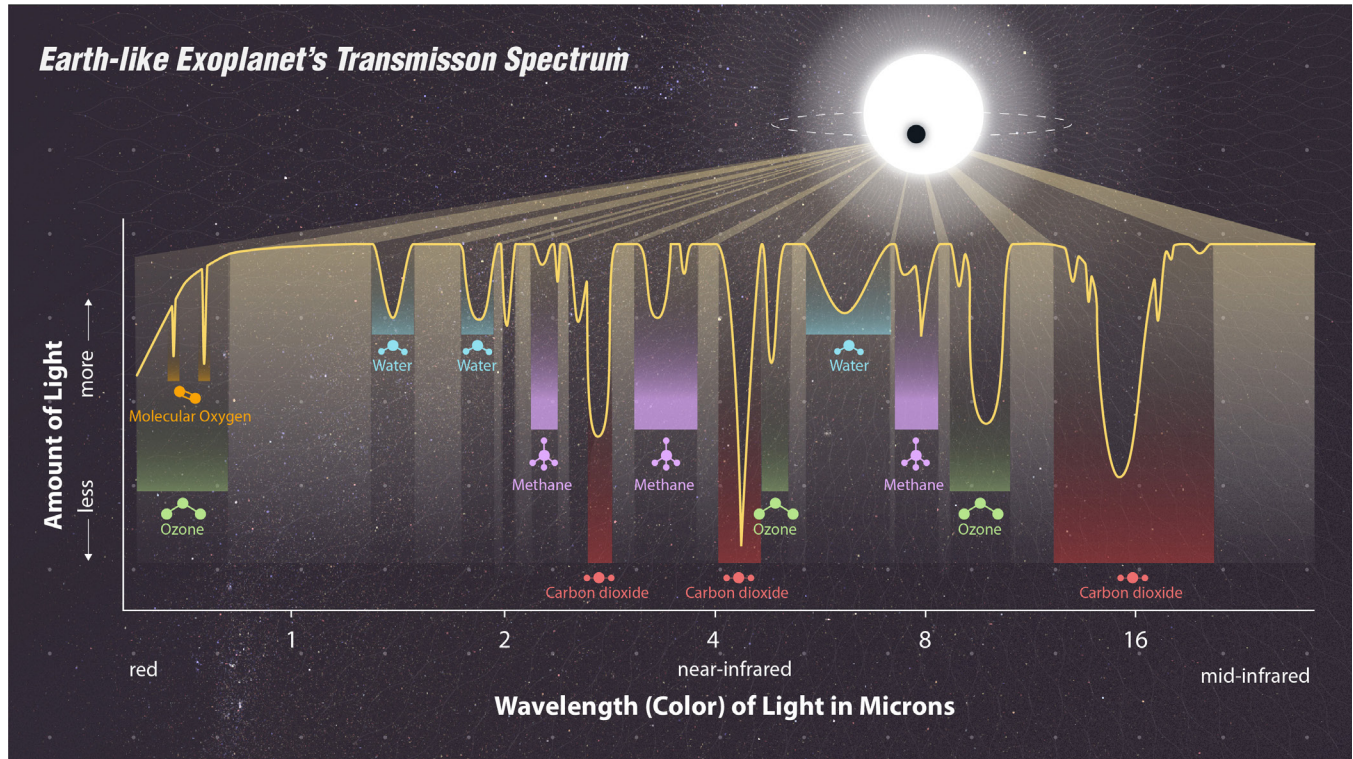
[Studying infrared](#) light also helps us see closer back to the beginning of everything. Through a process called cosmological redshifting, light is stretched as the universe expands, so light from stars that is emitted in shorter ultraviolet and visible wavelengths is stretched to the longer wavelengths of infrared light.

Webb is an improved combination of the Hubble and Spitzer space telescopes — Hubble’s sensitivity and resolution, but Spitzer’s view of the infrared universe.

Why Spectroscopy?

Spectroscopy is a [powerful tool to learn about distant objects](#) in the universe. A spectrum, like an image, is a way to display light from a distant object. Spectra can reveal which elements and molecules make up an object. Webb’s spectrographs [stretch light out so that it can be analyzed](#) in detail to determine characteristics, such as temperature, composition, density, distance, and motion, of different particles. Different molecules as well

as atoms of each element emit and absorb characteristic frequencies of light, and these characteristics allow identification of the presence of an element, even in small quantities. Spectra allows us to read this light. Webb is equipped with [eleven modes of spectroscopy](#), each of which combine the use of different filters and detectors to address [specific scientific questions](#). NIRSpec's [microshutter array](#) gives Webb the ability to capture spectra from dozens of different stars or galaxies at the same time.



Mission Goals



Search for the first galaxies formed in the early universe



Observe the formation of stars, from young stellar nurseries to the formation of planetary systems



Study galaxies near and far to inform the evolution of galaxies



Measure physical and chemical properties of planetary systems, including our own solar system, and investigate the potential for life in those systems

The Unexpected and Unknown

Webb also has the capacity to reveal completely unexpected aspects of our universe, as Hubble has done. Webb's observations, which are designed to answer specific scientific questions, forge additional questions that can be addressed in future observation cycles and by future missions and observatories, such as the Nancy Grace Roman Space Telescope.

Early Universe



Webb will aim to help us piece together how the universe developed by directly observing when it was young.

It is designed to explore a [time period known as the Epoch of Reionization](#), which came after the dark ages that followed the big bang. During the dark ages, the universe was cast in a gaseous fog of neutral hydrogen and helium, making it opaque to some types of light. As the first luminous objects formed and evolved, the high-energy light they emitted ionized the gas through which it propagated, making it more transparent.

How did the universe become completely ionized, or transparent, eventually leading to the “clear” conditions detected in much of the universe today?

To find the first galaxies, [Webb will make ultra-deep near-infrared surveys of the universe](#). This capability, combined with unprecedented resolution and sensitivity, will allow Webb to take us farther than ever in answering our questions about the early eras of our universe.

Webb will address several key questions to help us unravel the story of the formation of structures in the universe.

When and how did reionization occur?

What sources cause reionization?

What are the [first galaxies](#)?

Galaxies Over Time



Galaxies host stars, planets, gas, dust, and life as we know it. They show us how the matter in the universe is organized on large scales.

From the way matter is constructed at the subatomic particle level to the immense structures of galaxies and [dark matter](#) that span the cosmos, each scale Webb studies will give important clues as to how the universe is built and evolves.

The distribution of galaxies can help scientists investigate dark matter and dark energy throughout our universe. Webb is designed to study all stages and ages of galactic evolution. Webb will capture light from the first galaxies in their beginning stages of development after the big bang; [measure star formation rates](#) within galaxies near and far; and create detailed maps of gas, dust, and even dark matter in our local universe.

Webb's studies are designed to help us understand the diversity of galaxy composition and structure over space and time; how galaxies, like our own home galaxy, form, interact, and change; and how supermassive black holes and their host galaxies influence each other:

How are galaxies formed?

How do they [change](#)?

How are the chemical elements distributed through the galaxies?

What happens when small and large galaxies [collide or join together](#)?

Star Lifecycle



Stars are the essential sources of raw material in the universe — they recycle and distribute the elemental building blocks of everything we observe: new stars, nebulae of gas and dust, planets, and even humans. All life on Earth contains the element carbon, and all carbon was originally formed in the core of a star.

Webb's infrared capabilities allow scientists to [probe deeply into star-forming regions](#) to study the conditions that lead to new stellar systems and [investigate stellar nurseries](#) where very young stars live. Webb's mid-infrared wavelengths will study the [dust itself](#), and how those environments contribute to the formation, evolution, and diversity of stars and planetary systems. It will also analyze the composition and structure of the interstellar medium, cold molecular clouds that collapse to form stars, and the gas and dust ejected from dying stars.

Webb's observations are designed to answer questions surrounding [star formation](#) and evolution, stellar populations, star diversity, [interactions between stars and their environment](#), and relationships between stars and planets:

How do clouds of gas and dust collapse to form stars?

Why do most stars form in groups?

Exactly how do [planetary systems form](#)?

How do stars evolve and release the heavy elements they produce back into space for recycling into new generations of stars and planets?

Other Worlds



The surfaces and atmospheres of objects, such as moons, planets, and exoplanets, within planetary systems, [including our own solar system](#), can provide insights into our understanding of the natural universe and our place within it.

Webb will study the [atmospheres of exoplanets](#) – planets orbiting other stars – to determine which molecules and elements exist there and what they indicate about the world. Webb expands on the work of other observatories like Kepler, TESS, Hubble, and ALMA in detecting and characterizing fully grown planets, planets in the process of forming, and [protoplanetary disks](#) orbiting other stars in the Milky Way.

Webb's infrared capabilities will also allow astronomers to characterize the surfaces and atmospheres of objects within our own solar system, including [planets](#), moons, comets, [asteroids](#), and [Kuiper Belt Objects](#). Astronomers hope to better understand how other planetary bodies in our solar system have evolved over time and compare them to Earth, potentially unlocking clues to the origins of our planet and life as we know it.

The surfaces and atmospheres of objects can provide insights into our understanding of planetary systems:

Are there other [Earth-like planets](#)?

How many different types of exoplanets exist?

What is the origin and evolution of rock-, ice-, and gas-rich objects in our solar system?

How is our solar system similar to or different than other planetary systems?



THE SPACECRAFT

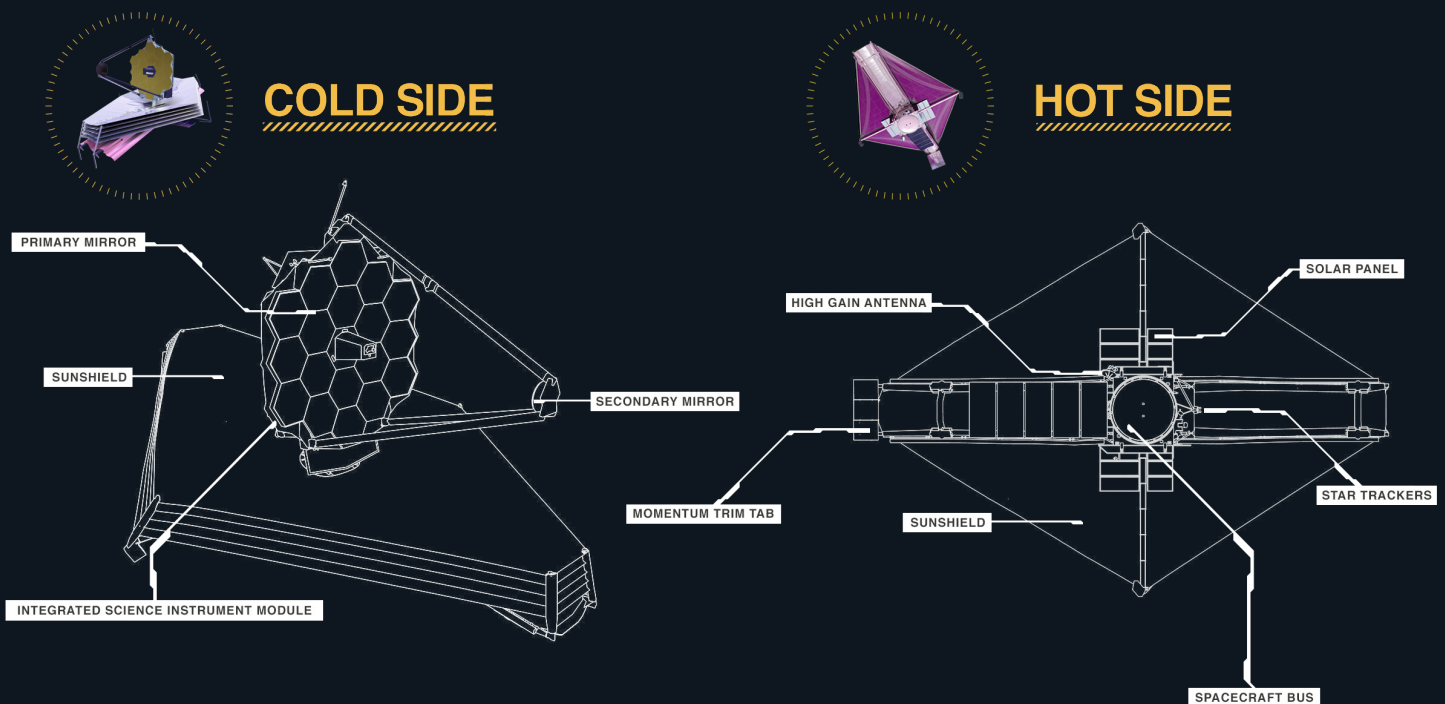
Overview

As the largest and most complex space science telescope ever sent into space, the **James Webb Space Telescope is a technological marvel**. By necessity, Webb takes on-orbit deployments to the extreme.

The observatory is made up of three main sections: the optics and scientific instruments, the sunshield, and the spacecraft bus. Webb is an infrared telescope, which presents two main challenges for engineers and scientists: The mirror needs to be very large to collect enough light, and it has to be kept cold to keep unwanted sources of infrared from interfering with the light being observed. The sunshield divides Webb's two sides: a hot side facing the Sun and Earth where the spacecraft bus sits, and a cold side facing out into space, away from the Sun and Earth.

To enable the cooling process, unlike the Hubble Space Telescope and the typical backyard telescope, Webb employs an open design. Placing the telescope and instrument package behind a large sunshield exposed with a wide view to space, rather than inside a long tube, allows the telescope to easily radiate its heat away and get extremely cold passively.

From construction to testing to integration, engineers and scientists developed many innovations and state-of-the-art technologies to ensure Webb's successful operations once in space.



Mirrors

A Three-Mirror System

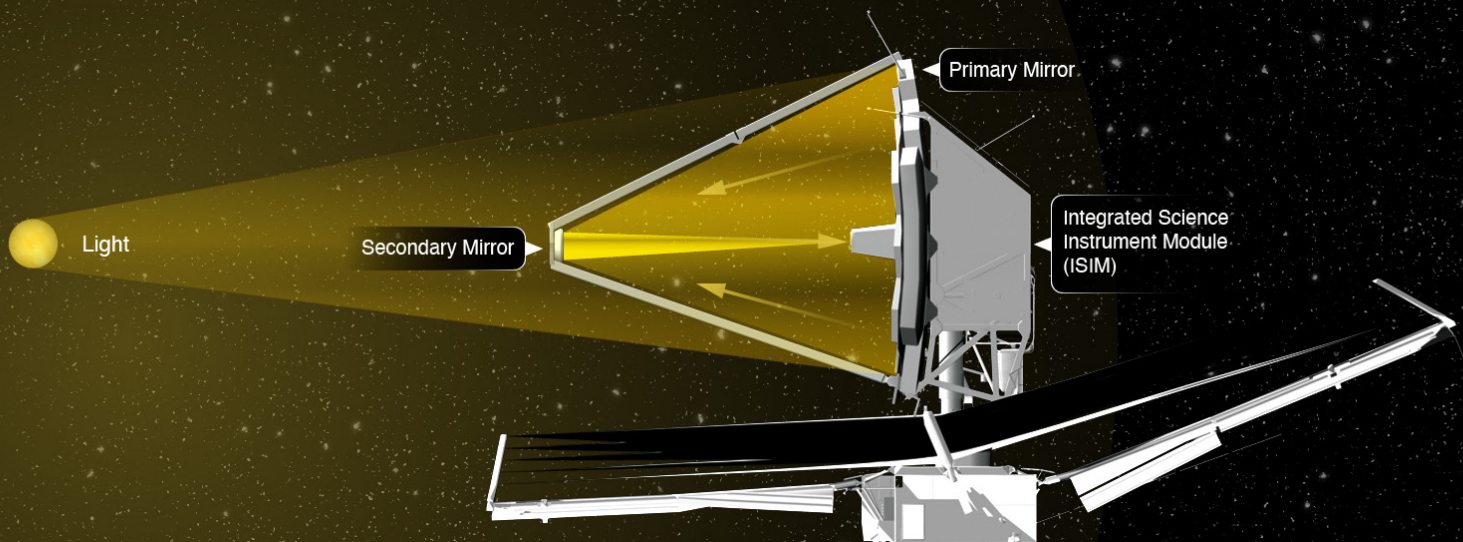
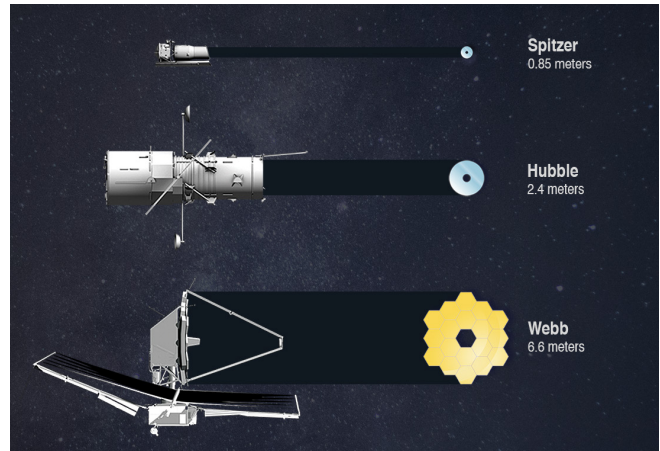
FORM AND FUNCTION: [Webb's primary mirror](#) is one of the most distinctive features of the observatory. The 21.5-foot (6.5-meter) concave mirror is made up of 18 hexagonal-shaped mirror segments, each 4.3 feet (1.32 meters) in diameter, flat to flat.

A telescope's sensitivity, or how much detail it can see, is directly related to the size of the mirror area that collects light from the objects being observed. A larger surface area collects more light, just like a larger bucket collects more water in a rain shower than a small one.

A mirror this large has never before been launched into space. In fact, Webb's primary mirror is so large that it is unable to fit inside any rocket available in its fully extended form. Six mirror segments (three on either side) are folded up at launch and deployed once the telescope is in space.

The hexagonal shape of Webb's primary mirror allows for a roughly circular, segmented mirror, without any significant gaps taking up space between the segments. The primary mirror is segmented to decrease the weight of the overall mirror, as a single, very large mirror would be prohibitively massive and also require a tremendously massive support structure. Each segment of Webb's mirror has been made movable so that they can co-align to work as a single large optic. A roughly circular shape also helps focus the light into the most compact region on the detectors.

Webb's secondary mirror is a smaller, round, convex mirror only 2.4 feet (0.74 meters) in diameter. It is supported by three 25-foot-long (7.6-meter-long) struts, or arms, that extend from the primary mirror. These struts are folded up for launch and will stretch out during deployment.



The tertiary and fine steering mirrors are located within the black nose cone protruding from the center of Webb's primary mirror, known as the Aft Optics Subsystem (AOS). Light that is captured by the primary mirror gets directed onto the secondary mirror, which sends light onto the tertiary mirror and lastly the fine steering mirror before reaching focus at the science instruments arrayed immediately behind the primary mirror.

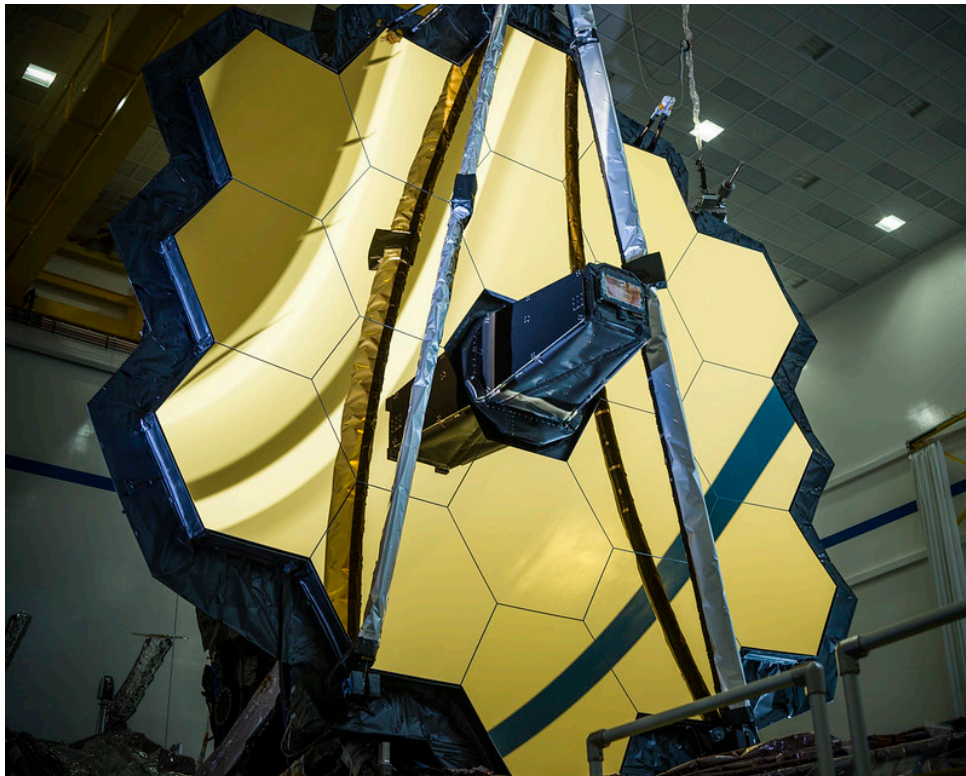
MATERIALS: Webb's mirrors are made of beryllium and coated with a microscopically thin layer of gold, which optimizes them for reflecting infrared light. The average thickness of the gold is just 1,000 angstroms (100 nanometers) – only about 700 atoms thick and about a thousand times thinner than a human hair. Beryllium was selected as the primary material for Webb's mirrors because it is light yet strong for its weight, and good at holding its shape across the cryogenic range of temperatures. These characteristics are ideal for Webb, as the primary mirror must be both extremely large and extremely cold in order to fulfill its scientific goals in space.

Engineering Challenges

SIZE AND WEIGHT: The Webb team had to find new ways to build the mirror so that it would be light enough – only one-tenth of the mass of Hubble's mirror per unit area – yet very strong. Each of Webb's beryllium mirror segments weighs only approximately 46 pounds (20 kilograms).

EXTREME TEMPERATURES: Webb's mirror must be cooled to cryogenic temperatures – less than 50 kelvins (less than -223 degrees Celsius, or -370 degrees Fahrenheit). Typically, materials shrink as they get cold, and because Webb's mirrors and instruments were built at room temperature but will operate at extremely cold temperatures, engineers had to build the Webb telescope “precisely wrong” to ensure its components would shrink to the right shape and dimensions once in space.

FOCUS: One hundred and thirty-two actuators, or tiny mechanical motors, provide the answer to achieving a single perfect focus by allowing the primary mirror segments to be aligned as if they are one perfect single mirror.

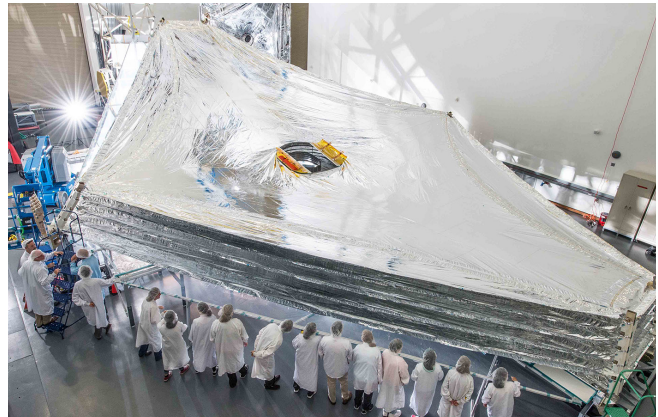


Sunshield

A Five-Layer Feat of Engineering

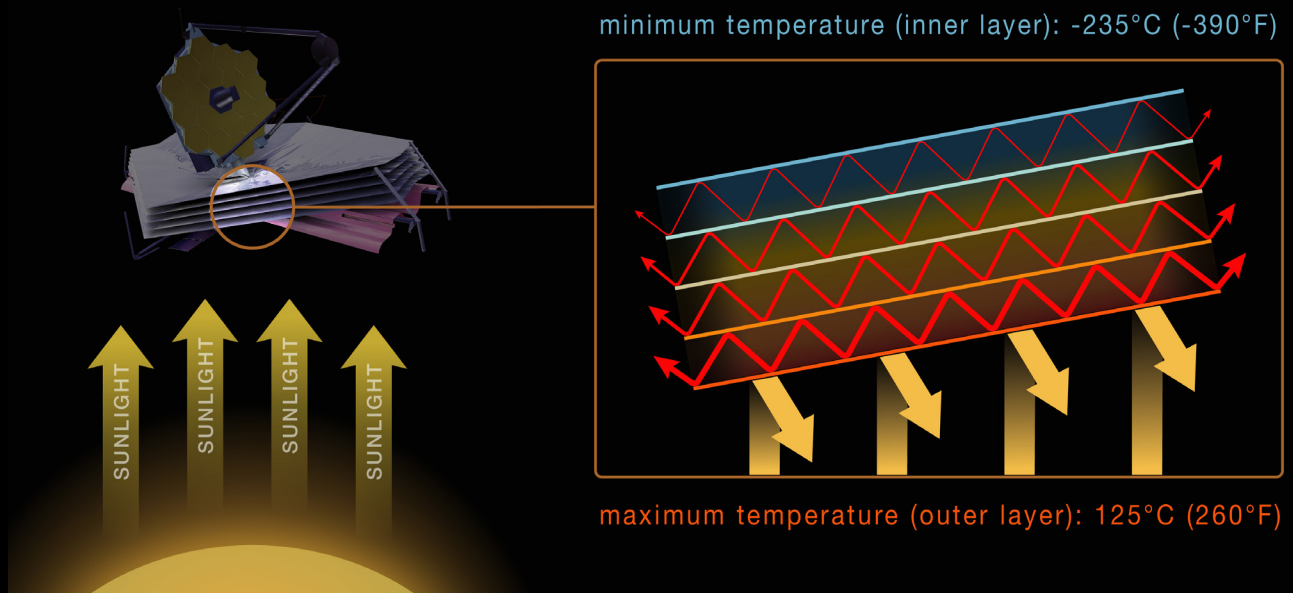
FORM AND FUNCTION: Webb’s kite-shaped [sunshield](#) is roughly the size of a tennis court and carefully constructed of five layers. The outermost layer is only 0.002 inches (0.05 millimeters) thick, while each of the other four layers are 0.001 inches (0.025 millimeters) thick. All of the layers are slightly different sizes and shapes, with the outermost layer relatively flat and the largest, and the innermost layer more curved and the smallest. The layers are also closer together at the center and farther apart at the edges.

The specific number of layers will allow enough heat to be blocked and redirected by the sunshield so that the telescope can reach its extremely cold operating temperatures, with some built-in margin. The light but durable layers are separated to reduce the transfer of heat from one layer to the next, meaning that each successive layer of the sunshield will be cooler than the one below it. Together, the five layers reduce exposure from the Sun by a factor of one million, from over 200 kilowatts to a fraction of a watt.



The sunshield will act as a divider between the observatory’s “warm side” and “cold side.”

The “warm side” refers to the parts of the observatory that will face the Sun. The sunshield’s layer that faces the Sun will get as hot as 383 kelvins, or about 230 degrees Fahrenheit! Meanwhile, the “cold side” with the mirrors and science instruments must be kept at cryogenic temperatures in order to detect extremely faint heat signals in the universe. The layer of the sunshield closest to Webb’s optics will get as cold as 36 kelvins, or about -394 degrees Fahrenheit. The vantage point of Webb’s orbit at the second Sun-Earth Lagrange point enables the observatory to keep its optics and instruments shaded from heat and light of the Sun, Earth, and Moon, which would interfere with sensitive infrared observations.



MATERIALS: The sunshield membranes are made of Kapton, a material with extensive heritage on spacecraft that has high heat-resistance and remains stable across a wide range of temperatures. Each layer of the sunshield is coated with aluminum, and the two layers closest to the Sun have an additional silicon coating that has been treated (“doped”) to make it electrically conductive. The silicon coating is about 50 nanometers thick, while the aluminum coating is about 100 nanometers thick. [More about the sunshield coating.](#)

Engineering Challenges

PACKING AND STOWING: Folding and stowing the sunshield involved carefully taking into account how the structure would unfold in space. The challenges of this process were made more complex by the delicacy of the thin layers and the sunshield’s intricate shape.

UNFOLDING: There are 107 “pins,” or membrane release devices, that restrain the sunshield in its folded configuration but will release to unfold the sunshield. An elaborate system of motors, pulleys, and cables actuates and extends the sunshield structure and deploys and tensions the five membrane layers into a very precise configuration.

WEAR AND TEAR: The sunshield layers are constructed with ripstops to minimize potential damage if smaller holes form from debris and micrometeorites. This has been shown through testing to arrest tears from propagating.

EXTREME TEMPERATURES: The material of the sunshield must work over a very wide range of temperatures and not become brittle and fracture when extremely cold nor become soft and stretch when searing hot.

Spacecraft Bus

Subsystems

The [spacecraft bus](#) provides the necessary support functions for the operation of the observatory. **Webb's spacecraft bus is home to six major subsystems:**

ELECTRICAL POWER SUBSYSTEM: The Electrical Power Subsystem converts sunlight shining on the solar array panels into the electrical power needed to operate everything on the observatory, and distributes it to all subsystems.

ATTITUDE CONTROL SUBSYSTEM: The Attitude Control Subsystem senses the orientation of the observatory, maintains the observatory in a stable orbit, and provides the coarse pointing of the observatory to the area of sky that the instruments will observe.

COMMUNICATION SUBSYSTEM: The Communication Subsystem is the “ears and mouth” for the observatory. The system receives commands from and transmits data back to the Space Telescope Science Institute's Mission Operations Center.

COMMAND AND DATA HANDLING (C&DH) SUBSYSTEM: The Command and Data Handling (C&DH) Subsystem is the “brain” of the spacecraft bus. The system has a computer, the Command Telemetry Processor (CTP), that takes in the commands from the Communications Subsystem and directs them to the appropriate recipient. The C&DH also has the memory/data storage device for the observatory, the Solid-State Recorder (SSR). The CTP will control the interaction between the science instruments, the SSR, and the Communications Subsystem.

THERMAL CONTROL SUBSYSTEM: The Thermal Control Subsystem maintains the operating temperature of the spacecraft bus, helping to ensure the observatory is at the proper operating temperature at all times.

PROPULSION SUBSYSTEM: The Propulsion Subsystem contains the fuel tanks and rocket engines that, when directed by the Attitude Control Subsystem, are fired to maintain the orbit and to help manage momentum. [More about how Webb manages momentum.](#)

Pointing the Webb Telescope

To turn and point at different objects in space, Webb uses six reaction wheels that store and exchange angular momentum to rotate the observatory. The reaction wheels work in combination with three star trackers and six gyroscopes that provide feedback on where the observatory is pointing and how fast it is turning. This achieves “coarse” pointing (arcminutes) sufficient to point the telescope at the right part of the sky, enough for the Fine Guidance Sensor (FGS) instrument to “take over” and achieve the “fine” pointing (arcseconds) necessary for observing. The Fine Steering Mirror (FSM) will be used to compensate for any minute vibrations aboard the observatory and steady the beam of light coming from the telescope and going into the science instruments to achieve milli-arcsecond precision. The FSM will also be used to do very small angle repointings, such as viewing the same object by different instruments, without having to move the whole observatory.

[More about Webb's gyroscopes.](#)

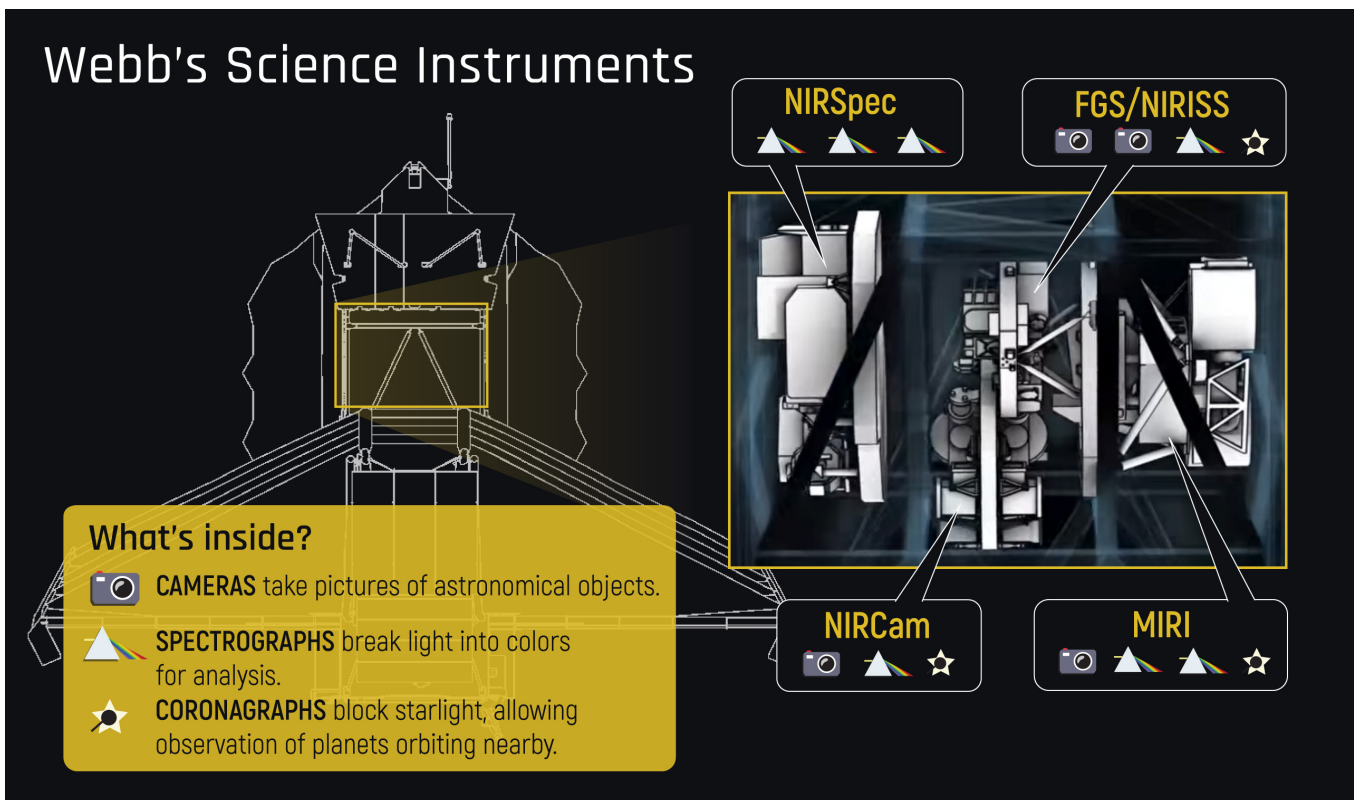
Instruments

Instruments and Capabilities

Webb's unprecedented scientific power is a function of both the size of its primary mirror and the extreme sensitivity and precision of its four scientific instruments. Webb's instruments are contained within the Integrated Science Instrument Module (ISIM), which is what engineers refer to as the main payload. The ISIM is situated on the cold side of the telescope, protected by Webb's sunshield from the visible and infrared light of the Sun, Earth, and Moon.

The definition of the kelvin temperature scale is that 0 kelvins is "absolute zero," the lowest possible temperature. Water freezes at 32 degrees Fahrenheit, 0 degrees Celsius, or about 273 kelvins. The near-infrared instruments (NIRCam, NIRSpec, FGS/NIRISS) will work at about 39 kelvins (-234 degrees Celsius or -389 degrees Fahrenheit) through a passive cooling system. The mid-infrared instrument (MIRI) will work at a temperature of 7 kelvins (-266 degrees Celsius or -447 degrees Fahrenheit), using a helium refrigerator, or cryocooler system.

There are two overarching observation modes in which Webb can operate: imaging and spectroscopy. Webb's four science instruments will receive the light collected by the telescope and use a variety of tools – cameras, spectrographs, coronagraphs, and other specialized pieces – designed to maximize the scientific knowledge gained from every observation. Each instrument also has a field of view that is unique in area, shape, and orientation. In some cases, different observing modes within an instrument cover fields of view of different sizes and shapes.



Webb's four instruments are specially designed to use specific observation modes, components, and field of view to learn more about a wide range of objects in space, including stars, planets, galaxies, and dark energy.

Near-Infrared Camera (NIRCam)

NIRCam provides high-resolution imaging and spectroscopy for a wide variety of investigations. NIRCam is Webb's primary imager and operates over a wavelength range of 0.6 to 5 microns, where dust becomes transparent. NIRCam is equipped with coronagraphs, instruments that allow astronomers to take pictures of very faint, dim objects around a central bright object by blocking the bright light source, useful in investigations seeking to determine characteristics of planets orbiting nearby stars. NIRCam was built by a team at the University of Arizona and Lockheed Martin's Advanced Technology Center.

Near-Infrared Spectrograph (NIRSpec)

NIRSpec is considered a very versatile tool of Webb's for near-infrared spectroscopy. NIRSpec operates over a wavelength range of 0.6 to 5 microns. In addition to standard single-slit spectroscopy to gather spectra of specific objects, NIRSpec is designed to observe 100 objects simultaneously – the first spectrograph in space with this multi-object capability. This is 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. NIRSpec was built for the European Space Agency by Airbus Industries with the microshutter array and detector subsystems fabricated by NASA.

Near-Infrared Slitless Spectrograph/Fine Guidance Sensor (NIRISS/FGS)

NIRISS provides near-infrared imaging and spectroscopic capabilities. As the only instrument equipped with an aperture mask, NIRISS has the unique ability to capture images of bright objects at a resolution greater than the other imagers. NIRISS operates over a wavelength of 0.6 to 5 microns. NIRISS is a contribution of the Canadian Space Agency.

Housed in the same assembly as NIRISS is Webb's Fine Guidance Sensor (FGS). The FGS is a camera system designed to make sure Webb is stable and pointing in exactly the right direction throughout the observation. The FGS detects and identifies guide stars and ensures that Webb is locked onto those stars for the entire observation.

Mid-Infrared Instrument (MIRI)

MIRI provides imaging and spectroscopy capabilities in the mid-infrared wavelengths. MIRI is equipped with a camera, coronagraphs, spectrographs, and an integral field unit, which is a combination of camera and spectrograph used to capture and map spectra across a field of view. MIRI operates over a wavelength range of 5 to 28 microns. As the only mid-infrared instrument, astronomers rely on MIRI to study redshifted light of distant galaxies, newly forming stars, faintly visible comets, and objects in the Kuiper Belt.

Because MIRI sees farther into the infrared than the other instruments, it has to be kept even colder than its counterparts. Webb's two-stage cryocooler works like the world's most effective refrigerator, pumping a warmth-absorbing gas through the instrument. The first stage brings MIRI's temperature down to 18 kelvins, and the second stage brings the MIRI detectors to below 7 kelvins — that's just 7 degrees above absolute zero, the theoretical temperature at which all motion freezes, even the movement of atoms.

MIRI was provided by the European Consortium with the European Space Agency and by NASA's Jet Propulsion Laboratory.

Integration and Testing

Building an infrared observatory of this magnitude, power, and complexity has never been attempted before.

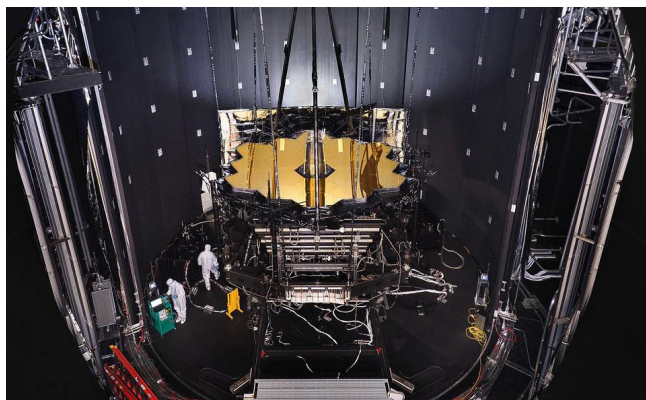
In order to ensure seamless operation in space, the cutting-edge technology incorporated into Webb was rigorously tested prior to launch. Due to its large size and unique shape the entire Webb observatory cannot be tested as one fully assembled unit in a simulation of the environment it will operate in.



It is also infeasible to replicate the cold environment for the space-facing telescope and instruments, and the hot environment on the Sun-facing side of the sunshield, and run end-to-end optical tests on the whole deployed observatory in a vacuum chamber. This led engineers to test and qualify the observatory in two halves – the telescope and instruments as one unit, and the combined spacecraft bus and sunshield as the other.



Each half was put through qualification levels of acoustic and sine sweep vibration, to simulate launch conditions, followed by performance testing in a thermal-vacuum chamber, and then following assembly of these two ‘super-elements’ the observatory was subjected to additional acoustics and sine sweep vibration testing to verify the workmanship of the final assembly.



All flight-deployable items on the observatory were deployed multiple times to ensure they will work once in space, including offloading weight to deploy mechanisms designed to work in the weightlessness of space.

Innovations and Spinoffs

Technological Innovations

The James Webb Telescope will have a unique and profound role in transforming our understanding of astrophysics and the origins of galaxies, stars, and planetary systems. In order to carry out its mission, [10 innovative and powerful new technologies](#) ranging from optics to detectors to thermal control systems have been developed.

Infrared detectors

Light from faint astronomical objects is converted into faint electrical signals by the detectors in each of the James Webb Space Telescope's scientific instruments. Webb needs extraordinarily sensitive detectors to record the feeble light from far-away galaxies, stars, and planets. It needs large-area arrays of detectors to efficiently survey the sky. Webb uses two types of detectors in order to sense shorter or longer wavelength light.



Near-infrared detectors

Webb's near-infrared detectors are mercury-cadmium-telluride (HgCdTe) "H2RG" detectors that cover 0.6 to 5 microns. By varying the ratio of mercury to cadmium, it is possible to tune the material to sense longer or shorter wavelength light. Webb takes advantage of this by using two compositions of mercury-cadmium-telluride: one with proportionally less mercury for 0.6 to 2.5 microns, and another with more for 0.6 to 5 microns.



Mid-infrared detectors

Webb's mid-infrared detectors are made of arsenic doped silicon and cover 5 to 28 microns.

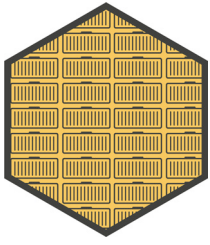
Wavefront algorithms

Wavefront sensing and control is used to sense and correct any errors in the telescope's optics, which is essential in ensuring all of Webb's 18 segments successfully function as a single giant mirror. Ball Aerospace engineered a scaled telescope testbed to develop and demonstrate this technology. [More about wavefront algorithms.](#)



Cryocooler

Webb's MIRI instrument carries detectors that need to be at a temperature of less than 7 kelvins to operate properly. This temperature is not possible on Webb by passive means alone, so Webb carries an innovative "cryocooler" that is dedicated to cool MIRI's detectors. [More about the cryocooler.](#)



Microshutter array

Microshutters are tiny windows with shutters that each measure 100 by 200 microns, or about the size of a bundle of only a few human hairs. The microshutter device can select many objects in one viewing field for simultaneous high-resolution observation. This means more scientific investigations are carried out in less time.

[More about the microshutter array.](#)

Cryogenic data acquisition integrated circuit

These detector output signals aboard Webb are very susceptible to being overwhelmed by electrical noise. Therefore, converting analog signals to digital ones right near the detectors before sending them through wires to other processing and communications electronics away from the instruments is key to Webb science data integrity and quality, and consequently scientific measurement sensitivity.

[More about the cryogenic data acquisition integrated circuit.](#)



Sunshield coatings

The sunshield's membrane layers, each as thin as a human hair, are made of Kapton, a tough, high-performance plastic coated with a reflective metal. Each layer is coated with aluminum, and the Sun-facing sides of the two hottest layers also have a "doped-silicon" (or treated silicon) coating to reflect the Sun's heat back into space.

[More about the sunshield coatings.](#)

Lightweight cryogenic mirrors

A telescope's sensitivity, or how much detail it can see, is directly related to the size of the mirror area that collects light from the objects being observed. Webb's large mirror needs to be very cold so the faint infrared light from distant galaxies would not be lost in the infrared glow of the mirror. [More about the lightweight cryogenic mirrors.](#)



Lightweight cryogenic backplane

The backplane must carry more than 2.5 tons of hardware, including Webb's primary mirror and Integrated Science Instruments Module (ISIM). It is required to be essentially motionless and extremely steady so the mirrors can see far into deep space. To meet this requirement, the backplane was engineered to be steady down to 32 nanometers.

Heat switches

The need to protect instruments from contamination during cooldown, and to decontaminate them in the event of an anomaly, requires the capability to warm the instruments. Webb could use heat switches to temporarily break the thermal path from the instruments to their radiators, allowing power-efficient warming of the instruments.



Webb Spinoffs

As with other NASA missions and projects, specialized technologies developed for the James Webb Space Telescope over the mission's lifetime have also benefited life on Earth.

HELPING HUMAN EYES: In the testing of Webb's powerful mirrors, "wavefront sensing" is used to measure the shape of the mirrors during fabrication and control the optics once the telescope is in orbit. A new "scanning and stitching" technology developed for the Webb telescope led to a number of innovative instrument concepts for more accurate measurement for contact lenses and intraocular lenses. The scanning and stitching technology improvements have enabled eye doctors to get much more detailed information about the shape and "topography" of your eye, and in seconds rather than hours.

HELPING IMPROVE HUBBLE'S VIEW: Webb investments in cryogenic Application-Specific Integrated Circuits (ASICs) led to the development of the ASICs that are now flying on the Hubble Space Telescope. This is a unique example of "future heritage": a program that was in development (Webb) invented a technology for a program well into the operations phase (Hubble). ASICs are small, specialized integrated circuits that enable an entire circuit board's worth of electronics to be condensed into a very small package. Webb's investments into this technology allowed the ASICs to be programmable, which was important in the repair of Hubble's Advanced Camera for Surveys that has produced stunning views of our universe.

LASER INTERFEROMETERS: One of the toughest challenges for Webb engineers was to find a way to test mirrors and composite structures at the incredibly cold -450 degree Fahrenheit temperature they will operate in space. With the desired precision of nanometers, vibration is a constant problem. To solve that problem, 4D Technology Corporation of Tucson, Arizona, has developed several new types of high-speed test devices that utilize pulsed lasers that essentially "freeze out" the effects of vibration.

DETECTOR TECHNOLOGY IMPROVING OTHER TELESCOPES: The benefits of the near-infrared detectors developed for Webb's instruments have already spread far and wide in the world of science. Infrared sensors based on the technology developed for Webb are now the universal choice for astronomical observations, both from space and the ground. This technology is also being used for Earth science and national security missions. An early pathfinder version of Webb's HAWAII-2RG 4 Megapixel array has been used in several NASA missions including Hubble, Deep Impact/EPOXI, WISE, and the Orbiting Carbon Observatory, and the HAWAII-2RG is already in use at dozens of ground-based observatories around the world. The availability of these high-performance detectors developed for Webb has been critical to a breathtaking collection of missions, both present and future.

IMPROVING ELECTRIC MOTORS: NASA Planetary Gear System technology developed to give precise nanometer positioning capabilities for Webb is now being employed by Turnkey Design Services, LLC (TDS), of Blue Island, Illinois, to improve electric motors. This revolutionary piece of technology allows more efficient operation of the motors and is more cost-effective than traditional gearbox designs.



MANAGEMENT

NASA Headquarters Leadership

Meet the entire NASA Webb team

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Associate Administrator of NASA's Science Mission Directorate

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Paul Hertz

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Program Scientist of the James Webb Space Telescope Program Chief Scientist of the Astrophysics Division

Eric P. Smith

Deputy Program Scientist of the James Webb Space Telescope Program Education and Public Outreach Lead for the Astrophysics Division

Hashima Hasan

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Bridget Samuelson