International Journal of Social Science and Economic Research

ISSN: 2455-8834

Volume:07, Issue:02 "February 2022"

THE JAMES WEBB SPACE TELESCOPE

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DOI: 10.46609/IJSSER.2022.v07i02.016 URL: https://doi.org/10.46609/IJSSER.2022.v07i02.016

Received: 14 Feb. 2022 / Accepted: 21 Feb. 2022 / Published: 28 Feb. 2022

ABSTRACT

The James Webb Space Telescope (JWST) is the scientific successor to the Hubble Space Telescope. It is a cryogenic infrared space observatory and includes three passively cooled near-infrared instruments. It will be looking further back in time and observing the universe in infrared. The JWST is developed by NASA, in partnership with the European and Canadian Space Agencies. Technology development, mission design, construction, integration and verification testing were complete and the JWST was launched on 25th December 2021 on the Ariane 5 launch vehicle from Kourou, French Guiana. It has reached Point L2 and has begun calibrations.

Introduction to James Webb Space Telescope

The James Webb Space Telescope being is a large, space-based observatory that is well optimized for infrared wavelengths, which will help extend the discoveries of the Hubble Space Telescope. It will have more extended wavelength coverage and significantly improved sensitivity. The longer wavelengths will enable Webb to look further back in time and findthe first galaxies that formed in the early Universe, peering inside dust clouds where stars and planetary systems are forming today.

It was first named Next Generation Space Telescope or NGST but later called JWST or James Webb Space Telescope.

The James Webb Space Telescope was initially called the "Next Generation Space Telescope," or NGST because Webb will build on and continue the Hubble Space Telescope's science exploration. Discoveries by Hubble and other telescopes have had a big impact on astronomy and have raised new questions that now require a new, different, and more powerful telescope. In an engineering sense, Webb is also a "Next Generation" telescope, introducing many new

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ISSN: 2455-8834

Volume:07, Issue:02 "February 2022"

technologies like the lightweight, deployable primary mirror that will be a benchmark for future missions. Then, On 10 September 2002, the Next Generation Space Telescope was renamed in honor of James E. Webb, NASA's second administrator.

Importance of James Webb Space Telescope

The James Webb Space Telescope, a space telescope with approximately a 6.5-meter primary mirror, is one of the most extensive primary mirror setups in any space observatory to date having an ability to work infrared. It will be the major observatory of the next decade. Enabling thousands of astronomers worldwide to study every phase of the history of our Universe. Astronomers would be able to observe the first glows after the Big Bang and even the Solar Systems capable of supporting Earth-like life and also the evolution of our very own solar system.

Webb is the scientific successor to Hubble as its science goals were motivated by results received from Hubble. Hubble's science motivated astronomers to look for longer wavelengths to "go beyond" what Hubble has already accomplished. In particular, many distant objects are more highly redshifted, and their light is pushed from the UV and optical into the near-infrared. Thus observations of these distant objects require an infrared telescope. The reason that Webb is not a replacement for Hubble is that their capabilities are not identical. Webb will be looking at the Universe in infrared, while Hubble only studies it majorly at optical and ultraviolet wavelengths even after having some infrared capability. Webb having a much bigger mirror than Hubble enables a larger light-collecting area which means that Webb is able to peer farther back into time than what Hubble was capable of doing. In addition, Hubble is in a very close orbit around the Earth, whereas Webb will be 1.5 million kilometers (km) away at the second Lagrange (L2) point.

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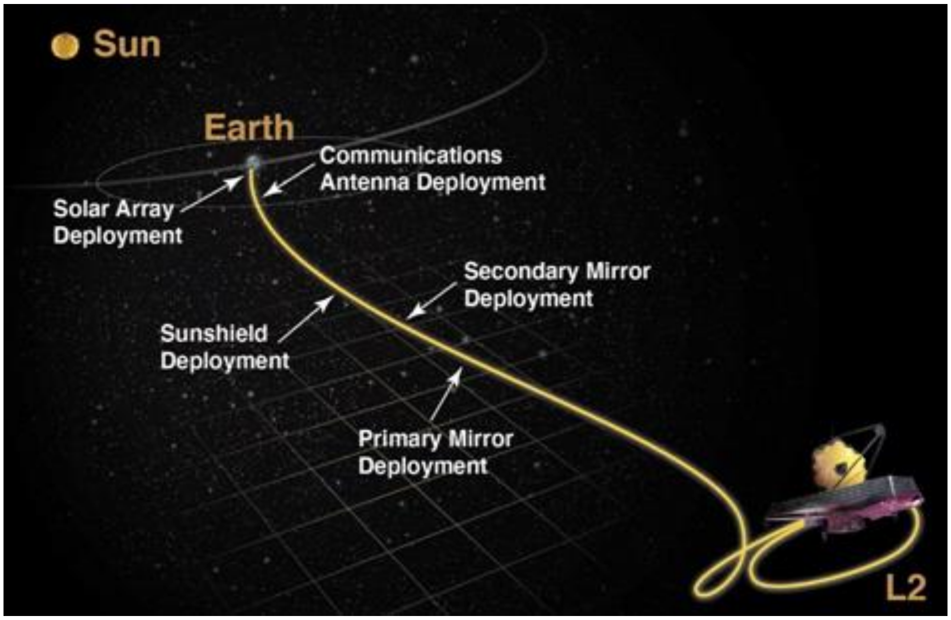

(Figure1: Deployment Path)

https://jwst.nasa.gov/ImagesContent/about/WebbFlightPathAndDeployments.jpg

The Uniqueness of the James Webb Space Telescope

JWST is a remarkable feat regarding the innovation involved in the functioning of the space observatory. Several innovative and powerful new technologies ranging from optics to detectors to thermal control systems have been developed, especially for the James Webb Space Telescope. Webb is having a mirror that is 6.5 meters (21.3 feet) in diameter and a tennis court-sized sunshield. i.e the mirror and sunshield are bigger than the total width of therocket used to launch them, therefore they will be folded up for launch and will deploy once Webb is in space.

The following technologies were developed for James Webb Space Telescope but ended up facilitating purposes much more comprehensive than just the telescope: Measuring Eyes: New Wavefront Optical Measurement Devices Leading to Medical Spinoffs-

For accurate measurement of the shape of Webb's mirrors during manufacturing, many new improvements are made in the area of wavefront sensing technology. This measurement device is called a Scanning Shack-Hartmann Sensor. These newly developed technologies forThe Webb Program have enabled eye doctors to get much more detailed information aboutthe shape of their eyes in seconds rather than hours. "The Webb telescope program has enabled several

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ISSN: 2455-8834

Volume:07, Issue:02 "February 2022"

improvements in measurement technology for the measurement of human eyes, ocular diseases diagnostics, and potentially improved surgery," Dr. Dan Neal of Abbott Medical Optics Inc. in Albuquerque, NM, said.

Laser Interferometers: High-Speed Optical Sensors Leading to Commercial Applications- The toughest challenge for Webb engineers was to find a way to test mirrors and composite structures at the chilly -450 degrees F temperature in which they will operate in space. When desired precision of nanometers is needed, vibration is a major constant problem. To solve it, 4D Technology Corporation of Tucson, Arizona, developed several new types of high-speed test devices which utilized pulsed lasers that essentially "froze out" the effects of vibration. "The JWST program has proven to be a tremendous benefit for the creation of new jobs and technology beyond its direct funding. 4D has generated over $30 million in revenue from a wide range of applications in the astronomy, aerospace, medical and semiconductor industries based on the technologies developed for JWST", according to 4D Technology CEO James Millerd.

Restoring Hubble: Integrated Circuits Used in Camera Repair-

Webb's investments in cryogenic Application-Specific Integrated Circuits (ASICs) led to the ASICs now being installed on the Hubble Space Telescope. This is a great example of "future heritage" which is a program in development, invented a technology for the program well into the operations phase of Hubble. ASICs are very small, specialized integrated circuits that enable an entire circuit board's worth of electronics to be condensed into a tiny package. Webb's investments into the technology allowed the ASICs to be programmable, which was significant in repairing Hubble's Advanced Camera for Surveys that have produced stunning views of our Universe.

Astronomical Detectors: Webb Detector Technology being the Universal Choice-

The advantages of the near-infrared detectors developed for JWST's instruments have already spread wider in the world of technology. "Infrared sensors which are based on the technology developed for JWST are now a universal choice for astronomical observations, both from space and the ground," Dr. James Beletic, Senior Director at Teledyne, said. This technology is also being used for Earthly science and national security missions. An early pathfinder version of JWST's HAWAII-2RG 4 Megapixel array has been used in many NASA missions, including Hubble, Deep Impact/EPOXI, WISE, the Orbiting Carbon Observatory and the HAWAII-2RG are already in use at various ground-based observatories worldwide. The availability of these high-performance detectors developed for Webb has been critical to a breathtaking collection of present and future missions.

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Microshutter Technology:

The micro shutters are a new technology developed for the James Webb Space Telescope mission. They are tiny windows with shutters that measure 100 by 200 microns, or just about the size of a bundle of a few human hairs. Arrays of these small windows are a vital component of one of Webb's instruments, the Near-Infrared Spectrograph or NIRSpec.

It will record the spectra of light from distant objects. (Spectroscopy is a science of measuring light intensity at various different wavelengths. The graphical representations of these measurements are known as spectra.) What is unique about the micro shutter device is that it can simultaneously observe various objects in one viewing, and it can be programmed for any field of objects in the sky.

Many other spectroscopic instruments have flown in space before. Still, none could provide high-resolution (spectroscopic) observation of up to 100 objects in one viewing, which means much more scientific investigation can be done in less time.

Sunshield Membrane Coatings:

The James Webb Space Telescope's primary science is infrared light, essentially heat energy. Therefore, the telescope itself must be very cold and stable to detect the highly faint heat signals of astronomical objects that are very far away. This means that they not only have to protect Webb from sources of light and heat like the Sun and the Earth but also have to make all the telescope elements themselves very cold so they do not emit their heat energy that could interfere with sensitive instruments onboard. The temperature also must be kept at a constant temperature so that materials are not shrinking or expanding which throws off the precise alignment of the optics.

To accomplish this, Webb deploys a tennis-court-sized Sunshield made of five thin layers of Kapton E with aluminum and doped silicon coatings to reflect the Sun's heat into space. The Kapton is a commercially available polyimide film from Dupont, while the coatings are applied to a specialized Webb specification.

Delays in the Launch

One of Hubble's most fundamental limitations is the wavelength range it can observe. Like telescopes on Earth, Hubble is eminently capable of monitoring the full suite of visible light wavelengths. However, unlike telescopes on Earth, Hubble can also observe the ultraviolet portion of the spectrum insignificant detail; the combination of the Space Telescope Imaging

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ISSN: 2455-8834

Volume:07, Issue:02 "February 2022"

Spectrograph (installed in 1997) and the Cosmic Origins Spectrograph (installed in 2009) enables us to explore wavelengths that are otherwise blocked by our atmosphere.

However, on the lower-energy end of the spectrum — in the infrared — even Hubble's cutting-edge instruments stand a challenge: the fact that the telescope itself is warm. Our eyes may be lousy infrared detectors, but our skin is pretty good at it, which is why we can "feel" the heat from hot objects, even if their radiation is invisible to our eyes. So if we had wanted Hubble to observe at longer wavelengths, we needed to cool it to lower temperatures. If our instruments and optics are too warm, we cannot record meaningful data beyond a specific wavelength.

But, Hubble's perch is in low-Earth orbit, where it has to contend with not just the radiation from the Sun but also with the heat reflected from Earth itself, which is a terrible location for overcoming these obstacles.

Part of the reason that the James Webb Space Telescope has taken a long time to develop is just because of this challenge. Designed to observe wavelengths of up to ~10-15 times longer than Hubble is currently capable of seeing, Webb has had to overcome a series of challenges:

- It has to implement a passive cooling system that would enable constant observations at wavelengths longer than Hubble's limits,
- The implementation of a set of infrastructures that shields Webb and all of its instruments onboard from the Sun's radiation,
- The implementation of an active cooling system that enables observations at even lower temperatures and longer wavelengths than the passive system enables
- Moreover, the placement of the telescope has to be at a location where it no longer needs to contend with any emitted radiation from any object other than our Sun.

The first three challenges resulted in the development of a 5-layer sunshield that permanently stays between the telescope's optics and the Sun with an active cooling system that allows not only a range of the near-infrared part of the spectrum but even the mid-infrared (corresponding to temperatures of ~7 K and wavelengths of ~30 microns). This design, complex but novel to implement, will enable Webb to reveal the Universe to far greater precision than any previous observatory, including NASA's Spitzer or WISE or ESA's Herschel, its three most closely-related predecessors.

But, the fact that we have to locate Webb so far away from Earth is what majorly limits its

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ISSN: 2455-8834

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lifetime. Ideally, we would be able to orient Webb in such a way that the Sun, Earth, and Moon always lie on one side of the telescope so that the sunshade can bear them, while on the other side, the optics and instruments can remain cool and shielded from them. Also, we would like it so that the telescope would move with planet Earth in its orbit as then we could send-and-receive signals from Webb which would include downloading its data as fast as we can collect it and issuing time-sensitive commands — consistently that does not depend on where the telescope is concerning our planet.

Timeline of significant events for JWST;

- 1996: Next Generation Space Telescope initiated
- 2000: NEXUS canceled (JWST technology demo)
- September 2002: NGST named James Webb Space Telescope
- 11 September 2003: $824.8 million prime contract for JWST awarded to TRW
- January 2007: 9/10 Technology development items pass non-advocate review
- April 2010: Technical part of Mission Critical Design Review (MCDR) passes
- November 2011: JWST survives a cancellation attempt
- March 2013: FGS/NIRISS installed in ISIM
- 4 July 2013: MIRI installed in ISIM
- March 2014: NIRCam installed in ISIM
- March 24–25, 2014: NIRSpec integrated into ISIM
- June 2014: The first combined test of all four instruments, including cryogenic testing in the Goddard Space Environment Simulator
- February 2015: The hexagonal segments of the primary mirror were completed
- December 2015: Contract for JWST's launcher signed with a launch date of October 2018
- March 2016: Cryogenic testing of instruments and mirrors completed with Secondary mirror and Aft Optics Subsystem being installed on OTE

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ISSN: 2455-8834

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- November 2016: JWST construction completed (still needed testing)
- January 2017: JWST is fine after experiencing an anomaly during vibration testing in Dec 2016
- 27 March 2018: JWST launch delayed to at least May 2020 as issues with the spacecraft element require further testing
- 27 June 2018: JWST launch postponed to 30 March 2021, based on recommendations by an Independent Review Board
- 16 July 2020: JWST launch postponed to 31 October 2021 due to impacts from the coronavirus (COVID-19) pandemic, as well as technical challenges
- 1 June 2021: JWST launch postponed to no earlier than November 2021 due to concerns regarding the readiness of the Ariane5 launch vehicle and launch site
- 8 September 2021: JWST launch delayed to 18 December 2021
- 22 November 2021: JWST launch postponed to no earlier than 22 December 2021 to allow additional testing after experiencing vibrations due to an unplanned clamp release
- JWST launched on 25th December 2021

Pre-launch Plans Timeline for JWST;

- 2016: OTE tests complete
- 2017: OTIS tests complete
- 2017: Spacecraft (including sunshield) tests complete
- 2018: Observatory I&T complete
- October 2018: Planned launch date as of 2016
- Early 2019: Planned launch date as of October 2017
- May 2020 or later: Scheduled launch date as of March 2018
- 30 March 2021: Scheduled launch date as of June 2018

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- 31 October 2021: Scheduled launch date as of July 2020
- November 2021 or later: Scheduled launch date as of June 2021
- 22 December 2021: Scheduled launch date as of November 2021
- 25 December 2021: Launch Scheduled

Controversy over JWST Name;

In March 2021, several scientists in *Scientific American* urged NASA to reconsider the telescope's name based on Webb's alleged complicity in LGBTQ discrimination. In his 2004 book about the lavender scare, historian David K. Johnson wrote that, while serving as undersecretary of state for the Harry S. Truman administration in the early 1950s, James Webb met the president to discuss a way in which the White House might help investigate whether homosexual employees posed a security risk, in tandem with a Senate subcommittee dedicated to that task. In January 2021, astrophysicist Hakeem Oluseyi explained that a quote displayed on Webb's Wikipedia article from 2011 to 2015, which implied he was homophobic, had been wrongly attributed to him.

In September 2021, it was reported that NASA had decided not to rename the telescope. Former administrator Sean O'Keefe, who chose to name the telescope after Webb, denounced the discrimination of "talented professionals based on their personal preferences" but stated that to suggest Webb should "be held accountable for that activity when there is no evidence even to hint [that he participated in it] is an injustice." In response to this decision, one member of NASA's Astrophysics Advisory Committee (APAC) resigned.

Conclusion

To conclude, the James Webb Space Telescope has recently been launched has reached the Lagrange Point 2 (L2) and will soon be calibrated and fully deployed. Once deployed it will be of huge benefit for further scientific research and will enable astronomers to look further back in time and observe the universe in greater detail. The technologies built for JWST have already been proved useful for a much wider area of work than just astronomy.

JWST was launched in Ariane 5 Rocket on December 25, 2021. It successfully separated from Ariane 5 Rocket and deployed its solar arrays to begin its journey through space to its L2 place which is about 1 million miles from Earth. The following days, JWST made multiple course-correction maneuvers. On December 29, 2121, the sunshield deployment was initiated. By

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ISSN: 2455-8834

Volume:07, Issue:02 "February 2022"

January 09, 2022, JWST was fully deployed and was heading for L2. On January 25, 2022, JWST successfully reached its new home, Lagrange Point 2. Moving on, JWST will be calibrating its parts (especially its mirrors) for the next 4-5 months, following which we will be able to witness the first pictures from the exiting cryogenic space telescope.

(Figure2: JWST inside Ariane5 Rocket)

https://www.esa.int/ESA_Multimedia/Images/2009/10/JWST_stowed_inside_the_Ariane_52

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ISSN: 2455-8834

Volume:07, Issue:02 "February 2022"

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