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UNCOVERING THE NEW MYSTERIES OF OUR UNIVERSE: THE ORIGINS OF THE JAMES WEBB SPACE TELESCOPE

BY SHREYA RAMESH

INTRODUCTION

Within billions of galaxies in our universe, there are trillions of star systems, each with its own planets, moons, asteroids, and comets. Our planet exists in its own pocket of outer space, and it is easy to forget that ours is within just one solar system in the vast universe. We have barely begun to uncover and answer the mysteries of the cosmos and our very existence, and there are plenty of answers we do not yet have.

The Hubble Telescope is one of the most well-known telescopes in modern history, thanks to its pivotal role in helping us begin to visualize and understand the universe we call home. However, despite its vital contribution to the advancement of astronomy, its dated technology has begun hindering us from answering the increasingly complex questions we have about our universe. To address this issue, NASA recently launched the James Webb Space Telescope (JWST), named after NASA's second administrator, who is credited with the success of the Apollo missions. This telescope is the culmination of decades of cutting-edge research and technological advancements meant to provide us with unique, never-before-seen insights into the mysteries of the universe.

ORIGINS

In the 1940s, almost a century before the James Webb Space Telescope was launched, Hubble was conceived as a thought experiment.[1] Astronomers dreamed of having a telescope, positioned outside of the Earth's atmosphere, that would be powerful enough to observe the universe. Following years of planning, the project's design and creation began in 1977. In 1990, the telescope was then launched into orbit on the Space Shuttle Discovery mission.[1] Everything was running smoothly until scientists discovered an aberration in one of Hubble's main mirrors a few months after deployment, resulting in distorted images. The first servicing mission to clean the lenses took place in 1993, and after this service, Hubble took what is arguably one of its most impactful images, the Hubble Deep Field, in 1995. The Hubble Deep Field focused on a single section of space and took 342 separate exposures over the course of 10 days.[1] In the end, the combined images helped us visualize precisely how many galaxies and stars exist in a tiny patch of our sky. Now, the James Webb Telescope will offer us the chance to build on this knowledge and push our understanding even further.

> "Now, the James Webb Telescope is here to dive deeper and continue answering hard-hitting questions about our universe."

Figure 1: The James Webb Space Telescope.

ENGINEERING AND DESIGN

James Webb is an infrared telescope equipped with unique technology designed to capture signals from some of the farthest and never-before-seen reaches of space. The telescope is currently positioned at the second Lagrange point of the Earth-Sun system, a point in space such that the telescope maintains its displacement from the Earth as it revolves around the Sun.[2] The telescope uses three primary features to make observations: the Optical Telescope Element, the Integrated Science Instrument Module, and the Spacecraft Element.[3]

The Optical Telescope Element contains one of the telescope's iconic features: the foldable, hexagonal mirror. The unit consists of 18 gold-coated, hexagonal mirror segments, made of beryllium, that come together to form a 25 square-meter primary mirror—seven times bigger than Hubble's.[4] The large primary mirror maximizes the amount of light collected, which increases the sensitivity of the telescope and produces sharper results. Scientists designed the foldable mirror as a solution to the issue of fitting the telescope's large structure on a space transport system. Beyond eased transport, the foldable design also allows for scientists to adjust the hexagonal mirrors.[4] The hexagonal shape also directs the incoming light to be concentrated and focused on key areas of the telescope's detectors.[5]

The Integrated Science Instrument Module consists of several important devices such as a near-infrared camera and spectrograph. These instruments are meant to receive and interpret signals from far-away objects in space, including galaxies and other star systems.[6] Infrared signals are valuable when the observed object is not very bright or has little energy compared to neighboring objects. Such signals also easily pass through dust and other sources of signal interference due to these signals' longer wavelengths compared to visible light.[7]

Additionally, JWST's sensors can help us see what galaxies and other objects looked like in the past. When light from far-away galaxies and objects travels through space, its wavelength gets longer since the rate of the universe's expansion is faster than the speed of light.[7] As a result of this Doppler shift phenomenon, the light that reaches the sensors is "stretched out" light from a source that is rapidly moving further away, and therefore also very old. James Webb can then use this data to gather information and make inferences about our universe and its history.

Once the infrared signals from a source have been gathered, the signals are diverted into different detectors depending on their wavelength. Shorter wavelengths (0.6-5 μm) are diverted through mercury-cadmium-telluride H2RG detectors while signals of slightly longer wavelengths (5-28 μm) are diverted through arsenic-doped silicon detectors.[8] After the light travels through the detectors, the constituent photons pass through a thin layer of semiconductor absorber and are processed through a silicon readout integrated circuit (ROIC) that interprets the results.[8]

In order to ensure that JWST can continue its operations in the harsh conditions of outer space, NASA engineers created the Spacecraft Element of James Webb. The Spacecraft Element consists of the sun-shielding system and the support functions of the spacecraft, including the electrical power, communications, data handling, and propulsion systems, collectively known as the "Spacecraft Bus". The sun-shielding system is critical to main operations as it ensures that the sensors onboard the telescope work properly by shielding them from the sun's heat. The precise sensors usually require temperatures as low as 50 K (-370 Fahrenheit), and exposure to direct sunlight causes overheating and malfunction.[9] To keep these sensitive components cool, the sunshield, which is coated with five layers of

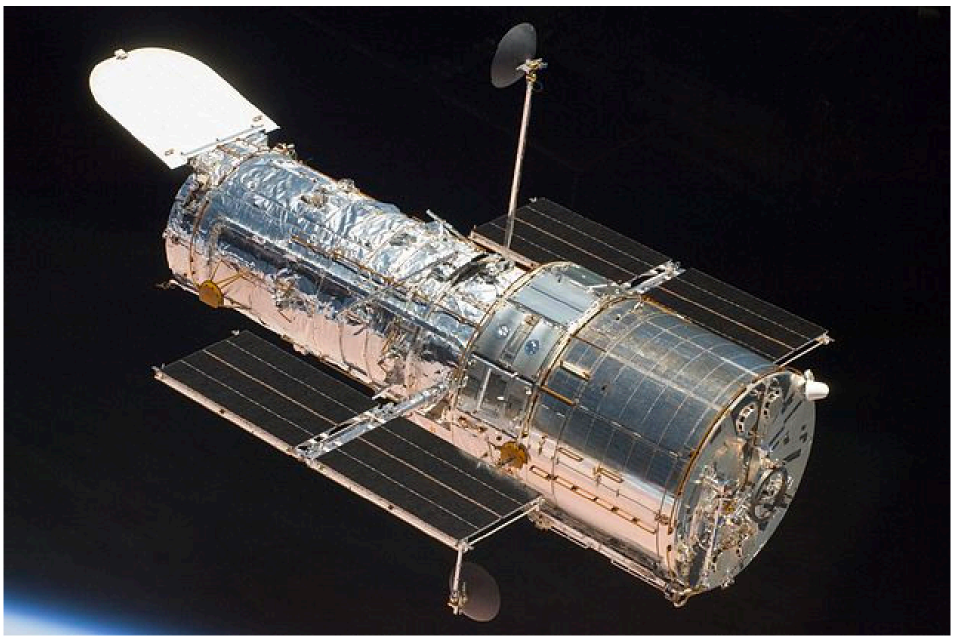

Figure 2: The Hubble Space Telescope in orbit around the Earth.

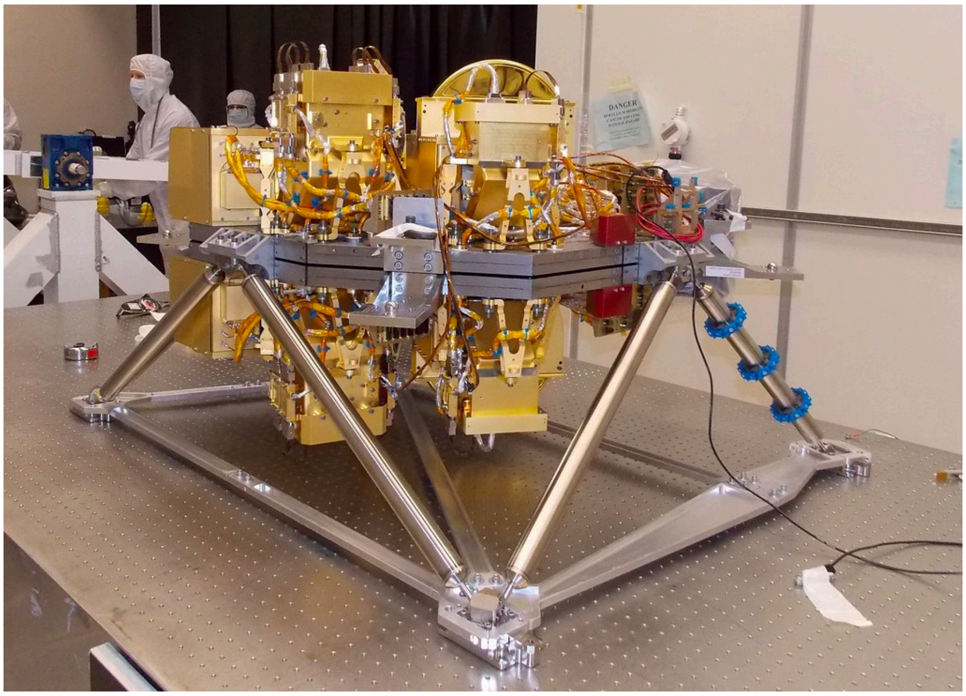

Figure 3: Integrated Science Instrument Module.

"Over the course of its decades-long development, it marked a wave of groundbreaking optical technology focused on creating innovative solutions to complex problems."

aluminum, doped-silicon, and Kapton—a lightweight material that helps to irradiate heat—acts as a giant shade.[9] In addition, JWST has a cryocooler to keep the Mid-infrared Instrument (MIRI), a device that observes wavelengths from 5 to 28 microns, at less than 7 K (-447 Fahrenheit), MIRI's optimal temperature. The cryocooler is a novel three-stage cooling system that uses liquid helium and has no moving parts, minimizing vibrations and allowing for clear images.

WHAT COMES NEXT

The telescope is currently slated to be used for a wide variety of projects such as imaging exoplanets and cosmological phenomena. Scientists plan on investigating other solar systems nearby by using cutting-edge spectroscopy to analyze the physical and chemical properties of these planets.[11] They are also seeking to use the telescope for projects related to understanding the evolution of stellar populations as the telescope's infrared sensors enable astronomers to see through the dust in stellar nurseries. JWST allows us to see such systems with greater resolution and sensitivity than Hubble, such as for galaxies that are farther away.[12] By better understanding what causes star formation and the processes involved in stellar death, we can gain a broader insight into the origins of our solar systems and our universe.

UNDERSTANDING OUR PLACE

James Webb is an incredible step forward in the fields of astronomy and astrophysics. Over the course of its decades-long development, it championed a wave of groundbreaking optical technology focused on creating innovative solutions to complex problems. This telescope is a new chapter in deepening our understanding of the universe by solving century-old problems, and in the process, we may uncover larger mysteries that govern the universe. James Webb will soon help us better understand our universe and its future, and consequently, more about humanity and our place in the cosmos.

Figure 4: The specialized Sunshields on JWST.

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