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Q15

Launched on 25th December, 2021, James Webb Space Telescope has been much in the news since then. What are its unique features which make it superior to its predecessor Space Telescopes ? What are the key goals of this mission ? What potential benefits does it hold for the human race?

UPSC Civil Services Mains 2022 · GS III · 15 marks · Indian Economy

Indian Economy and issues relating to planning, mobilization of resources, growth, development and employment.

Core demand of the question

- State unique features of the James Webb Space Telescope compared with predecessors
- State its key goals and potential benefits. Note the 25 December 2021 **launch**

Revision summary

JWST launched on 25 December 2021 on Ariane 5.

It is an infrared telescope at Sun-Earth L2 with a ~6.5 m gold-coated beryllium mirror and a five-layer sunshield.

Hubble is smaller, in low Earth orbit, and strong in visible/UV; Spitzer was a smaller infrared precursor.

Goals are first light, galaxy assembly, star-planet formation in dust, and exoplanet spectroscopy.

Benefits are astrophysics, technology, and complementarity with Hubble and ground observatories. Fuel at L2 limits life.

Introduction

The **James Webb Space Telescope (JWST)** lifted off on **25 December 2021** on an Ariane 5 from French Guiana. It is the successor in ambition to **Hubble**, not a copy. Hubble looks mainly in **visible and ultraviolet** from low Earth orbit. Webb looks in the **infrared** from a distant cold perch, with a much larger mirror, to see the first galaxies, nearby exoplanet atmospheres, and star nurseries inside dust.

Body**Unique features versus predecessors**

- **Wavelength:** optimised for **near- and mid-infrared**. Dust-obscured star formation and highly redshifted early galaxies are faint in Hubble's visible band and bright to Webb.
- **Mirror:** a deployable **beryllium** primary about **6.5 metres** across (segmented, gold-coated), far larger than Hubble's 2.4-metre glass, so collecting area and resolution at infrared wavelengths jump.

- **Orbit: Sun-Earth Lagrange point L2**, about 1.5 million km out, not low Earth orbit. Hubble can be serviced; Webb was designed not to be. L2 lets a huge **sunshield** keep the optics cold.
- **Sunshield**: a five-layer tennis-court-scale shade so the telescope stays at cryogenic temperature; mid-infrared instruments need that cold.
- **Deployment**: folded for **launch**, then unfolded in space (mirror, shield, tower)-a complexity Hubble did not attempt.
- **Partnership**: NASA lead with **ESA and CSA**; Hubble was also NASA-ESA, but Webb's infrared instrument suite (NIRCam, NIRSpec, MIRI, FGS/NIRISS) is a new generation.
- Spitzer was an infrared predecessor but **smaller and warmer** in later years; Webb is the leap in aperture and L2 cooling.

Key goals

- **First light and reionisation**: galaxies and quasars in the early universe, when the first stars lit up.
- **Assembly of galaxies** over cosmic time.
- **Star and planet formation** behind dust clouds.
- **Exoplanet atmospheres** by transit spectroscopy: water, carbon dioxide, and other molecules.
- **Solar-system** infrared studies (objects too cool or dusty for Hubble's best band).

Potential benefits

- **Science**: rewrite galaxy-formation timelines; characterise potentially habitable-zone atmospheres (biosignature claims will still need extreme caution).
- **Technology spin-off**: cryogenics, lightweight optics, deployable structures, detectors.
- **Inspiration and STEM**, and a public window on origins questions.
- **Complementarity**: Hubble still does UV/visible; ground ELTs and ALMA fill other bands. Webb does not retire them.

Caution

- L2 is not a place for astronaut repair. Mission life is limited by **station-keeping fuel** and instrument health, even if early fuel estimates were generous.

Flow diagram

JWST 25 Dec 2021 -> Infrared L2 sunshield
 JWST 25 Dec 2021 -> 6.5 m segmented mirror
 Hubble -> Visible UV LEO
 Infrared L2 sunshield -> First galaxies exoplanet atmospheres
 6.5 m segmented mirror -> First galaxies exoplanet atmospheres
 First galaxies exoplanet atmospheres -> Science cryogenics STEM

Conclusion

JWST, launched 25 December 2021, is a cold infrared observatory at L2 with a 6.5-metre deployable mirror-unlike Hubble's smaller visible/UV telescope in low orbit. Its goals are first galaxies, dusty birth sites, and exoplanet airts. Benefits are knowledge, detectors, and a complement to Hubble, not a replacement of every wavelength.

Facts & figures

Launch

James Webb Space Telescope launched 25 December 2021 (Ariane 5, Kourou).

L2

Sun-Earth Lagrange point 2, about 1.5 million km from Earth; stable thermal environment with a sunshield.

Primary mirror

Segmented ~6.5 m gold-coated beryllium; Hubble's primary is 2.4 m.

Agencies

NASA-led with European Space Agency and Canadian Space Agency contributions.

MIRI / NIRCam

Mid-infrared and near-infrared camera instruments central to the science payload.

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