

JWST from below*

An overview of the construction of the James Webb Space Telescope (JWST) and discussion of current status

Optica, Rochester Section

Rochester, New York

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NASA Goddard Space Flight Center



*Apologies to R. Feynman ("Los Alamos from Below," *Reminiscences of Los Alamos, 1943—1945*, L. Badash et al. eds., D. Reidel Publishing Co., Dordrecht, p. 105, 1980).



Outline



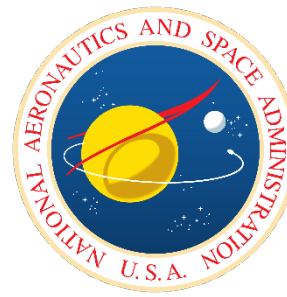
- About NASA
- About the Optics Branch at NASA Goddard Space Flight Center (GSFC)
- Introduction to the James Webb Space Telescope and its mission
- Latest updates

JWST construction occurred across the country and around the world (and at nearby NASA Goddard Space Flight Center, Greenbelt, Md.)



NASA

A little about NASA



NASA

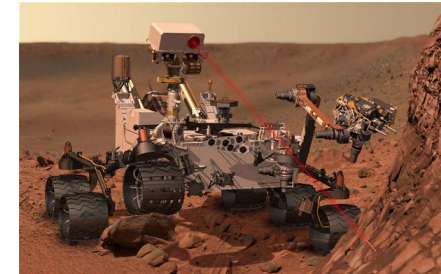
- US Government's civilian "space department"
- Partners with industry and academia, but in-house work, too
- Space exploration
 - Human space flight and exploration
 - Robotic exploration
 - Astronomy and other space science
- Earth science
 - Weather
 - Climate change
- Airplane research
- NASA works closely with companies, universities, and other countries
- We are living in a "golden age" for astronomy, planetary science, heliophysics, Earth science and space science!
- We are on the cusp of a new golden age for human space flight!
- Each NASA center has a different mission/purpose
- NASA Goddard Space Flight Center (GSFC) is focused on Earth and other science missions (not much manned space flight)

Our Vision Statement

We reach for new heights and reveal the unknown for the benefit of humankind

Our Mission

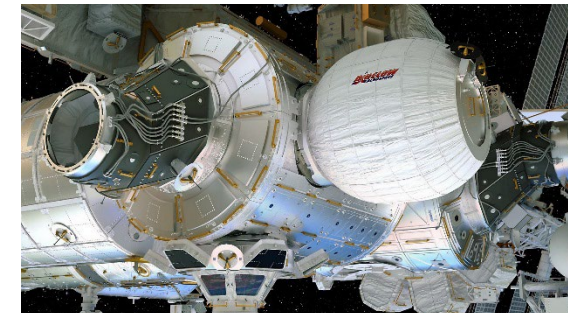
Drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality and stewardship of Earth

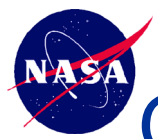


NASA



NASA

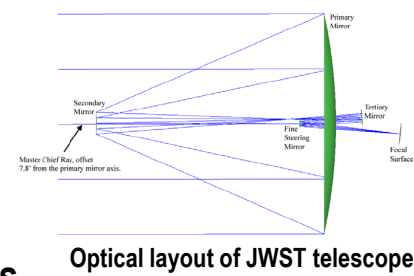




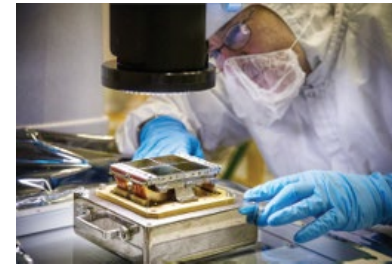
Optics Branch, GSFC



- All phases of optical (and some non-optical) system development for all types of flight (and some non-flight) projects, including R&D and early-phase efforts
- Mix of civil servant and contractor personnel (~130 total)
- Close engagement with science and engineering groups to deliver both in-house and externally-developed telescopes and instruments
- Partnerships and collaborations with many elsewhere in NASA, other Government, academia, and industry
- Unique, world-class facilities with a broad range of capability
- Divided into Groups
 - Design
 - Fabrication
 - Components
 - Alignment, Integration, and Test
 - Wavefront Sensing and Control



Optical metrology for the spacecraft



Alignment metrology for JWST NIRC2 detectors



Diamond machining of optics and precision, optomechanical surfaces



OSIRIS-REx OVIRS and optics team

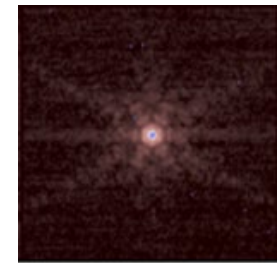
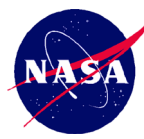


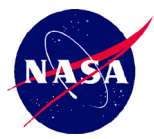
Image from JWST ground testing



James Webb Space Telescope (JWST)



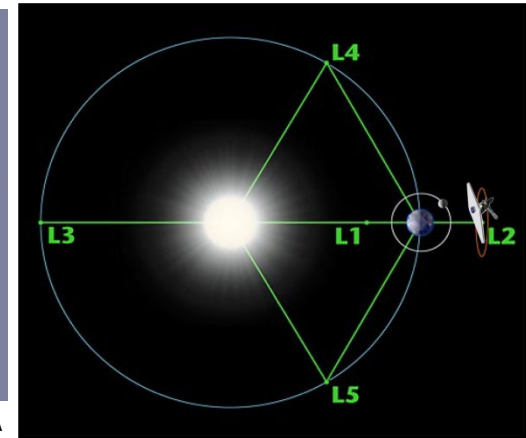
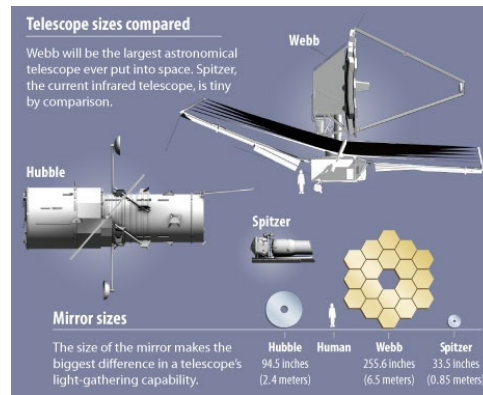
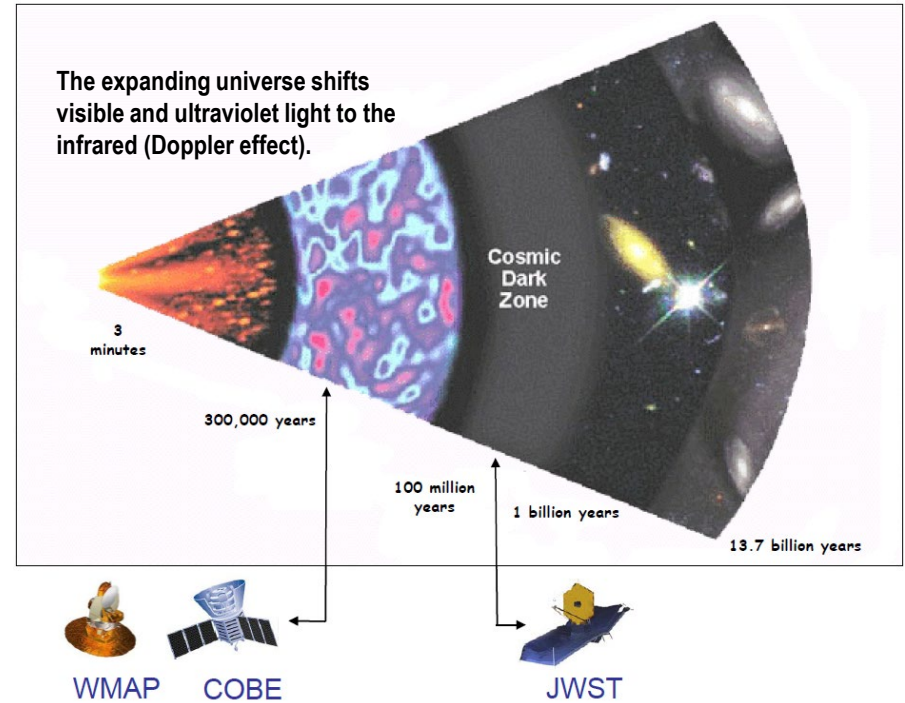
WEBB
TELESCOPE

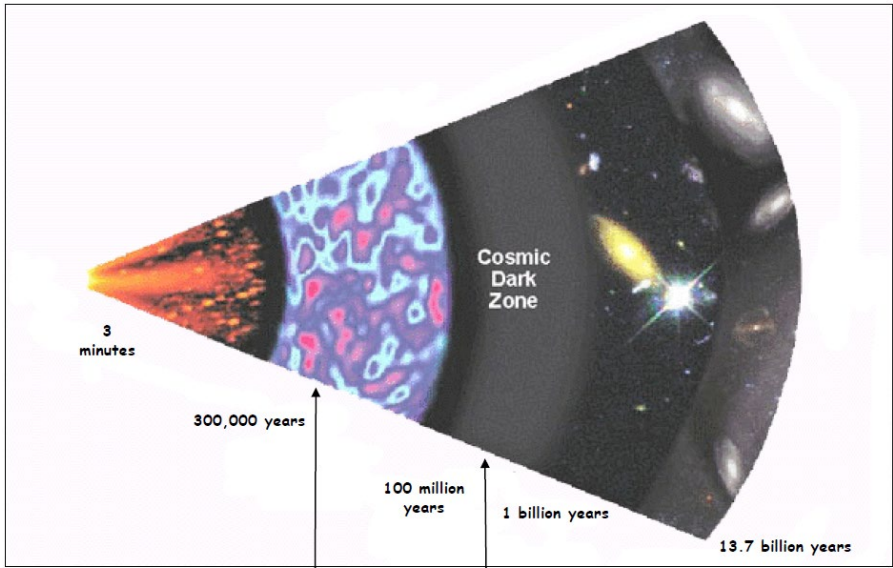


JWST is a general astrophysics mission



- JWST will operate in a manner similar to HST to enable a wide range of science investigations proposed by astronomers world-wide (scientific follow-on)
- General Observer community will drive science investigations
- Four science themes define the development of technical requirements for JWST:
 - First light and reionization: Identify the first bright objects in the early Universe and follow ionization history
 - Galaxy formation and evolution: Shed light on how galaxies and dark matter evolved to present
 - Star formation in our galaxy: Study the birth and early development of stars
 - Planetary systems: Observe the physical and chemical properties of solar systems (including our own)

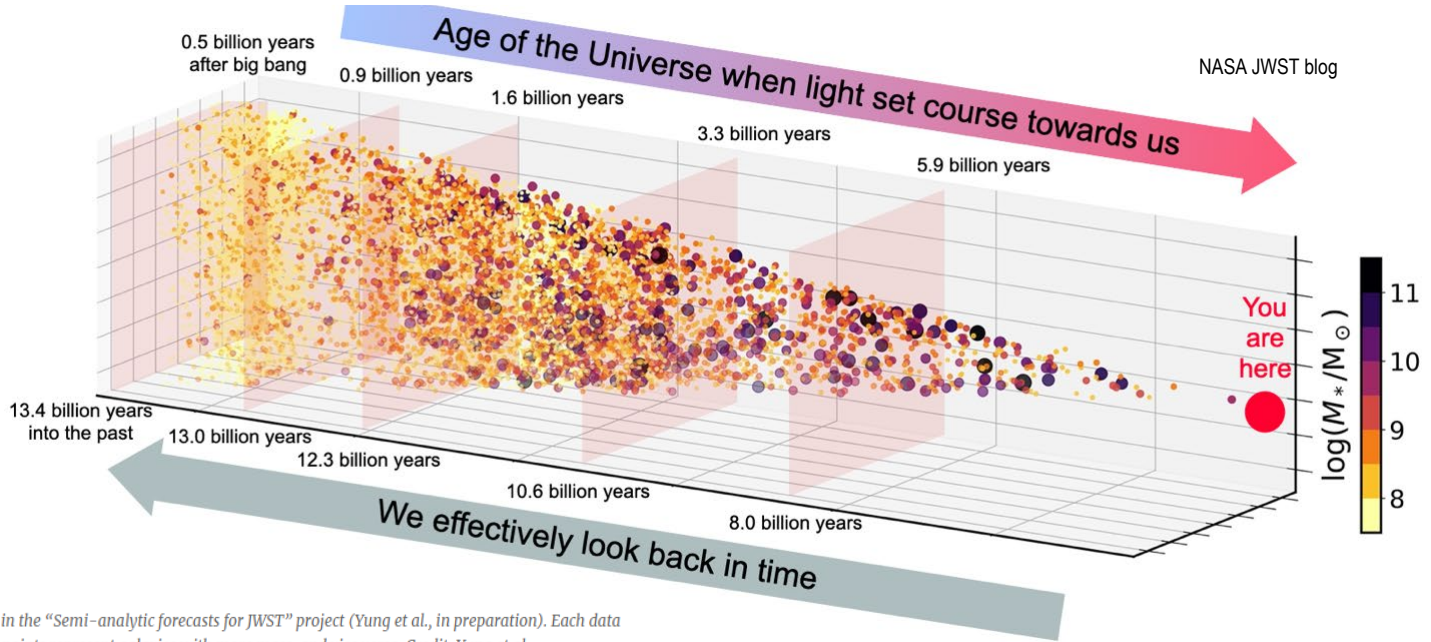
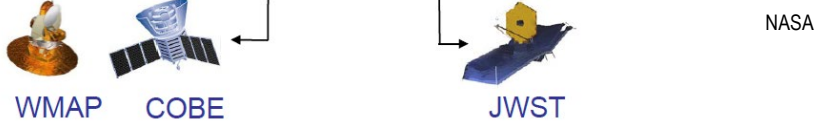




To “Drive advances in science...”, in this case **ASTROPHYSICS**.

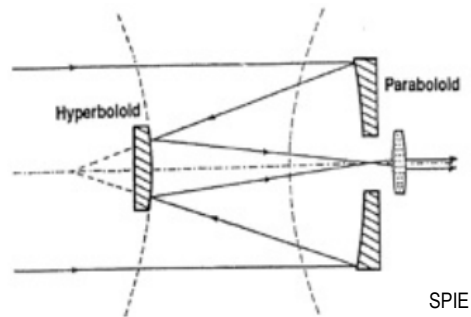
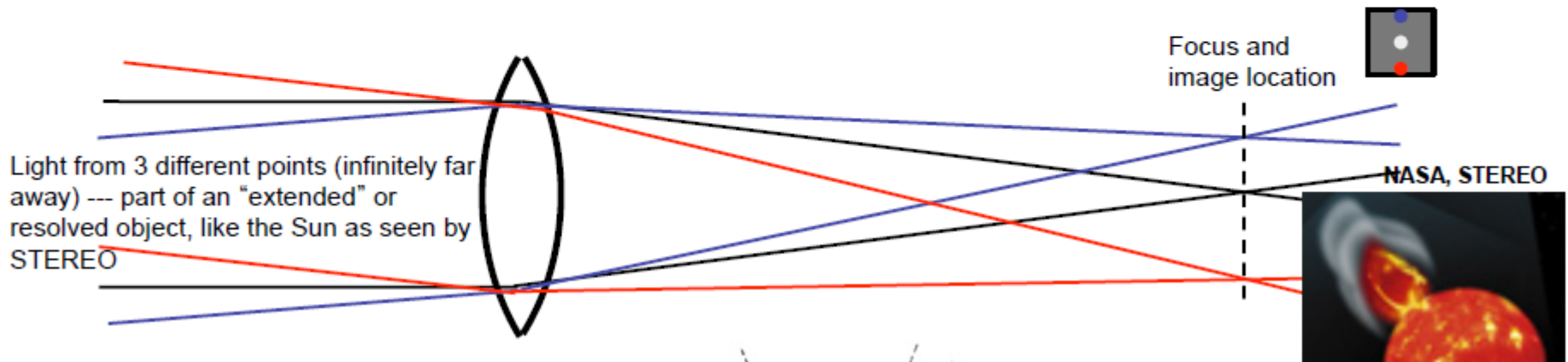
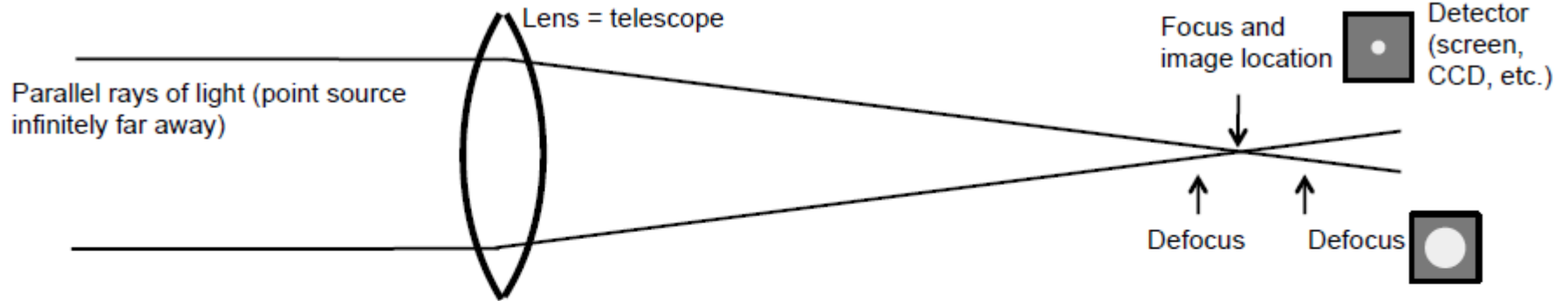
Astrophysics is humankind’s scientific endeavor to understand the universe and our place in it.

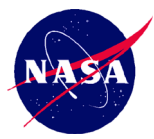
*How did our Universe begin and evolve?
How did Galaxies, Stars, and Planets come to be?
Are we alone?*



Side-view of the simulated universe as presented in the “Semi-analytic forecasts for JWST” project (Yung et al., in preparation). Each data point represents a galaxy. Larger and darker data points represent galaxies with more mass, and vice versa. Credit: Yung et al.

How does a telescope or camera work?

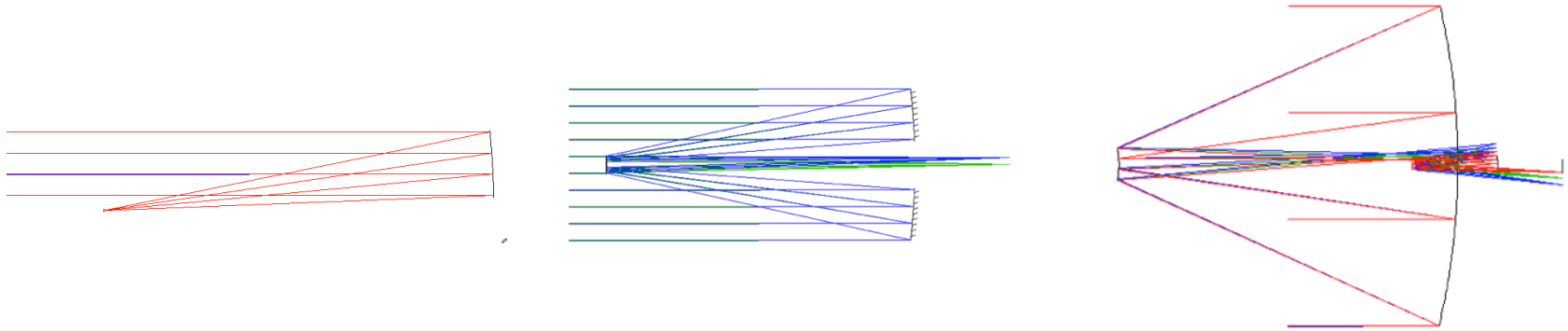




Why Telescopes?



- Telescopes are the natural choice of instruments used to directly observe distant objects that emit light.



NASA



Why Space?



1. No Atmosphere

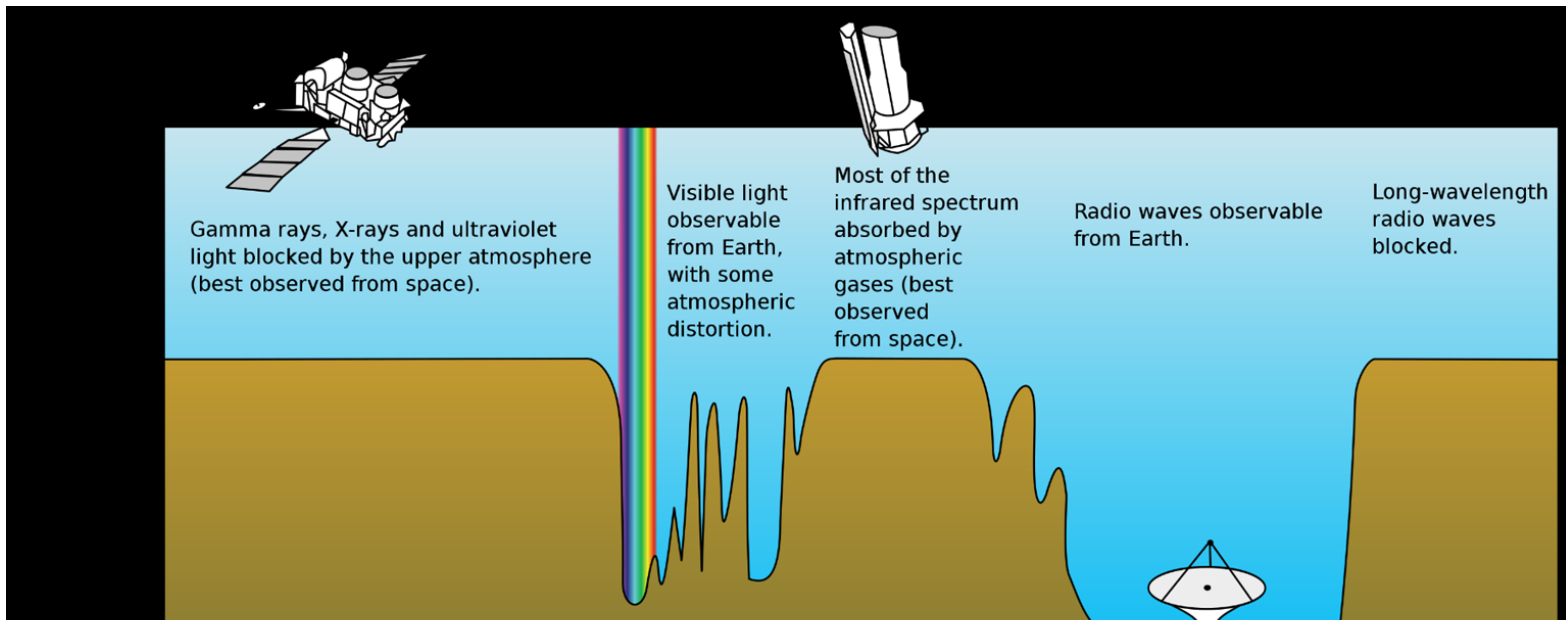
- No turbulence = better resolution
- No absorption = see all wavelengths

2. Very stable environment

- Can orbit with constant sun exposure (no day/night thermal changes)

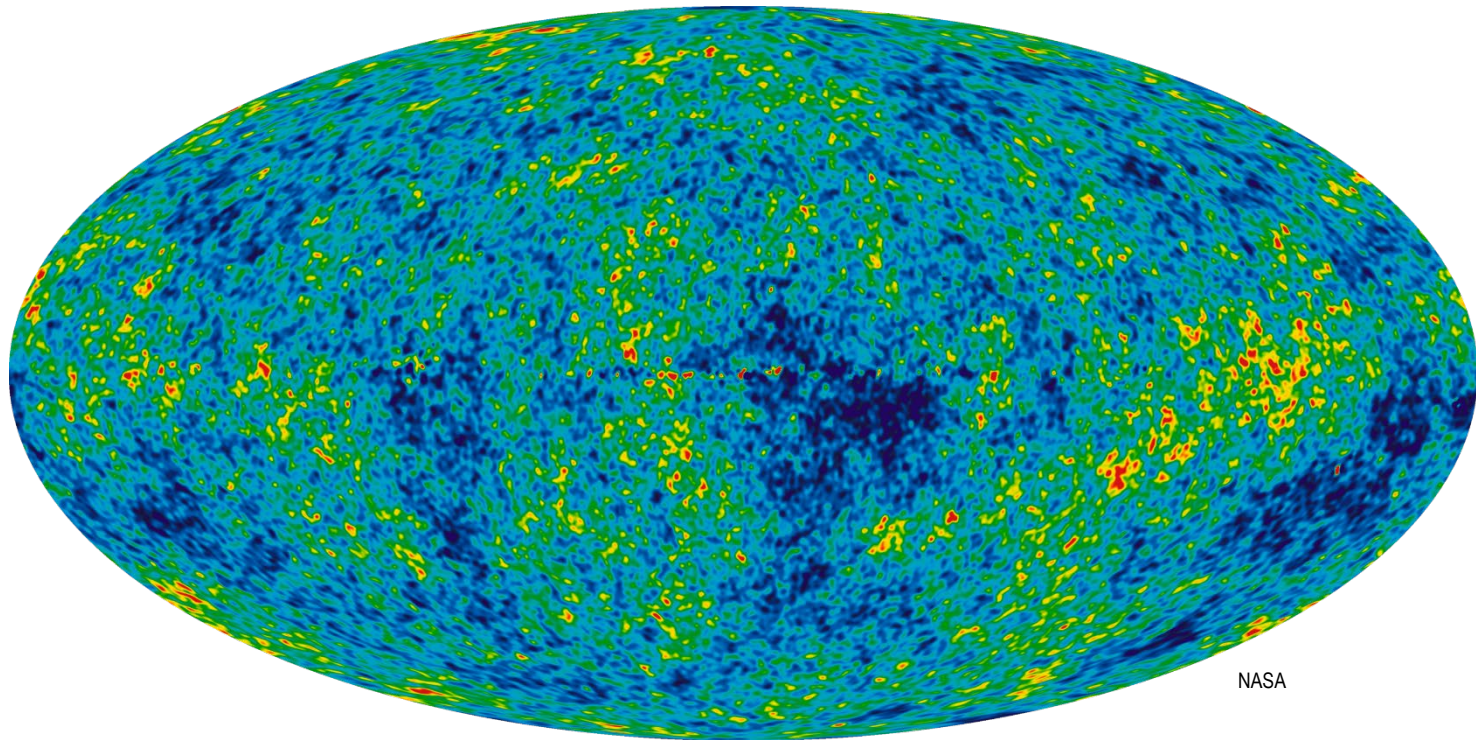
3. Can get very cold

- Better for observing in the **Infra-Red** spectrum (old visible-UV light)



Why **Space**? Space background is very cold

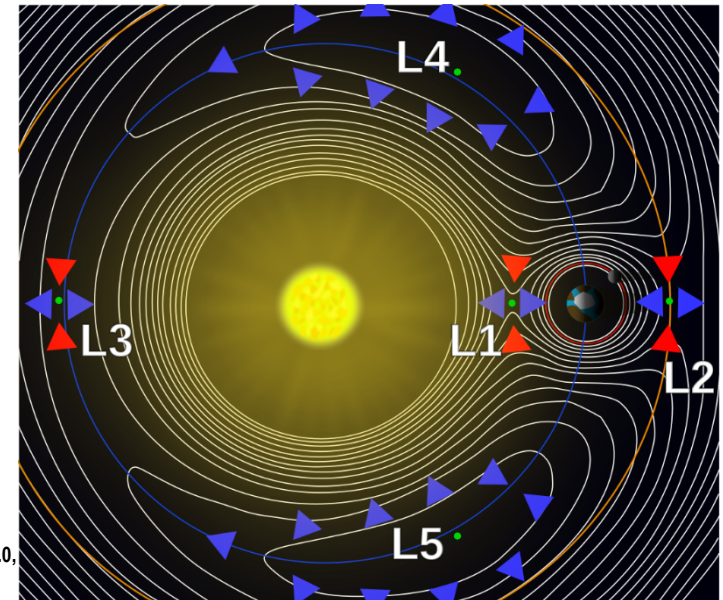
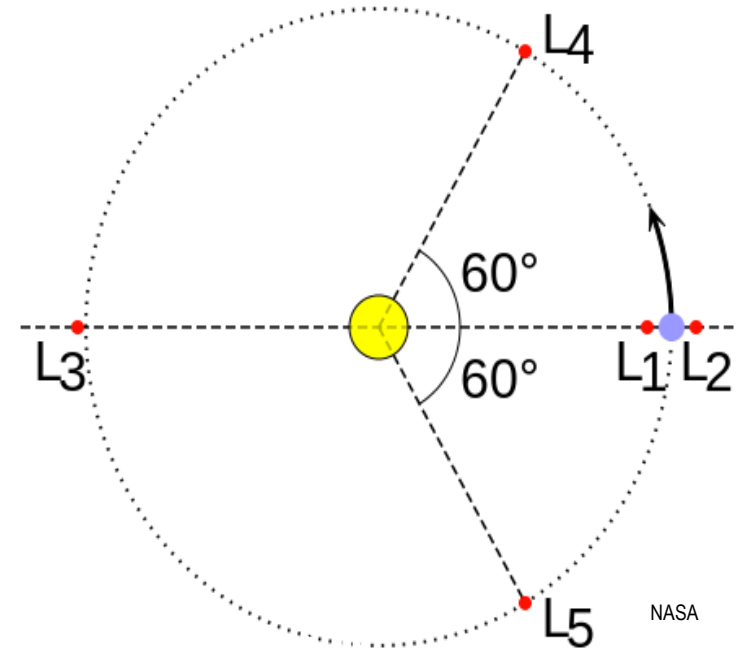
- Cosmic background temperature is < 3 K
- With sun shields and cryostats, entire observatories can be cooled actively to < 10 K, or passively to < 35 K



The Cosmic Microwave Background temperature fluctuations from the 7-year Wilkinson Microwave Anisotropy Probe data seen over the full sky. The image is a mollweide projection of the temperature variations over the celestial sphere. The average temperature is 2.725 Kelvin degrees above absolute zero (absolute zero is equivalent to -273.15 °C or -459 °F), and the colors represent the tiny temperature fluctuations, as in a weather map. Red regions are warmer and blue regions are colder by about 0.0002 degrees.

Why **Space**? Very Stable Environment: L2

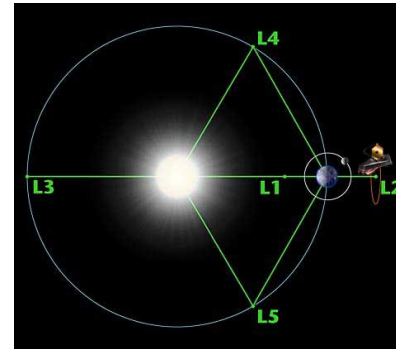
- The **Red** points labeled L1 to L5 represent “stable” gravity points in the Sun-Earth system (“Lagrange” points)
- L1 is favored Sun-observing Space Observatories
- L2 is favored for some Astronomical Space Observatories



JWST must be very cold to see infrared: 30K

Recipe on how to get **cold**:

1. Get far away from Earth (Sun-Earth L2 point)
2. Hide in the shade

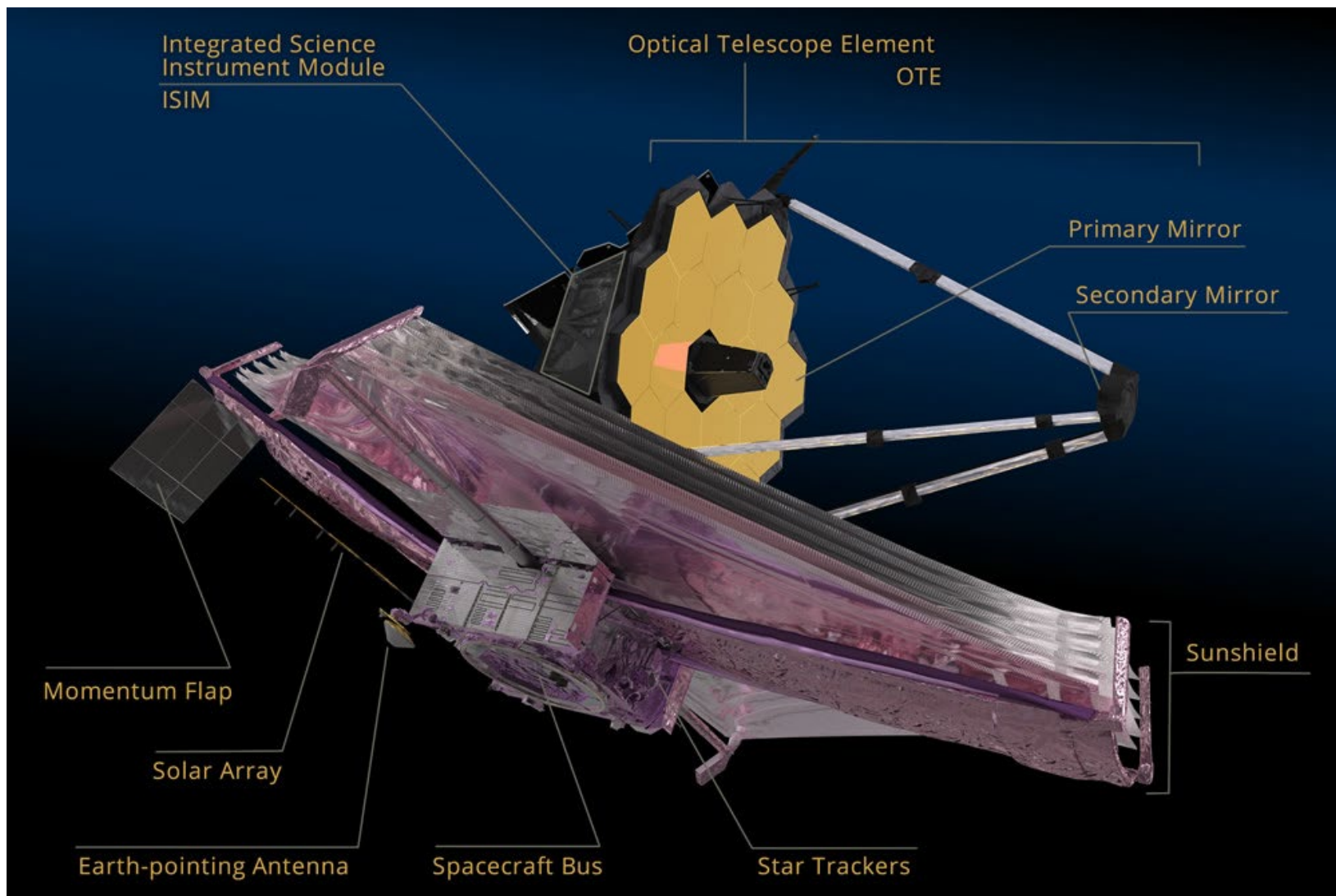


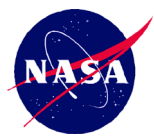
SUN
←



NASA

JWST Observatory Elements and Regions





JWST Observatory Elements and Regions



Integrated Science Instrument Module (ISIM)
 - Located inside an OTE provided ISIM Enclosure
 - Contains 4 Science Instruments (NIRCam, NIRSpec, MIRI, FGS / NIRISS)

Thermal Region 2
 - Components maintained at ambient temperatures on cold side of the observatory

ISIM Electronics Compartment (IEC)

OTE Backplane / ISIM Enclosure

Optical Telescope Element (OTE)
 - 6 meter Tri-Mirror Anastigmatic
 - 18 Segment Primary Mirror

Thermal Region 1
 - Components cooled to cryogenic temperatures

OTE Secondary Mirror

OTE Primary Mirror

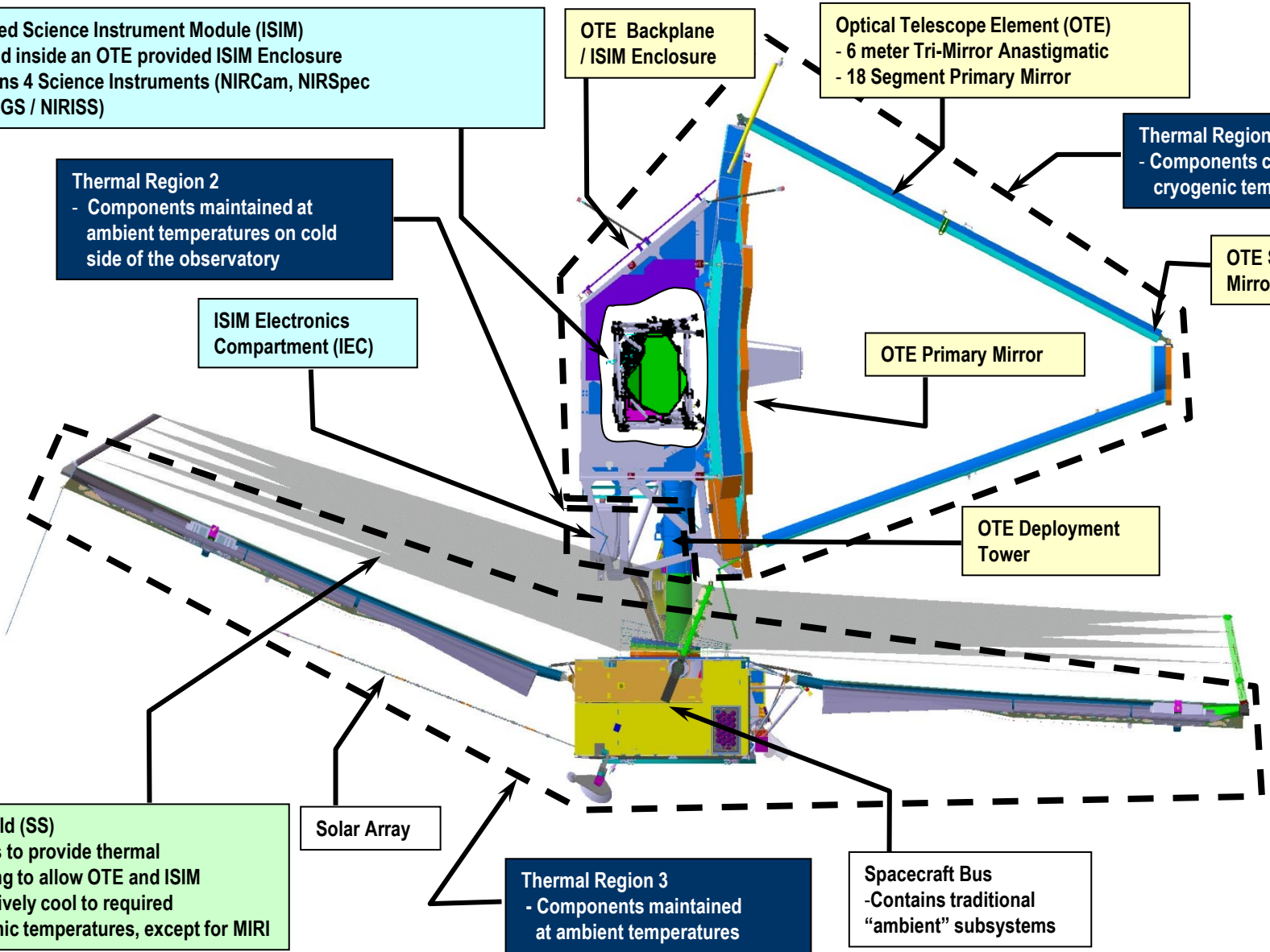
OTE Deployment Tower

Sunshield (SS)
 - 5 layers to provide thermal shielding to allow OTE and ISIM to passively cool to required cryogenic temperatures, except for MIRI

Solar Array

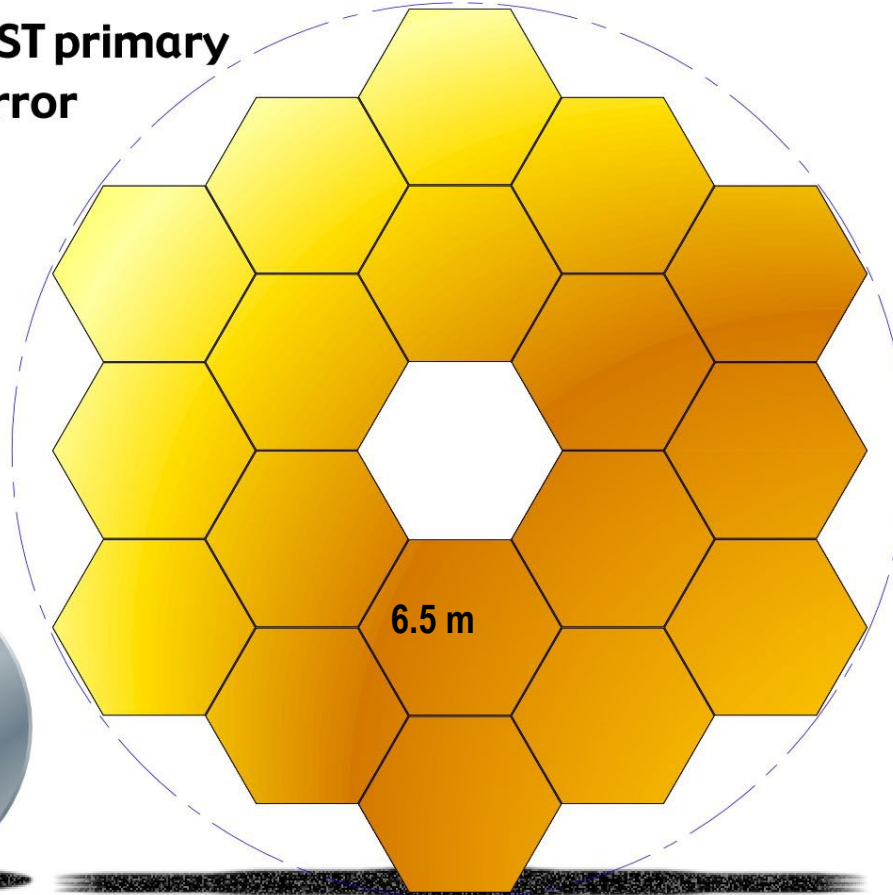
Thermal Region 3
 - Components maintained at ambient temperatures

Spacecraft Bus
 - Contains traditional "ambient" subsystems



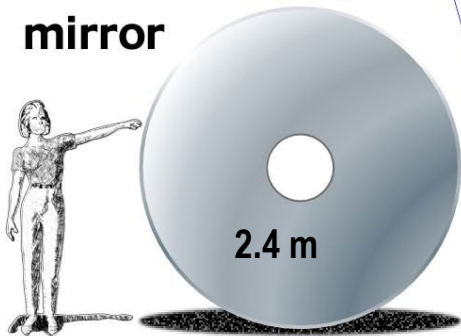
JWST vs. Hubble primary mirrors

JWST primary mirror



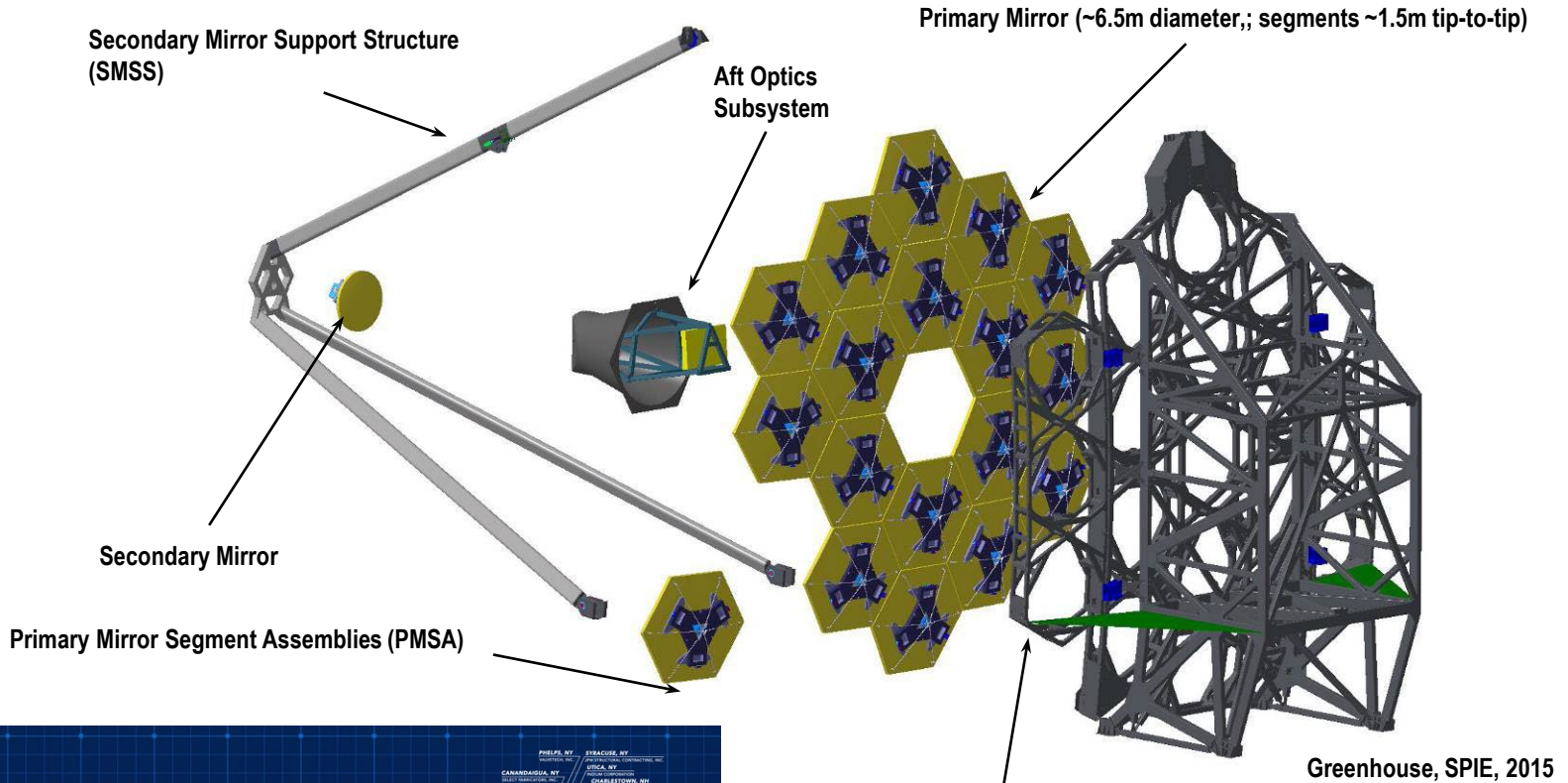
JWST's larger mirror gives increased sensitivity and higher spatial resolution

Hubble primary mirror



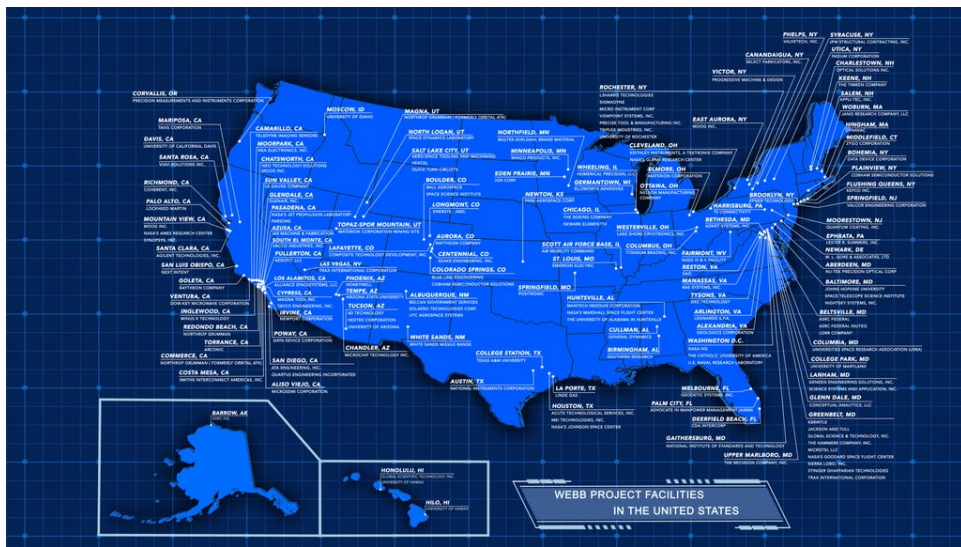


Optical Telescope Element (OTE)



Primary Mirror Backplane Assembly (PMBA) and Backplane Support Frame (BSF)

- Composite tube frame construction
- Two deployable Wings



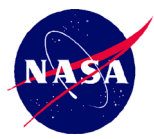


Videos --- let's see if we can get these to work

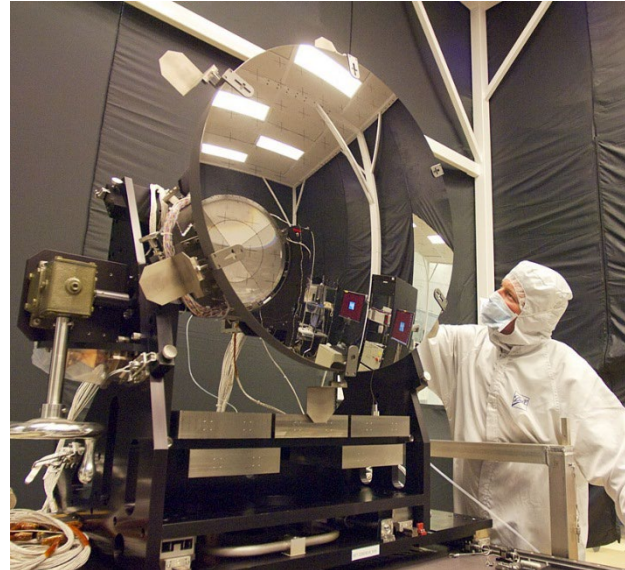
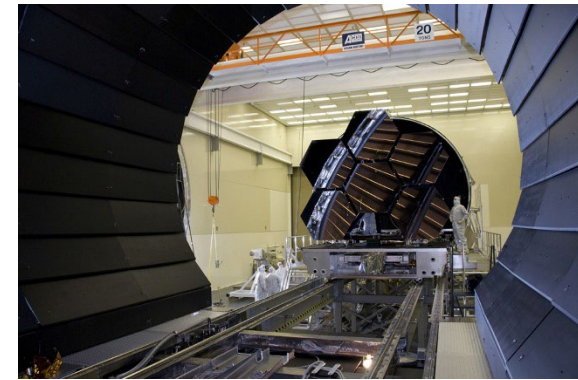
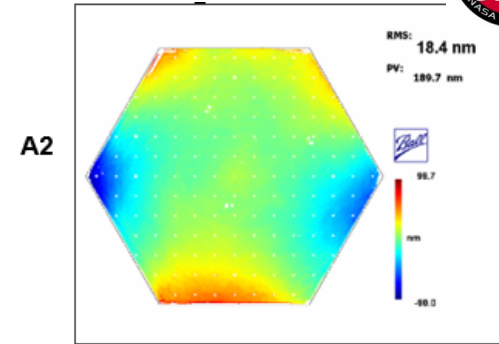
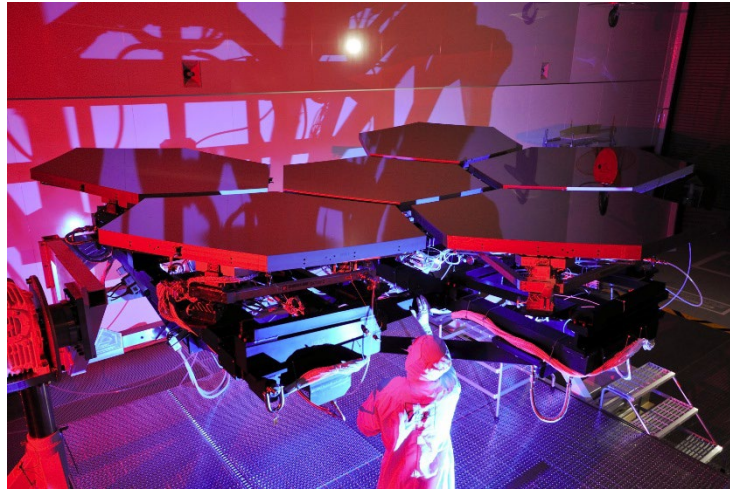


- **Some things to note:**
 - The Earth and Sun are always on the spacecraft (warm) side of the sunshield, like a beach umbrella
 - JWST is too big for a rocket nose cone (fairing), so it was launched folded up, then parts deployed as it headed out to L2, like a Transformer toy

- **Deployment video:** https://www.youtube.com/watch?v=RzGLKQ7_KZQ
- **Launch:** <https://www.youtube.com/watch?v=v6ihVeEoUdo>
- **Video gallery:**
 - <https://webb.nasa.gov/content/multimedia/videos.html>



Primary mirror segments tested at NASA Marshall Space Flight Center



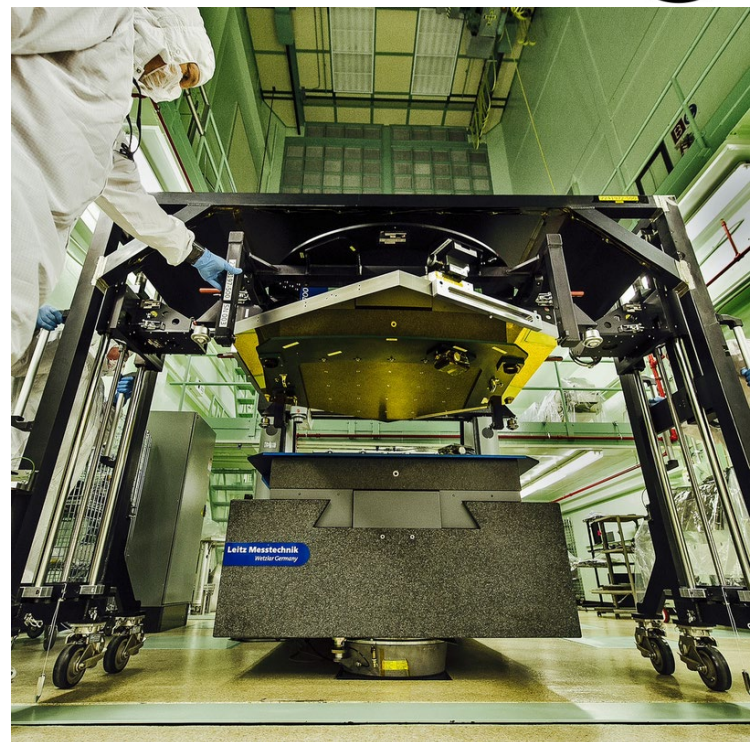
NASA OTE build-up at NASA Goddard (L3 Harris & GSFC)



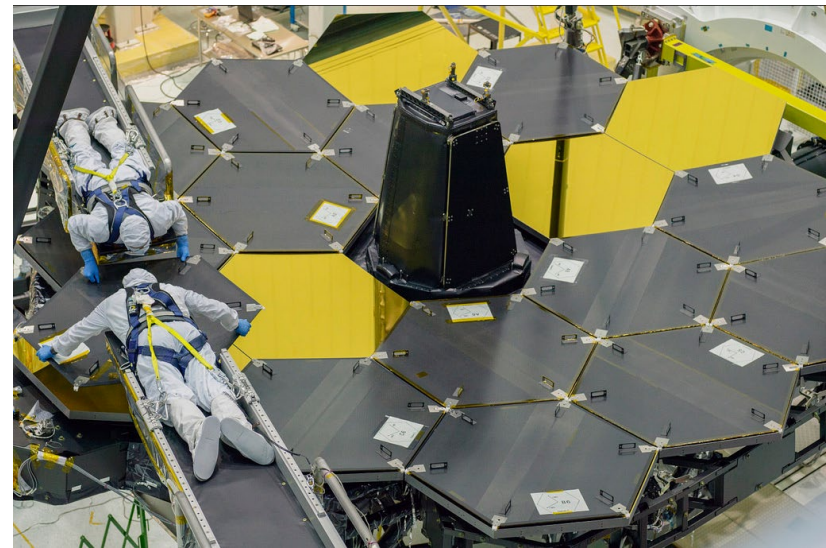
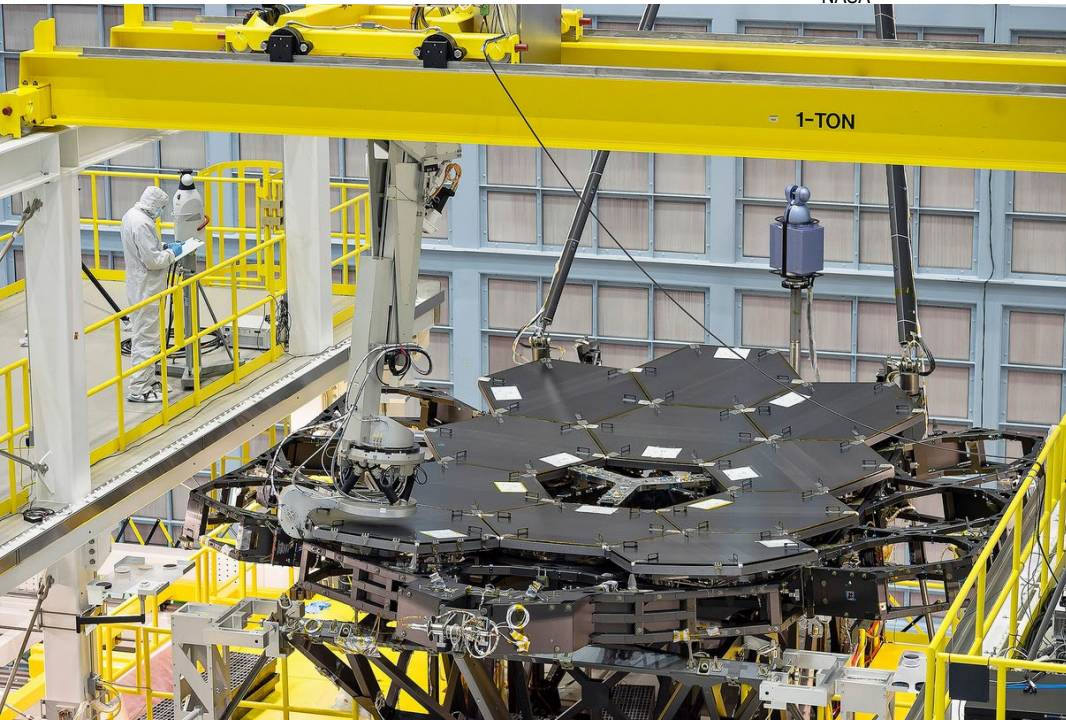
- Mirror metrology
- Integration and alignment



NASA NASA

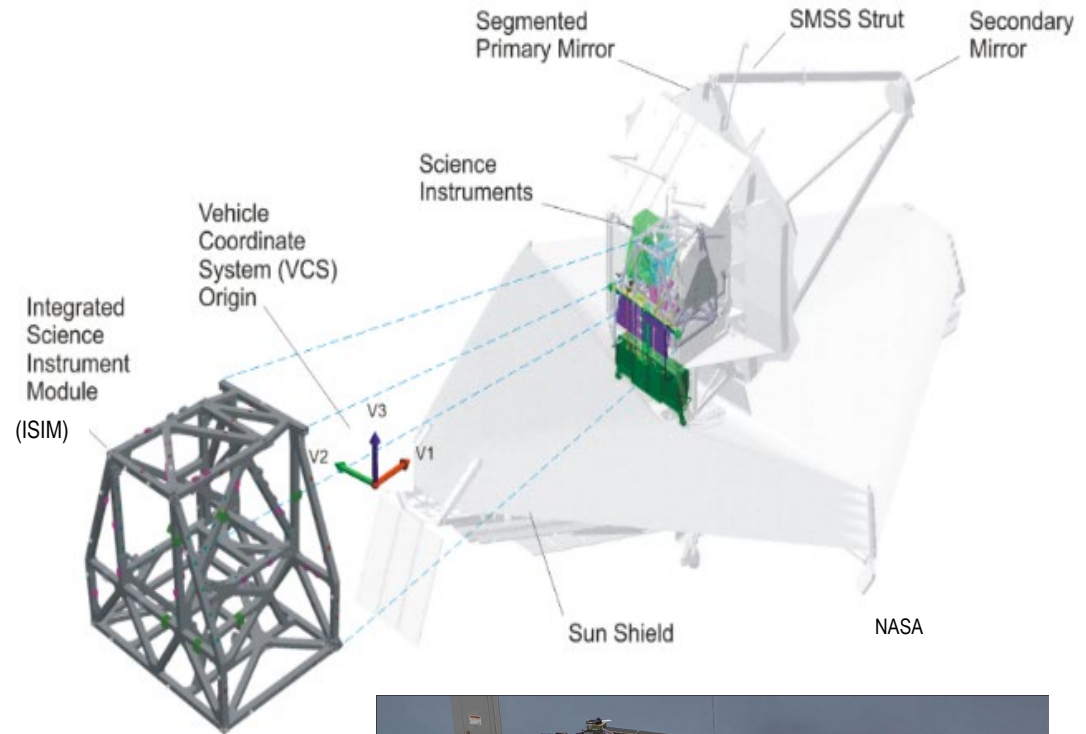


NASA



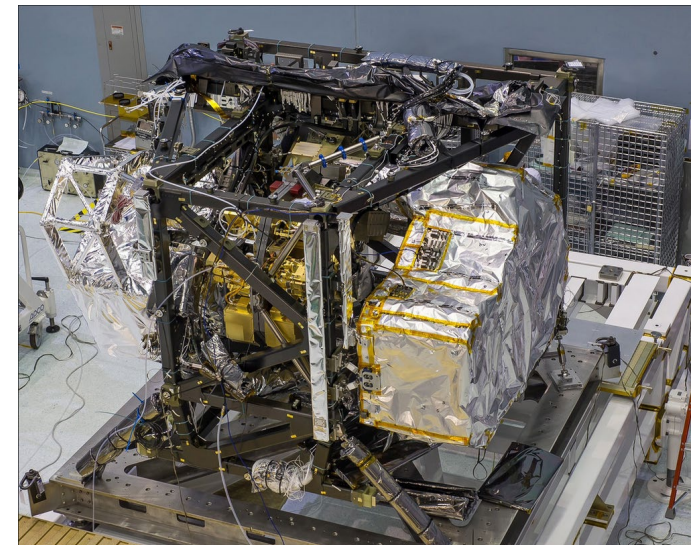
Integrated Science Instrument Module (ISIM)

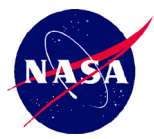
- **Housed behind the primary mirrors**
- **Aligned to exit pupil and focal surface of telescope**



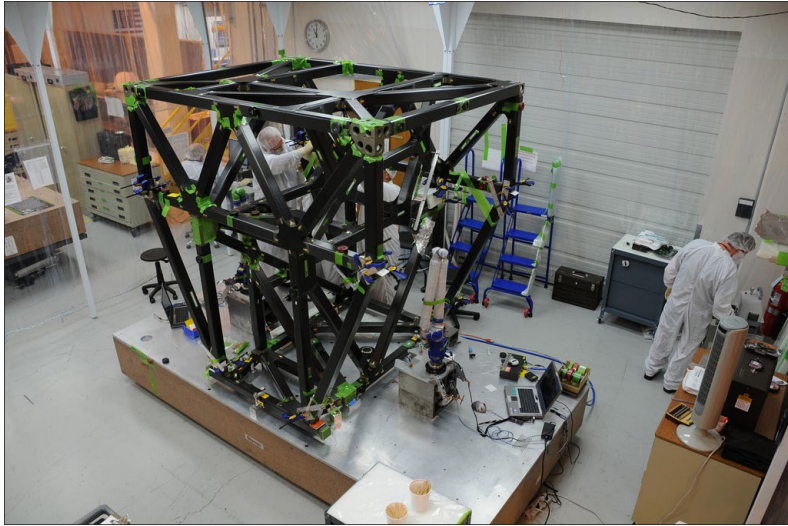
Four instruments on ISIM

- **Near-Infrared Camera (NIRCam)**
- **Near-Infrared Spectrograph (NIRSpec)**
- **Mid-Infrared Instrument (MIRI)**
- **Fine Guidance Sensor (FGS) and Near-Infrared Imager and Slitless Spectrograph (NIRISS)**



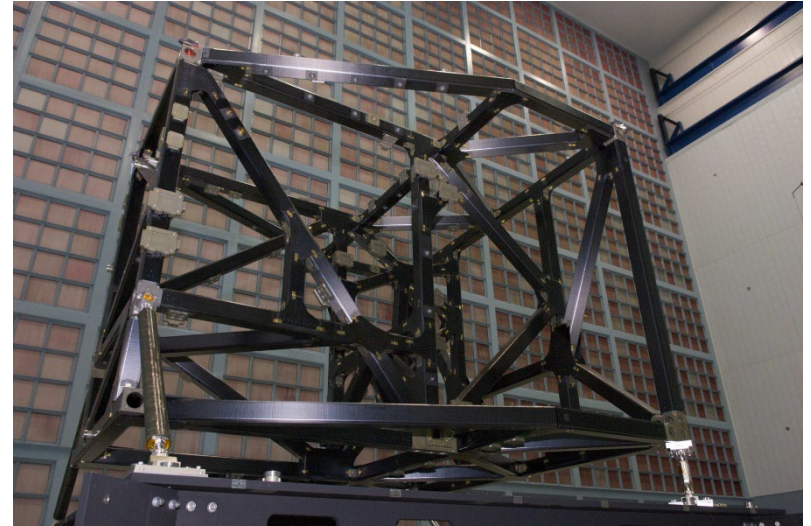


ISIM Structure (ATK, Utah and GSFC)



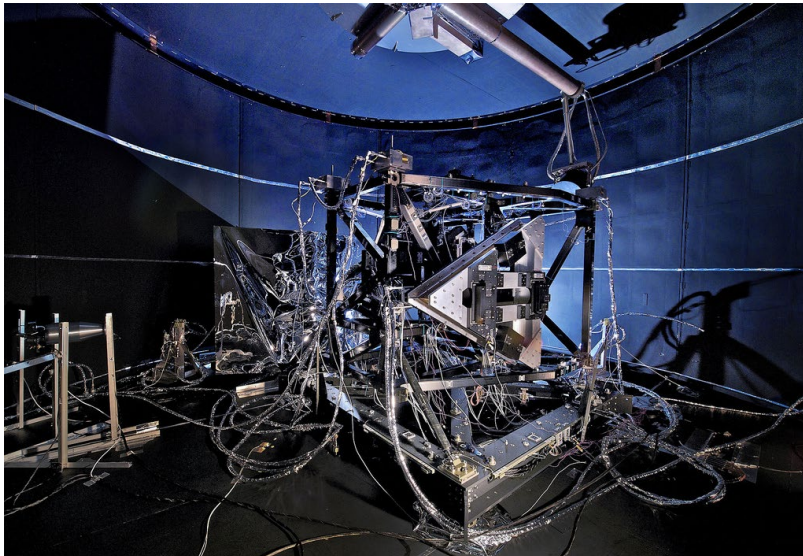
Structure bonding at ATK (Utah)

NASA



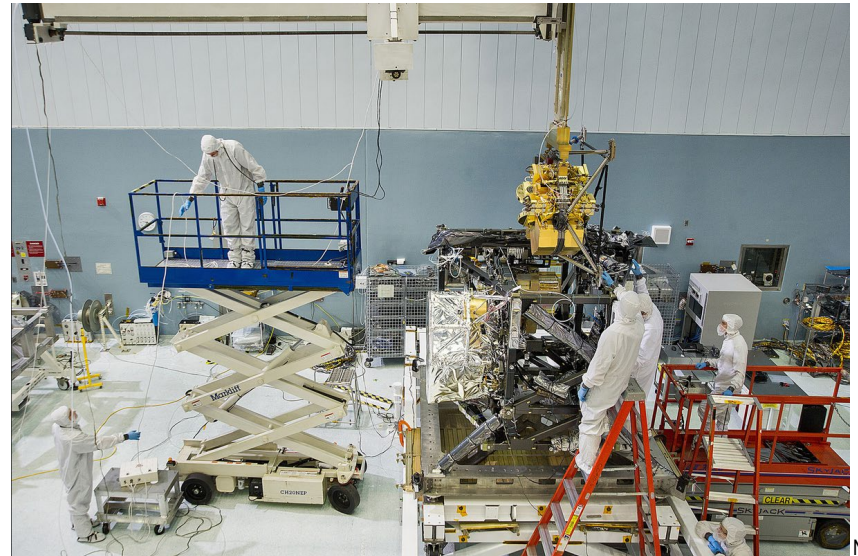
Structure on kinematic mounts (from L3 Harris)

NASA



Structure cryogenic metrology testing (photogrammetry)

NASA



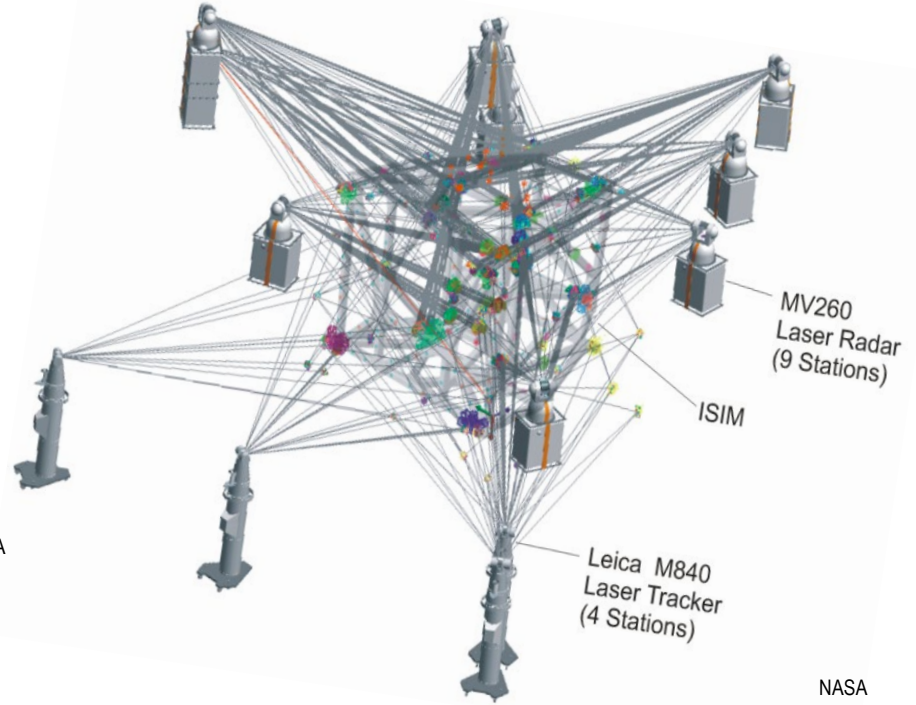
Integration of science instrument optical assemblies

NASA

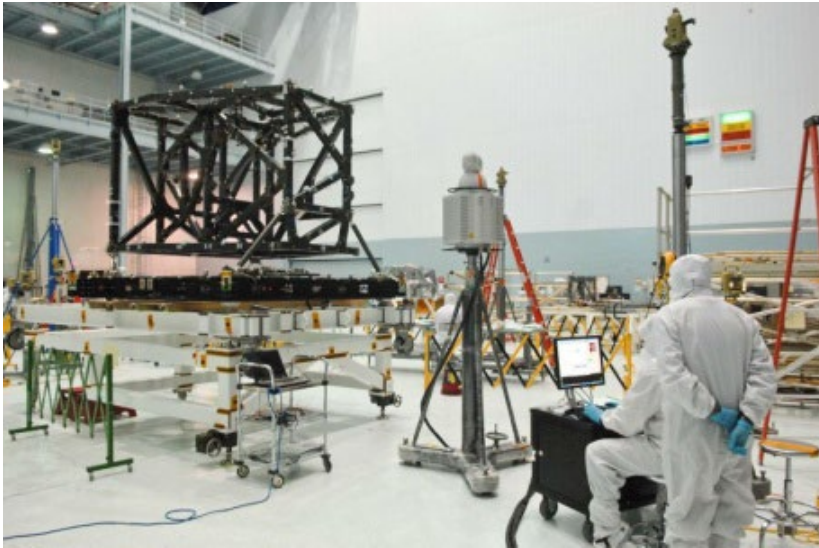
NASA Characterizing & customizing the ISIM Structure



NASA



NASA



NASA



NASA



LMCO

Near-Infrared Camera (NIRCam)
University of Arizona
Lockheed Martin, Palo Alto



NASA

Near-Infrared Spectrograph (NIRSpec)
European Space Agency (ESA)
NASA Goddard Space Flight Center



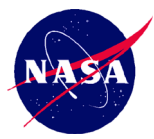
NASA

Fine Guidance Sensor (FGS)
Near-Infrared Imager and Slitless Spectrograph (NIRISS)
Canadian Space Agency

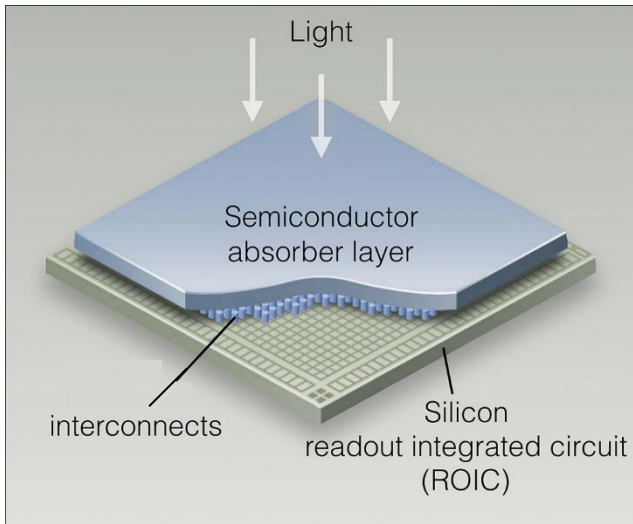


RAL

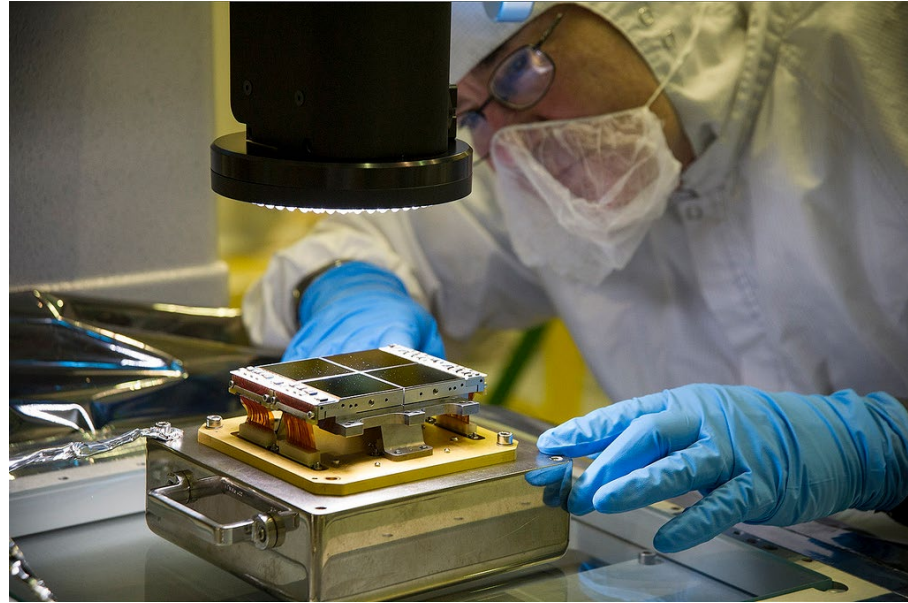
Mid-Infrared Instrument (MIRI)
European Consortium, ESA, NASA JPL



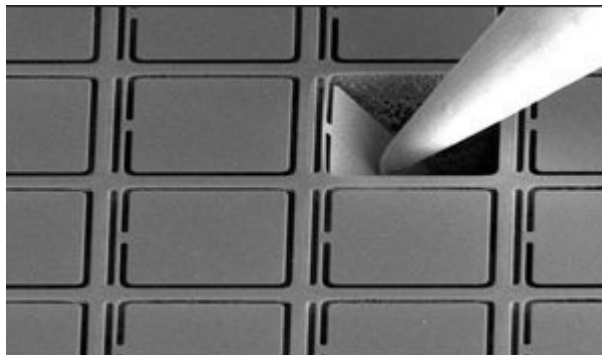
Detector and MEMS micro-shutter technology



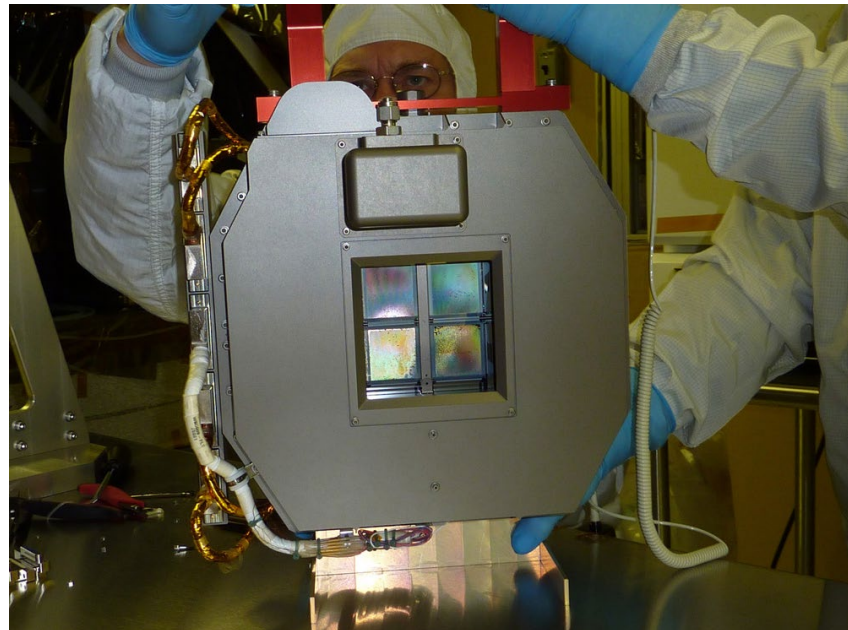
NASA



NASA



NASA



NASA

2017: JWST at NASA Goddard Space Flight Center

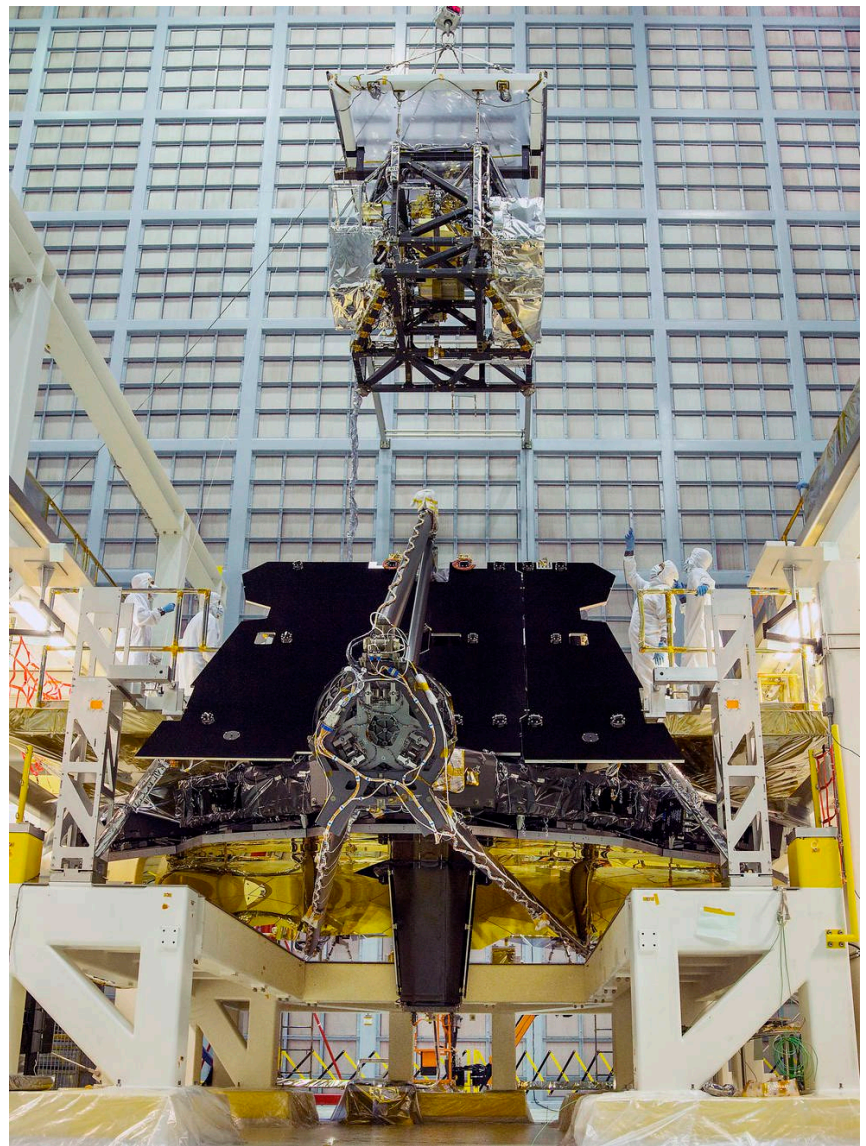


NASA

NASA Instruments and telescope come together (GSFC)



NASA



NASA

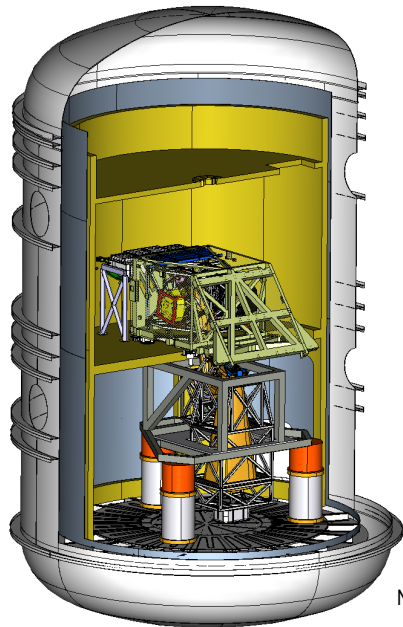


NASA

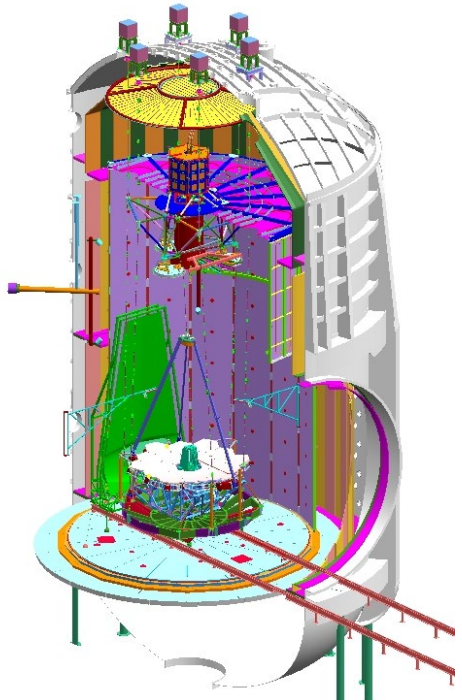
Cryogenic performance testing

NASA Johnson Space Center

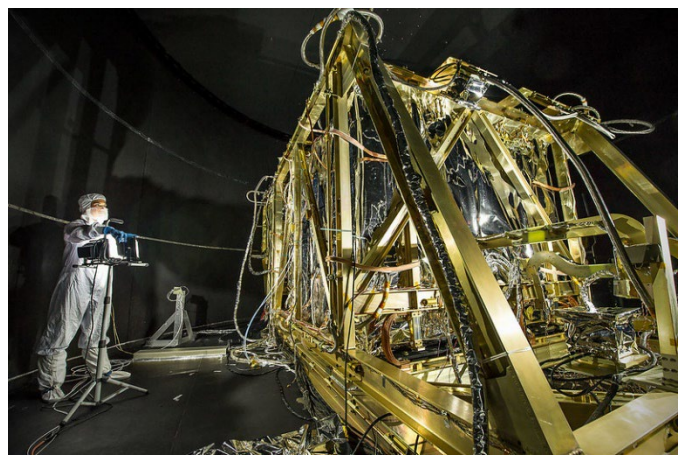
NASA Goddard Space Flight Center



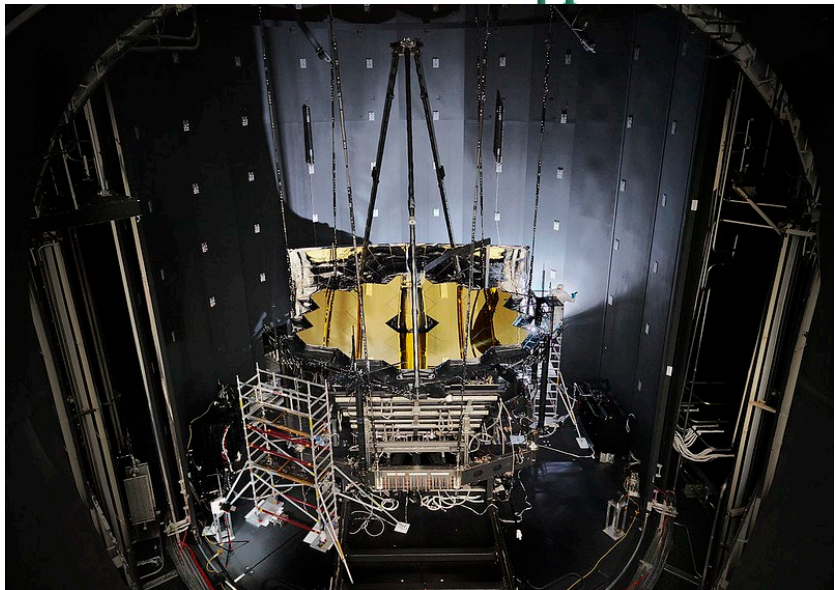
NASA



NASA



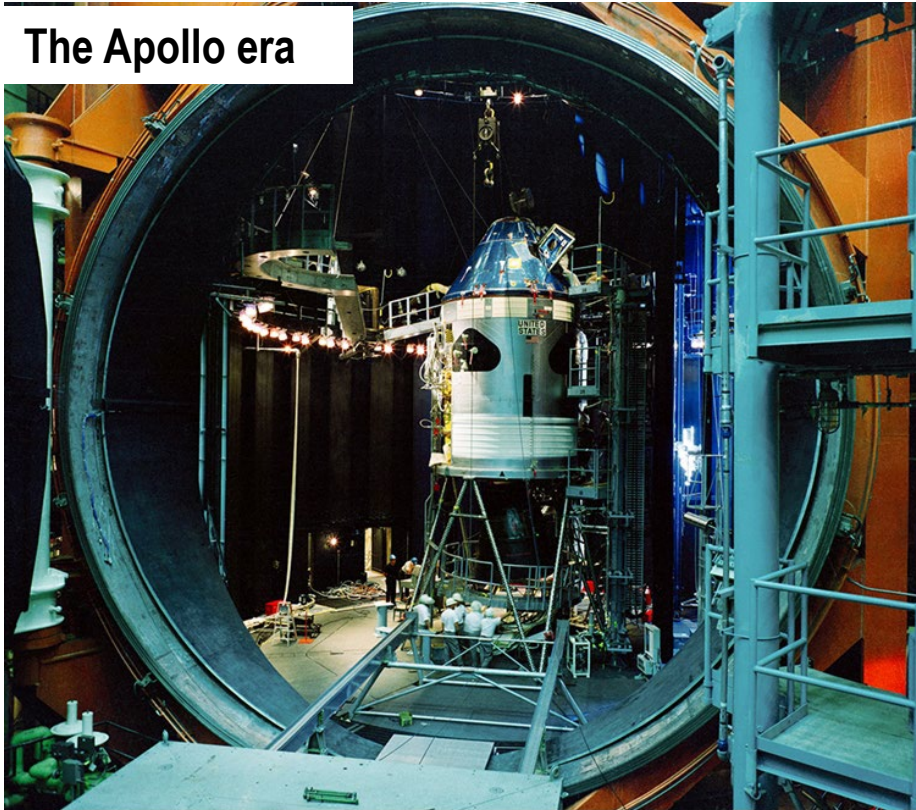
NASA



NASA

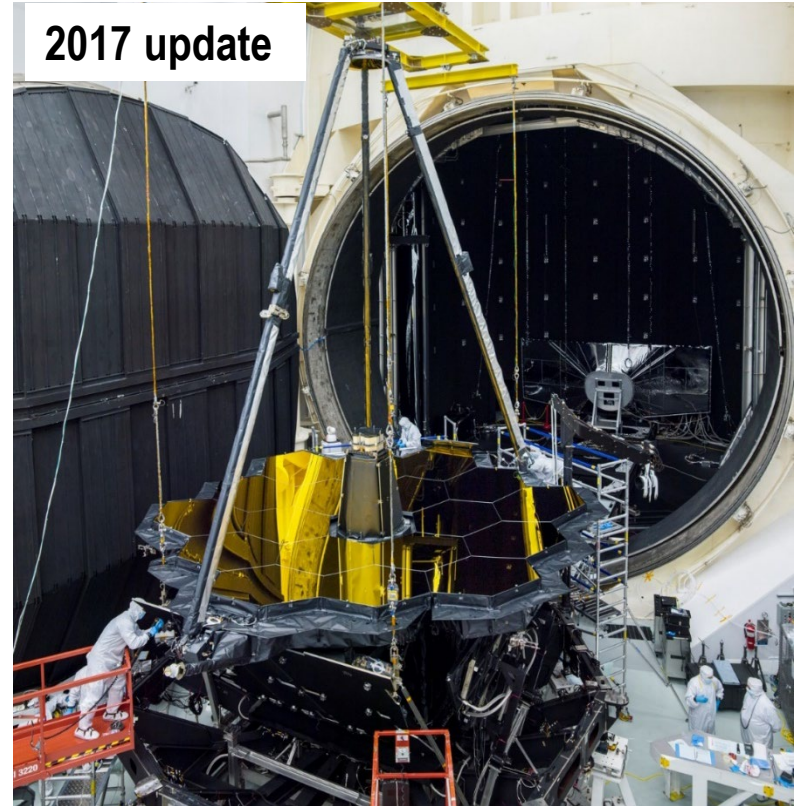
2017: JWST optical test: Historic Chamber A

The Apollo era



NASA

2017 update



NASA

National Historic Landmark at NASA Johnson, outfitted for JWST

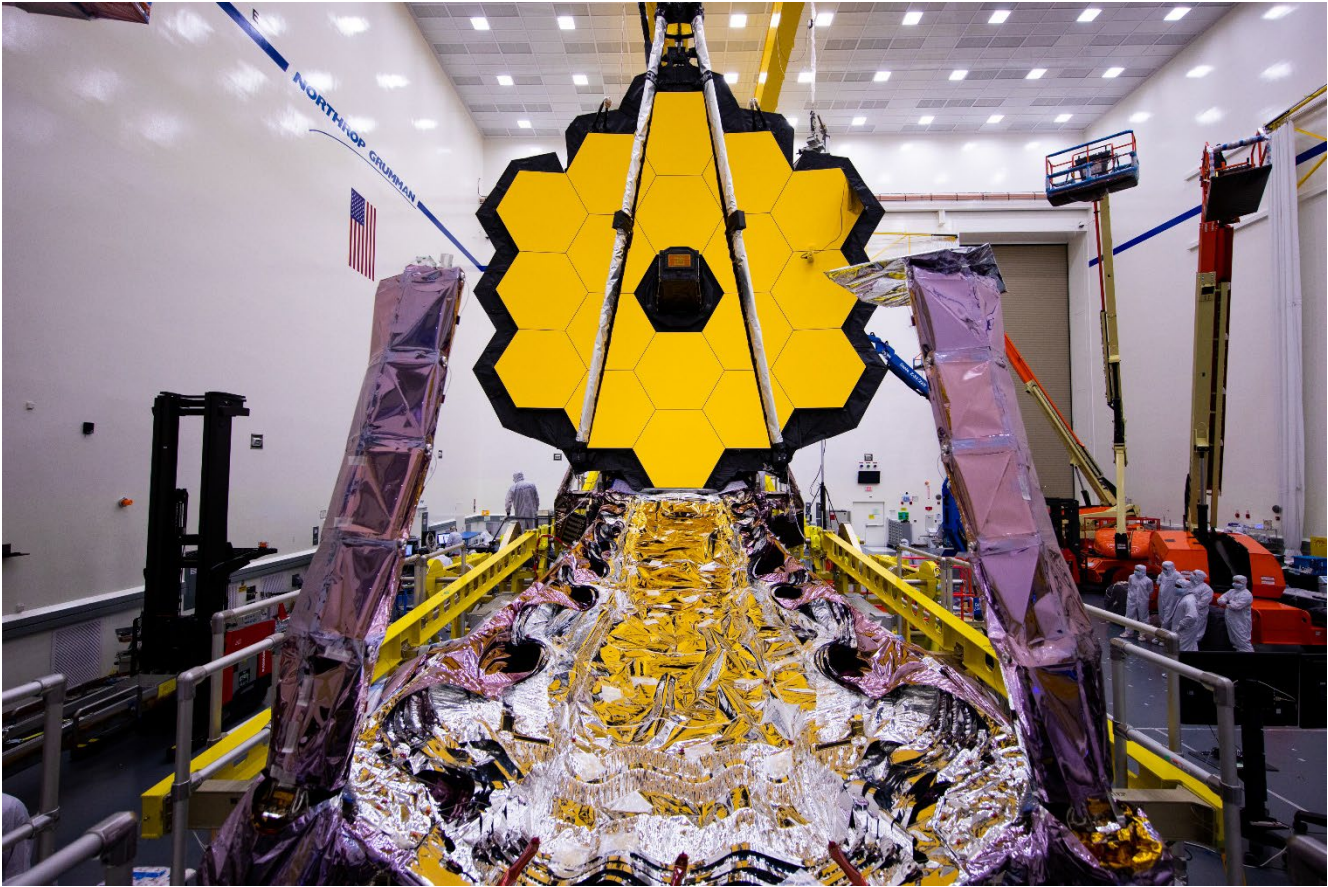
2019-20: JWST integration to spacecraft bus



**Northrop Grumman
Los Angeles, CA**

NASA

2021: Final Deployment Testing



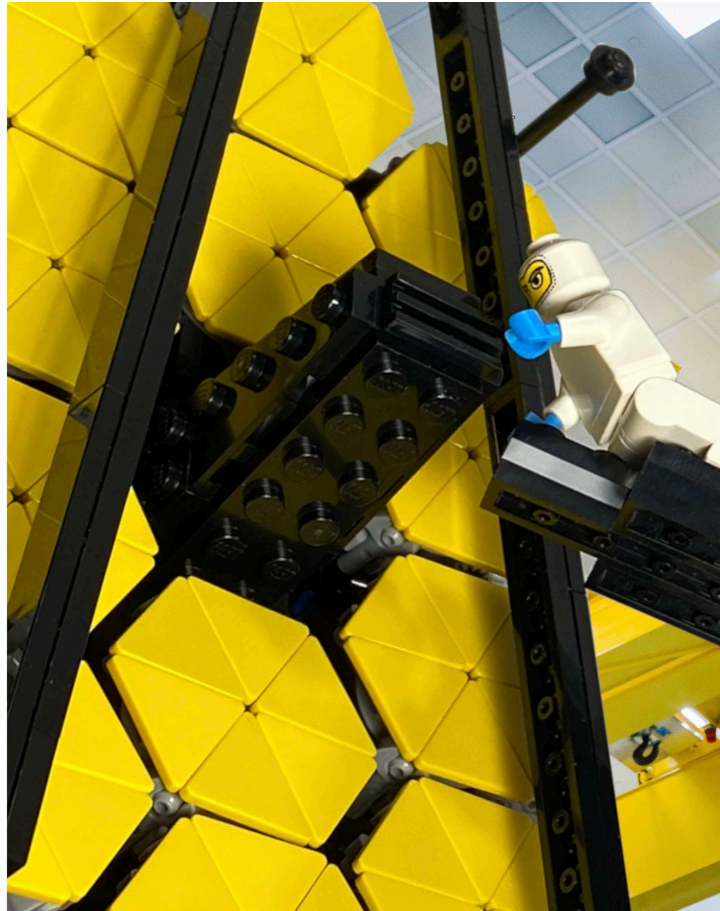
Northrop Grumman
Los Angeles, CA

NASA

Cover removed from Aft Optics



NASA



2021 (September): JWST Travels to ESA facility



NASA

October 2021: JWST at the Launch Site

Oct 12, 2021
RELEASE 21-132

NASA's Webb Space Telescope Arrives in French Guiana After Sea Voyage



NASA

Credit: ESA

NASA's James Webb Space Telescope successfully arrived in French Guiana Tuesday, after a 16-day journey at sea. The 1,500-mile voyage took Webb from California through the Panama Canal to Port de Pariacabo on the Kourou River in French Guiana, on the northeastern coast of South America.

The world's largest and most complex space science observatory will now be driven to its launch site, Europe's Spaceport in Kourou, where it will begin two months of operational preparations before its launch on an Ariane 5 rocket, scheduled for Dec. 18.

After the custom-built shipping container carrying Webb is unloaded from the MN Colibri, Webb will be driven to the launch site.
Credits: NASA/Chris Gunn

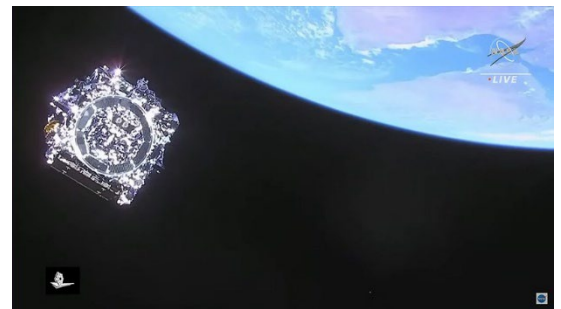
Launch, 25 Dec 2021



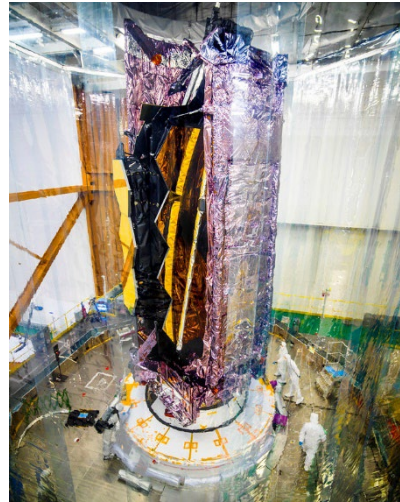
ESA



NASA



NASA



ESA



NASA



NASA

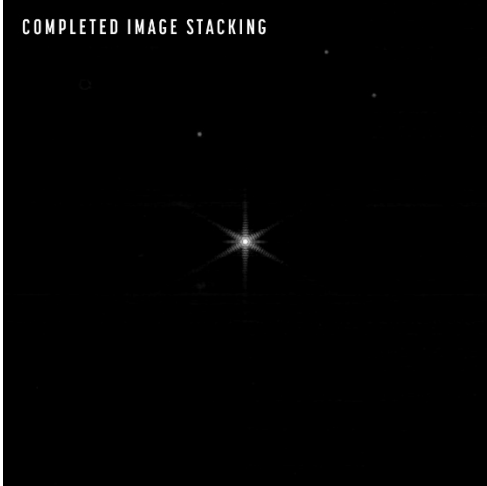
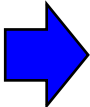
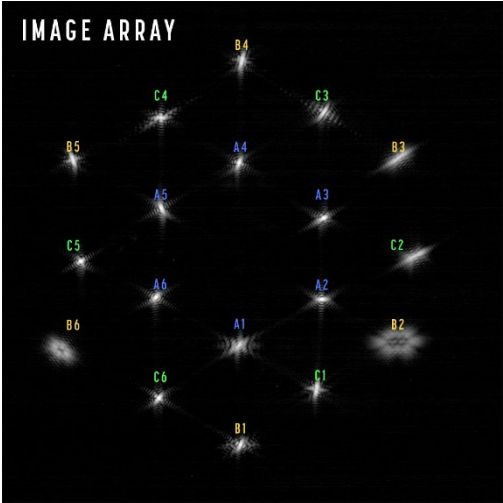
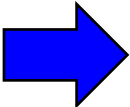


NASA



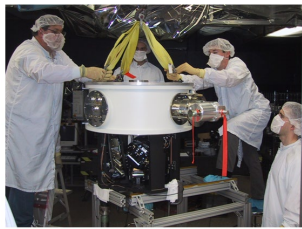
NASA

On-orbit commissioning (NASA JWST blog)

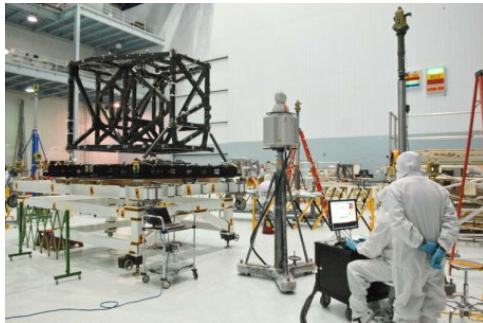




Timescale to build a large space telescope...



NASA



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More about JWST

- www.jwst.nasa.gov
- <http://www.jwst.nasa.gov/science.html>
- <https://blogs.nasa.gov/webb/>
- <https://www.flickr.com/photos/nasawebbtelescope/>

Questions?