

# The James Webb Space Telescope Mission



**Matt Greenhouse**

JWST Project Office

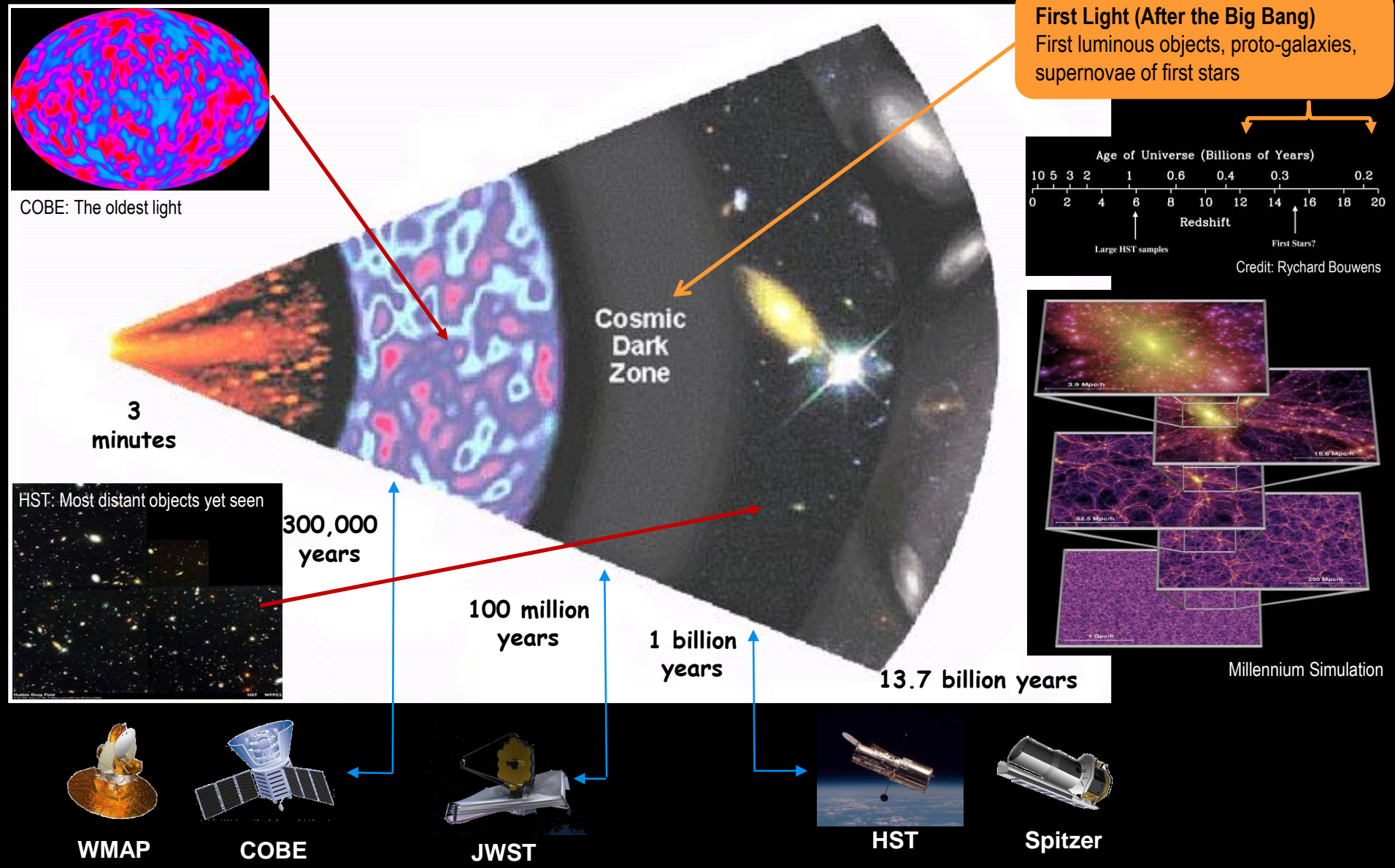
NASA Goddard Space Flight Center

7 September 2015

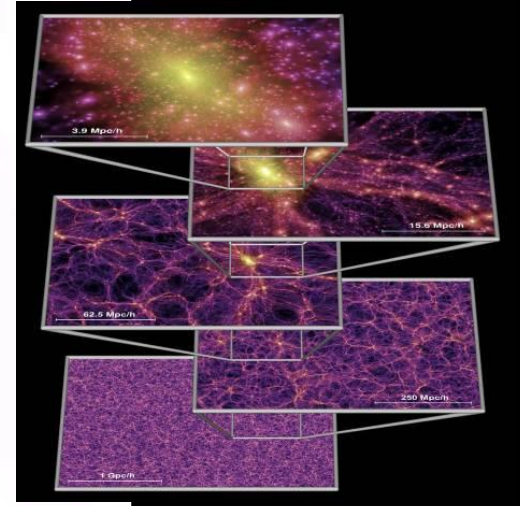
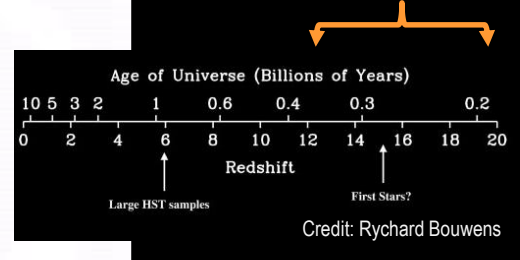
@NASAWebbTelesc

#JWST

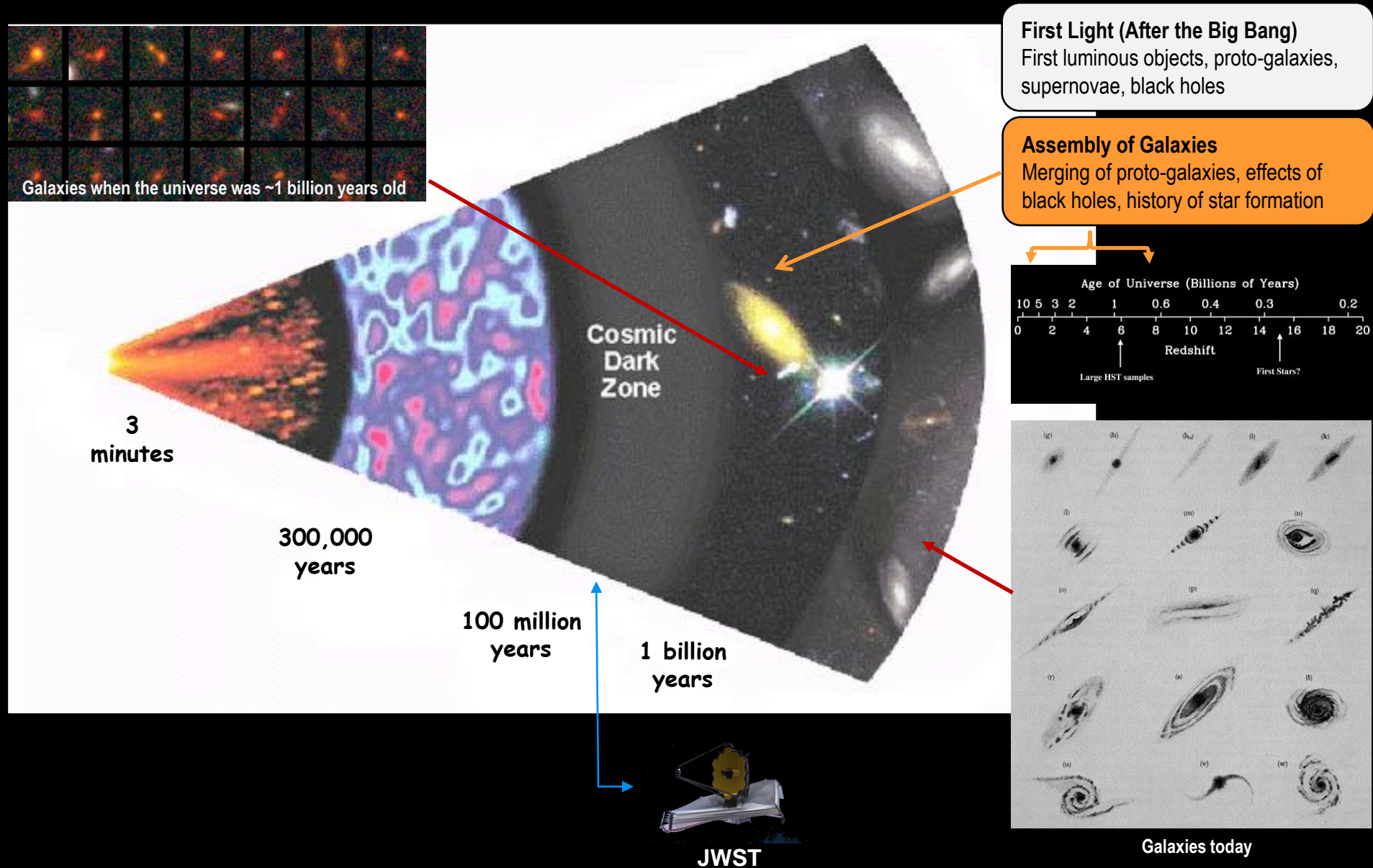
# JWST is designed to look back in time to see the first galaxies



**First Light (After the Big Bang)**  
 First luminous objects, proto-galaxies, supernovae of first stars

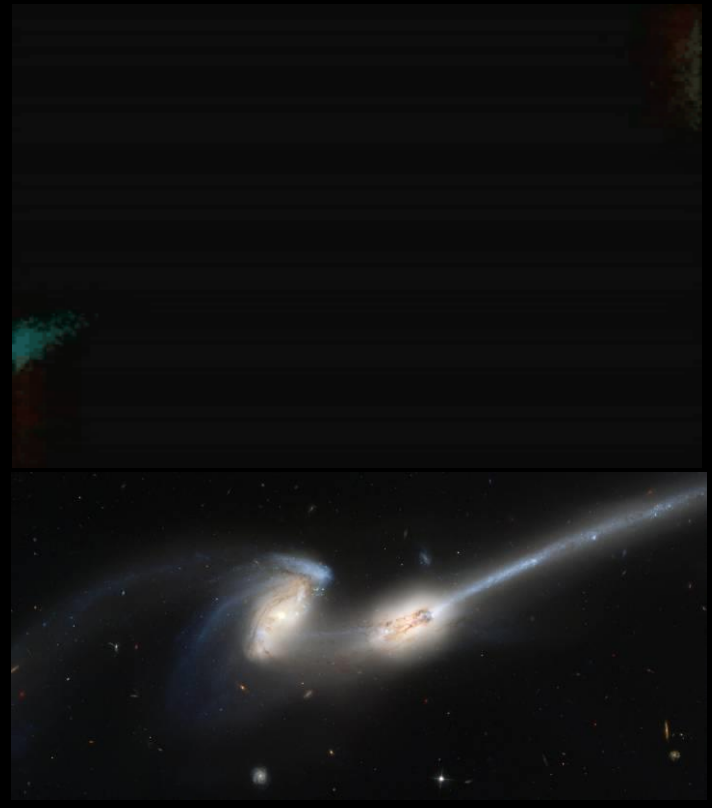
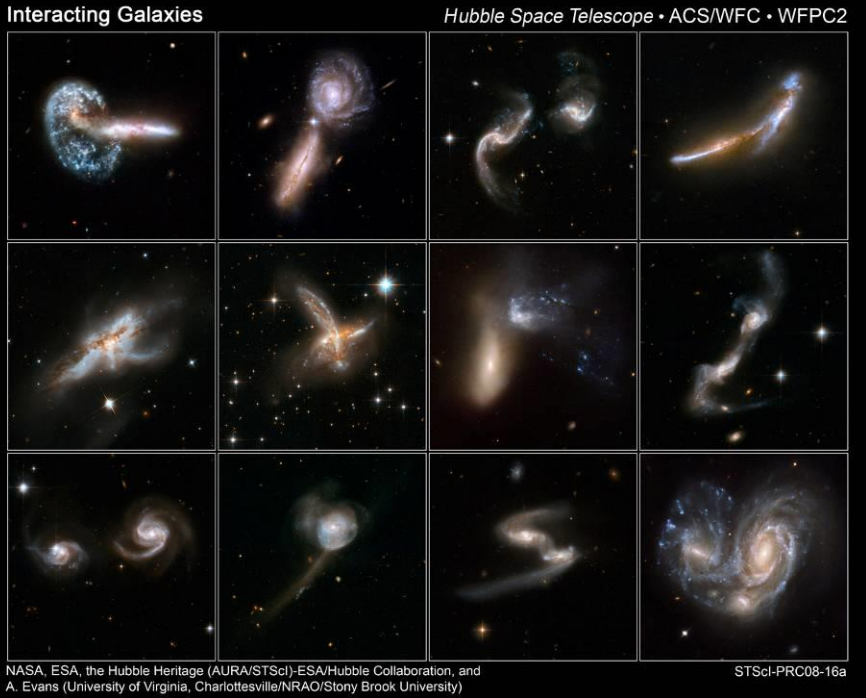


# JWST will image the infrared universe with unprecedented clarity



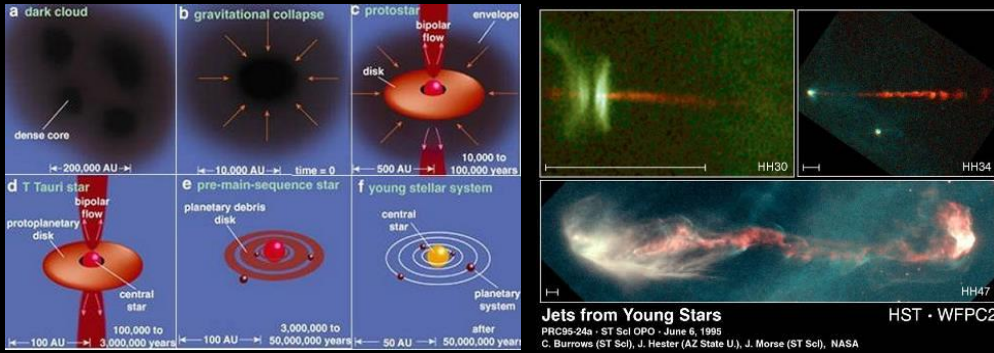
# JWST will see how the structure and composition of galaxies evolve across cosmic time

[Click Video](#)

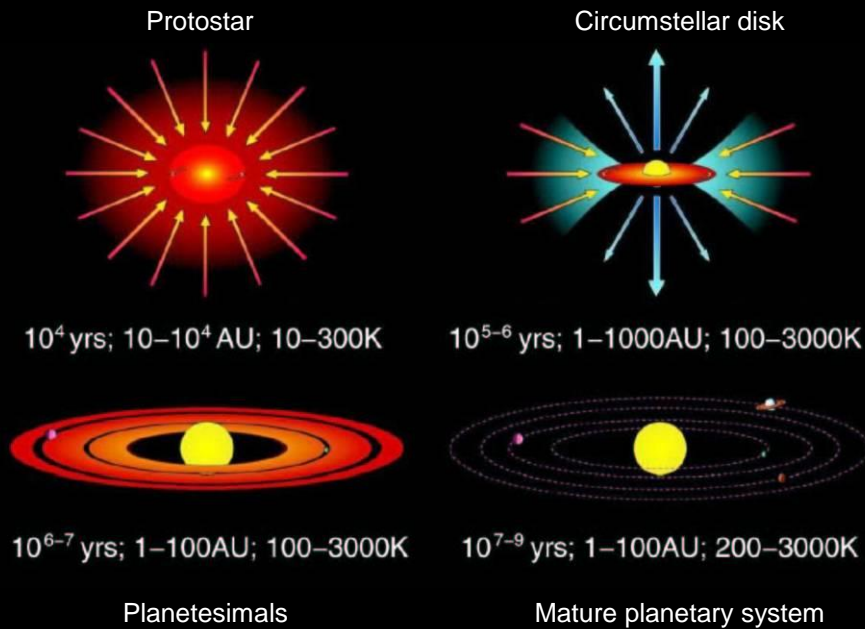


# JWST will see into the birthplaces of stars to reveal how they form

**Birth of Stars and Planetary Systems**  
How stars form and chemical elements are produced

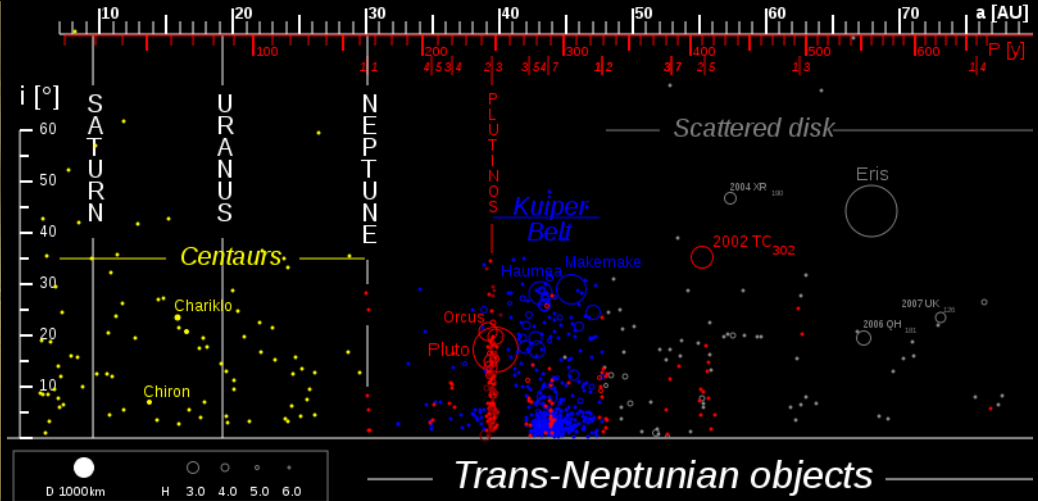


The Eagle Nebula as seen in the near-infrared



# JWST will observe how planetary systems form and evolve

Artist Concept



## First Light (After the Big Bang)

First luminous objects, proto-galaxies, supernovae, black holes

## Assembly of Galaxies

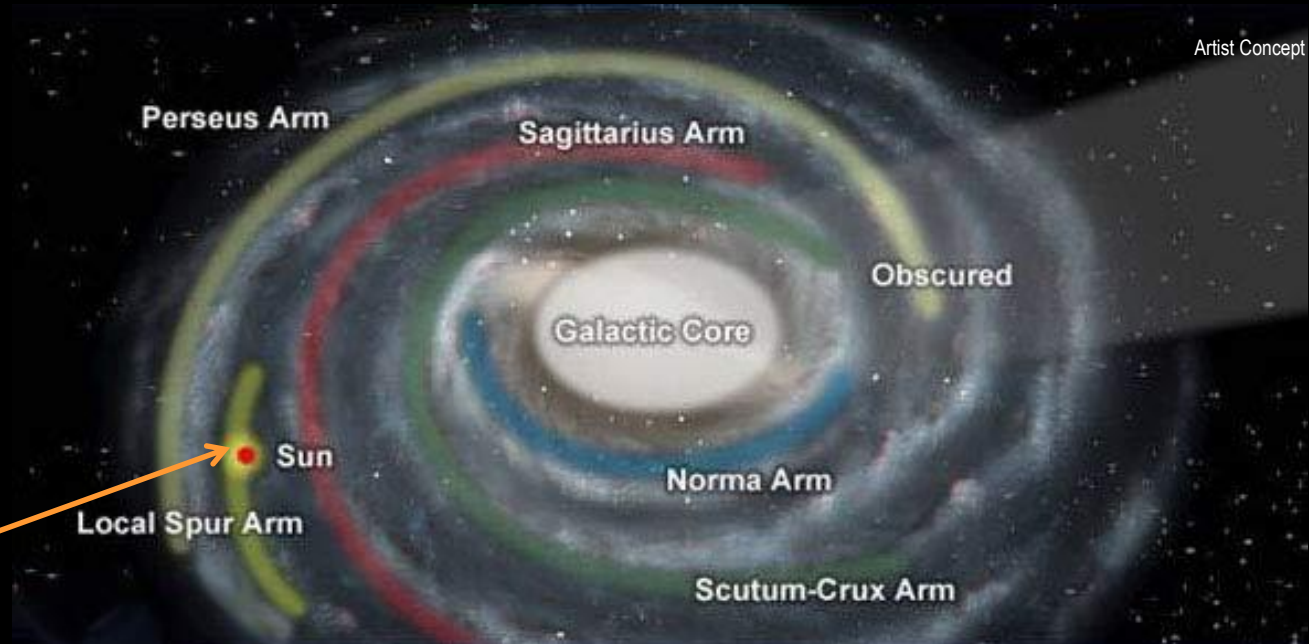
Merging of proto-galaxies, effects of black holes, history of star formation

## Birth of Stars and Planetary Systems

How stars form and chemical elements are produced

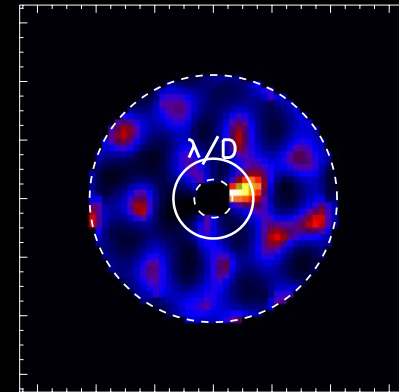
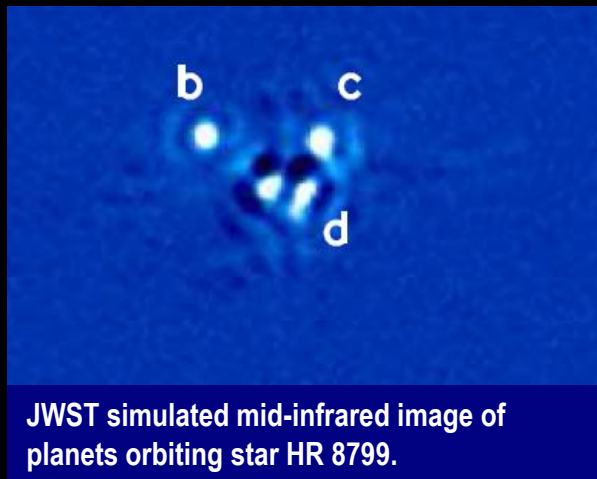
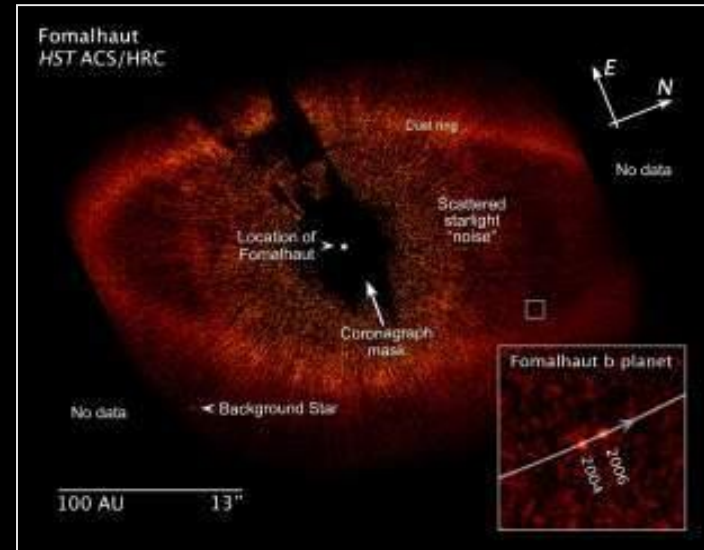
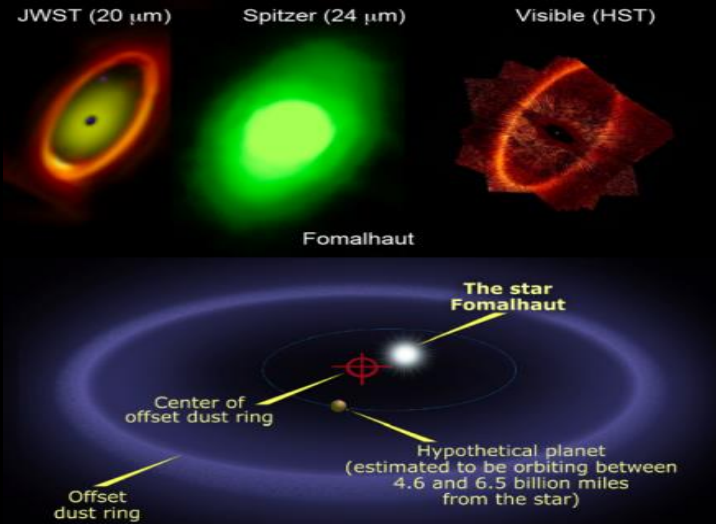
## Planetary Systems & Origins of Life

Formation of planets



Artist Concept

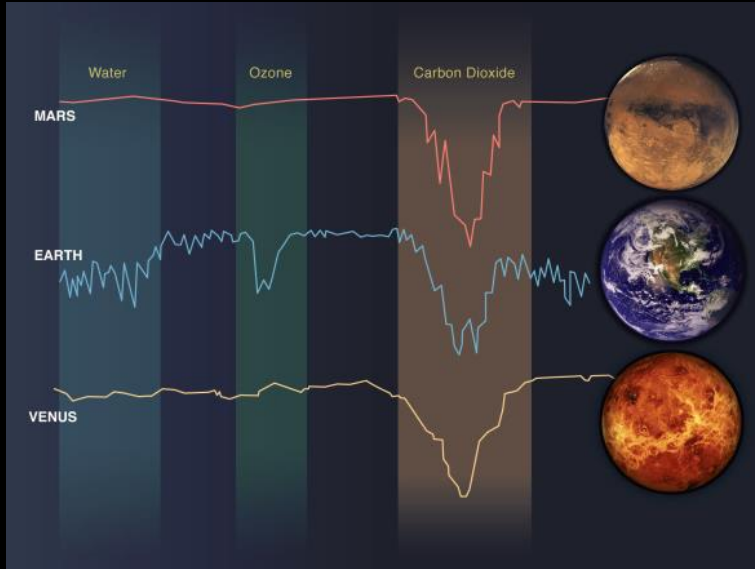
# JWST will image exoplanets (planets orbiting stars other than the Sun)



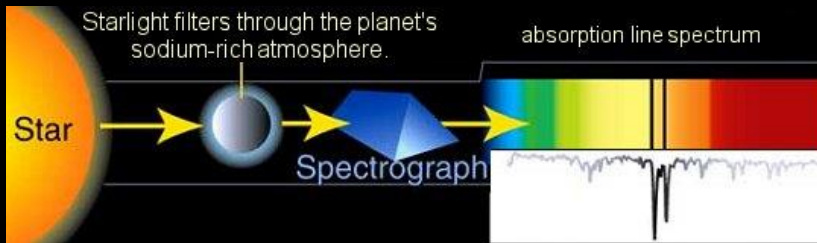
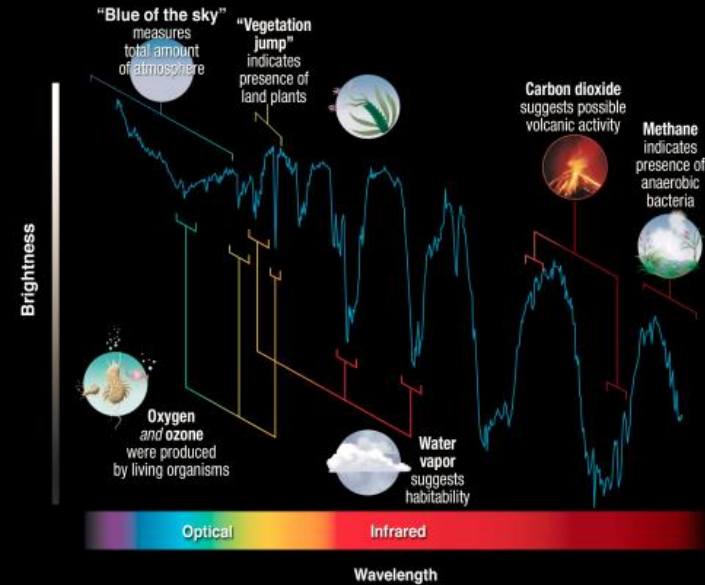
JWST simulated near-infrared image of a 1-2  $M_{\text{Jup}}$  planet at  $\sim 1$  AU of a M0V star 10 pc from the Sun.

# JWST will revolutionize understanding of exoplanet atmospheres

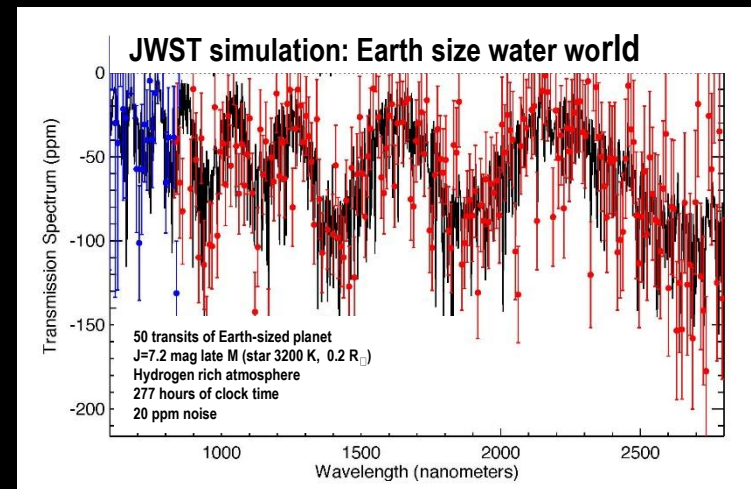
Composition is revealed by spectroscopy



So is the presence of life!

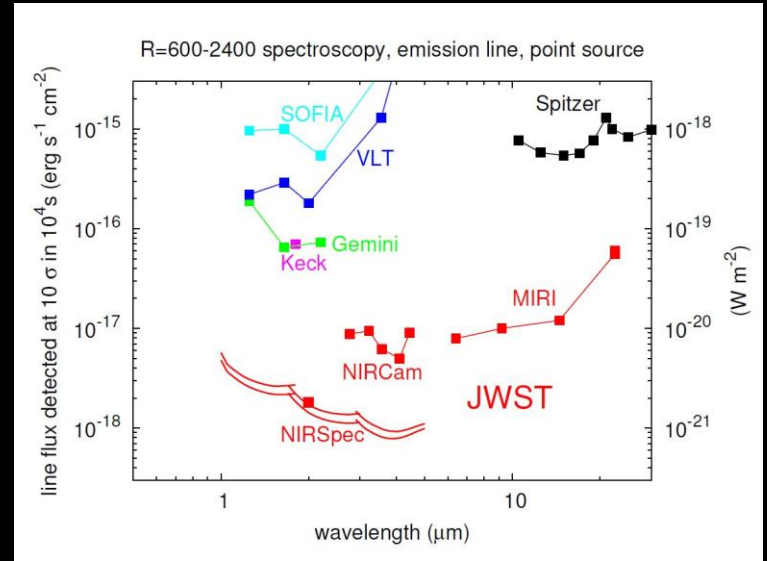
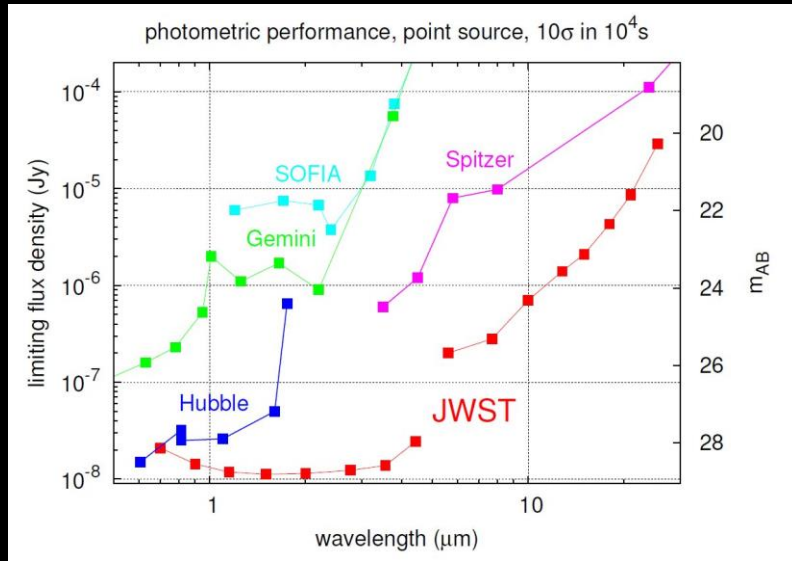


There are tens of billions of habitable worlds in our galaxy. JWST can detect liquid water on an exoplanet that is a few times the size of the Earth.

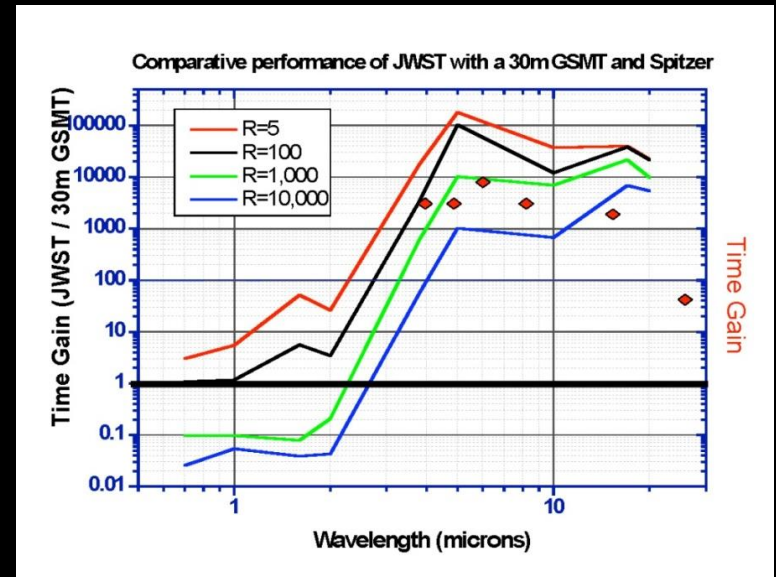
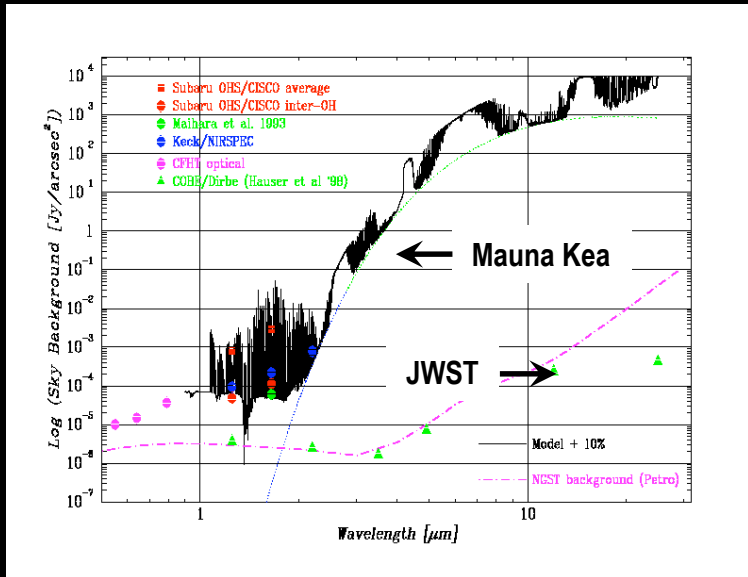




# JWST will achieve unprecedented infrared sensitivity



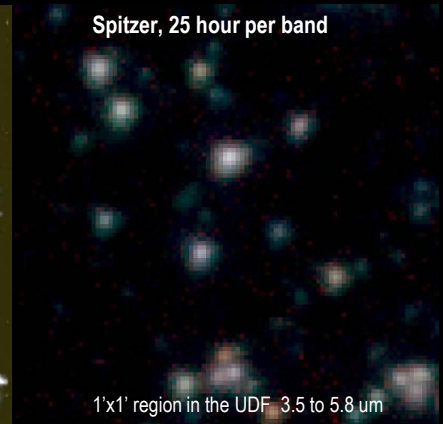
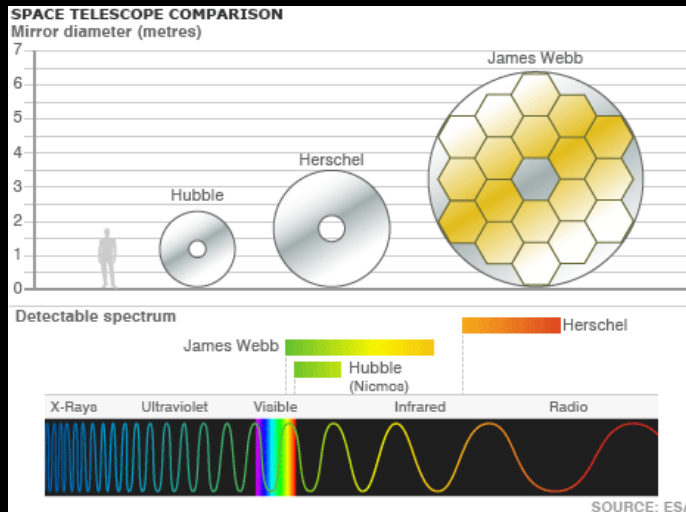
However, 30 m ground-based facilities can exceed JWST performance for  $R > 1000$  spectroscopy at wavelengths  $< 1.7$  microns



# JWST requires the largest cryogenic telescope ever constructed

To achieve its science objectives, the JWST mission requires:

- 7X the light gathering capability of the Hubble Space Telescope
- Observing capability spanning the optical to mid-infrared spectrum
- Hubble-like angular resolution in the near-infrared



JWST will provide the first high definition view of the infrared universe

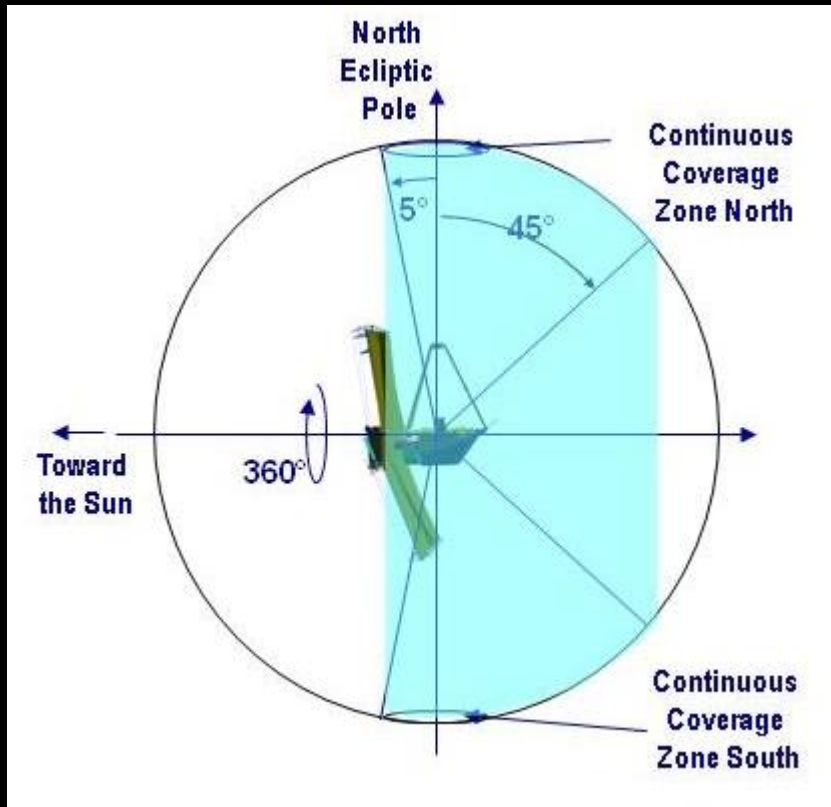
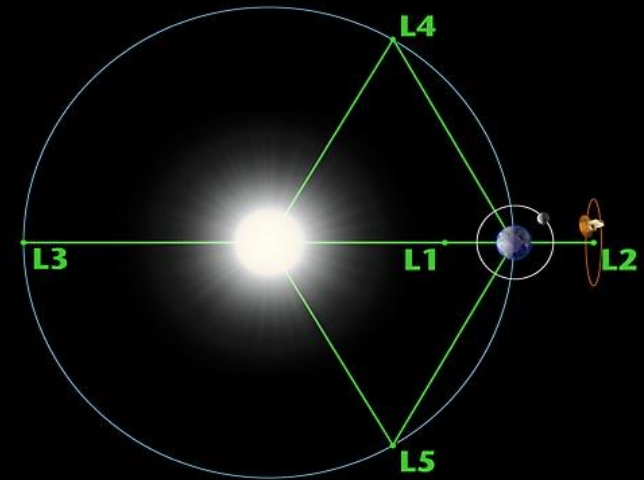
To meet these requirements, the JWST team had to solve two key problems:

- Provide a primary mirror that is larger in diameter than available rocket fairings
- Achieve a high stability cryogenic 40K (-233 C, -388 F) operating temperature

# The JWST will be placed in orbit about the Sun-Earth L2 point approximately 1.5 million km from Earth

An L2 point orbit was selected for JWST to enable passive cryogenic cooling

- Station keeping thrusters are required to maintain this orbit
- Propellant sized for 11 years ( $\Delta v \sim 93$  m/s)
- $\sim 100$  day direct transfer trajectory



The JWST can observe the whole sky while remaining continuously in the shadow of its sunshield

- Field of Regard is an annulus covering 35% of the sky
- The whole sky is covered each year with small continuous viewing zones at the Ecliptic poles

# The JWST program is a multi-agency partnership

## James Webb Space Telescope System

### Launch Segment



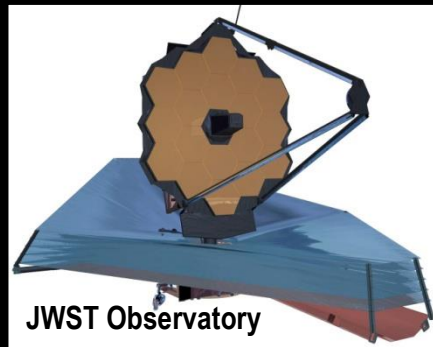
Ariane Launcher

### Launch Vehicle

### Payload Adapter

### Launch Site Services

### Observatory Segment



JWST Observatory

### Optical Telescope Element (OTE)

### Integrated Science Instrument Module (ISIM)

NIRCam MIRI NIRSpec FGS

### Spacecraft Element (SE)

### Spacecraft Bus

### Sunshield

### Ground Segment



Deep Space Network



Space Telescope Science Institute

### Science and Operations Center (SOC)

### Common Systems

- Provided by NASA
- Provided by ESA
- Provided by CSA



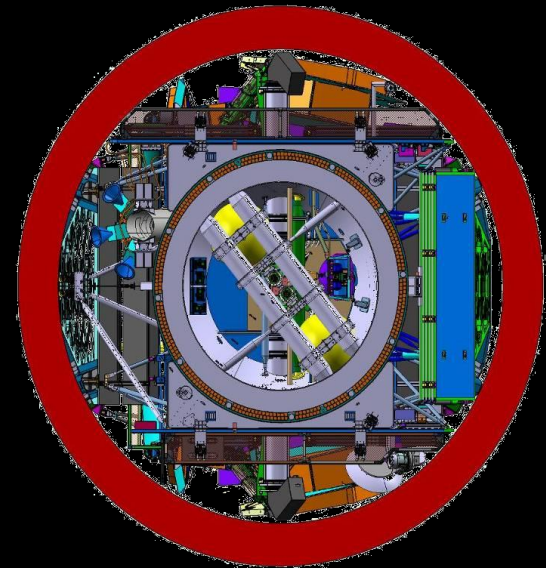
# The telescope requires a segmented deployable mirror



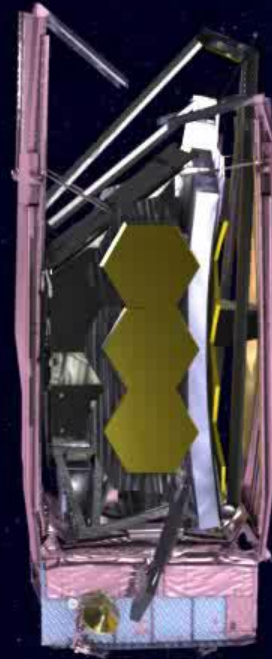
Ariane 5 ECA



- JWST is designed to integrate with an Ariane V launch vehicle and 5 m diameter fairing
- Launch from Kourou Launch Center (French Guiana) with direct transfer to L2 point.
- Payload launched at ambient temperature with on orbit cooling to 50 K via passive thermal radiators
- JWST payload: 6530 kg



# Deployment Sequence Overview



# The JWST space vehicle consists of three elements

## Optical Telescope Element (OTE)

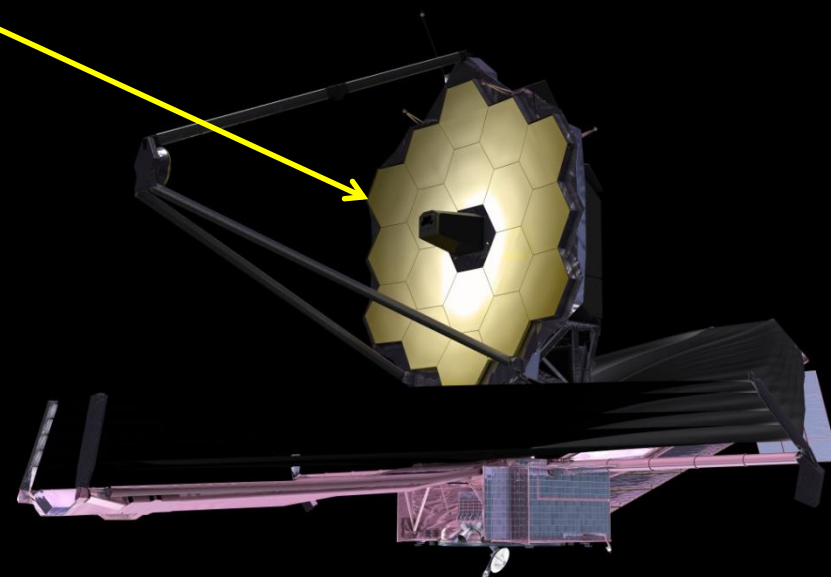
Collects star light from distant objects

## Integrated Science Instrument Module (ISIM)

Extracts physics information from star light

## Spacecraft

Attitude control, telecom, power & other systems



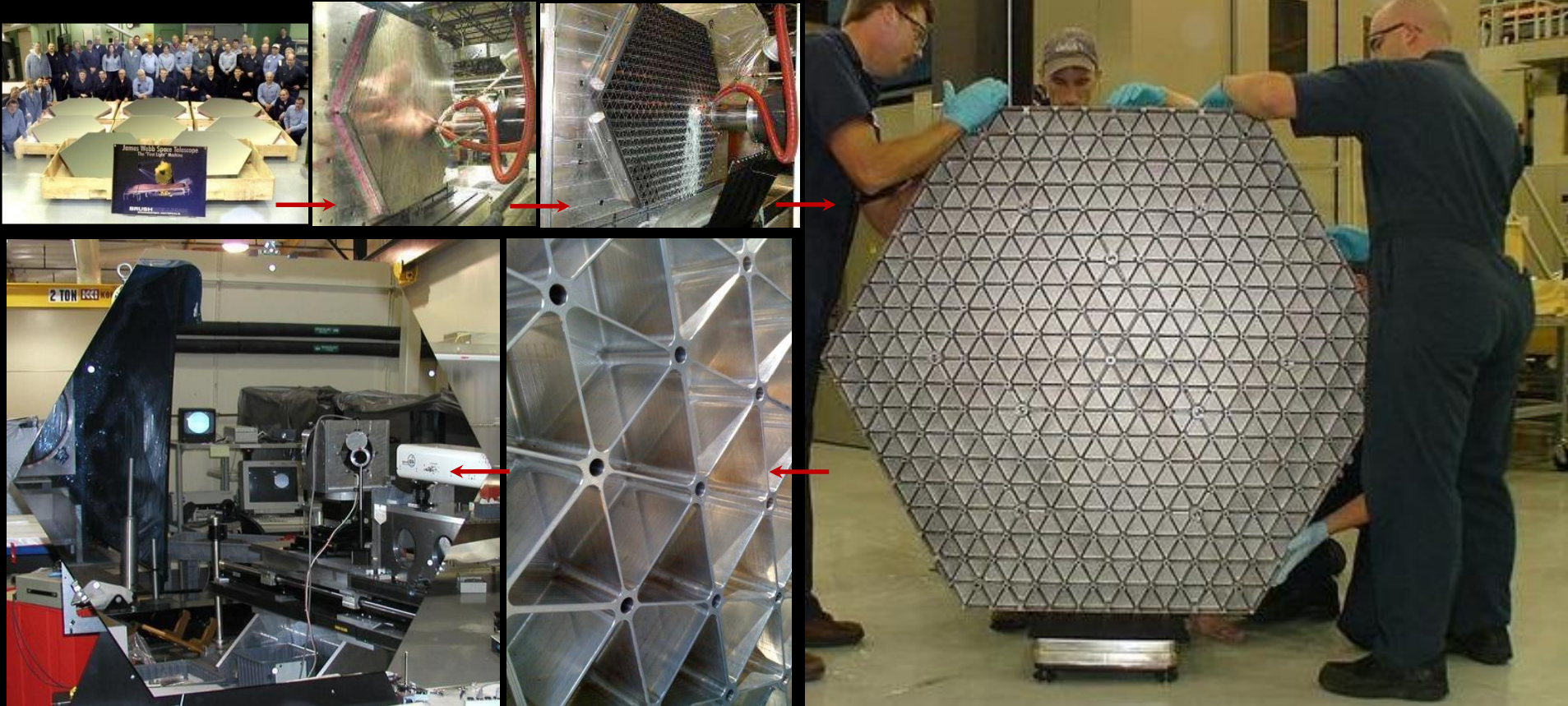
# The telescope mirrors are fabricated from Beryllium

## Key physical properties of Beryllium:

- low coefficient of thermal expansion at 50 K
- high thermal conductivity
- high stiffness to mass ratio
- Type O-30 spherical powder
- uniform CTE, high packing density, low oxide content

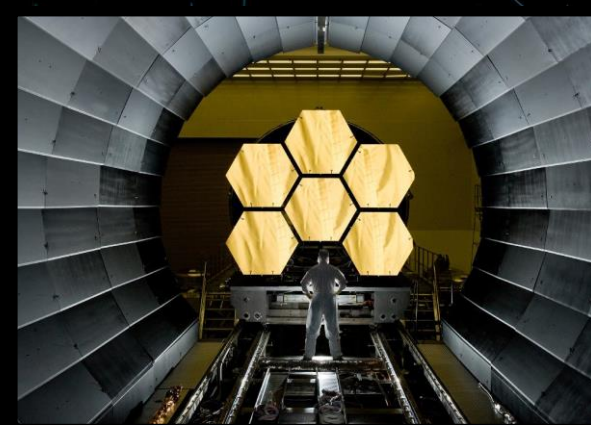
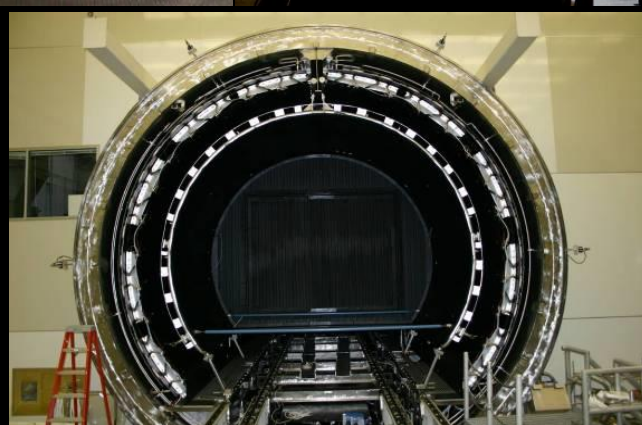
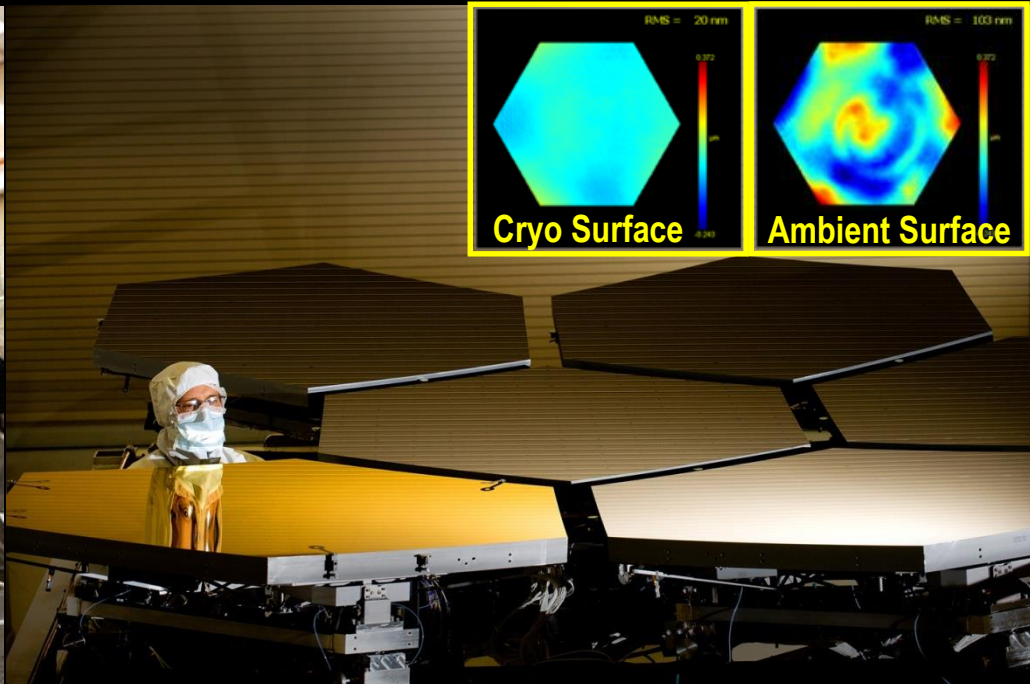
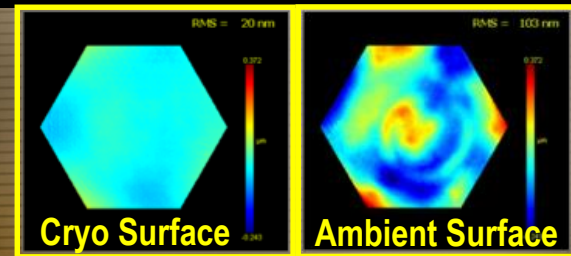
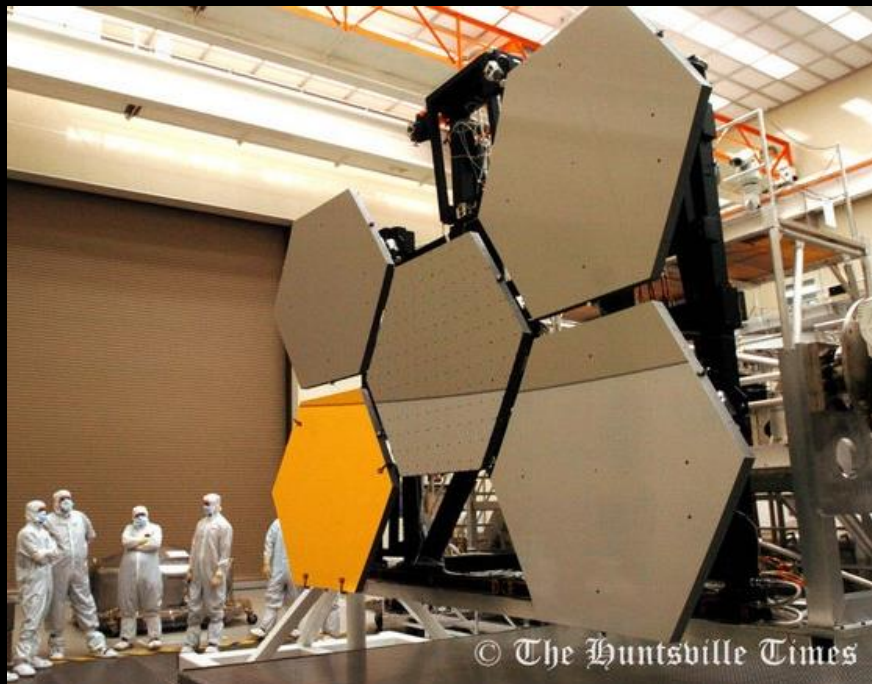
## Primary mirror mass properties

- substrate: 21.8 kg
- segment assembly: 39.4 kg
- OTE area density:  $\sim 28 \text{ kg m}^{-2}$ 
  - HST (ULE)  $\sim 180 \text{ kg m}^{-2}$  ( $\sim 6\text{X}$  heavier)
  - Keck (Zerodur)  $\sim 2000 \text{ kg m}^{-2}$  ( $\sim 71\text{X}$  heavier)

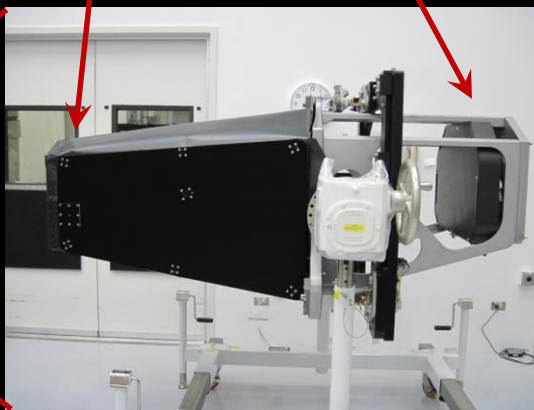
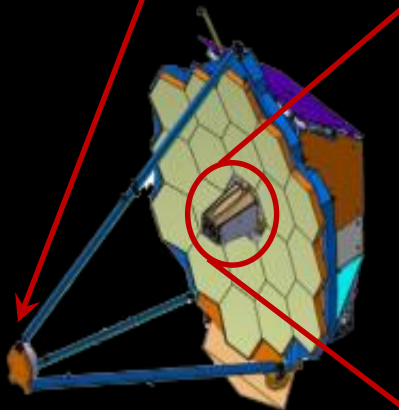
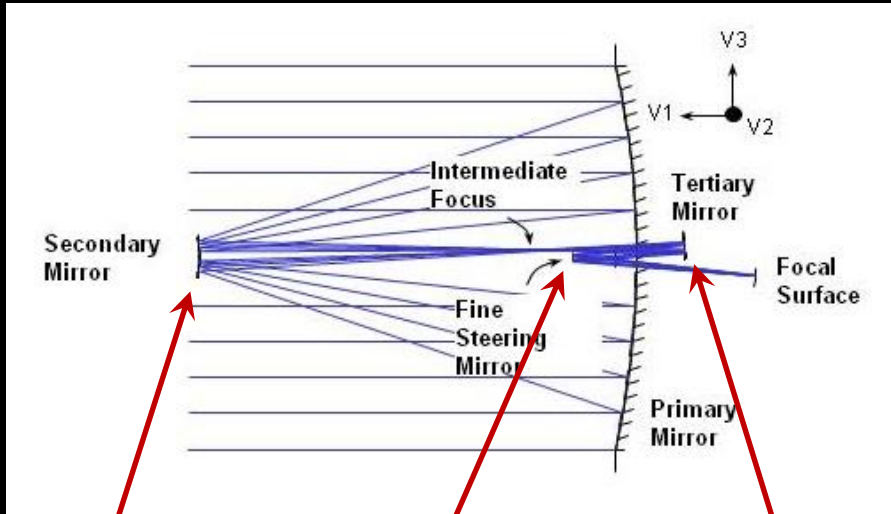




# A specially instrumented space simulation chamber at Marshall Space Flight Center was used to optically test the primary mirror segments at 50 K (-225 C, -370 F)

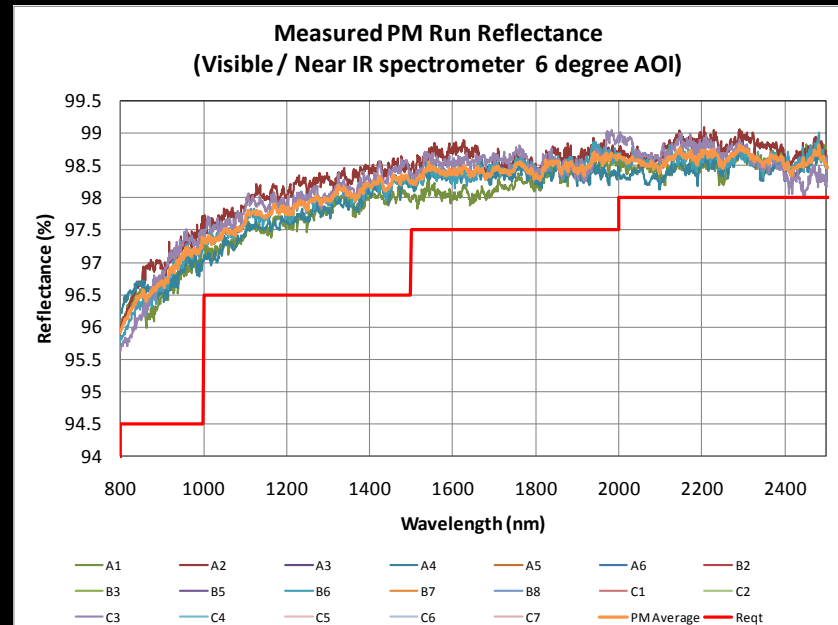


# All telescope optics are in-spec in every respect



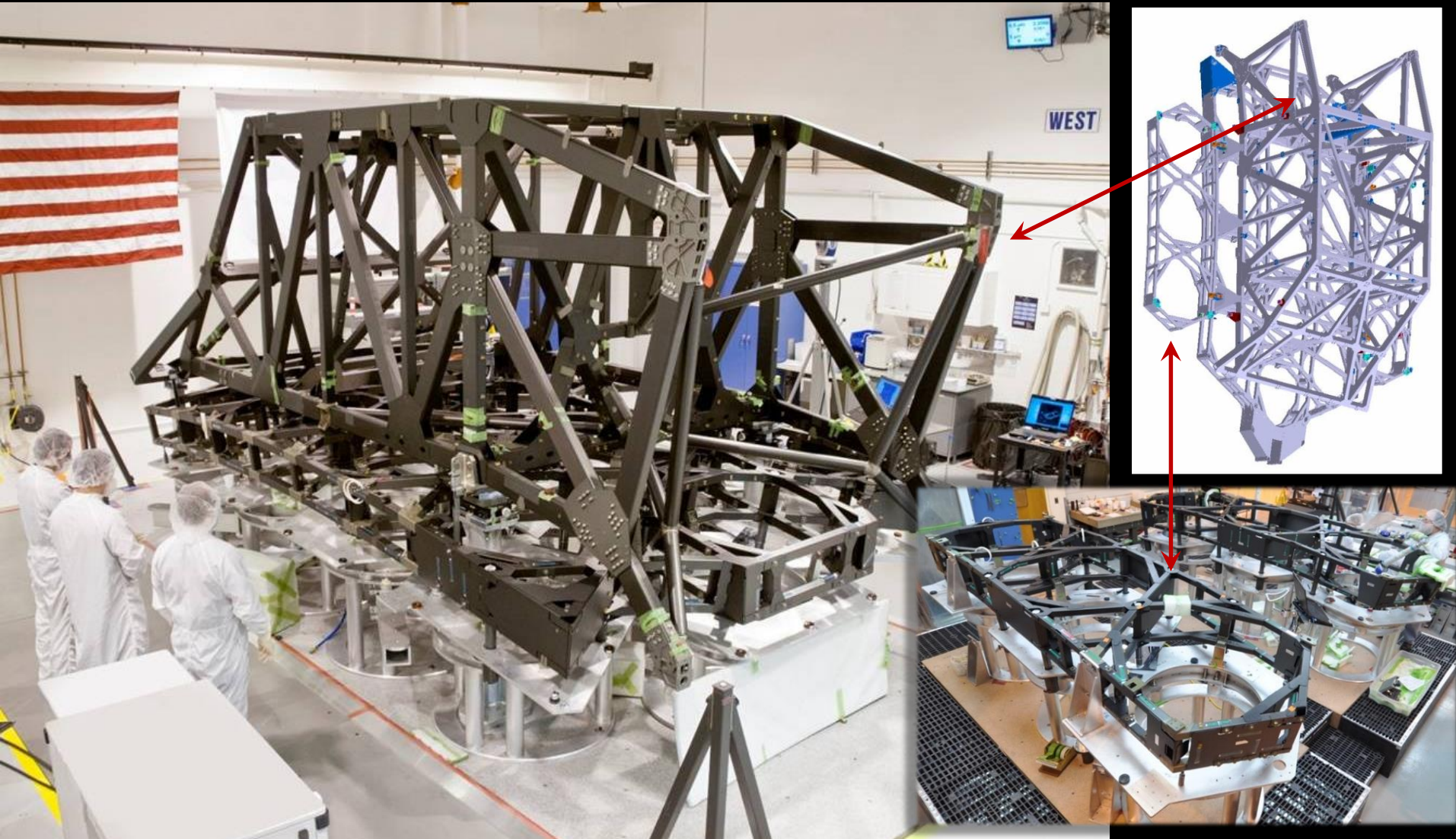
All of the mirrors are seen through testing to be smooth and reflective enough to enable the mission science objectives

Mirror	Total (RMS SFE)	Requirement (RMS SFE)
18 primary Segments (Composite Figure)	25.0	25.8
Secondary	19.8	23.5
Tertiary	20.5	23.2
FSM	14.7	18.7



# Buildup of telescope flight structure is complete

The structure consists of ~3,200 bonded composite piece parts



# Pathfinder and flight telescope structures in handling test



Pathfinder secondary mirror structure deployment test

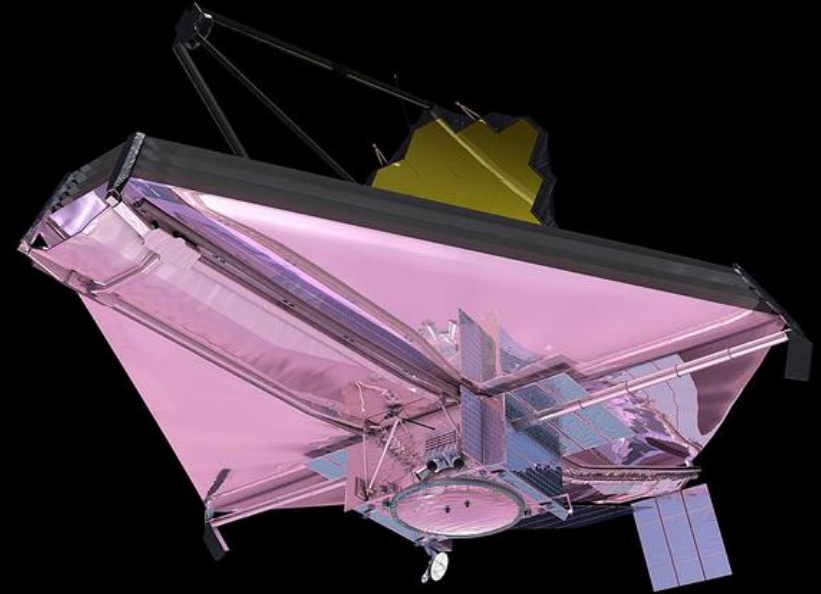
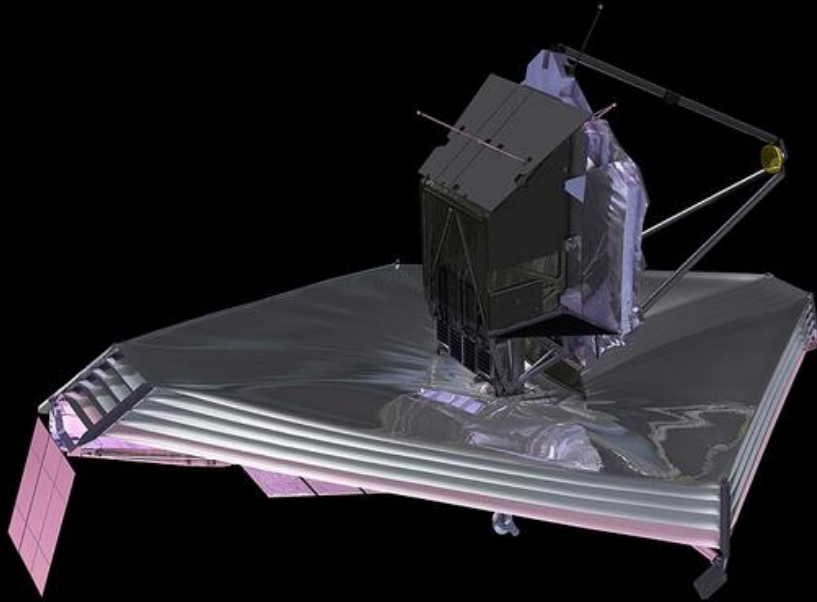


Flight backplane structure

# OTE pathfinder structure manual deployment test: June 2014

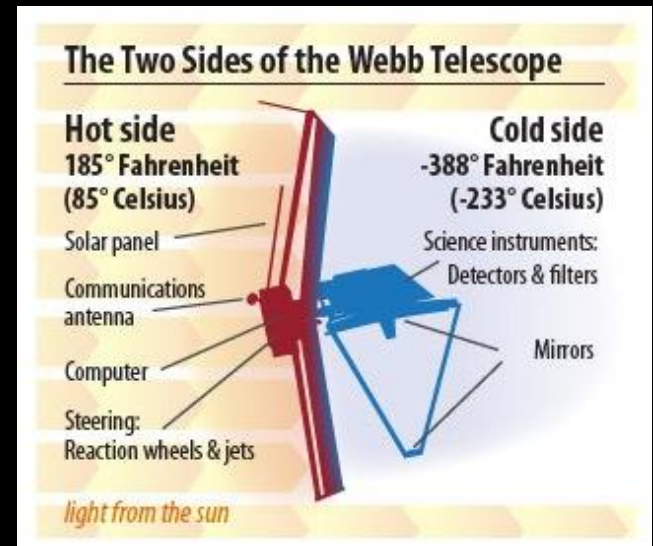


# The JWST's 5 layer sunshield has an SPF of $\sim 10^6$



## Sunshield Facts

- Measures 73 x 40 feet and has 5 layers
- Made of heat-resistant Kapton coated with silicon on sun side and aluminum on other surfaces
- Sun side reaches 358 K (85° C), dark side stays at 40 K (-233° C)
- Each of 5 layers consist of 50 pieces to form shape
- Seaming involves 7,000 inches of thermal welds
- Seam-to-seam accuracy  $\sim 0.05$  inch with shape of (tennis court size) layers accurate to a few tenths of an inch



# Sunshield Manual Deployment Test: June 2014



# The JWST space vehicle consists of three elements

## Optical Telescope Element (OTE)

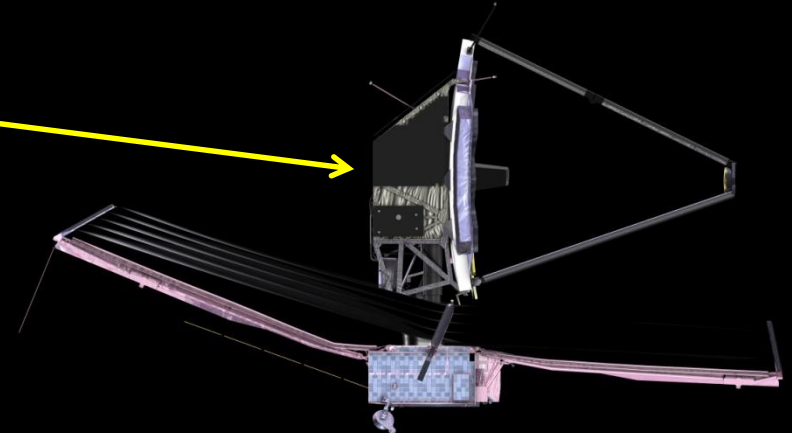
Collects star light from distant objects

## Integrated Science Instrument Module (ISIM)

Extracts physics information from star light

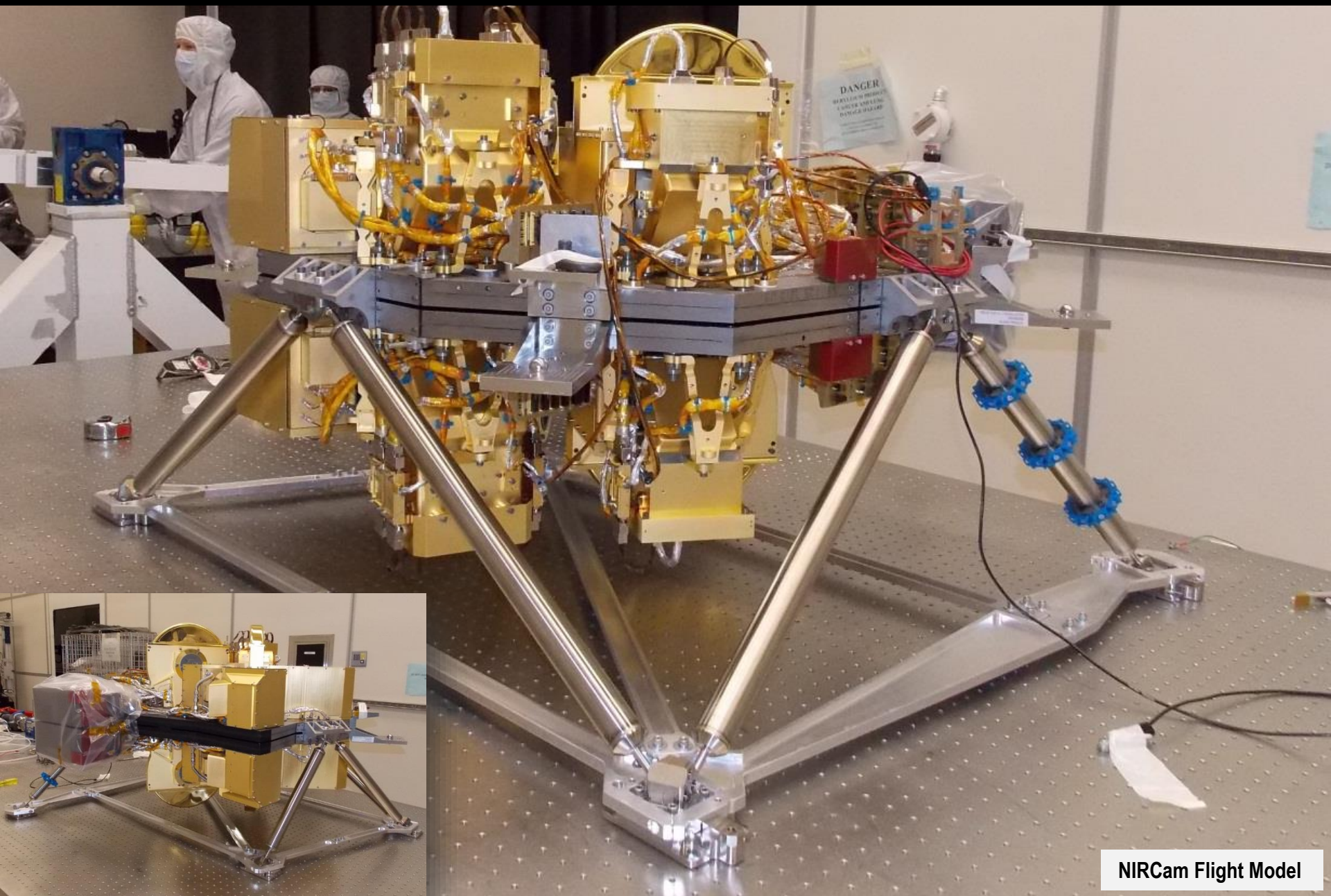
## Spacecraft

Attitude control, telecom, power & other systems





# The NIRCam will image the earliest epoch of galaxy formation



NIRCam Flight Model

# NIRSpec can obtain spectra of 100 compact galaxies simultaneously



FM2 test Jan 2013



# MIRI will provide humanity's first high definition view of the mid-infrared universe



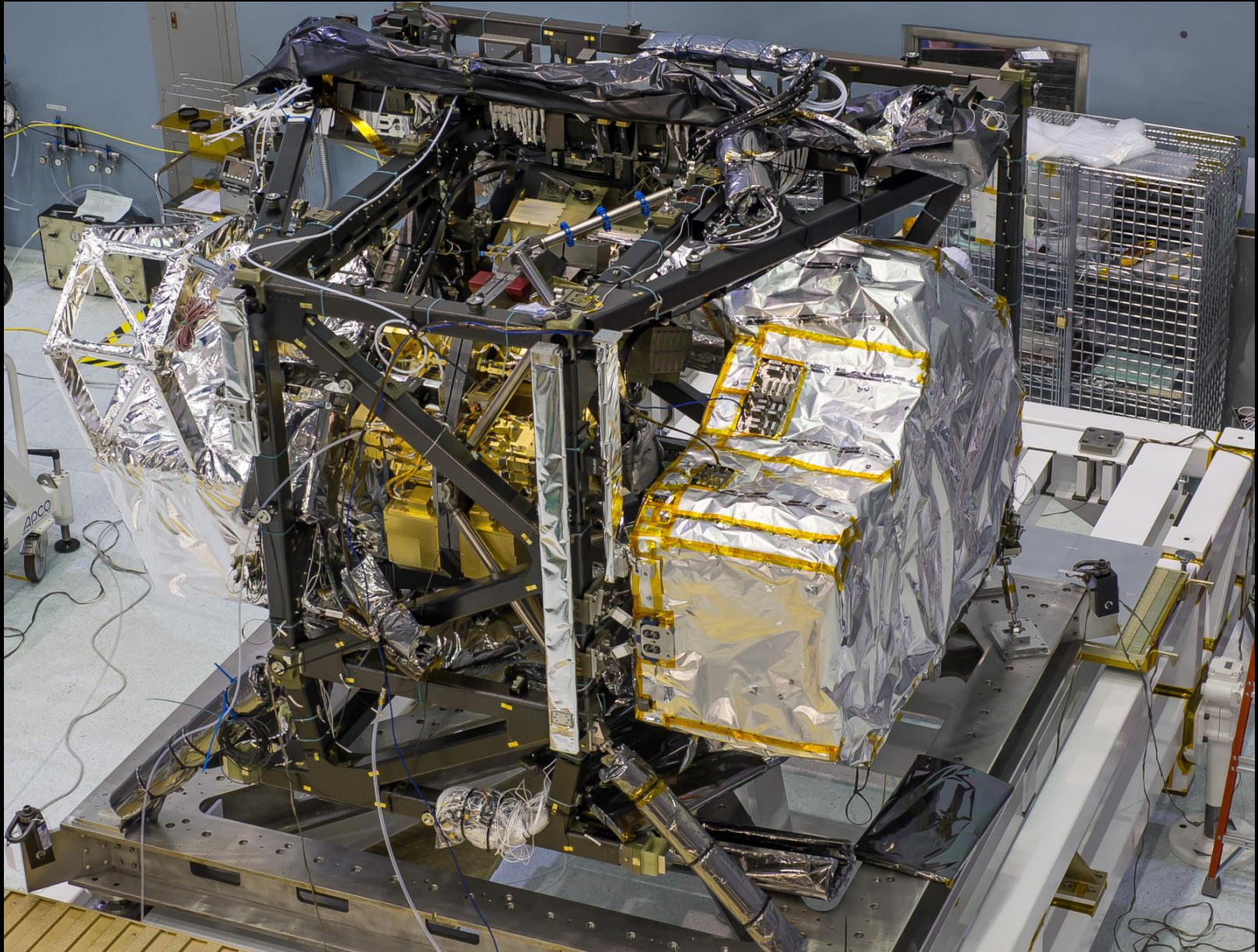
MIRI flight model

**FGS can sense pointing to 1 millionth degree precision  
NIRISS can image exoplanets that are too close to their star for coronagraphs**



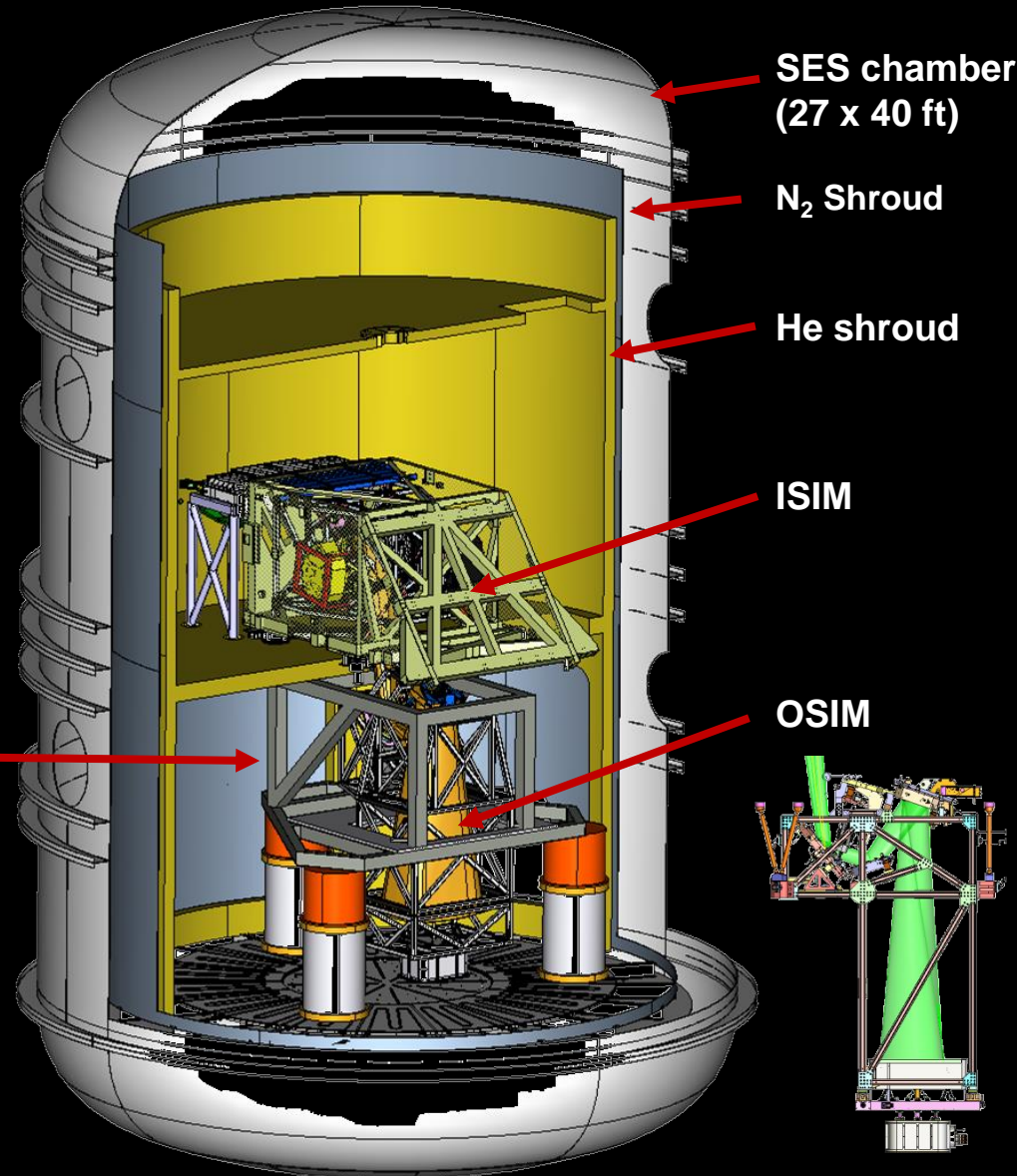
**Flight FGS**

**The JWST science instrument payload began construction during 2006 and is now in the final stage of testing ahead of integration with the telescope**



# ISIM is tested in the Goddard Space Environment Simulator (SES) chamber using a cryogenic telescope simulator (OSIM)

The 3rd of 3 SES test cycles of the ISIM  
Will begin during October 2015



# The telescope and instrument module will be integrated to each other at GSFC and will then be sent to Johnson Space Flight Center during 2016



Space Telescope Transporter for Air Road and Sea (STTARS)

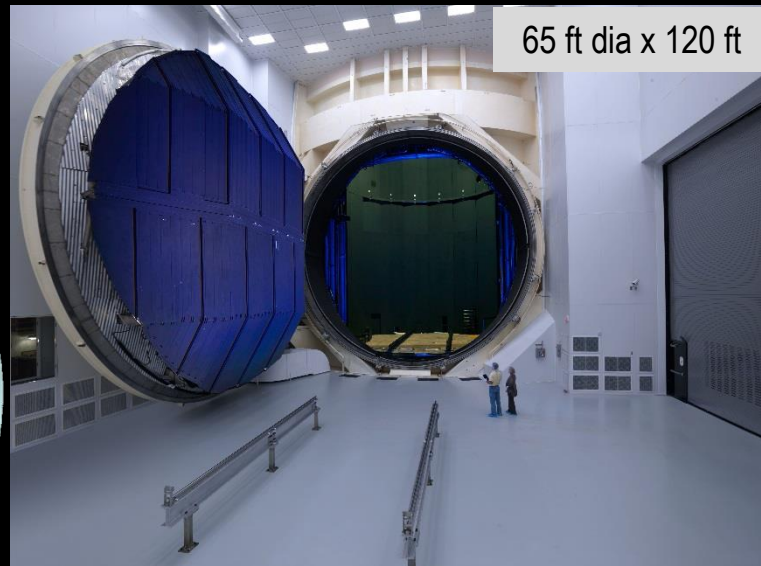
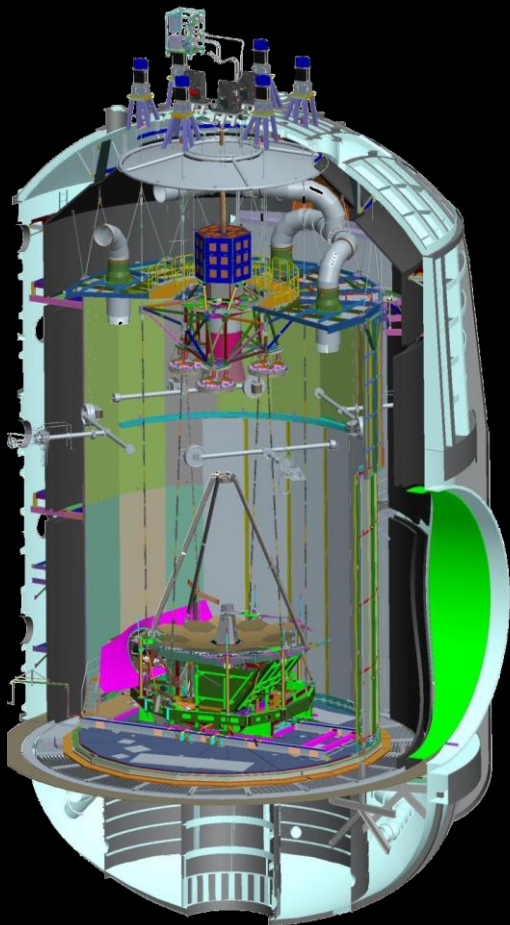
# Then .... the OTE + ISIM will be tested in the largest space simulation chamber in the world

Apollo era facility extensively refurbished for JWST

Largest deep cryogenic space simulation chamber in the world

Performance certification completed during Aug 2012

13 K and  $10^{-8}$  Torr reached during test



JSC Chamber A today

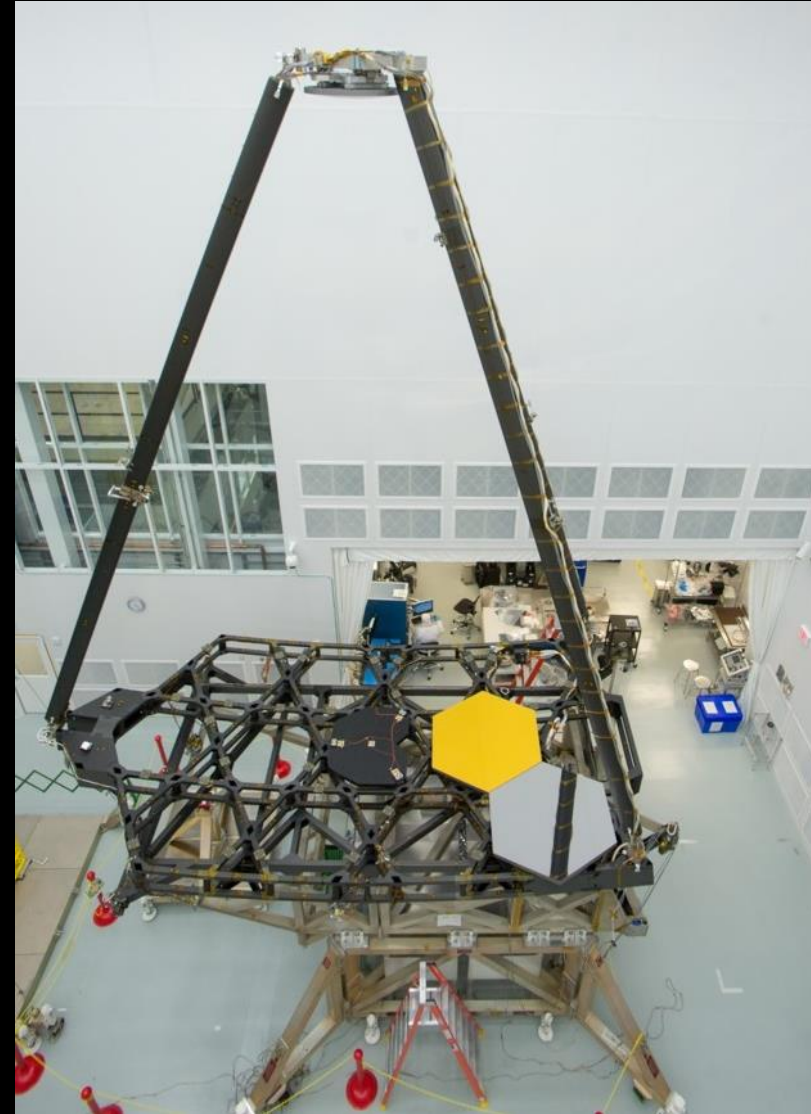
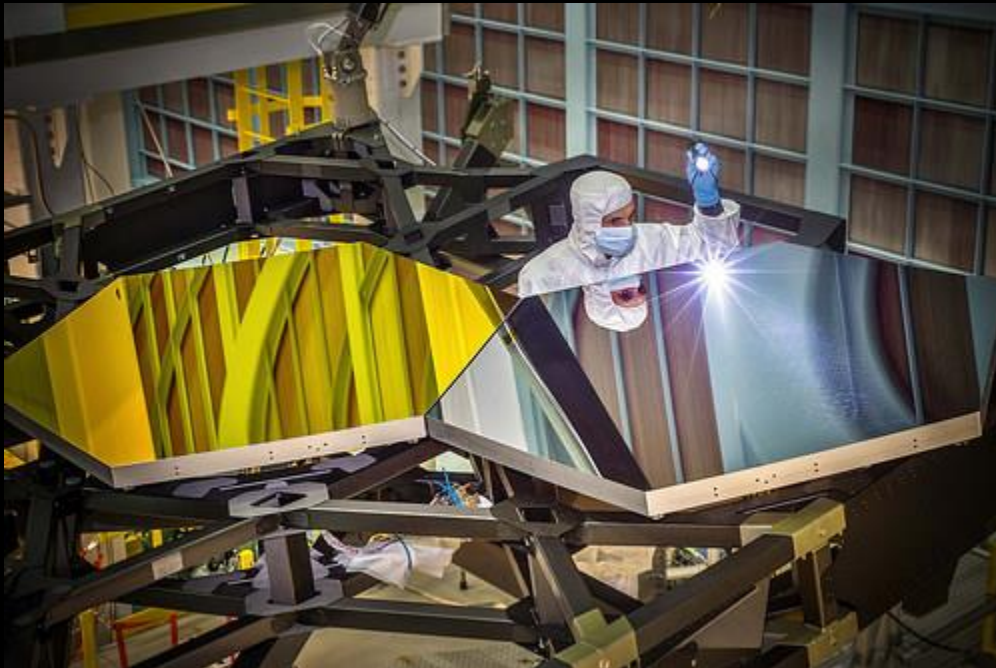


JSC Chamber A during Apollo

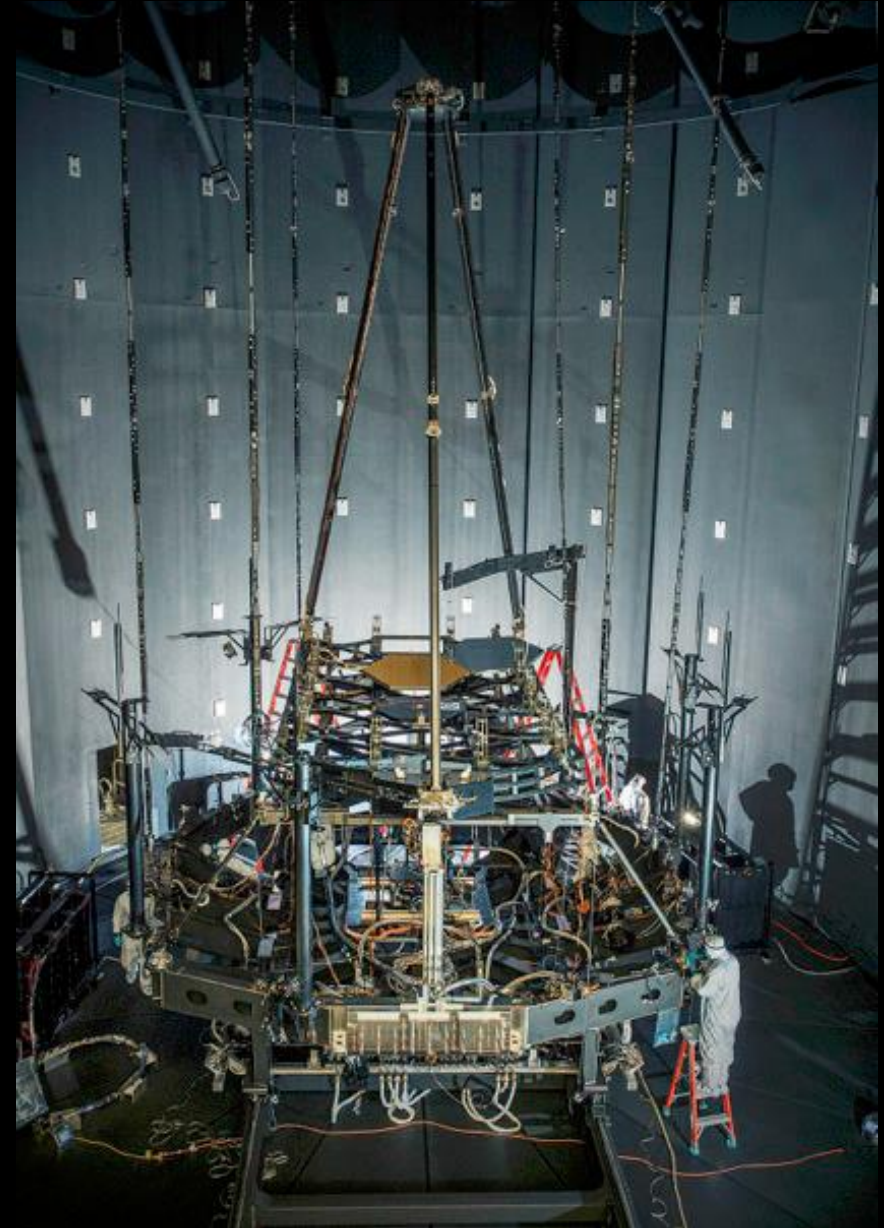


# The Pathfinder telescope structure began cryogenic testing at Johnson Space Flight Center during May 2015

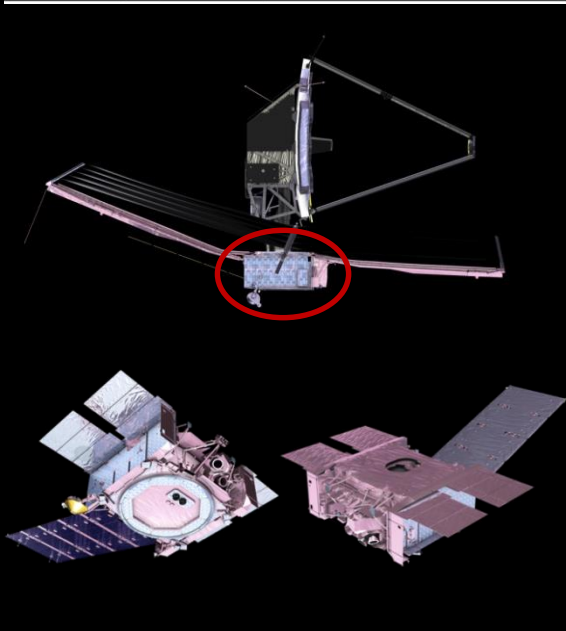
- The Pathfinder is flight-like in every respect expect:
  - Does not include the deployable “wings” of the backplane
  - Is populated with two flight spare mirror segments



# Space simulation testing of the pathfinder telescope structure began during May 2015



# The telescope and instrument module will then be sent to Northrop Grumman Aerospace Systems for integration with the spacecraft bus and sunshield during 2017



Space Telescope Transporter for Air Road and Sea (STTARS)

# Then ... The JWST will be transported by ship through the Panama Canal to French Guiana for launch during 2018



Roll on roll off transport ship built in the Netherlands by Merwede Shipyards  
Length 116m  
Displacement about 4200 metric tons  
Garage deck length 95m (plenty of room for STTARS)  
Speed: 15 knots



6900 Nautical Miles  
Approximately 20 days



Space Telescope Transporter for Air Road and Sea (STTARS)

**The End (of this presentation)**

**But**

**with JWST, we will see the beginning of *everything***

The first galaxies

The origins of galactic structure

The birth of stars

The creation of planets

and more

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