

The James Webb Space Telescope: Mission Overview and Status

Matthew A. Greenhouse and the JWST Science Working Group¹

Goddard Space Flight Center

Code 443.2

Greenbelt, MD 20771 USA

Abstract- The James Webb Space Telescope (JWST) is the infrared successor to the Hubble Space Telescope. It is a cryogenic infrared space observatory with a 25 m² aperture (6 m class) telescope yielding diffraction limited angular resolution at a wavelength of 2 μ m. The science instrument payload includes three passively cooled near-infrared instruments providing broad- and narrow-band imagery, coronagraphy, as well as multi-object and integral-field spectroscopy over the $0.6 < \lambda < 5.0$ μ m spectrum. An actively cooled mid-infrared instrument provides broad-band imagery, coronagraphy, and integral-field spectroscopy over the $5.0 < \lambda < 29$ μ m spectrum. The JWST is being developed by NASA, in partnership with the European and Canadian Space Agencies, as a general user facility with science observations to be proposed by the international astronomical community in a manner similar to the Hubble Space Telescope. Technology development and mission design are complete, and construction is underway in all areas of the program.

I. DESIGNING FOR DISCOVERY

The science motivation for the JWST mission was developed by a succession of international science working groups and is described by Gardner et al. 2006, with updates maintained by the JWST flight science working group¹ at: <http://www.stsci.edu/jwst/science/whitepapers/>. This science case forms the basis from which detailed science and mission requirements were derived to guide engineering design and development of the JWST as a research tool. The science observations that are actually implemented by the JWST will be proposed by the international astronomical community in response to annual peer reviewed proposal opportunities. The discovery potential of the JWST relative to other concurrent facilities is discussed in Thronson, Stiavelli, and Tielens 2009.

The emergence of the first sources of light in the universe (after decoupling) marks the end of the “Dark Ages” in cosmic history (Rees 1997). The ultraviolet radiation field produced by these sources created the ionization that is observed in the local intergalactic medium (IGM). The JWST design provides unique capability to address key questions about this era in cosmic evolution including: what is the nature of the first galaxies; how and when did ionization of the space between them occur; and what sources caused the ionization?

The JWST architecture is primarily shaped by requirements associated with answering the above questions. In contrast to the Hubble Space Telescope (HST), the JWST is designed as an infrared optimized telescope to observe the redshifted ultraviolet radiation from the first galaxies and supernovae of the first stars. To achieve the nJy sensitivity needed to observe this era ($z \sim 6-20$), the observatory must have a telescope aperture that is larger in diameter than the largest rocket faring, and the entire optical system must be cooled to $\sim 40-50$ K. Finally, the resulting large deployable cryogenic telescope must achieve HST-like angular resolution across the SWIR spectrum. The major observatory design features trace directly from these requirements and differ markedly from those of the HST.

The JWST science instrument payload is designed to probe the first galaxies with high angular resolution near-infrared image surveys in broad-band filters. This capability enables identification of primeval galaxies by searching their Lyman continuum break with multi-filter photometry. This prominent feature occurs in the near-infrared (1.3 – 2.6 μ m) for galaxies with redshifts in the range of 10 – 20. This broad-band technique exploits the maximum sensitivity of the observatory, such that the space density of galaxies can be probed to $z \sim 20$. JWST high angular resolution imagery across the 0.6 – 29 μ m spectrum will probe the assembly and evolution of galaxy morphologies to enable observation of when and how the Hubble sequence formed.

The JWST is designed to enable near-infrared multi-object spectroscopy of thousands of galaxies at several spectral resolutions ($\sim 10^2$, $\sim 10^3$). This capability will probe the chemical evolution and metallicity of galaxies, and the ionization state of the IGM across cosmic time. Low resolution multi-object spectroscopy will enable calibration of photometric redshifts for primeval galaxy studies. The JWST spectrometers include integral field capability over the 0.6 – 29 μ m spectrum that will enable detailed spectral, morphological, and kinematic studies of high redshift galaxies and local galaxy nuclei. JWST spectroscopy includes wide field scanning Fabry-Perot and narrow-band filter imagery at low ($\sim 1\%$) spectral resolution and high angular resolution to enable both wide field emission line imagery and high redshift surveys of emission line galaxies.

The JWST observatory design enables wide discovery potential beyond cosmology and galaxy studies. The JWST high angular resolution imagery and imaging spectroscopy across the 0.6 – 29 μ m spectrum will open a new window

¹ John C. Mather, Mark Clampin, Rene Doyon, Kathryn A. Flanagan, Marijn Franx, Matthew A. Greenhouse, Heidi B. Hammel, John B. Hutchings, Peter Jakobsen, Simon J. Lilly, Jonathan I. Lunine, Mark J. McCaughrean, Matt Mountain, George H. Rieke, Marcia J. Rieke, George Sonneborn, Massimo Stiavelli, Rogier Windhorst and Gillian S. Wright.

on observation of star formation in our own galaxy to reveal: how molecular clouds collapse; how environment effects star formation and vice-versa; the mass distribution of low mass stars; and the relationship between stellar debris disks and the formation of terrestrial planets.

The JWST instruments include coronagraphic imagery and spectroscopy capability that will enable a wide range of stellar debris disk studies and extra-solar planet observations at high angular resolution. High dynamic range modes of the JWST instruments will enable extra-solar planet transit photometry and spectroscopy across the above wavelength range. The JWST observatory enables non-sidereal tracking so that the full observatory capability can be used observe the outer solar system to enable comparative studies between stellar debris disks and our own solar system.

II. ARCHITECTING FOR SUCCESS

The large primary mirror area and cryogenic operating temperature are key drivers on the JWST mission architecture. The telescope is the largest space telescope ever constructed. Liquid cryogen cooling techniques used by prior infrared space observatories (IRAS, ISO, Spitzer) cannot be practically scaled to meet JWST requirements, and existing cryo-cooler technology could not meet the heat lift requirements of this large system. As a consequence, a passively cooled architecture was adopted for the majority of the system. A libration point orbit about the Sun-Earth L2 point was selected to meet this requirement. In this orbit, the observatory follows the earth around the sun such that the sun and earth always appear in the same direction. Hence, it is possible to continuously shield portions of the observatory from the sun and earth to enable passive cryogenic cooling. The orbit about the L2 point itself is sized to avoid eclipse; thus enabling continuous generation of power with solar arrays. This orbit has a period of approximately 6 months and is unstable, requiring use of station-keeping thrusters. Propellant for orbit maintenance and momentum management ultimately limits the lifetime of the observatory to approximately twice the duration of its required 5 year science mission.

The JWST can observe the whole sky while remaining continuously in the shadow of its sun shield. The space vehicle can pitch through an angle of 50 degrees and rotate completely about the earth-sun line to observe sources within an annulus that covers approximately 39% of the sky. As the observatory orbits the sun, this annulus sweeps over the whole sky each year with small continuous viewing zones at the ecliptic poles.

The JWST can reach this orbit in approximately 100 days after launch from Kourou Launch Center in French Guiana using an Ariane 5 ECA launch vehicle via a direct transfer trajectory. This class of launch vehicle provides adequate fairing volume and mass capability to enable an observatory design that meets the above science requirements. The 6.5 m diameter telescope and its tennis-court sized sunshield, are designed to be stowed within the Ariane 5 m diameter fairing along with the science instrument payload and spacecraft such that the observatory can deploy into its operational configuration (see animation at: www.jwst.nasa.gov/videos_deploy.html). The observatory is

launched warm and cooling begins after sunshield deployment en route to the L2 point.

During operations, the NASA Deep Space Network is used to support two 4 hr communications contacts each day during which approximately 470 Gbits of science and engineering data are downloaded. Both mission and science operations are supported by the Space Telescope Science Institute. Overall mission management, as well as guidance, navigation, and control, are provided by Goddard Space Flight Center.

III. COLLECTING THE FIRST LIGHT

A three mirror anastigmat (TMA) telescope design was selected to enable high image quality over a wide field of view. In contrast to ground-based telescopes, minimizing mass is a key design driver on the JWST telescope. Beryllium was selected as a material for the three TMA mirrors due to its high thermal conductivity, high stiffness to mass ratio, and low expansion coefficient at the ~50K operating temperature. A segmented primary mirror design was chosen to enable fold-up stowage. The deployed aperture is tricontagon in shape with a collecting area of 25 m². The primary mirror is composed of 18 hexagonal segments (1.32 m flat-to-flat) of three optical prescriptions. Each primary mirror segment and the secondary mirror are mechanized to provide in-flight position adjustment in 6 degrees of freedom. The primary mirror segments also have in-flight radius of curvature adjustment. A fine steering mirror is located near a pupil position. This mirror is servo controlled using an image-based fine guidance sensor located in the science instrument focal plane to enable 7 mas rms pointing stability. The mirrors are polished to a cryogenic figure error of approximately 20 nm rms via an iterative cryogenic test and polishing process. Gold was selected as a mirror coating to provide high throughput over the 0.6 - 29 micron spectrum. This coating choice limits the JWST to wavelengths >0.6 um. The 29 um long wavelength limit results from detector technology and cooling constraints. The telescope structure consists of a M55J-954-6 cyanate ester composite material that affords a high stiffness to mass ratio and a low cryogenic expansion coefficient to yield high optical alignment stability.

The mirror segment actuators are periodically adjusted in flight to ensure diffraction limited image quality throughout the mission. The observatory's main near-infrared science camera (Section 4) is used as the wavefront error sensor for this process. Initial coarse phasing of the segments is accomplished using dispersed Hartman sensing optics in this camera. The subsequent fine phasing is performed on defocused images using a modified Gerchberg-Saxton algorithm (Acton 2004). This process is designed to achieve a telescope Strehl ratio of 0.8 at a wavelength of 2 um. The dispersed Hartman coarse phasing process was demonstrated on the Keck telescope (Albanese 2006). The overall flight wavefront sensing and control process has been demonstrated on a 1/6 scale fully

functional model of the JWST telescope (Feinberg 2007, Contos 2008).

IV. EXTRACTING INFORMATION FROM STARLIGHT

The JWST science instrument payload contains four science instruments, a fine guidance sensor, and supporting systems for instrument control, command and data handling, cryogenic thermal control, and other functions (Greenhouse 2006, 2010). Near-infrared imagery is provided by the NIRC*am* instrument (Rieke 2005, 2008). This camera provides high angular resolution wide-field imagery over the 0.6 – 5 μ m spectrum. The detector pixel scale is chosen to optimally sample the telescope point spread function across this wavelength range by use of a dichroic beam splitter. Two identical optical modules image adjacent fields of approximately 4 square arcminutes to provide full redundancy for telescope wavefront sensing. Occulting coronagraphy, yielding a rejection ratio of $\sim 10^4$, is provided in both long and short wavelength channels. All focal plane arrays support high cadence sub-array exposures to provide a high dynamic range capability for exoplanet transit observations.

Near-infrared scanning Fabry-Perot imagery is provided by the FGS-TF instrument (Doyon 2008). This instrument provides a narrow-band imaging capability with the same size field of view as the NIRC*am* and over a similar wavelength range. Its applications include deep surveys for emission line objects over a flexible range of redshifts. The instrument includes occulting coronagraphy that can achieve a contrast ratio of $\sim 10^4$ using a speckle suppression technique that is enabled by the scanning capability of the etalon.

The FGS-TF shares an optical bench with the FGS-Guider. The latter is a fully redundant very broad-band camera that functions as the fine guidance sensor for the telescope fine steering mirror system. It delivers guide star centroid measurements with a noise equivalent angle of 4 mas at a rate of 16 Hz. Its wide field of view enables 95% probability of guide star acquisition over the whole sky and autonomous pattern recognition for guide star identification.

Spectroscopy over the 0.6 – 5 μ m spectrum is provided by the NIRSpec instrument (Bagnasco 2007). The NIRSpec affords a range of spectral resolutions that can be used with long slit, multi-object, and integral field aperture control modes. This instrument is the first multi-object aperture controlled spectrometer developed for space flight. It is designed to target 100 compact sources simultaneously within a 9 square arcminute field. Aperture control for multi-object spectroscopy is provided by a 0.25 Mpixel array of micro-shutters that are configured for the desired target field based on prior NIRC*am* imagery. A variety of fixed long slits are provided to enable high contrast and exoplanet transit spectroscopy. Integral field spectroscopy is provided over a 9 square arcsecond field via a conventional image slicer.

Imagery and spectroscopy over the 5-29 μ m spectrum is provided by the MIRI instrument (Wright 2008). This instrument provides broad-band imagery, low spectral resolution (1%) long slit spectroscopy, and medium spectral resolution ($\sim 10^3$) integral

field spectroscopy. The imaging mode includes both occulting and quadrant phase mask coronagraphy. The latter type enables very small inner working angle observations of stellar debris disks and exoplanet systems. When used in combination with the NIRSpec instrument, an optimally sampled integral field spectrum covering the whole 0.6 – 29 μ m JWST wavelength range can be obtained at medium spectral resolution.

The detectors for the JWST instruments define the state of art for high performance space flight infrared imaging arrays. The near-infrared instruments utilize HgCdTe 4 Mpixel sensor chip arrays (SCA) operated at ~ 40 K. Zodiacal background limited sensitivity is achieved in all broad-band instrument modes. The MIRI instrument utilizes Si:As 1 Mpixel SCAs operated at ~ 7 K. Significant gains in noise performance and SCA format were achieved over the prior mission state of art (HST/NICMOS & Spitzer/IRAC) during the JWST technology development phase to enable the above mission science goals. The near-infrared SCAs are designed to be edge-butt on three sides to from larger format focal plane array (FPA) assemblies. For example, the NIRC*am* short wavelength channel utilizes a 16 Mpixel FPA consisting of 4 of these SCAs, and the NIRSpec utilizes an 8 Mpixel FPA consisting of 2 SCAs. The mid-infrared SCAs are used individually in 1 Mpixel FPA assemblies.

V. MAKING SURE IT ALL WORKS

Testing at the scale and operating temperature of the JWST requires the largest deep cryogenic (~ 30 K) space simulation facilities in the world. The system is built up and tested in incremental steps in which each subunit is tested before it is integrated into the next higher level of assembly. As integration proceeds, larger and larger facilities are needed. The fully integrated instrument payload will be tested at Goddard Space Flight Center using a telescope simulator (Hagopian 2007, Ohl 2009). After integration with the actual telescope, the whole system is tested in a larger facility at Johnson Space Center (Atkinson 2008). Unlike the Hubble Space telescope, which resides in low earth orbit, the JWST cannot be serviced by astronauts due to its more distant L2 point orbit. However, in contrast to prior space observatories, the JWST telescope and instrument optical systems employ a high degree of freedom for in-flight adjustment (Barto 2008), and lessons learned from prior observatory test programs are carefully taken into account in design of the JWST test program (Feinberg 2008).

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The James Webb Space Telescope Mission

The background of the slide is a composite image of space. In the upper left, a portion of the Earth's blue and white horizon is visible. Below it, the Moon is shown in a dark, cratered phase. The central focus is the James Webb Space Telescope, depicted with its large, gold-colored segmented mirrors and complex support structure. The telescope is oriented towards a vibrant, colorful nebula with shades of blue, purple, and pink. The rest of the background is a deep black space filled with distant stars and the faint glow of the Milky Way galaxy.

Matt Greenhouse

JWST Project Office

NASA Goddard Space Flight Center

16 September 2011

JWST is a general astrophysics mission for use by the international astronomical community

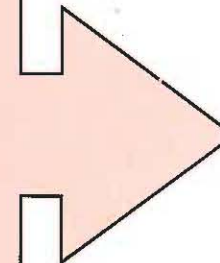
- **Often described as the successor to the Hubble Space Telescope, the JWST will serve astronomers world-wide in much the same way:**
 - Science & mission operations managed by the Space Telescope Science Institute
- **The science investigations performed by the JWST will be determined by the General Observer community.**
 - Observing time allocated through annual peer-reviewed proposal cycles
- **Four science themes have been defined by a succession of international community working groups to guide engineering development of the JWST:**

Identify the first bright objects that formed in the early Universe, and follow the ionization history.

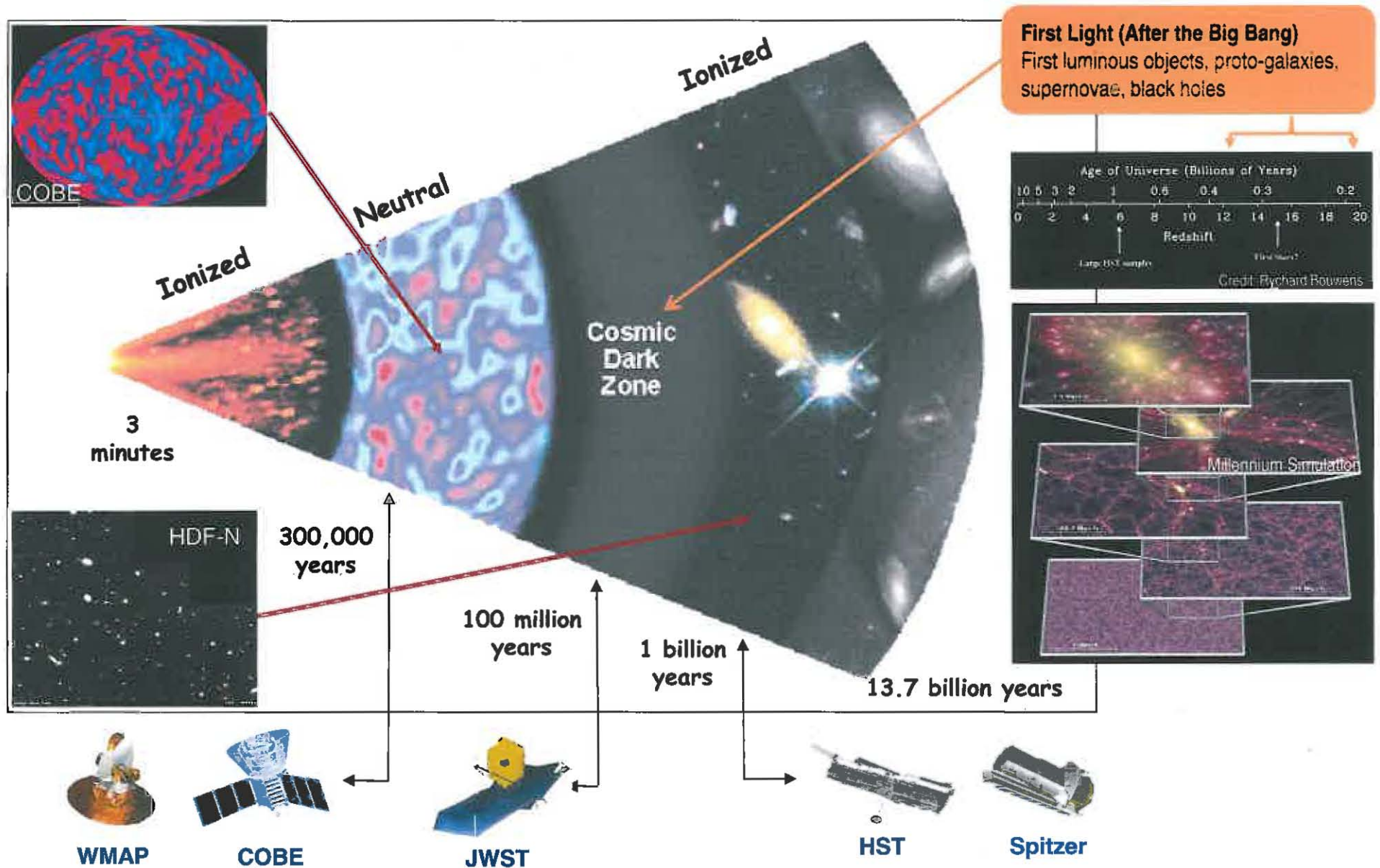
Determine how galaxies and dark matter, including gas, stars, metals, overall morphology and active nuclei evolved to the present day.

Observe the birth and early development of stars and the formation of planets.

Study the physical and chemical properties of solar systems (including our own) and where the building blocks of life may be present.

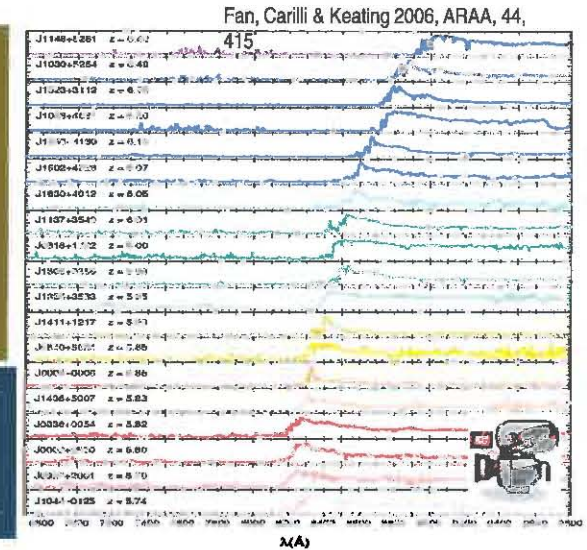
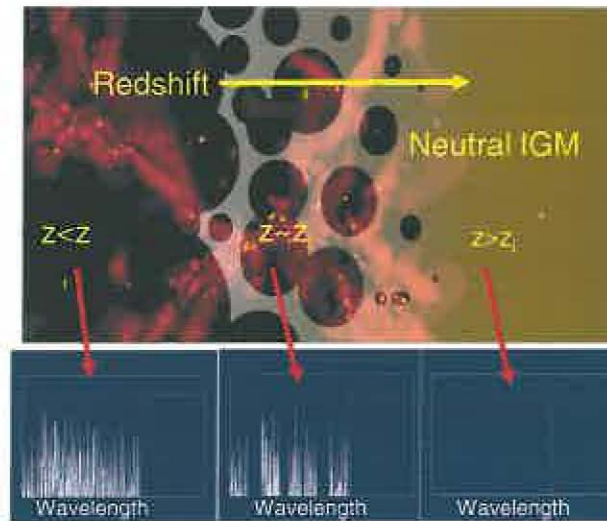


JWST is designed to observe formation of the first galaxies

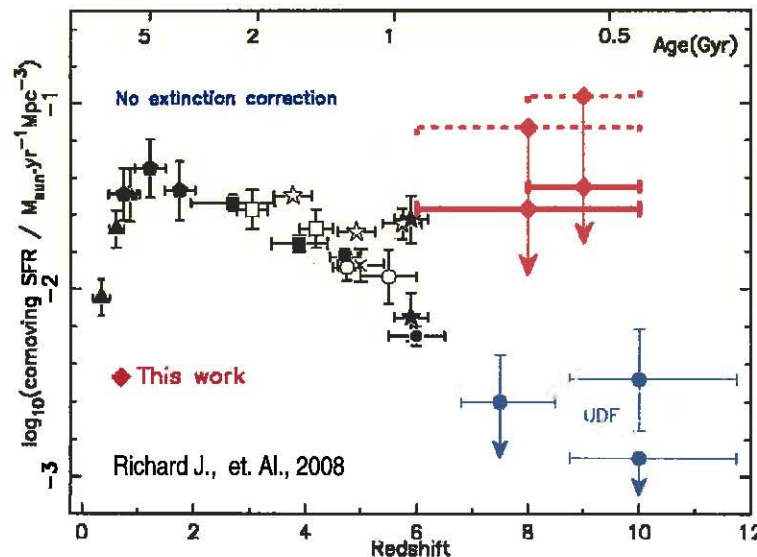


Key questions about the galaxy formation era:

- How did black holes form and interact with their host galaxies?
- What is the nature of the first galaxies?
- When did re-ionization of the inter-galactic medium occur?
- What caused the re-ionization?



$z = 7.6$ (Bradley & Illingworth 2008)

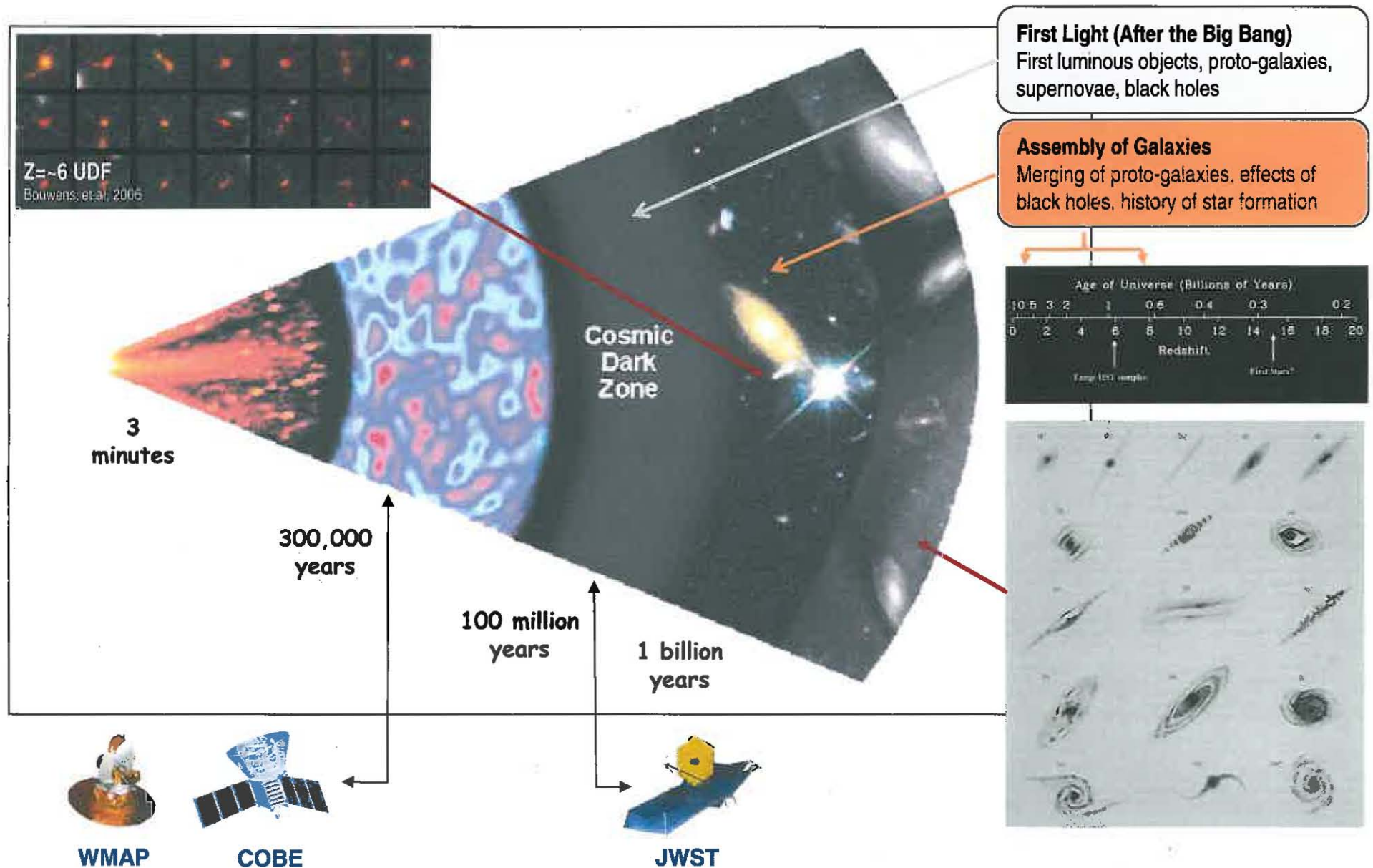


Key Enabling Design Requirements:

- Deep near-infrared imaging survey (1nJy)
- Near-IR multi-object spectroscopy
- Mid-IR photometry and spectroscopy

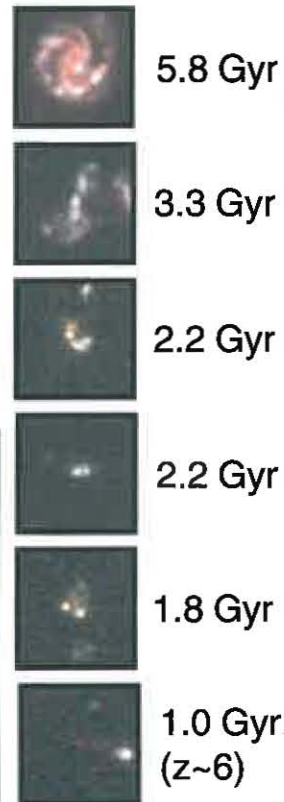
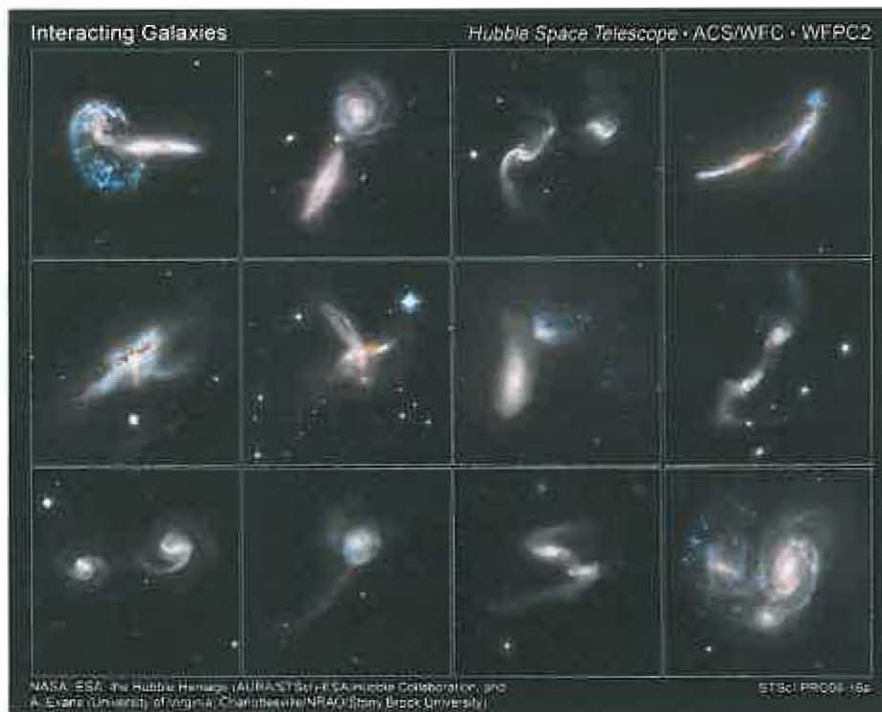
Redshift z	m_{AB}	F_v (nJy)	Lyman Break wavelength
0			0.12 μm
10	30.3	2.8	1.34 μm
15	30.9	1.6	1.95 μm
20	31.3	1.1	2.55 μm

JWST is designed to observe the evolution of galaxies



Key questions about galaxy evolution:

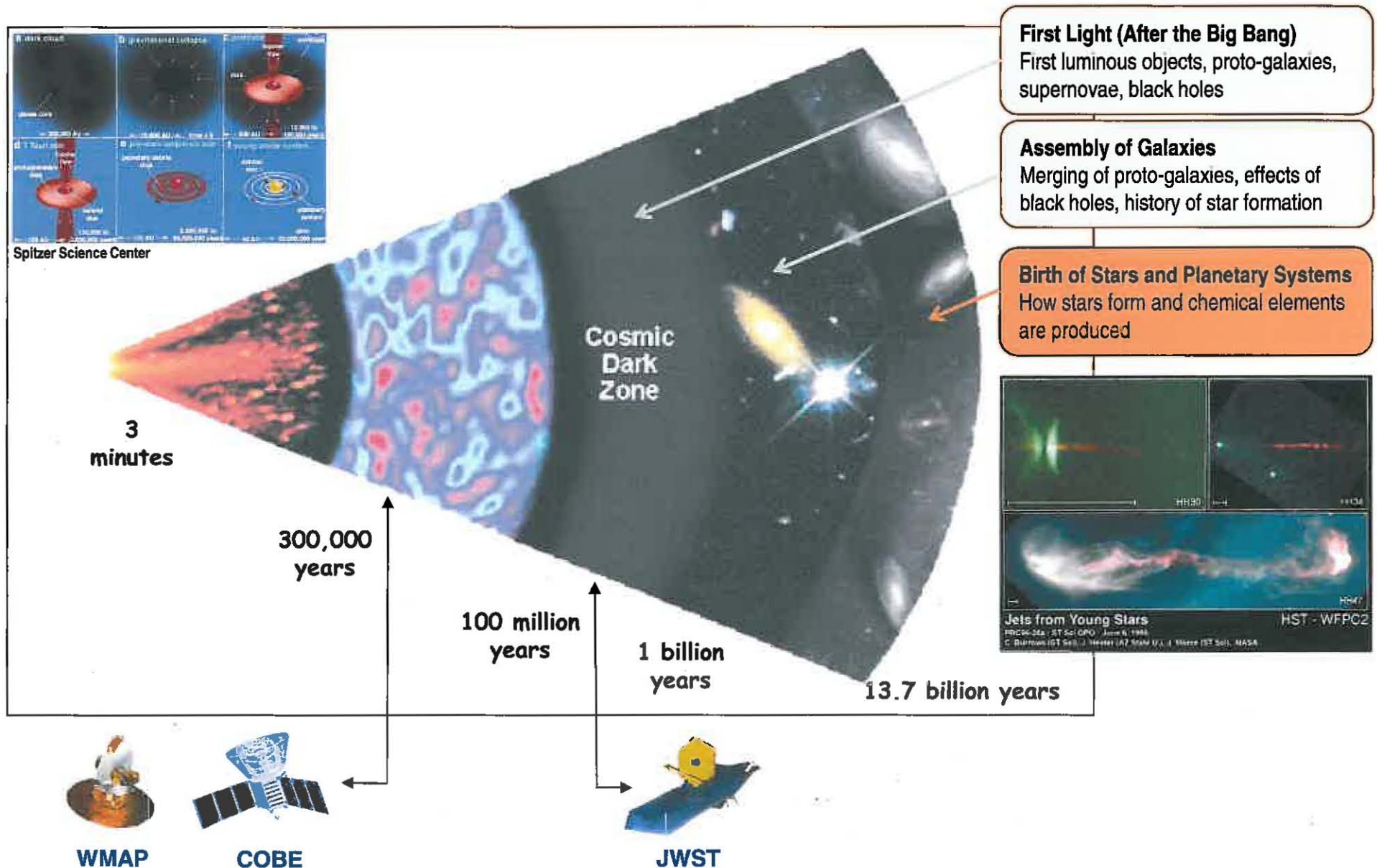
- When did the Hubble Sequence form?
- What role did galaxy collisions play in their evolution?
- How is the chemical evolution of the universe related to galaxy evolution?
- What powers emission from galaxy nuclei?



Key Enabling Design Requirements:

- Wide-area near-infrared imaging survey
- Low and medium resolution spectra of 1000s of galaxies at high redshift
- Targeted observations of galactic nuclei

JWST will observe how stars form in our galaxy

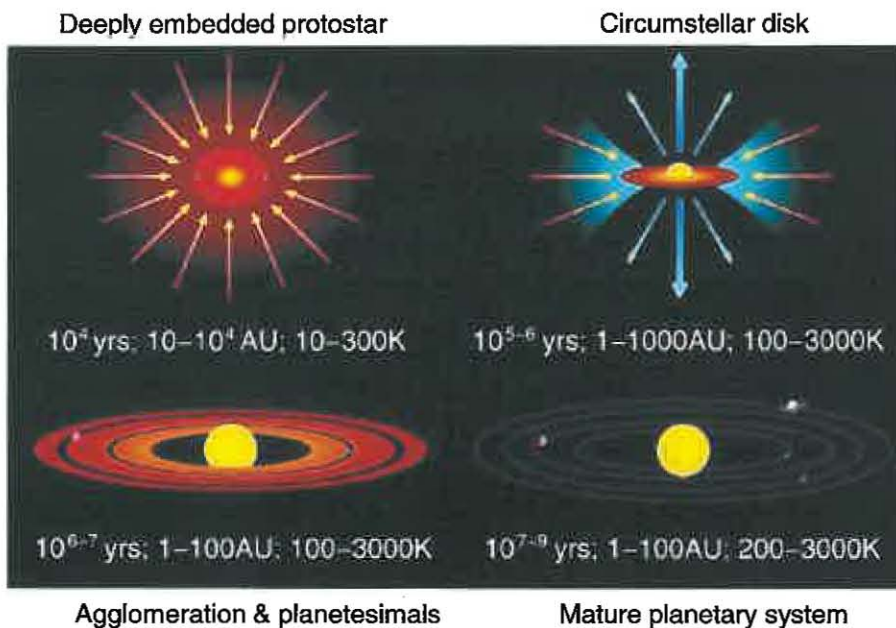


Key questions about star formation:

- How do molecular clouds collapse?
- How does environment affect star-formation?
 - Vice-versa?
- What is the mass distribution of low-mass stars?
- What do debris disks reveal about the evolution of terrestrial planets?



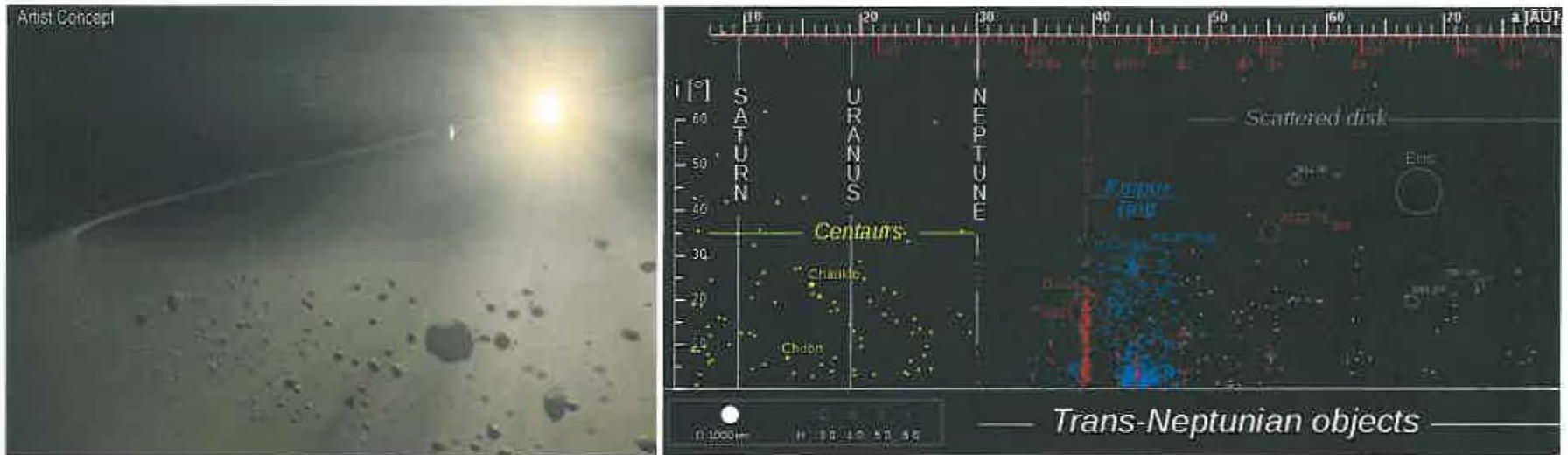
The Eagle Nebula as seen in the near-infrared



Key Enabling Design Requirements:

- High angular resolution near- and mid-IR imagery
- High angular resolution imaging spectroscopy

JWST will observe how planetary systems form and evolve



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

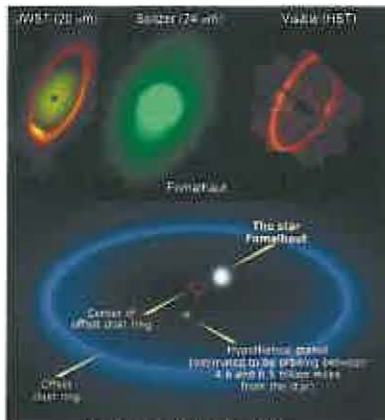
Planetary Systems & Origins of Life

Formation of planets

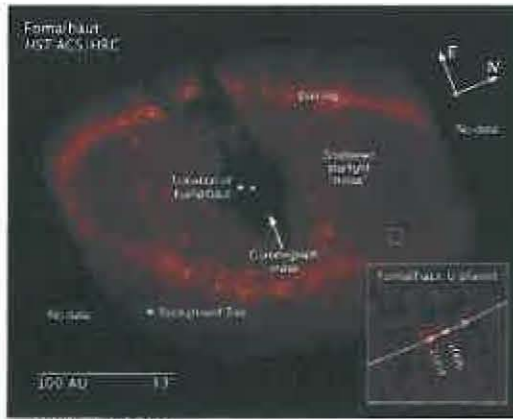


Key questions about planet formation:

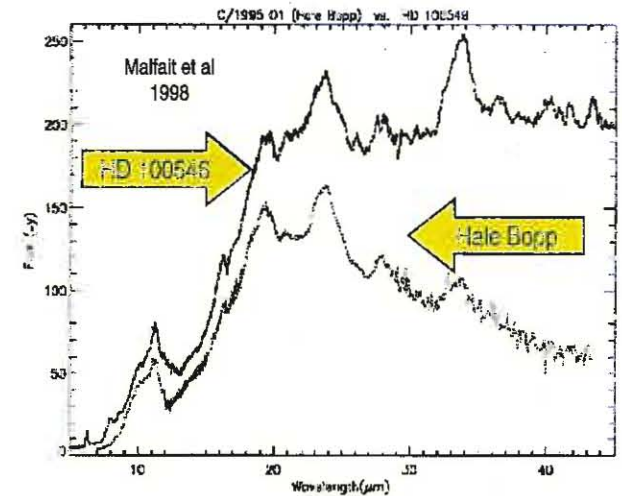
- How do planets form?
- How are circumstellar disks like our Solar System?
- How are habitable zones established?



Kalas, Graham & Clampin 2005

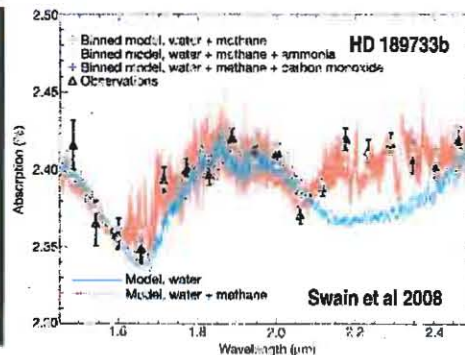


Kalas et al 2008

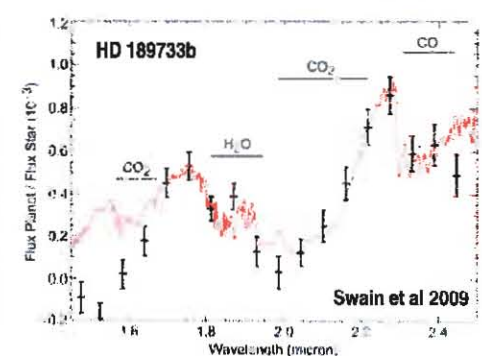
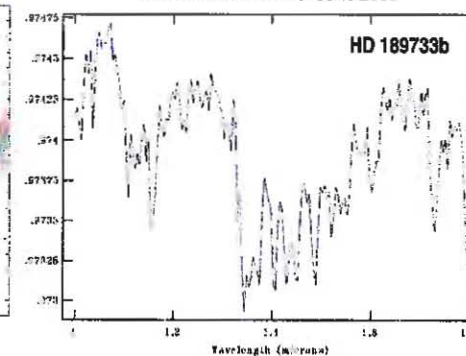


Key Enabling Design Requirements:

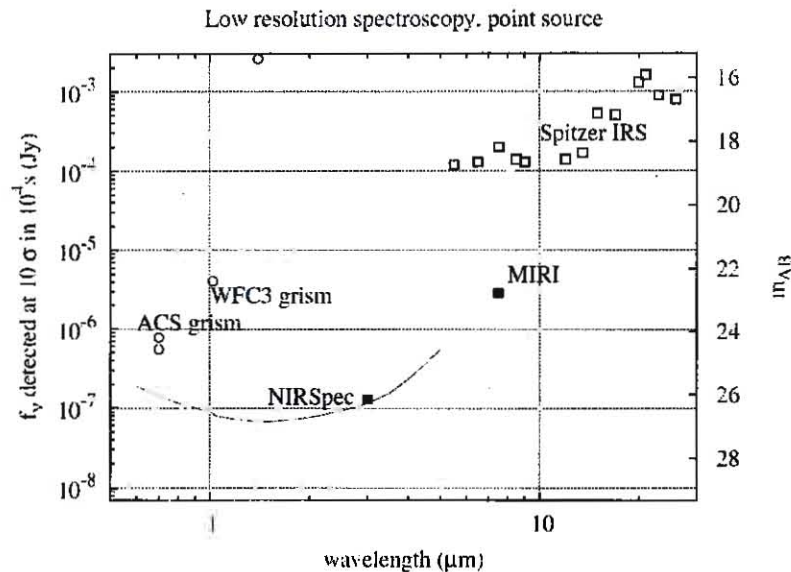
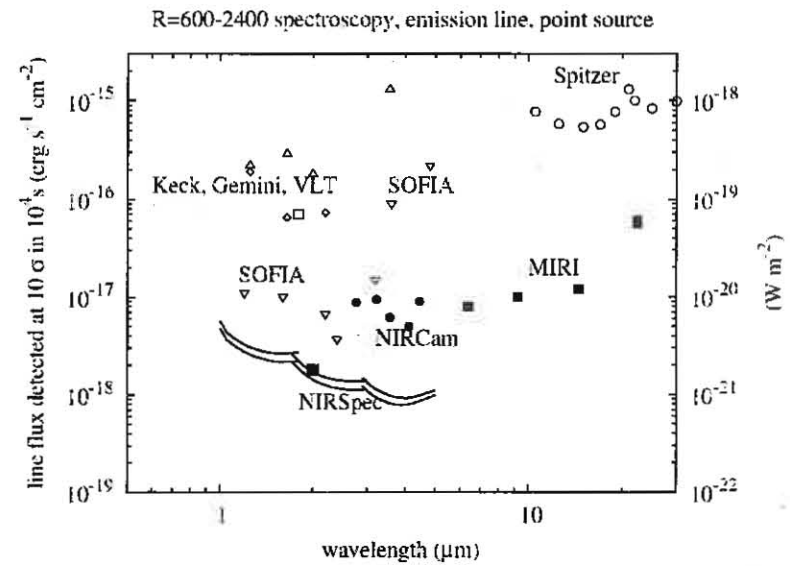
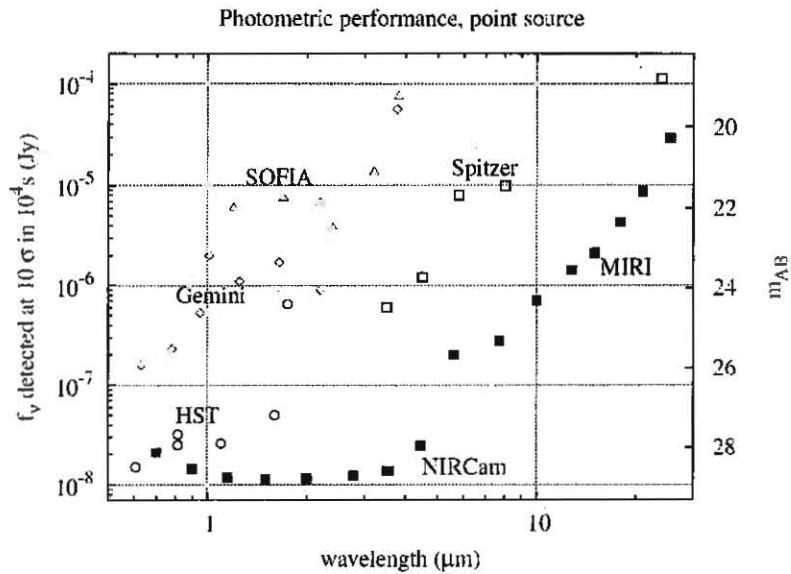
- Near- and mid-IR coronagraphic imagery
- Near- and mid-IR spectroscopy
- High cadence sub-array imagery & spectroscopy



JWST simulation: Greene 2009



The JWST will achieve unprecedented sensitivity over the 0.6 – 29 micron spectrum



See more at:
<http://www.stsci.edu/jwst/science/sensitivity>

JWST requires the largest cryogenic telescope ever constructed

To observe the early universe, the JWST mission requires:

7X the light gathering capability of the Hubble Space Telescope

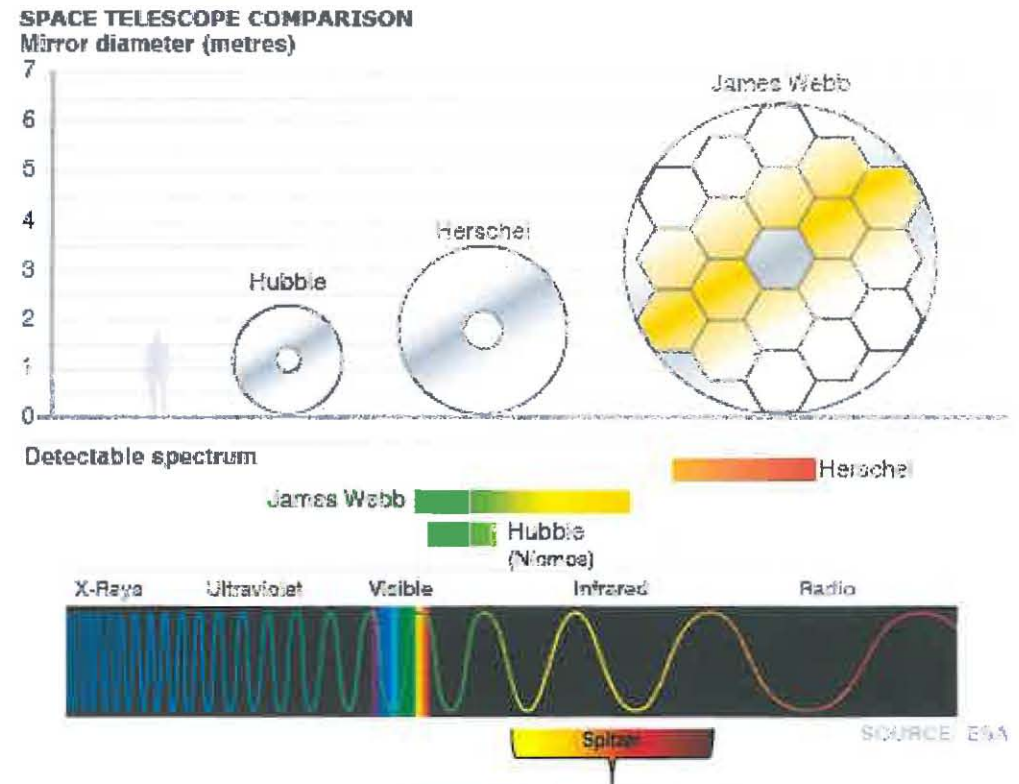
similar angular resolution in the near-infrared spectrum

wavelength coverage spanning the optical to mid-infrared spectrum

As a consequence, the observatory requires:

a primary mirror that is larger in diameter than available rocket fairings

a high stability 40-50K cryogenic operating temperature

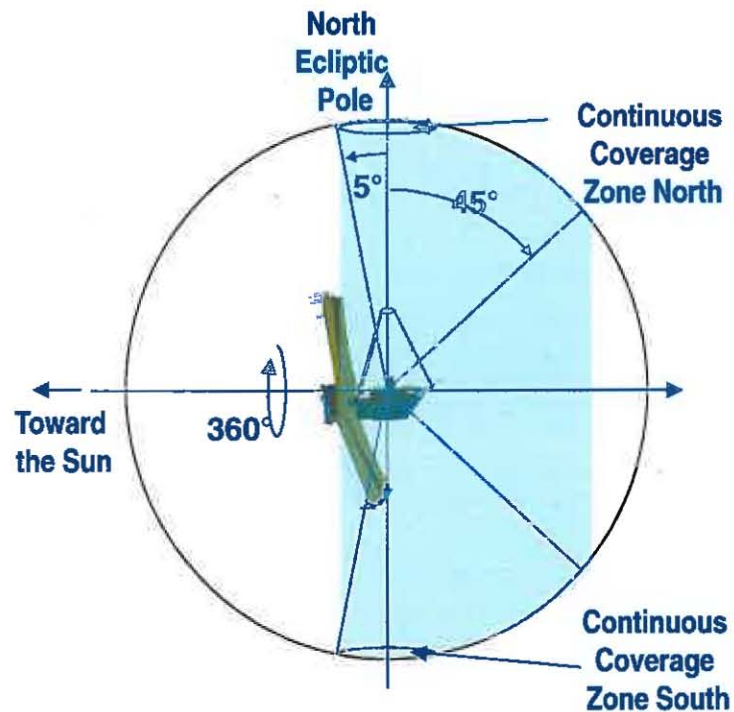
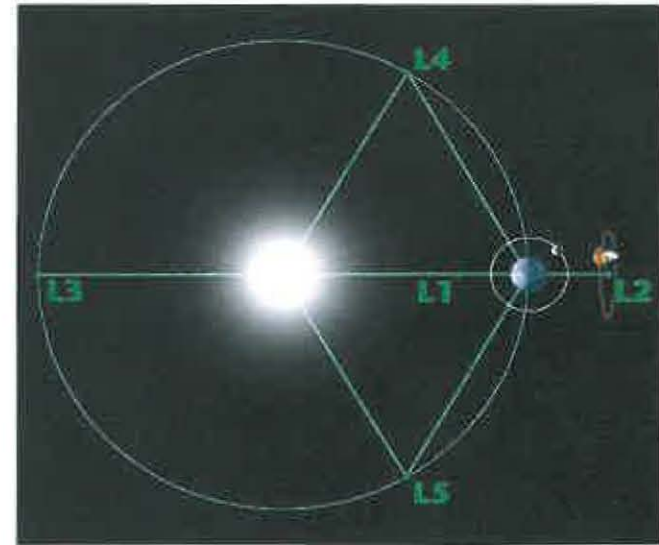


1'x1' region in the UDF
3.5 to 5.8 um



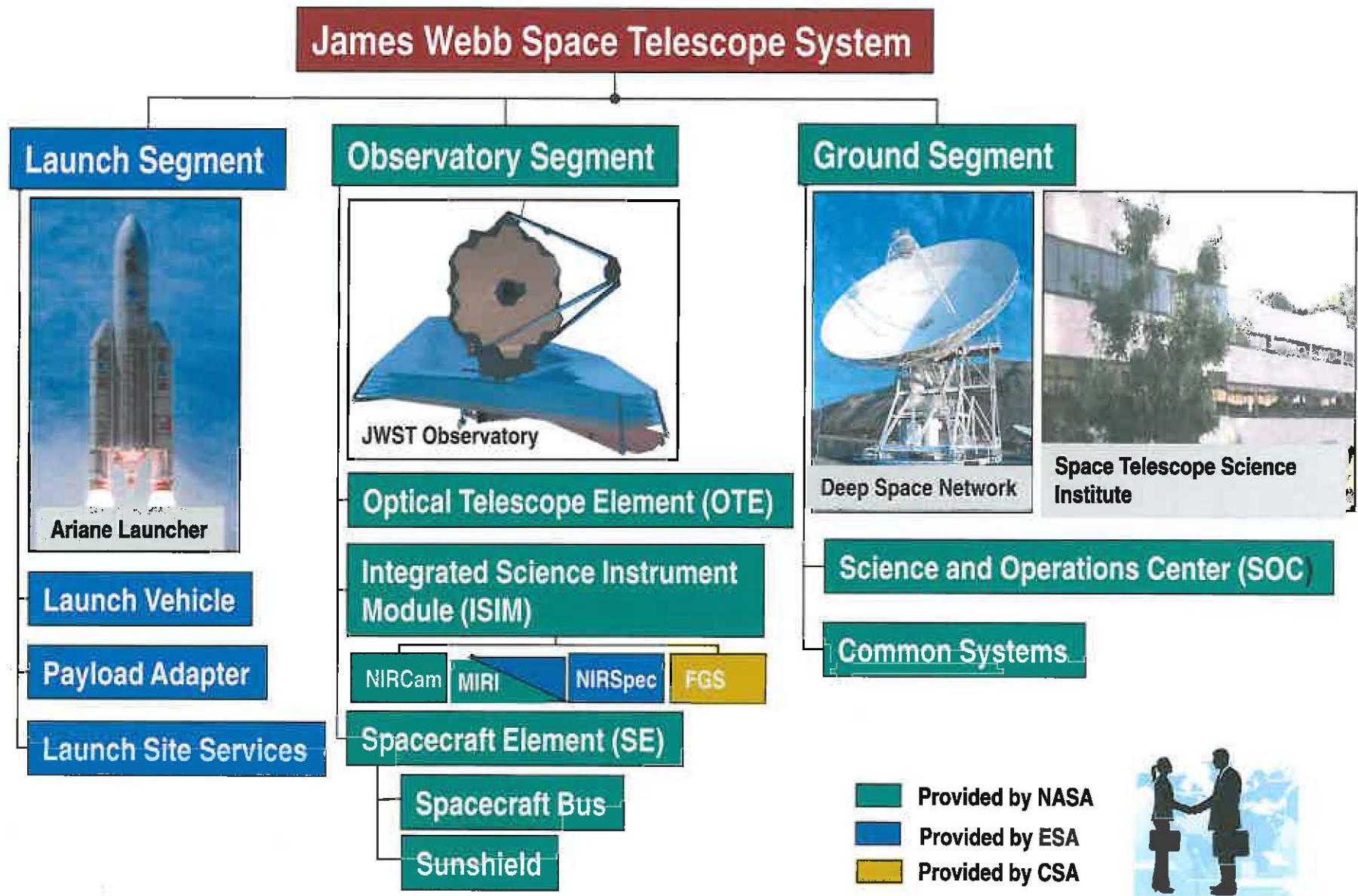
The JWST will be placed in orbit about the Sun-Earth L2 point approximately 1.5 million km from Earth

- 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)



- 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



Optical Telescope Element (OTE)

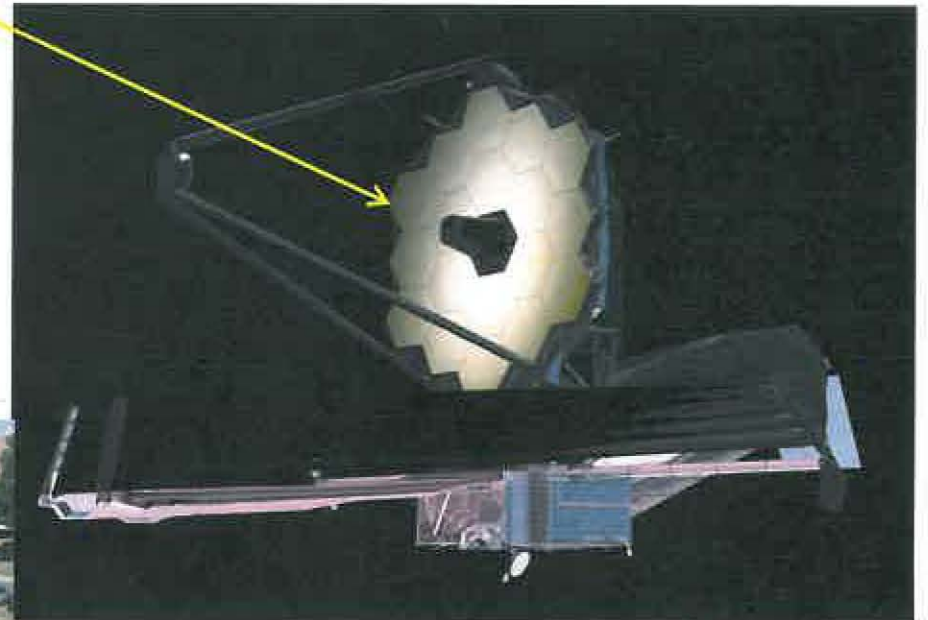
Collects star light from distant objects

Integrated Science Instrument Module (ISIM)

Extracts physics information from star light

Spacecraft

Attitude control, telecom, power & other systems



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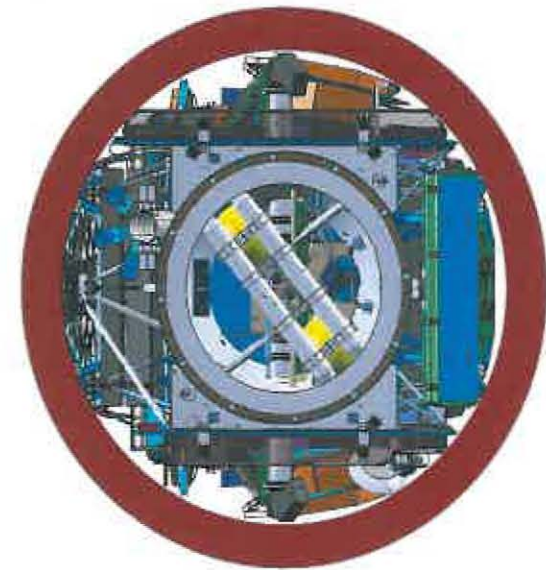
JWST requires a segmented deployable primary mirror

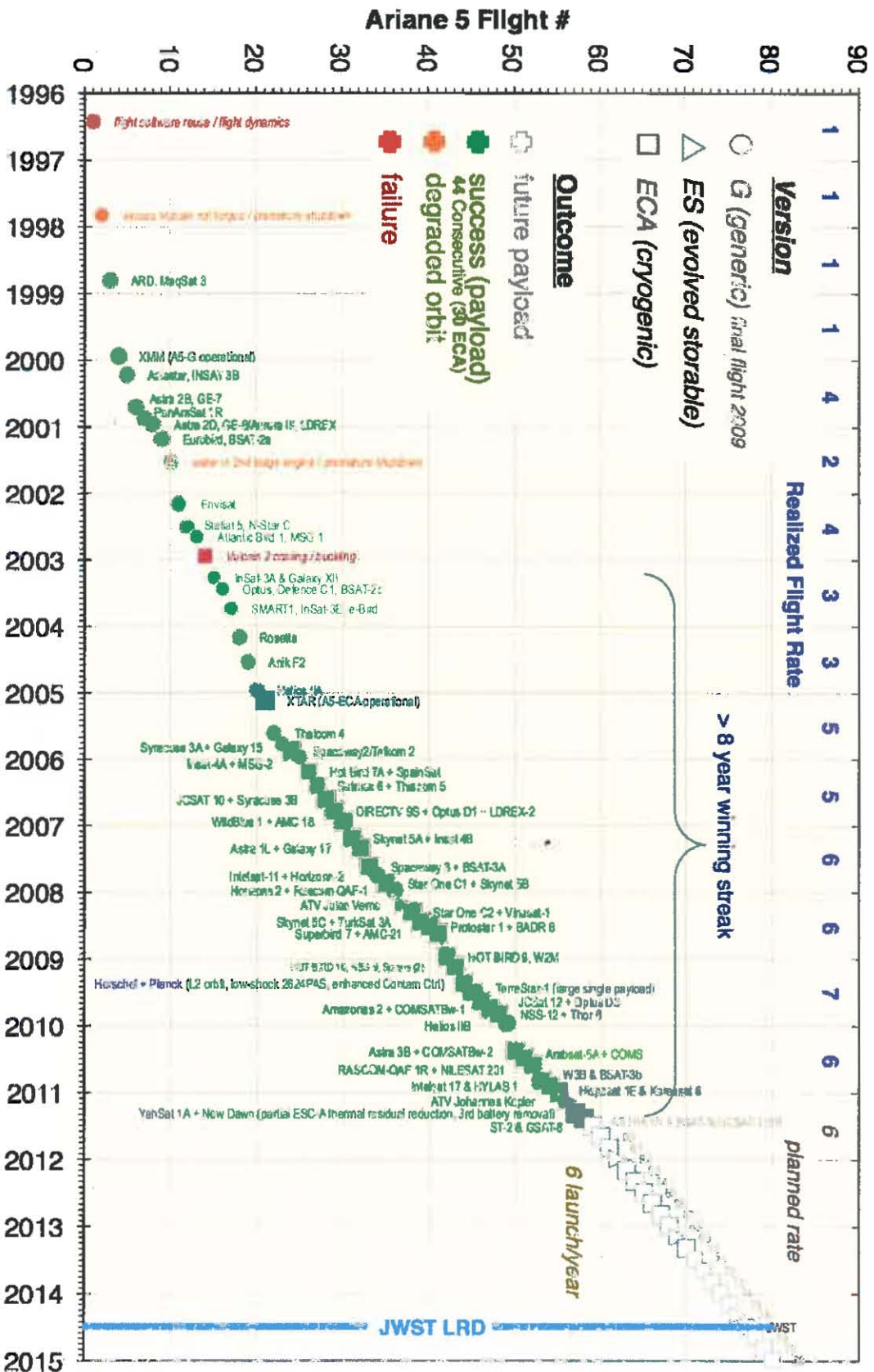


Ariane 5 ECA



- 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: 6330 kg

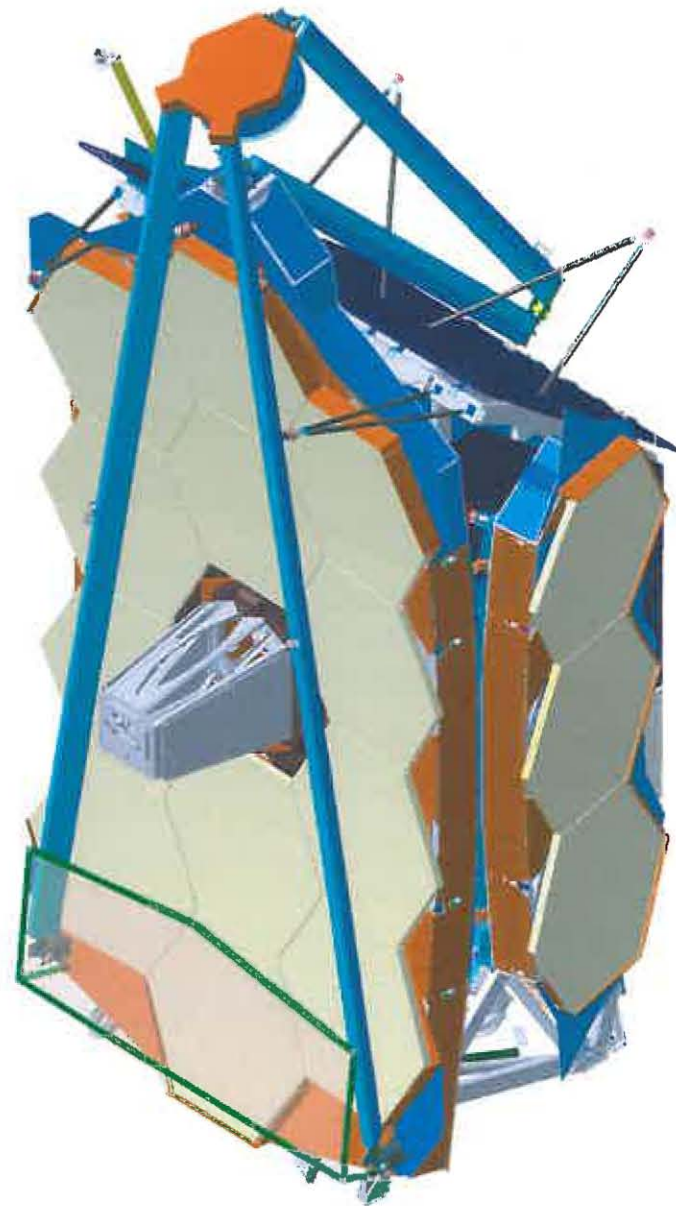
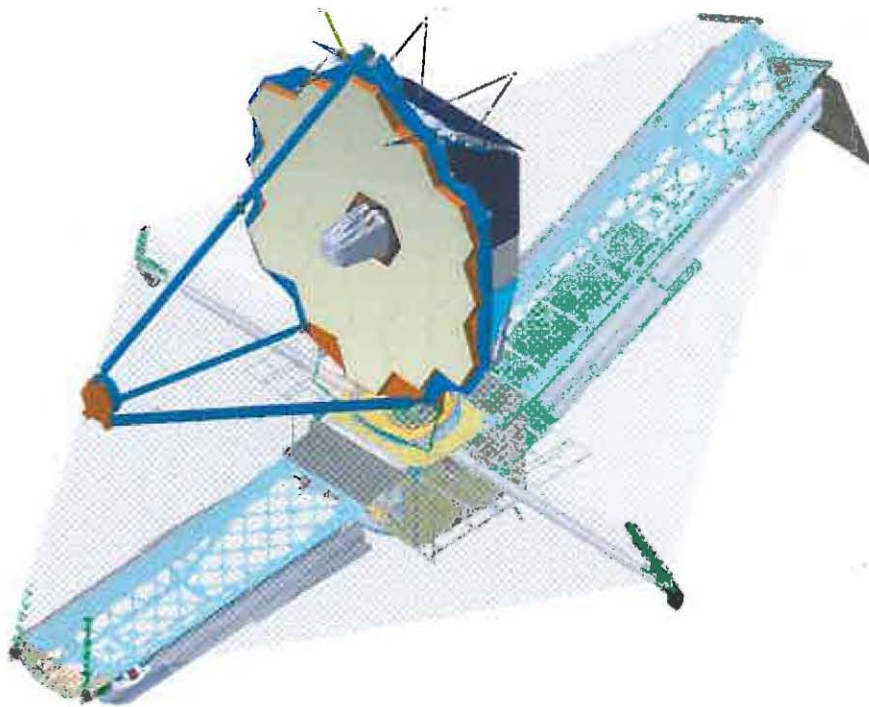




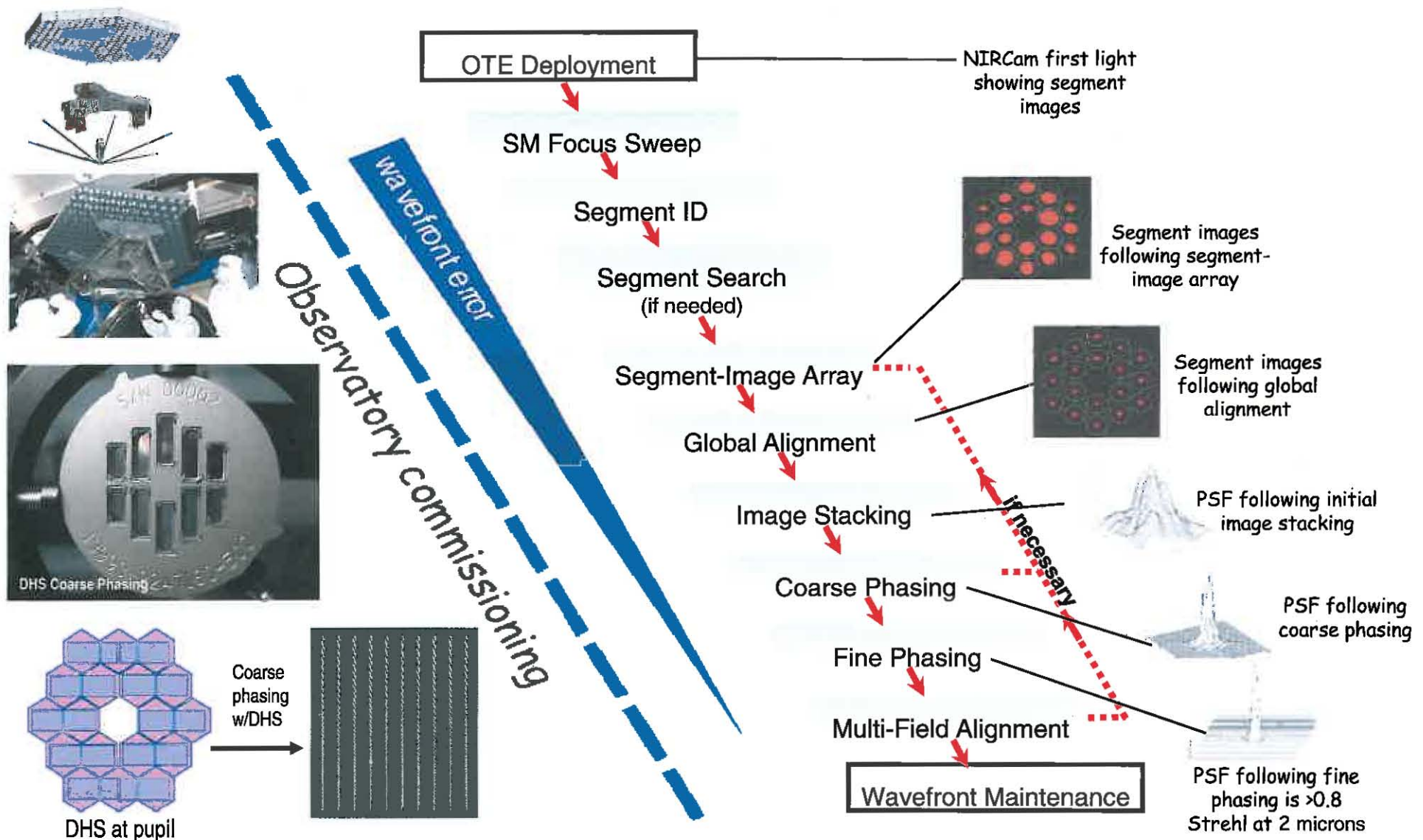
Deployment Sequence Overview



Click video



The mirror segment mounts are mechanized, and a wavefront control system will be used to adjust each segment during flight enabling them to perform together as a single large mirror.



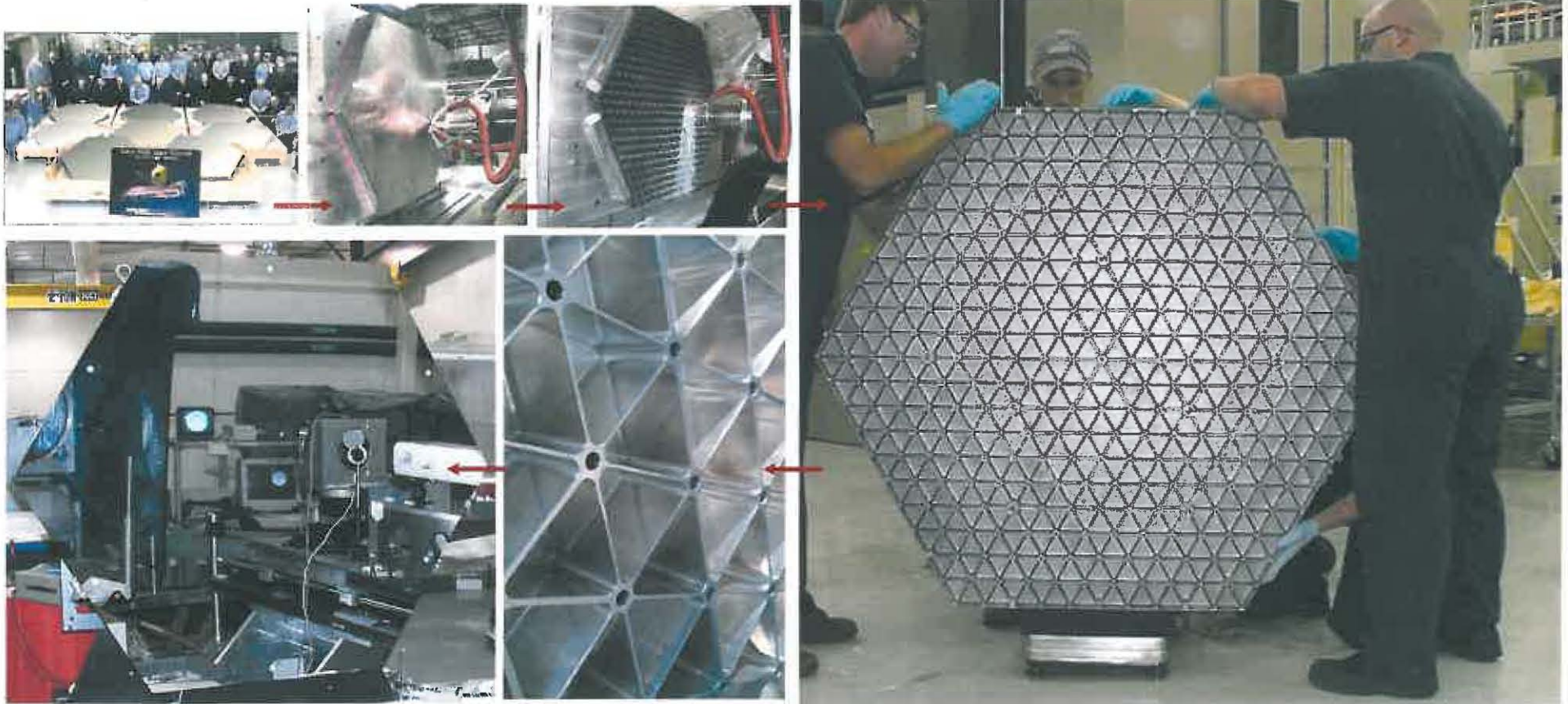
The telescope mirrors are fabricated from Beryllium

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

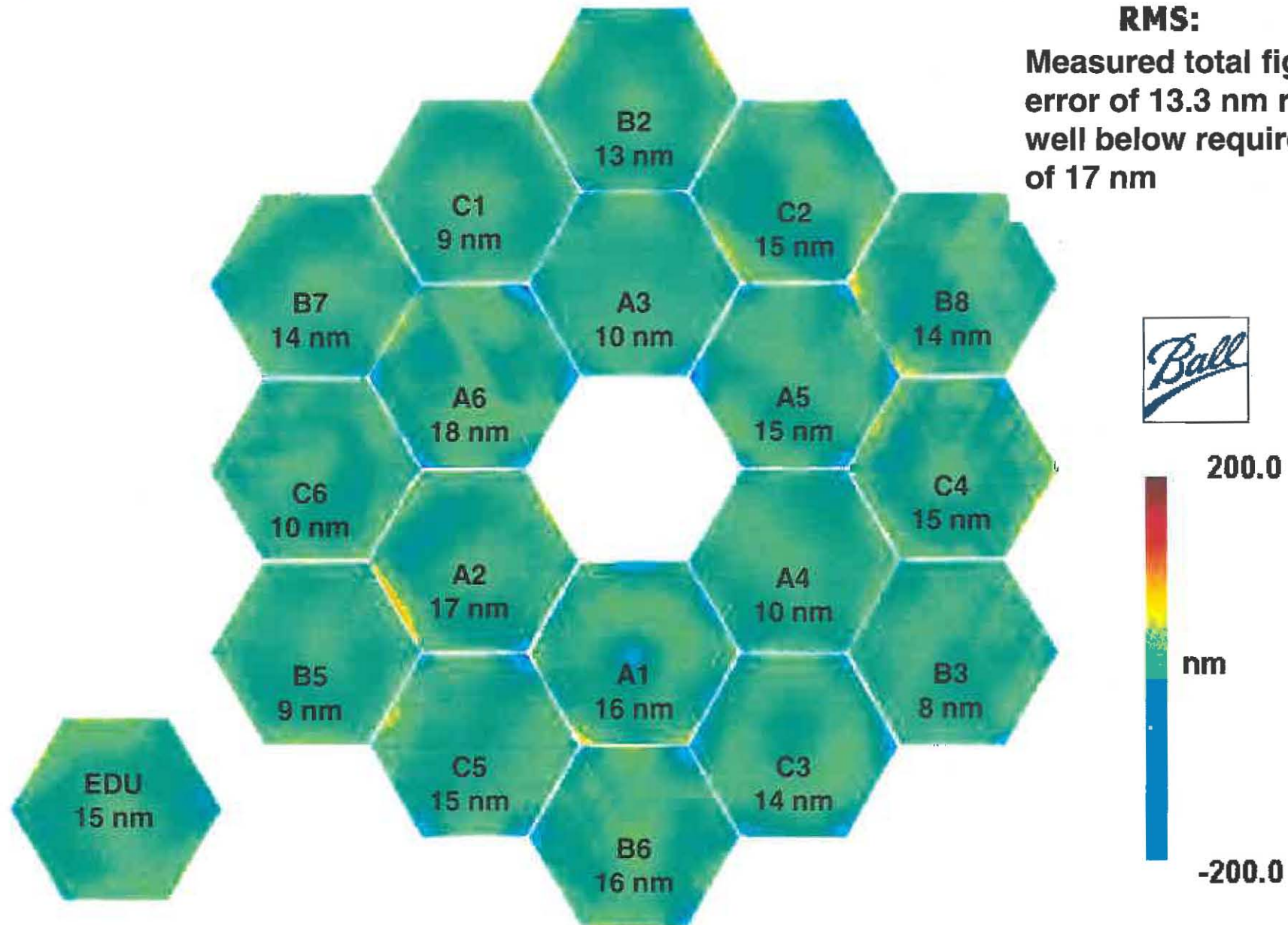
Primary mirror mass properties

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



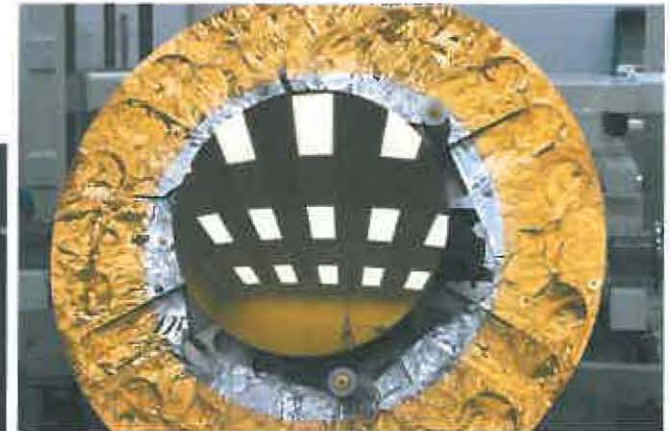


Primary mirror polishing and gold coating is completed

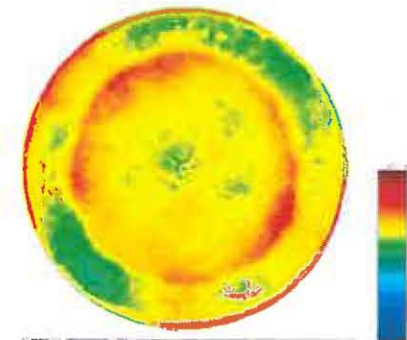




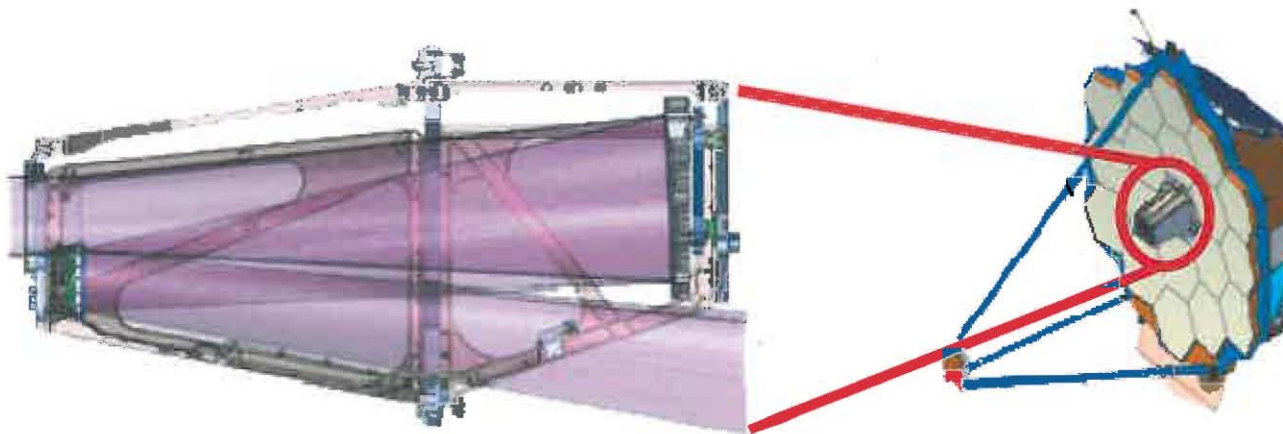
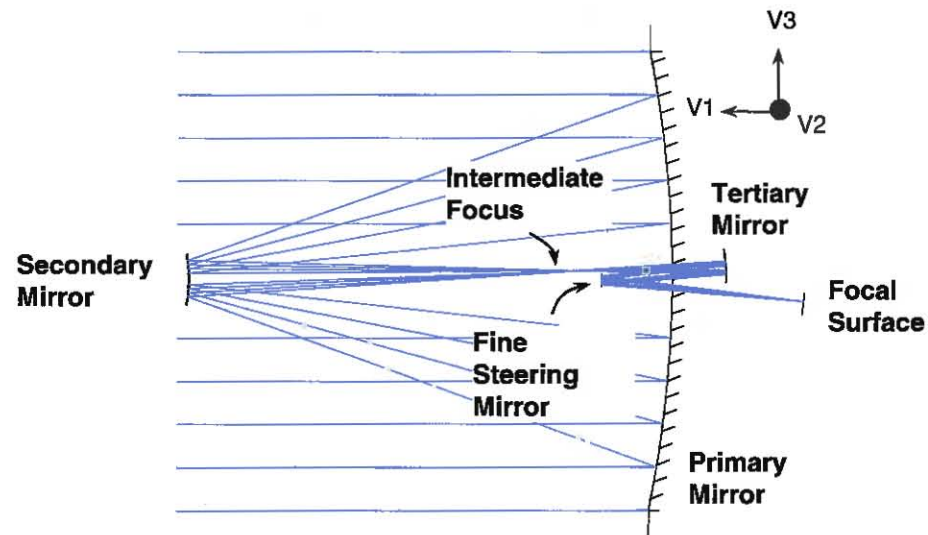
The secondary mirror has completed processing



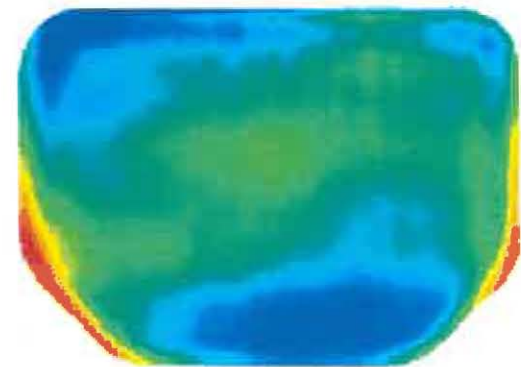
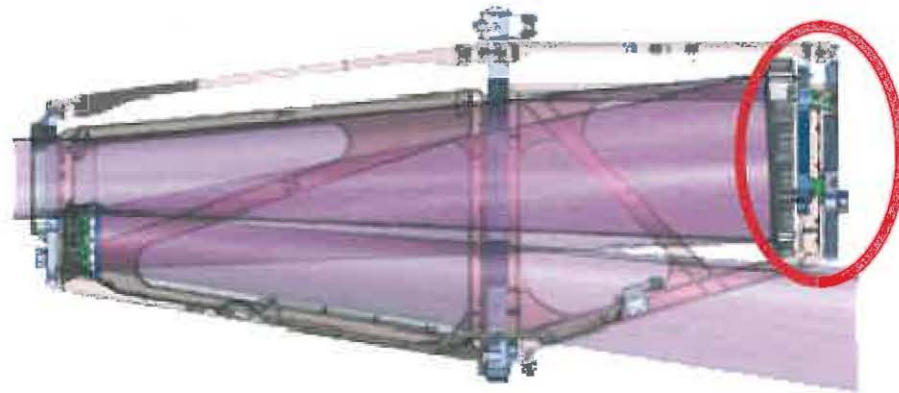
Description	Requirement	Measured
Low Frequency RMS	19 nm RMS	4.5 nm
Mid Frequency RMS	6 nm RMS	3.9 nm
High Frequency RMS	4 nm RMS	2.9 nm



The JWST telescope is a three mirror anastigmat equipped with a fine steering mirror

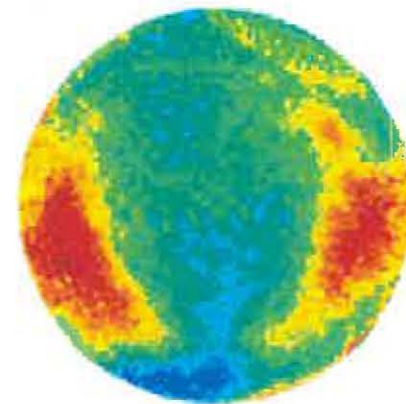
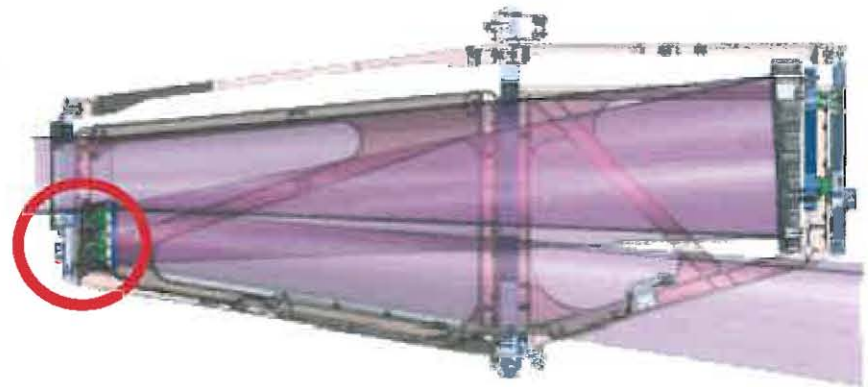
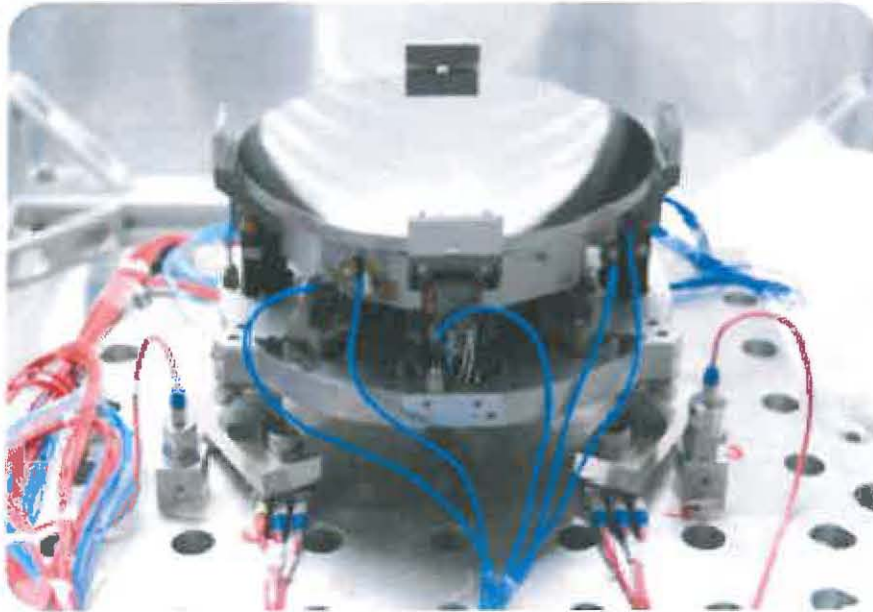


The tertiary mirror has completed processing



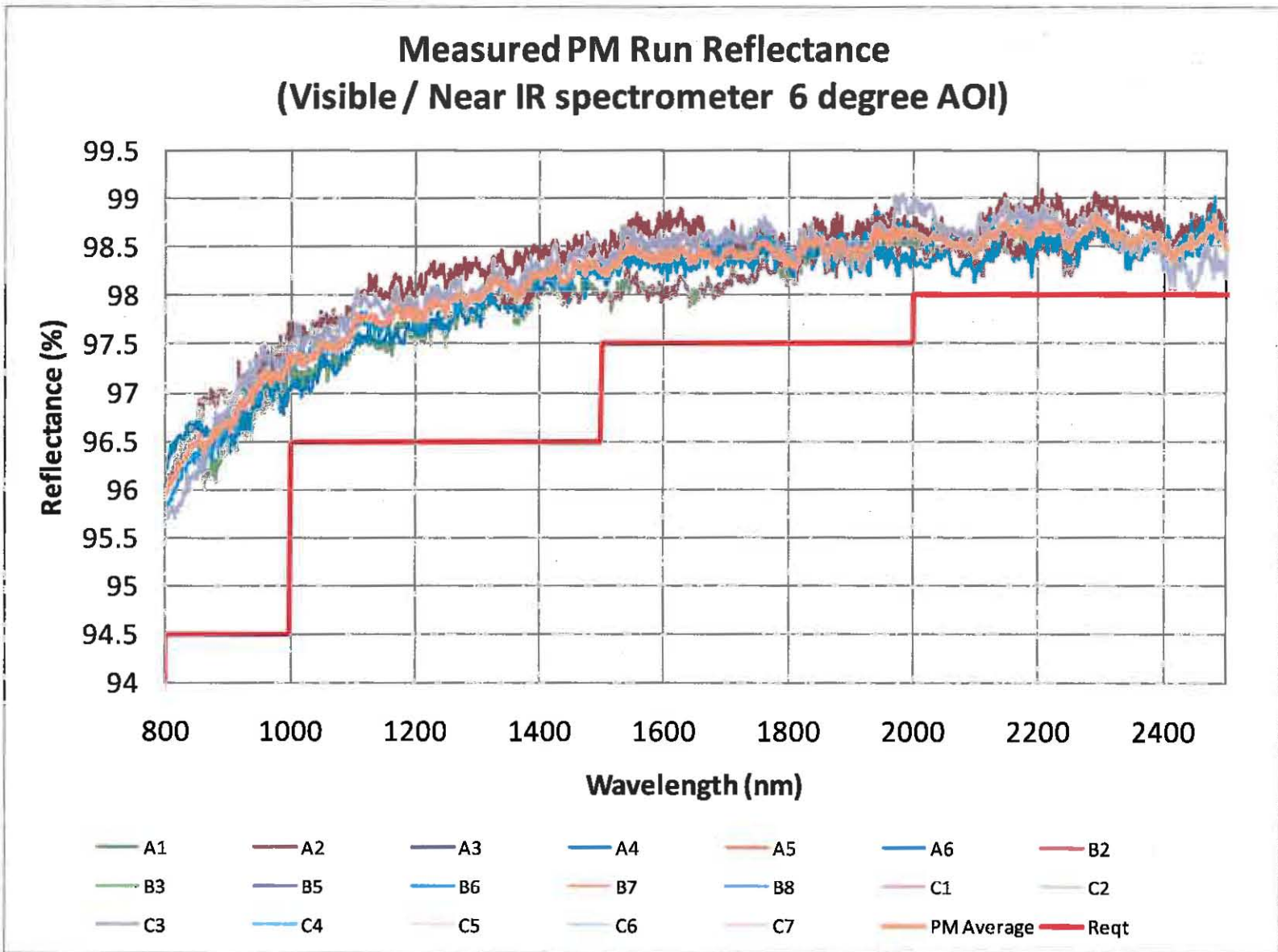
58 nm rms

The fine steering mirror has completed processing



2.3 nm rms

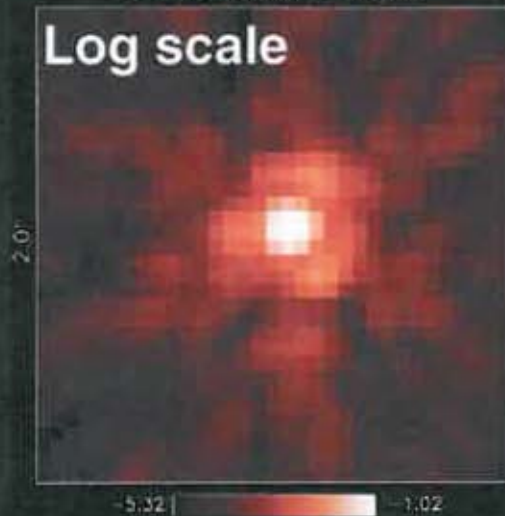
Telescope mirror coatings exceed reflectivity requirements



Predicted image quality meets requirements

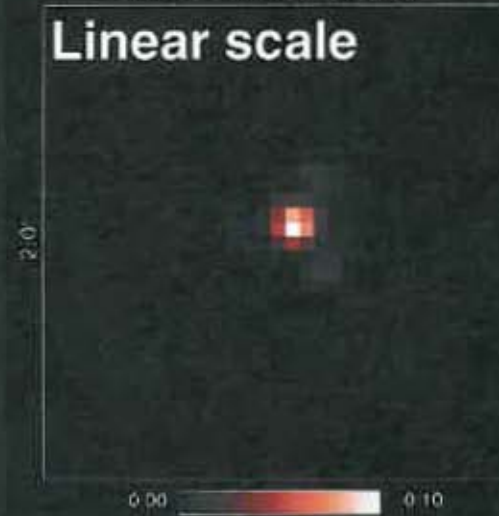
stretched image: psf_j_F200_w150p015_v_date022310_XRCF
bin size: 0.030" x 0.030"

Log scale



stretched image: psf_j_F200_w150p015_v_date022310_XRCF
bin size: 0.030" x 0.030"

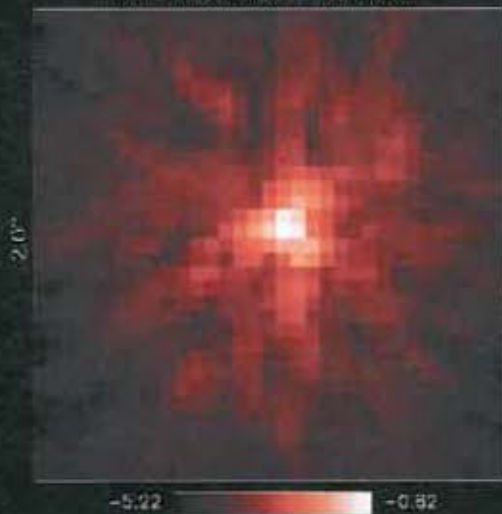
Linear scale



2 μ m (diffraction limited, Nyquist sampled by NIRCam)

2.0" x 2.0" box

stretched image: psf_j_F115_w150p015_v_date022310_XRCF
bin size: 0.030" x 0.030"



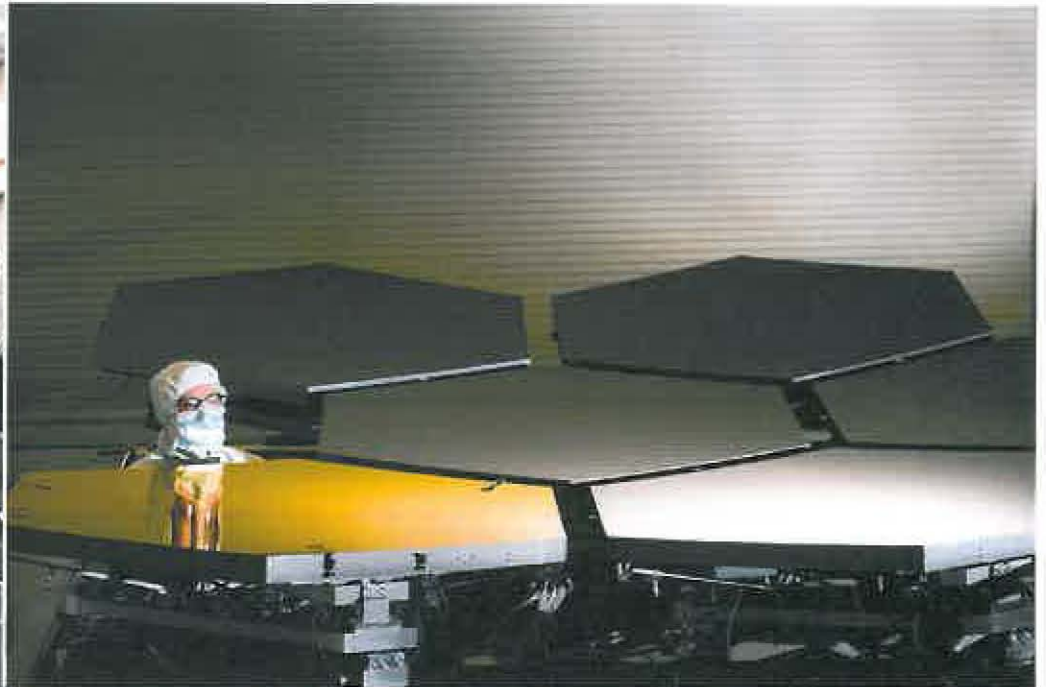
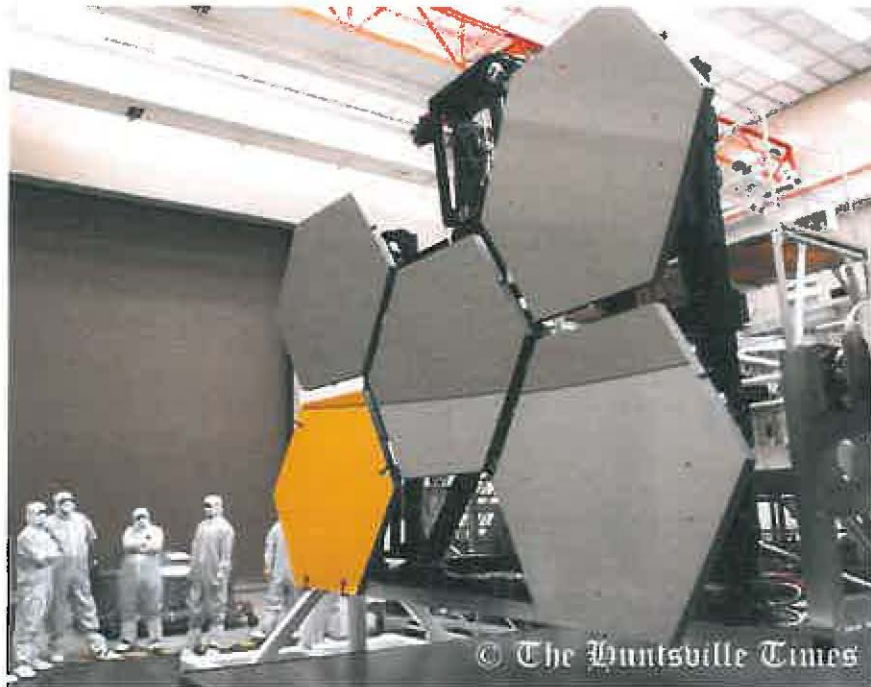
stretched image: psf_j_F115_w150p015_v_date022310_XRCF
bin size: 0.030" x 0.030"



1 μ m (Sub-Nyquist sharp core 0.03 arcsec, requires dithering)

2.0" x 2.0" box

A specially instrumented space simulation chamber at MSFC is used to optically test the primary mirror segments at 50 K (-225 C, -370 F)

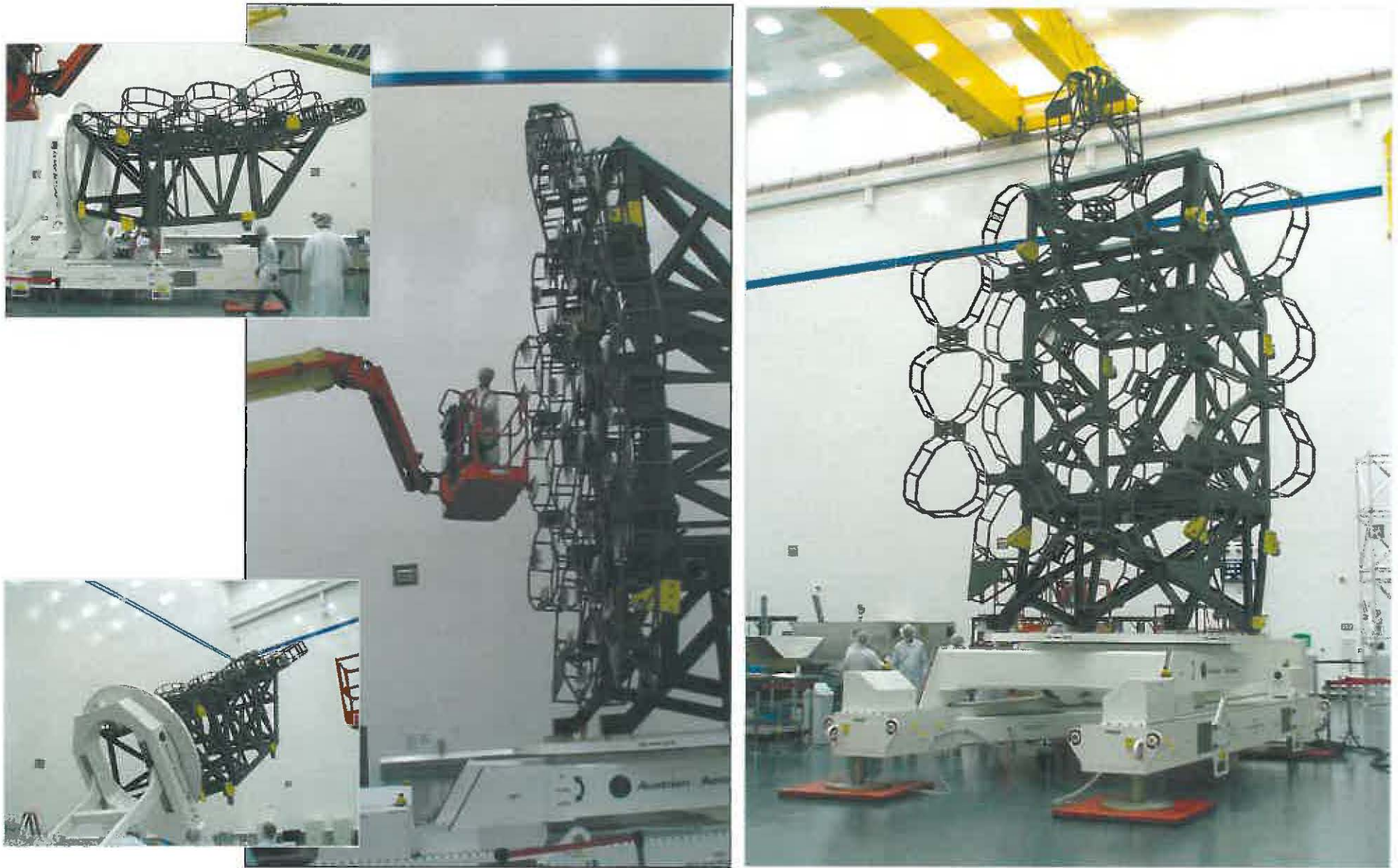


Buildup of telescope flight structure is nearing completion

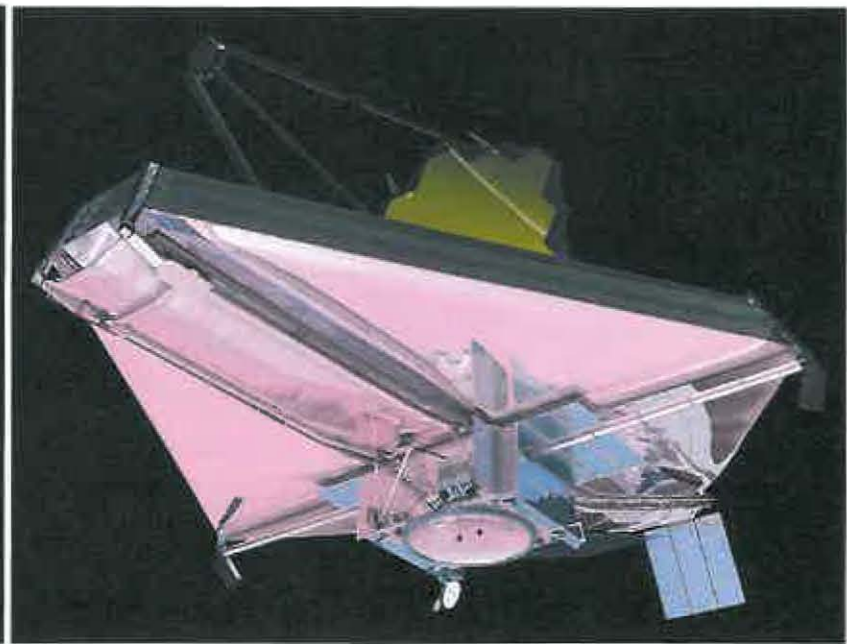
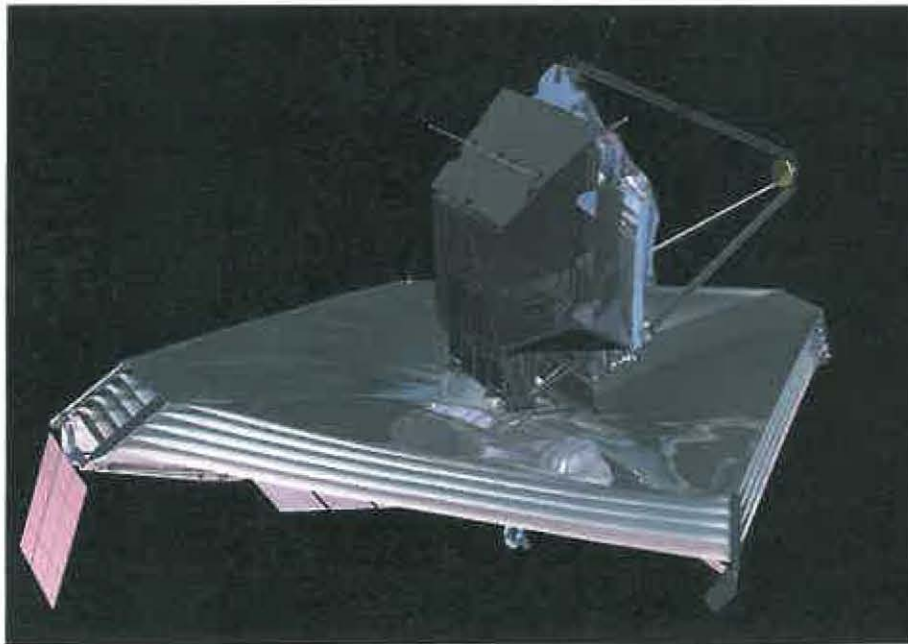
Assembly consists of ~3,200 bonded composite piece parts



Full scale OTE mockup in handling test at NGAS



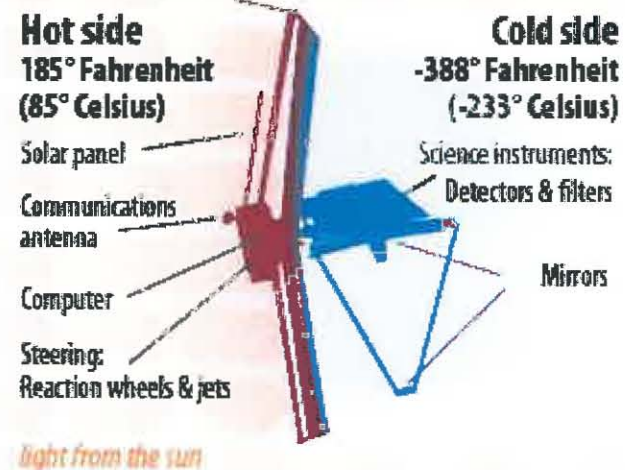
The JWST's 5 layer sunshield has an SPF of $\sim 10^6$



Sunshield Facts

- Measures 73 x 40 feet and has 5 layers
- Contains 400 temperature sensors
- Made of heat-resistant kapton
- Coated with silicon on sun side
- Sun side reaches 358 K (85° C)
- Dark side stays at 40 K (-233° C)

The Two Sides of the Webb Telescope



Sunshield thermal performance has been validated by a 1/3 scale test in a space simulation chamber



Optical Telescope Element (OTE)

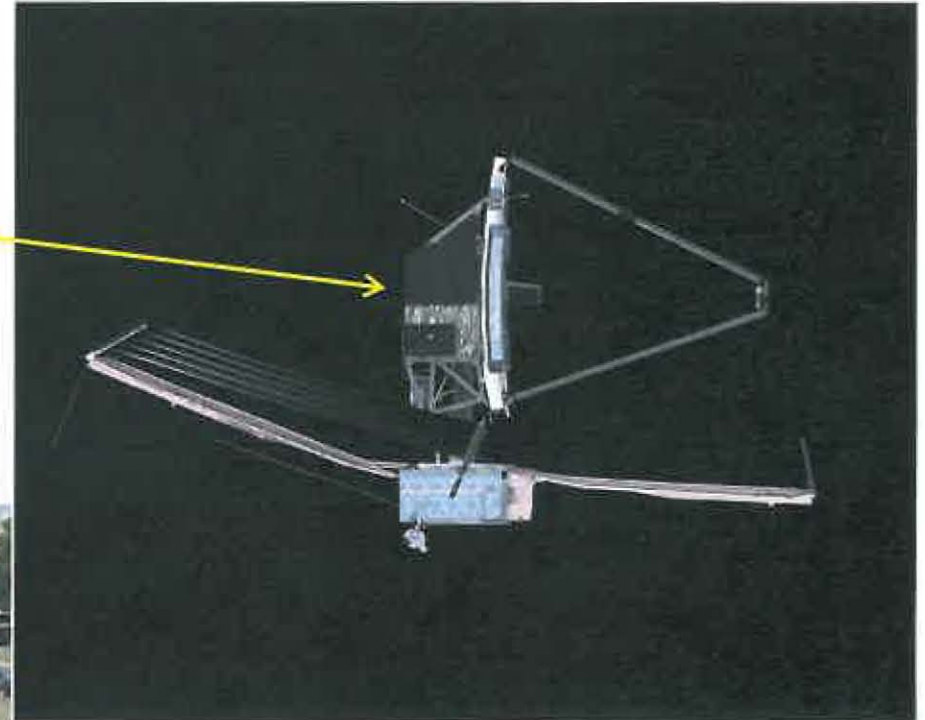
Collects star light from distant objects

Integrated Science Instrument Module (ISIM)

Extracts physics information from star light

Spacecraft

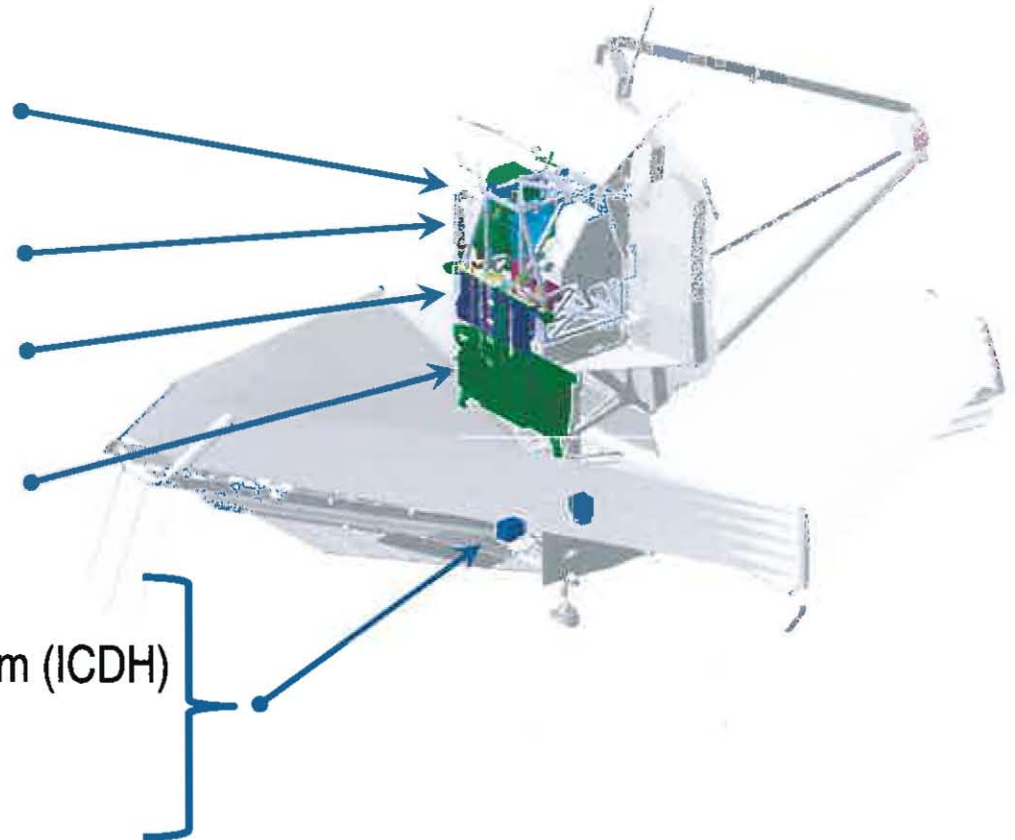
Attitude control, telecom, power & other systems



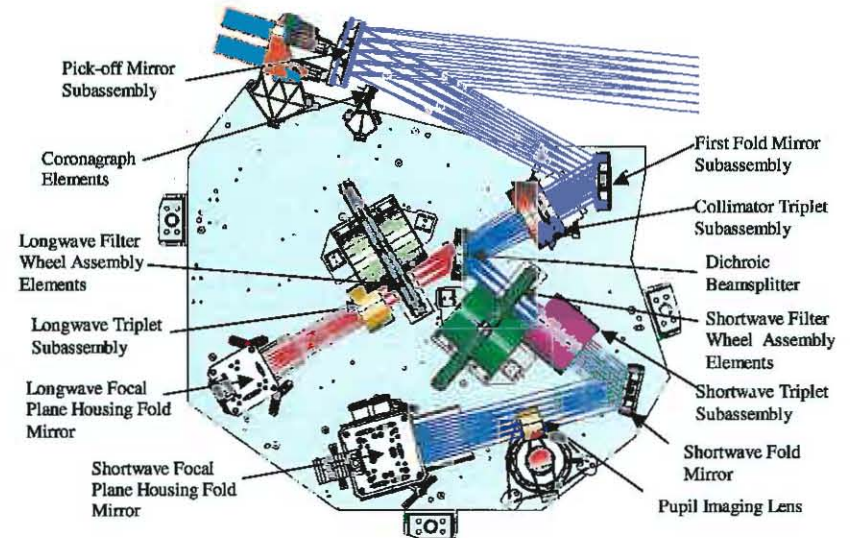
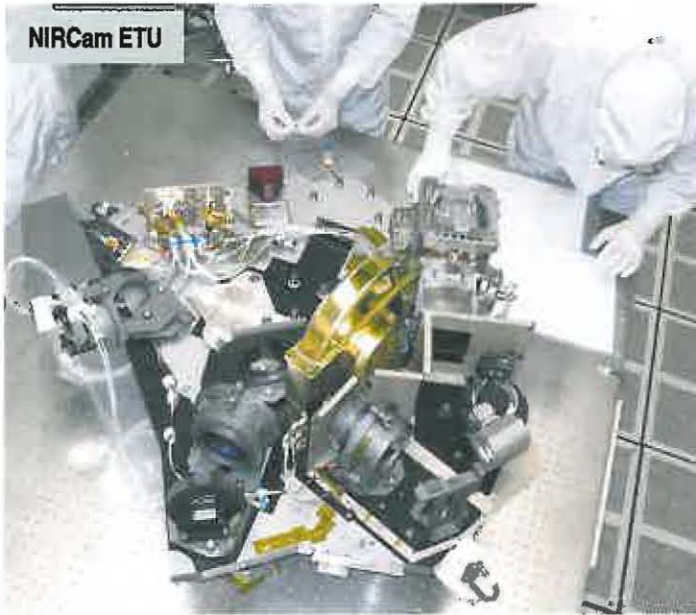
16 Sep 2011

ISIM is the science instrument payload of the JWST

- **ISIM is one of three elements that together make up the JWST space vehicle**
 - Approximately 1.4 metric tons, ~20% of JWST by mass
 - Completed CDR during 2009
- **The ISIM system consists of:**
 - Four science instruments
 - Nine instrument support systems:
 - Optical metering structure system
 - Electrical Harness System
 - Harness Radiator System
 - ISIM electronics compartment (IEC)
 - ISIM Remote Services Unit (IRSU)
 - Cryogenic Thermal Control System
 - Command and Data Handling System (ICDH)
 - Flight Software System
 - Operations Scripts System



NIRCam will provide the deepest near-infrared images ever and will identify primeval galaxy targets for the NIRSpec

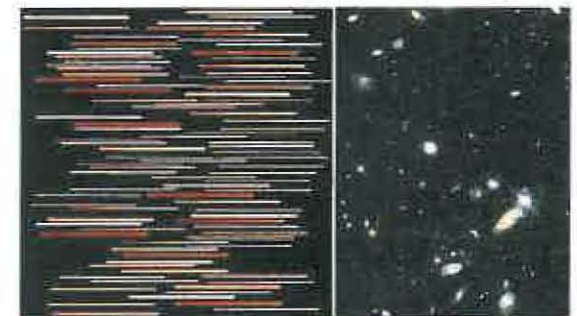
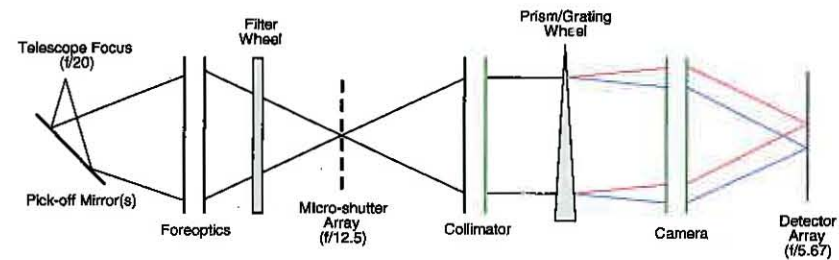


- Developed by the University of Arizona with Lockheed Martin ATC
 - Operating wavelength: 0.6 – 5.0 microns
 - Spectral resolution: 4, 10, 100 (filters + grism)
 - Field of view: 2.2 x 4.4 arc minutes
 - Angular resolution (1 pixel): 32 mas < 2.3 microns, 65 mas > 2.4 microns, coronagraph
 - Detector type: HgCdTe, 2048 x 2048 pixel format, 10 detectors, 40 K passive cooling
 - Refractive optics, Beryllium structure
- Supports OTE wavefront sensing

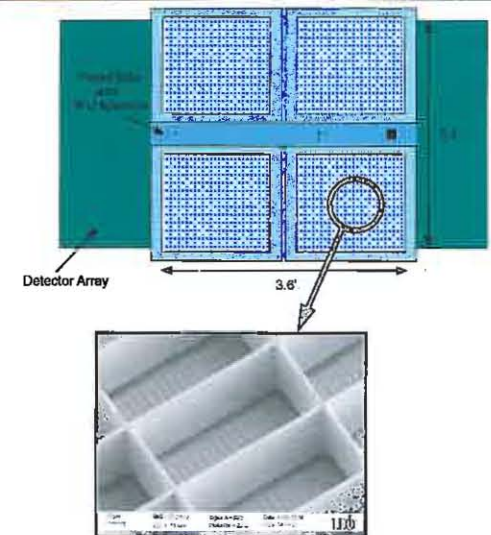
NIRCam is on schedule for delivery during 2012



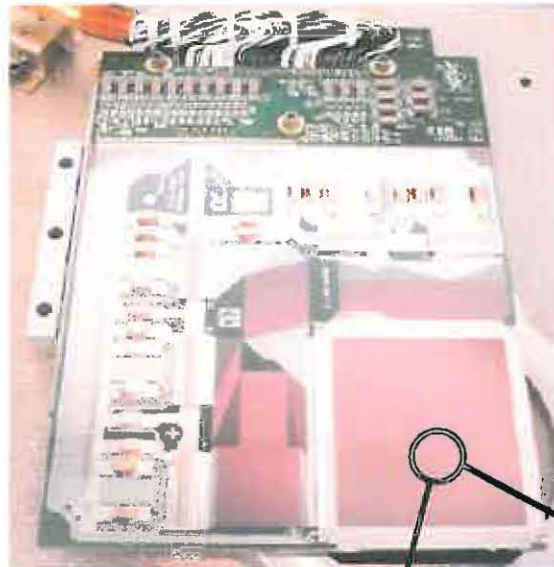
The NIRSpec will acquire spectra of up to 100 galaxies in a single exposure



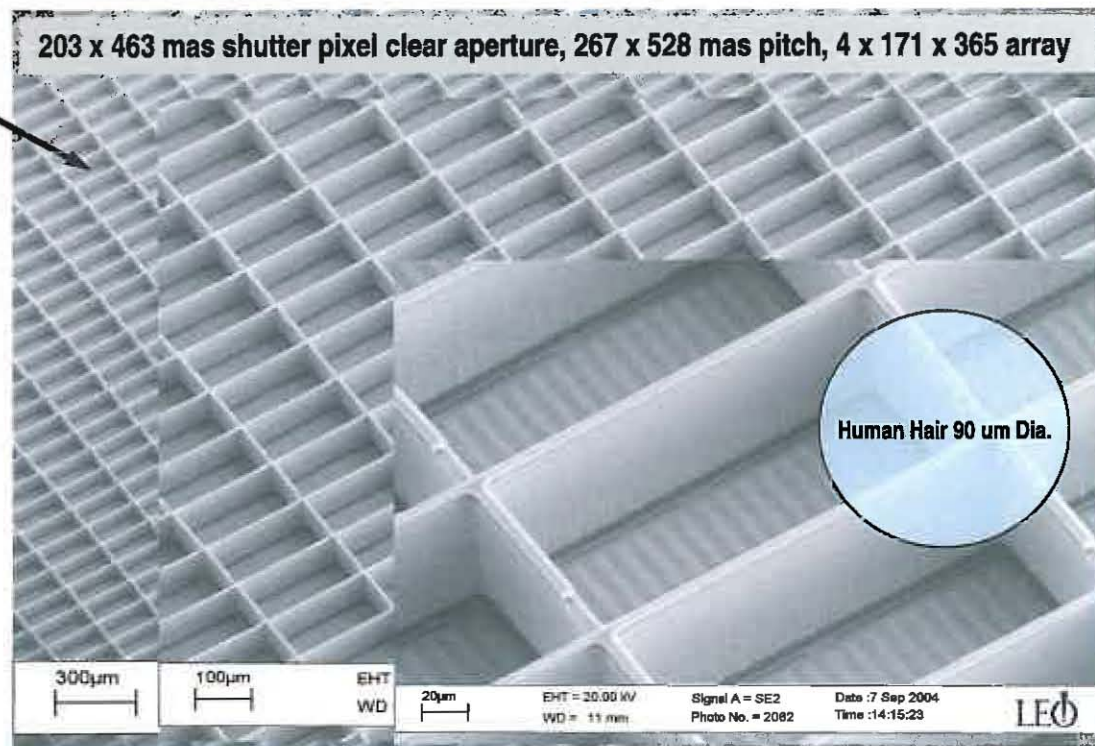
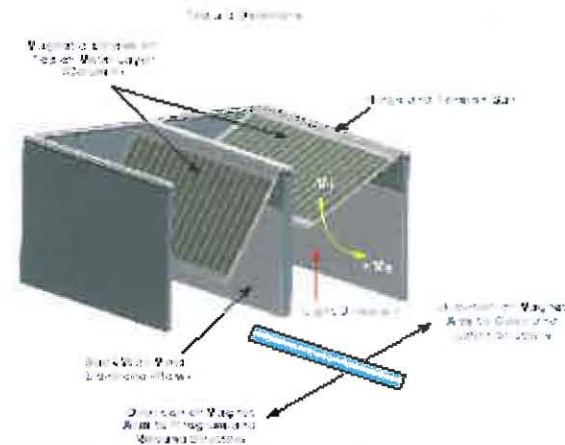
- Developed by the European Space Technology Center (ESTEC) with Astrium GmbH and Goddard Space Flight Ctr
 - Operating wavelength: 0.6 – 5.0 microns
 - Spectral resolution: 100, 1000, 3000
 - Field of view: 3.4 x 3.4 arc minutes
 - Aperture control:
 - Programmable micro-shutters, 250,000 pixels
 - Fixed long slits & transit spectroscopy aperture
 - Image slicer (IFU) 3x3 arc sec
 - Detector type: HgCdTe, 2048 x 2048 format, 2 detectors, 37 K passive cooling
 - Reflective optics, SiC structure and optics



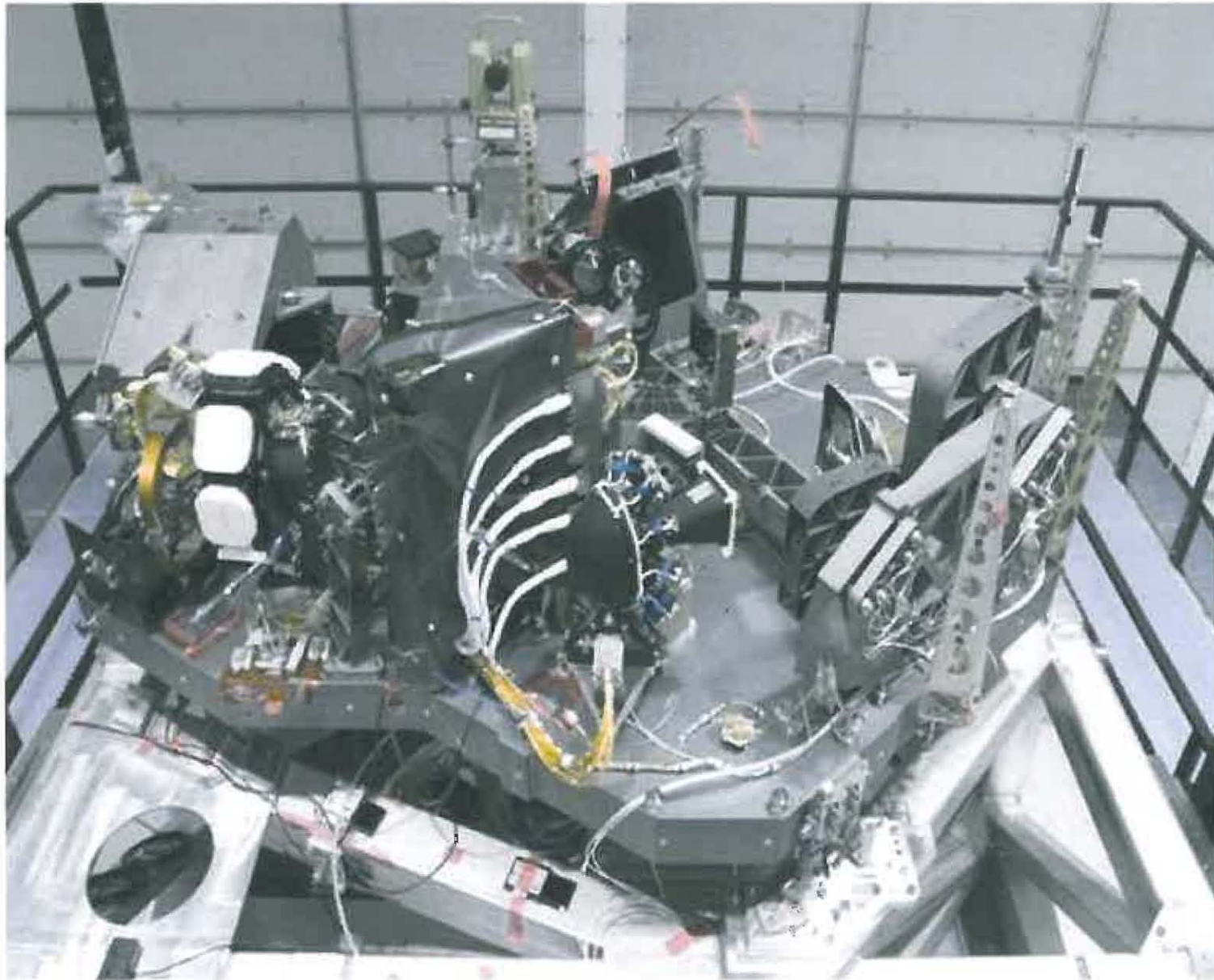
Aperture control: 250, 000 programmable micro-shutters System at TRL-8 and delivered to ESA June 2010



Flight MSA



NIRSpec is on schedule for delivery during 2012



The MIRI instrument will detect key discriminators that distinguish the earliest state of galaxy evolution from more evolved objects



Optical Assembly Structural/Thermal Model



Flight Model

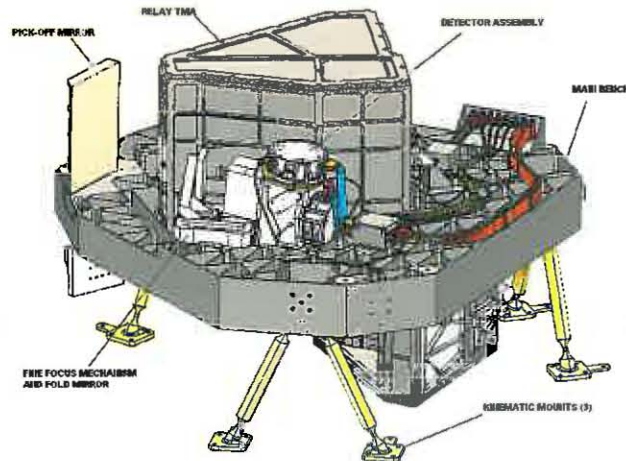
- Developed by a European Consortium and JPL
 - Operating wavelength: 5 - 29 microns
 - Spectral resolution: 5, 100, 2000
 - Broad-band imagery: 1.9 x 1.4 arc minutes FOV
 - Coronagraphic imagery
 - Spectroscopy:
 - R100 long slit spectroscopy 5 x 0.2 arc sec
 - R2000 spectroscopy 3.5 x 3.5 and 7 x 7 arc sec FOV integral field units
 - Detector type: Si:As, 1024 x 1024 pixel format, 3 detectors, 7 K cryo-cooler
 - Reflective optics, Aluminum structure and optics

Flight unit cryo-vacuum testing successfully completed during July 2011

MIRI is on schedule for delivery during 2011

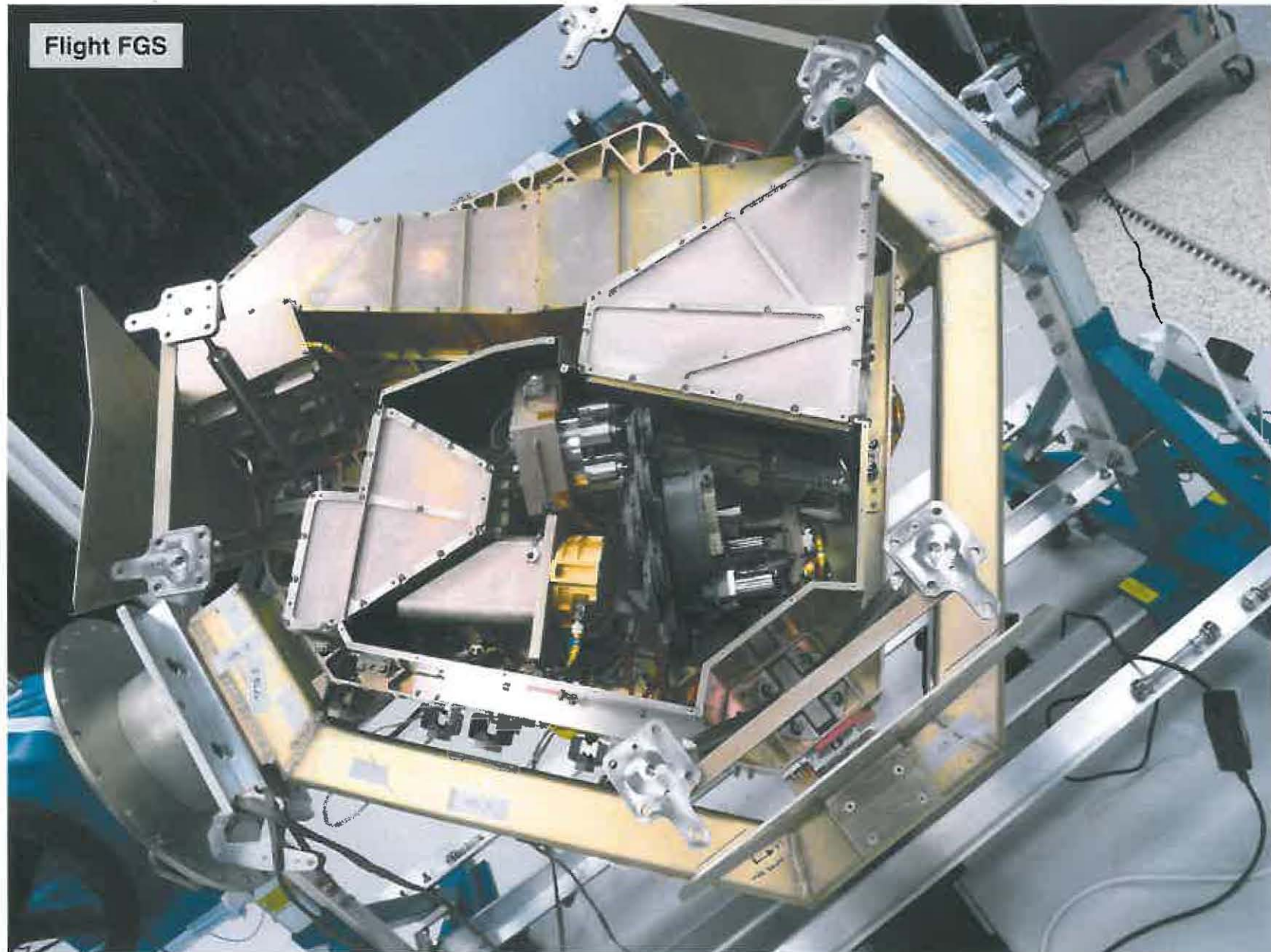


The FGS provides imagery for telescope pointing control & imaging spectroscopy to reveal primeval galaxies and extra-solar planets



- Developed by the Canadian Space Agency with ComDev
 - Broad-band guider (0.6 – 5 microns)
 - Field of view: 2.3 x 2.3 arc minutes
 - Science imagery:
 - Slitless spectroscopic imagery (grism)
 - R ~ 150, 0.8 – 2.25 microns optimized for Ly alpha galaxy surveys
 - R ~ 700, 0.7 – 2.5 microns optimized for exoplanet transit spectroscopy
 - Sparse aperture interferometric imaging (7 aperture NRM) 3.8, 4.3, and 4.8 microns
 - Angular resolution (1 pixel): 68 mas
 - Detector type: HgCdTe, 2048 x 2048 pixel format, 3 detectors
 - Reflective optics, Aluminum structure and optics

FGS is on schedule for delivery during 2012



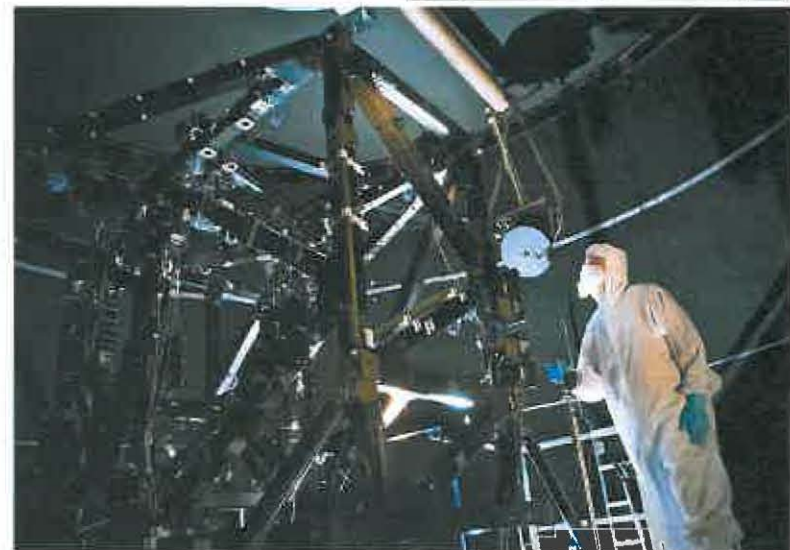
Instrument support systems are on schedule to support ISIM delivery to Observatory I&T

- The ISIM system consists of:
 - Four science instruments
 - **Nine instrument support systems:**
 - **Optical metering structure system**
 - Electrical Harness System
 - Harness Radiator System
 - ISIM electronics compartment (IEC)
 - Cryogenic Thermal Control System
 - ISIM Command and Data Handling System (ICDH)
 - ISIM Remote Services Unit (IRSU)
 - Flight Software System
 - Operations Scripts System



The ISIM structure has passed key verification tests for cryogenic dimensional reputability and distortion

- **Carbon-fiber/cyanate-ester composite material**
 - Primary launch-load bearing structure (warm launch)
 - High precision optical requirements
- **Key dimensional requirements for thermal cycling (300 to 30 K) verified to better than 25 micron precision**
 - Repeatability: 80 microns
 - Distortion: 500 microns
- **Cryogenic and ambient temperature strength proof tests completed**
- **Primary structure now flight qualified**



ISIM structure mounted for ambient strength proof test




Instrument support systems are on schedule to support ISIM delivery to Observatory I&T

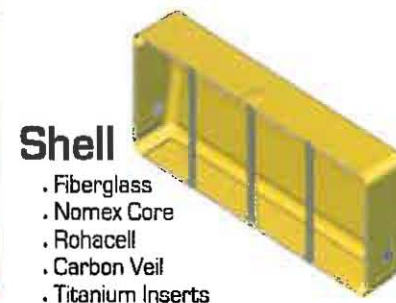
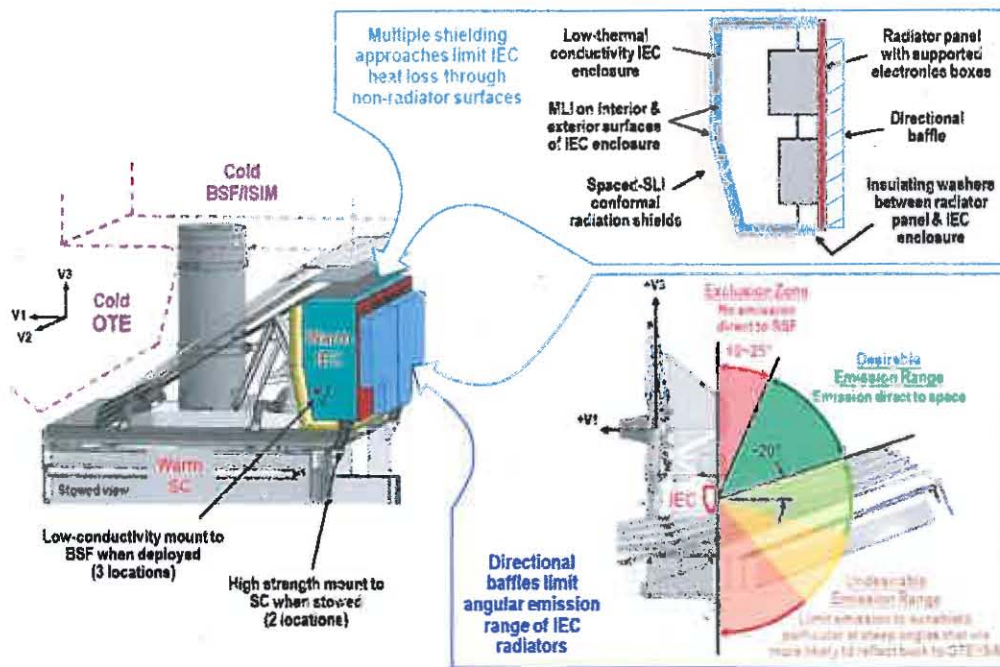
- **The ISIM system consists of:**

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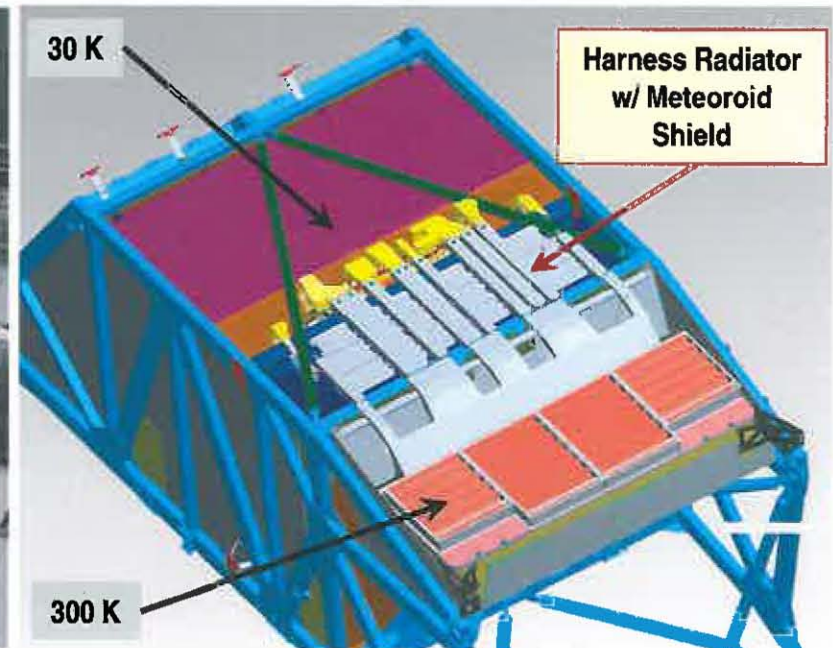
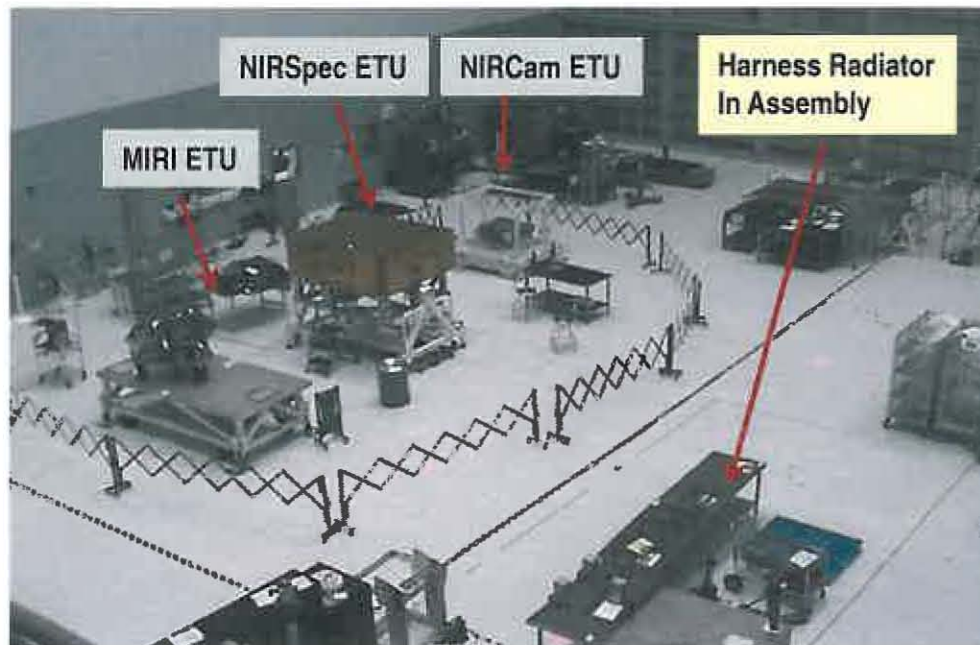
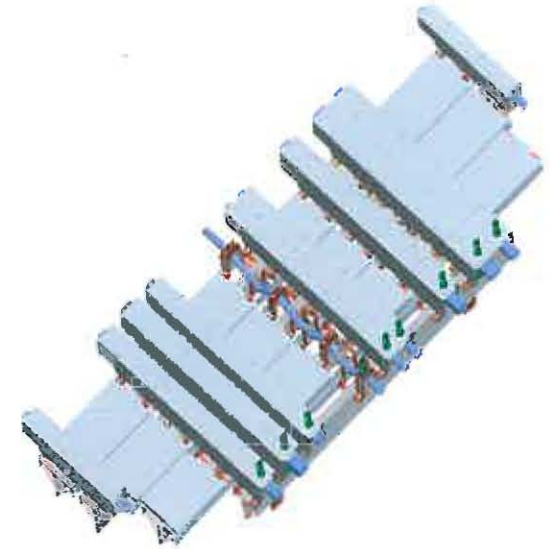
ISIM IEC and HR address one of the most difficult engineering challenges of the JWST

- The IEC accommodates 11 warm electronics boxes that must reside on the cryogenic side of the sunshield close to the science instruments
- Rejects ~220 W of power to space in a controlled beam pattern to achieve required observatory thermal balance and avoid thermal stray light
 - Radiator beam pattern verified in prototype test 
- Key test to-go: full thermal balance



Flight harness radiator system is in assembly

- Provides passive cooling for ~2,700 wires that run between the cryogenic science instruments and their warm electronics (~ 2 meters).
 - Reduces conductive harness heat load to 95 mW
- Provides micro-meter shielding to harnesses



Instrument support systems are on schedule to support ISIM delivery to Observatory I&T

■ The ISIM system consists of:

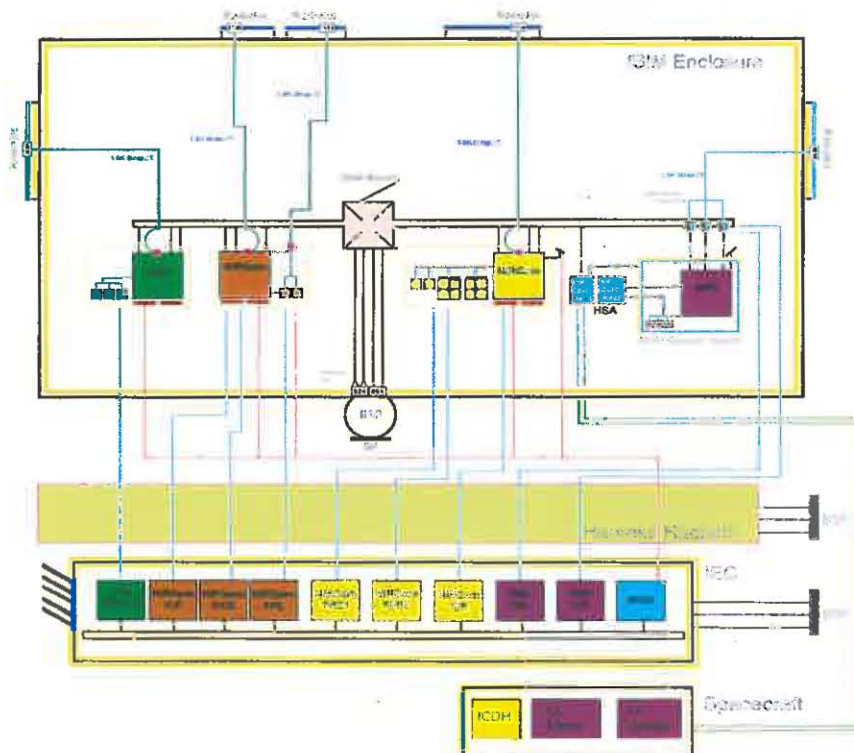
- Four science instruments
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 - Optical metering structure system
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 - **Cryogenic Thermal Control System**
 - ISIM Command and Data Handling System (ICDH)
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ISIM passive cryogenic cooling system is on track to meet heat lift and temperature requirements

■ Key requirements:

- Maintain science instrument cryogenic temperature within specified limits
- Maintain 50% margin to nominal power dissipation at CDR, 25% at launch.
- Provide controlled cool-down rate to avoid contamination by water and other molecules
- Provide decontamination re-warm if necessary
- Provide system wide telemetered thermometry



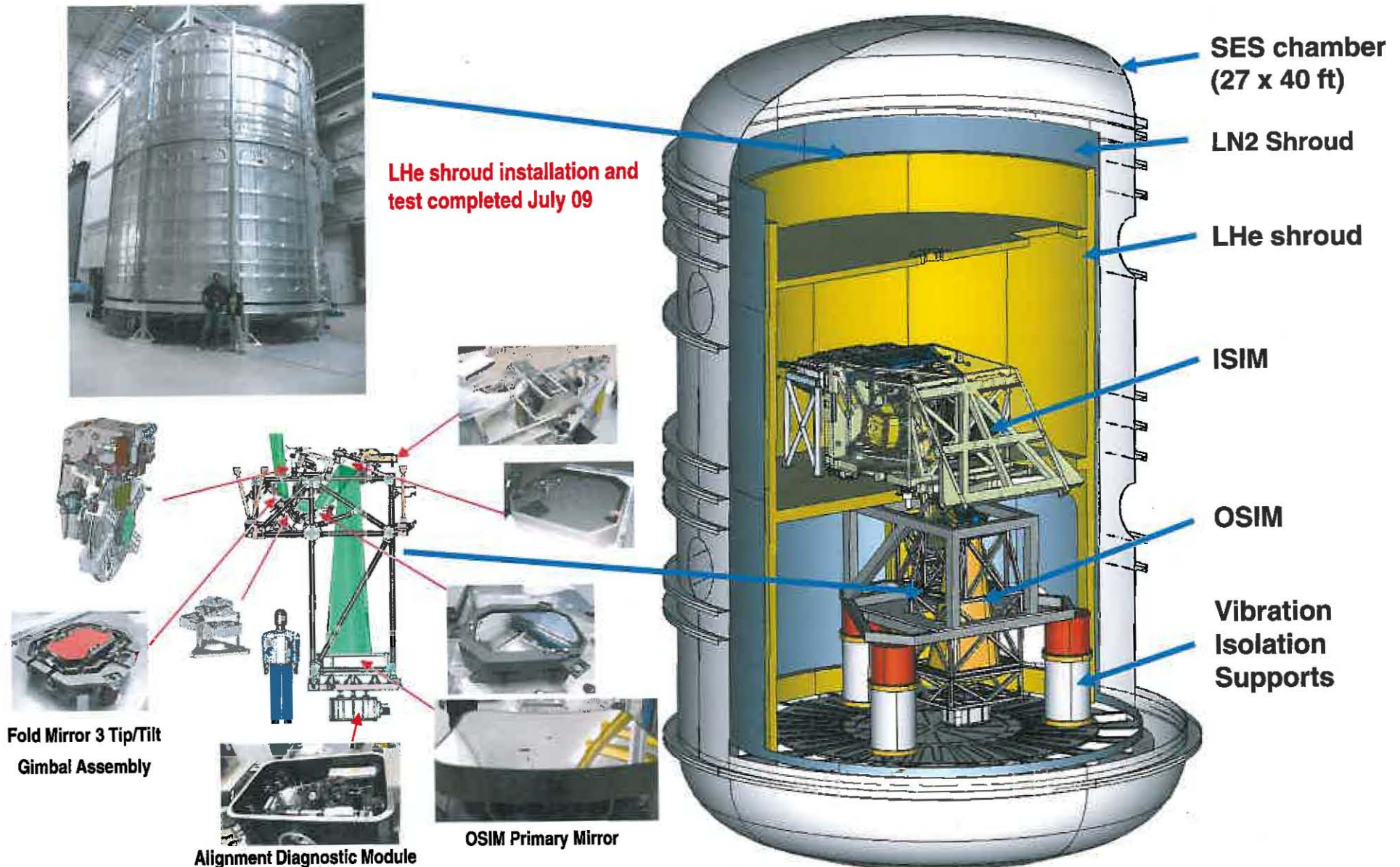
Flight high purity aluminum heat strap assemblies

Making sure it all works

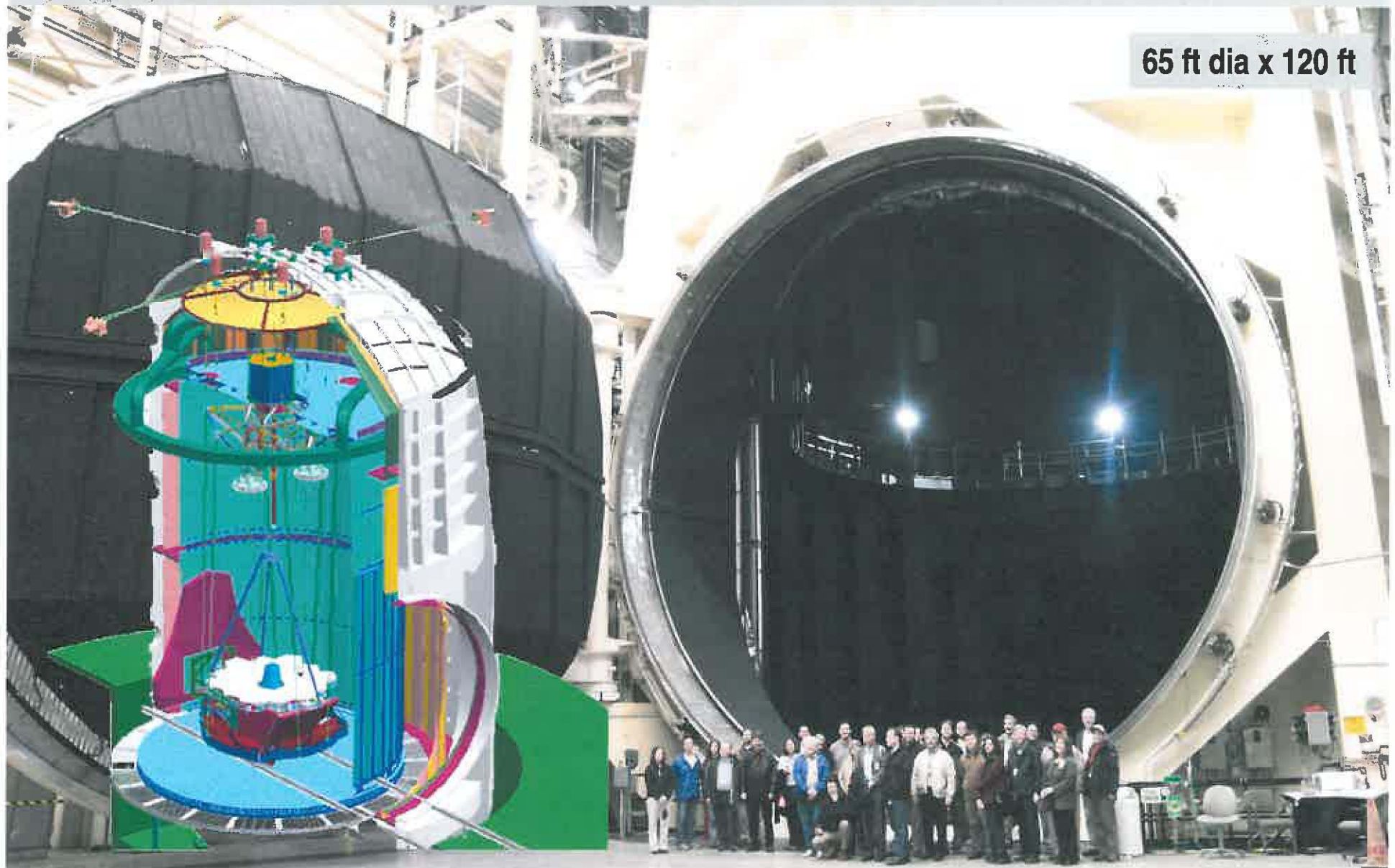
- **ISIM is flight qualified prior to delivery for integration with the Observatory element**

- **Primary ground support equipment:**
 - Cryogenic Optical Telescope Simulator (OSIM)
 - Simulates Optical Telescope Element (OTE) with high fidelity
 - Space environment simulator LHe shroud
 - Enables ISIM testing at operating temperature
 - Cryogenic photogrammetry system
 - Enables metrology of ISIM structure at operating temperature
 - ISIM Test Platform (ITP)
 - Simulates OTE mechanical interface at cryogenic operating temperature
 - Ambient science instrument mechanical interface fixture (ASMIF)
 - Simulates ISIM structure mechanical interface for each instrument with high fidelity
 - Science instrument test sets (SITS)
 - Simulates ICDH for each instrument

ISIM will be tested at ~35 K in the GSFC SES chamber using a cryogenic telescope simulator (OSIM)



Then the OTE + ISIM will be tested in a larger space simulation chamber at JSC



Learn more at:

www.jwst.nasa.gov

http://webbtelescope.org/webb_telescope/progress_report/



Watch the JWST being built at:

www.jwst.nasa.gov/webcam.html



Read about JWST science mission objectives at:

<http://www.jwst.nasa.gov/science.html>

<http://www.stsci.edu/jwst/science/whitepapers/>



Explore your science objectives with the JWST observing time estimator:

<http://jwstetc.stsci.edu/etc/>

Interact with the JWST Science Working Group:

<http://www.jwst.nasa.gov/workinggroup.html>

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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