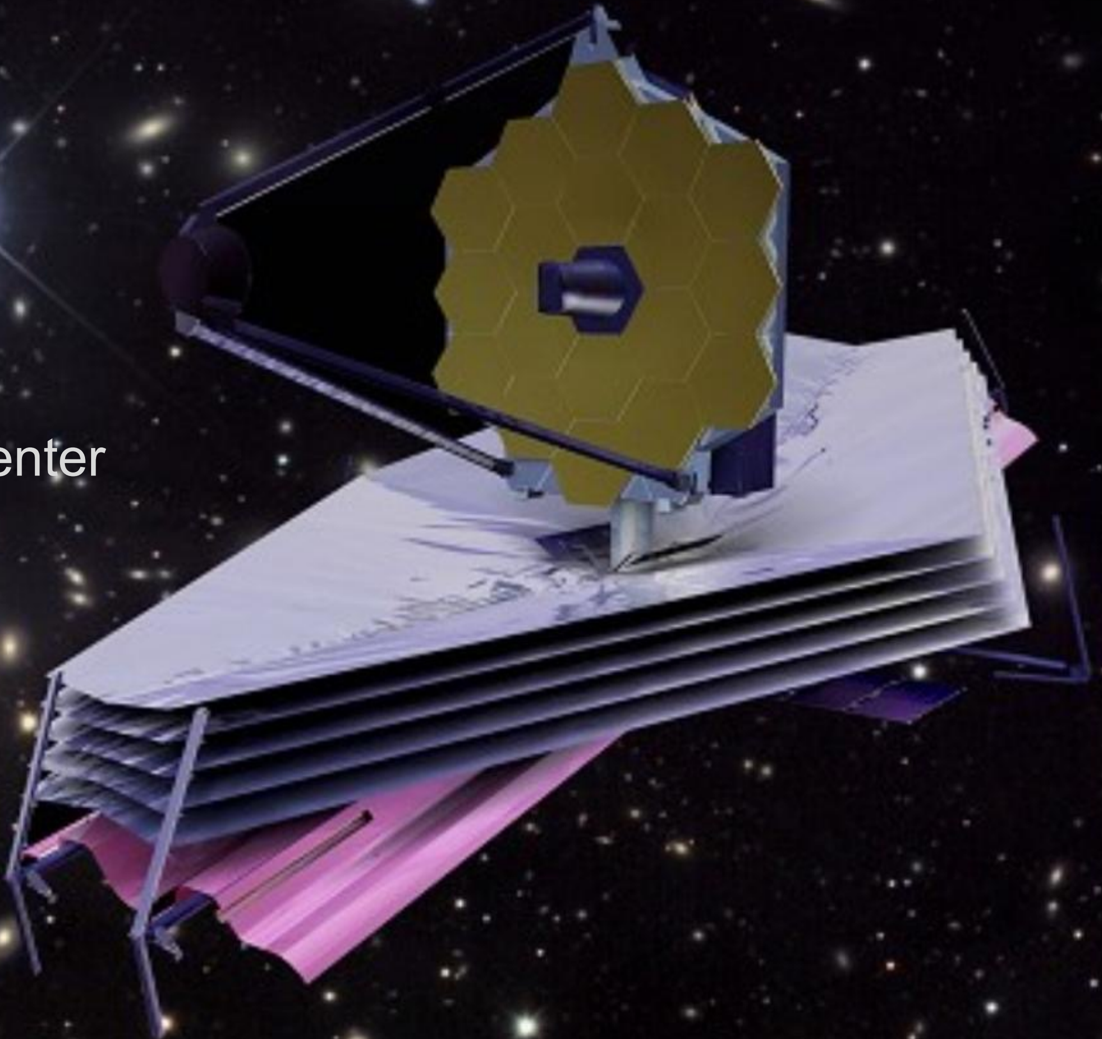
The James Webb Space Telescope Mission



Matt Greenhouse
JWST Project Office
NASA Goddard Space Flight Center
23 December 2009

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

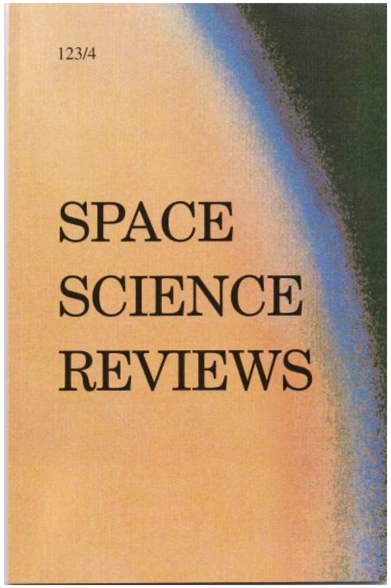
- **Often described as the successor to the Hubble Space Telescope, the JWST will serve astronomers world-wide in much the same way:**
  - Science & mission operations managed by the Space Telescope Science Institute
- **The science investigations performed by the JWST will be determined by the General 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.

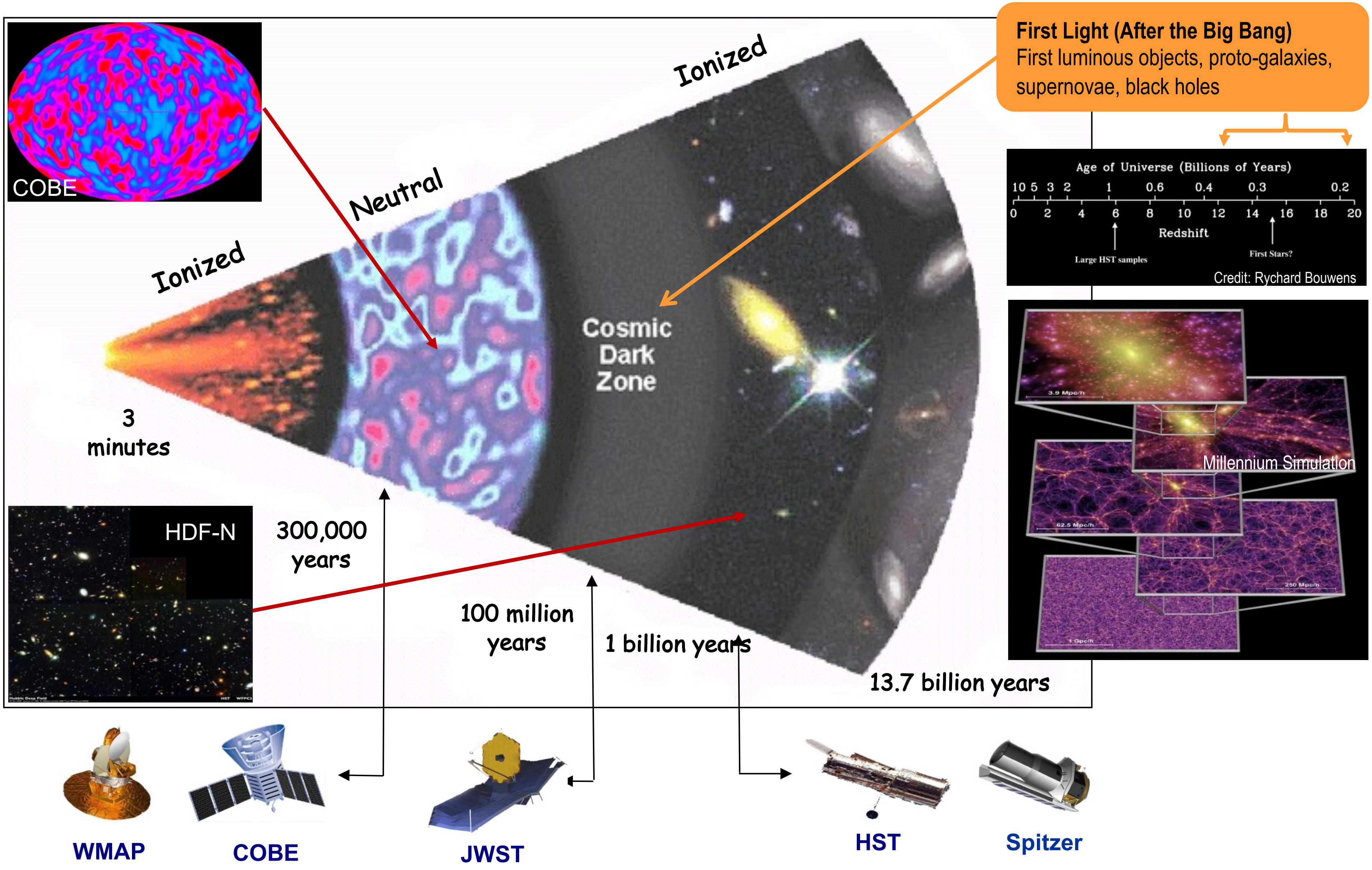
Study the physical and chemical properties of solar systems (including our own) and where the building blocks of life may be present.



123/4

SPACE SCIENCE REVIEWS

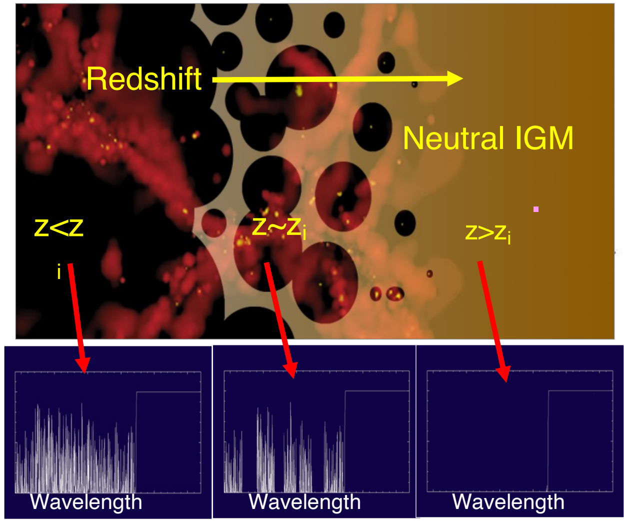
JWST is designed to observe formation of the first galaxies



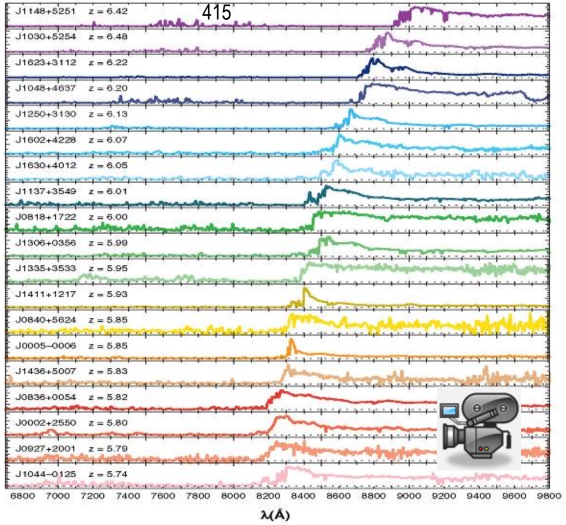
First Light (After the Big Bang)
First luminous objects, proto-galaxies, supernovae, black holes

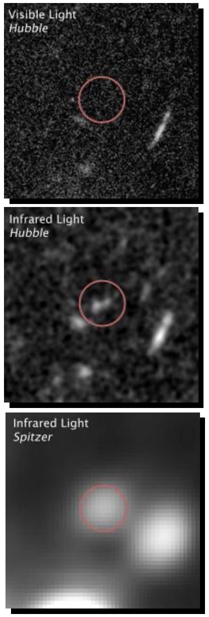
Key questions about the galaxy formation era:

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

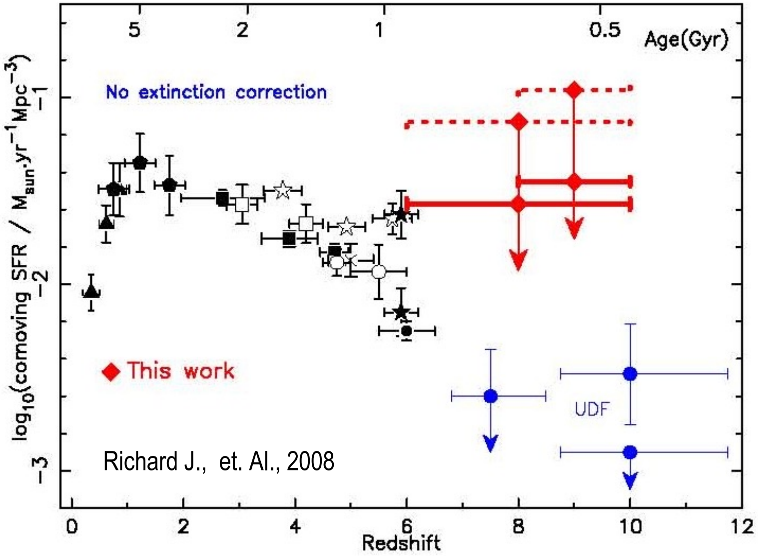


Fan, Carilli & Keating 2006, ARAA, 44, 415





z = 7.6 (Bradley & Illingworth 2008)



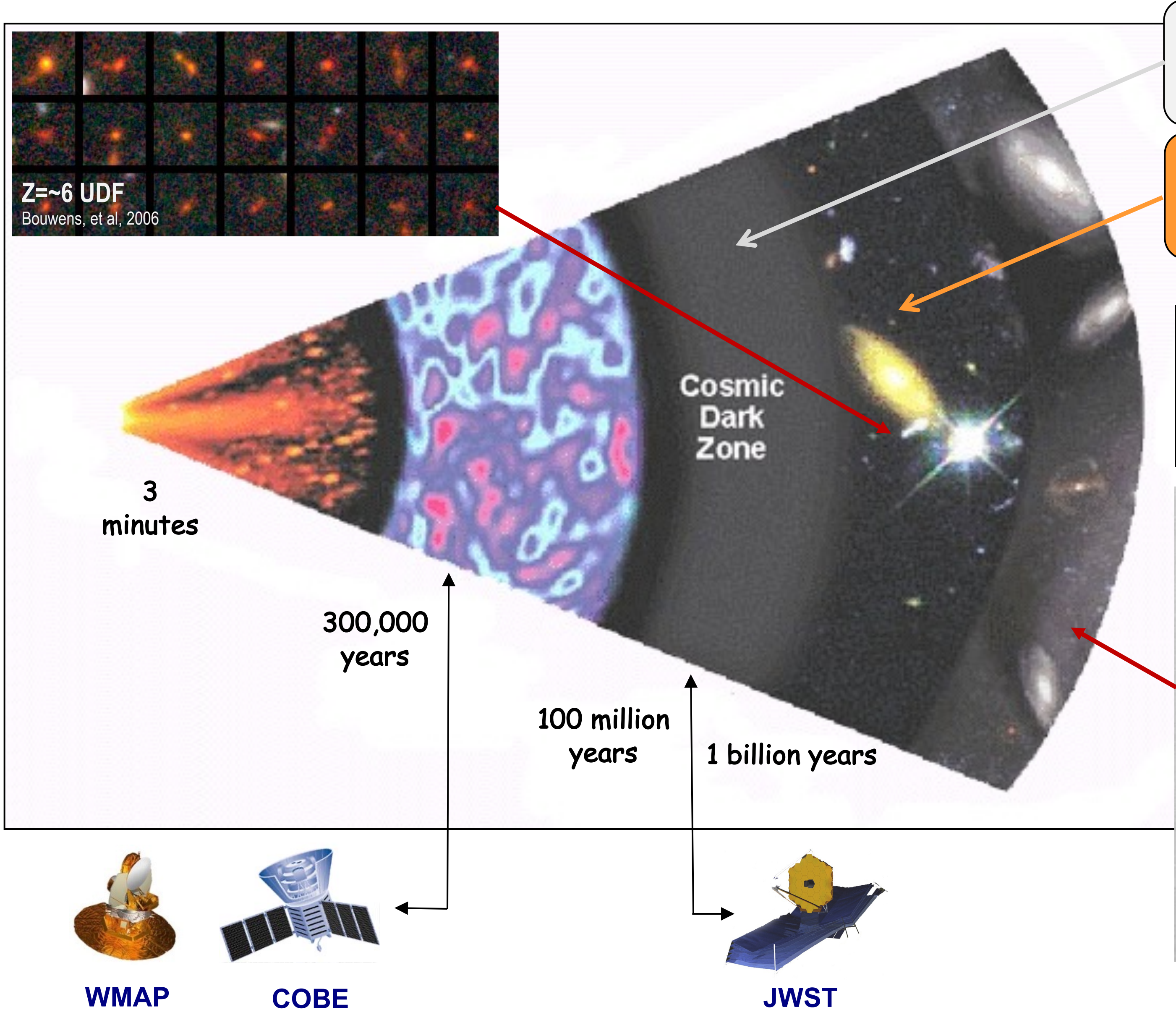
Richard J., et. Al., 2008

Key Enabling Design Requirements:

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

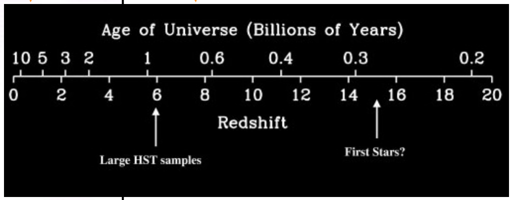
Redshift z	m_{AB}	Fν (nJy)	Lyman Break wavelength
0			0.12 μm
10	30.3	2.8	1.34 μm
15	30.9	1.6	1.95 μm
20	31.3	1.1	2.55 μm

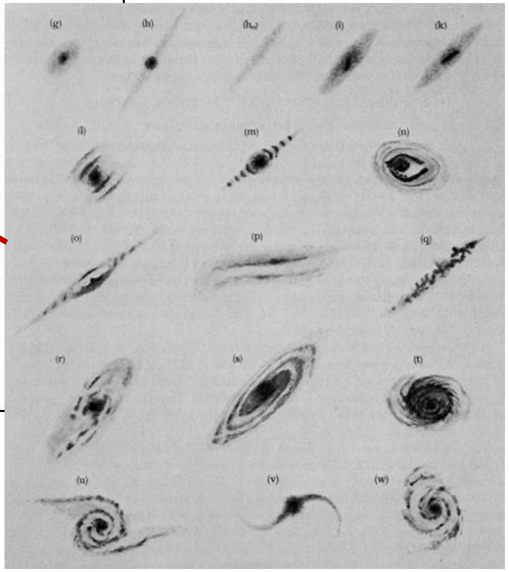
JWST is designed to observe the evolution of galaxies



First Light (After the Big Bang)
First luminous objects, proto-galaxies, supernovae, black holes

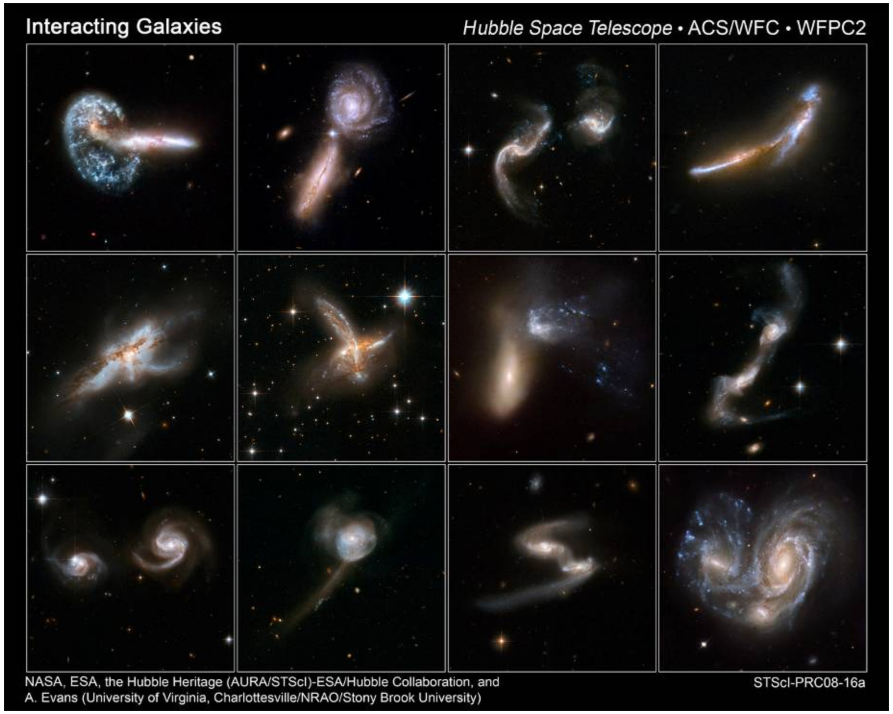
Assembly of Galaxies
Merging of proto-galaxies, effects of black holes, history of star formation





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?



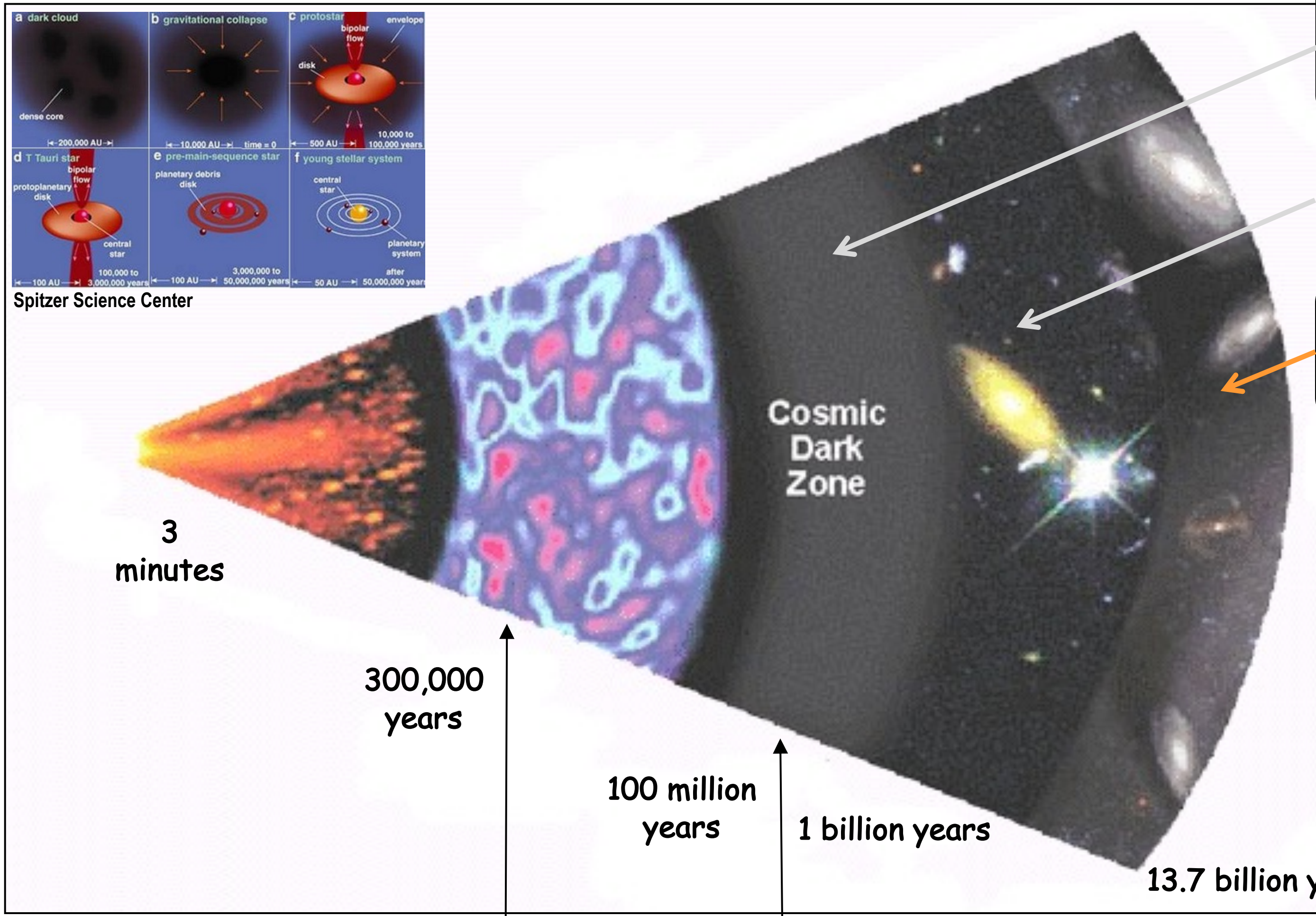
NASA, ESA, the Hubble Heritage (AURA/STScI)-ESA/Hubble Collaboration, and A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University)

STScI-PRC08-16a

Key Enabling Design Requirments:

- 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



Spitzer Science Center

3 minutes

300,000 years

100 million years

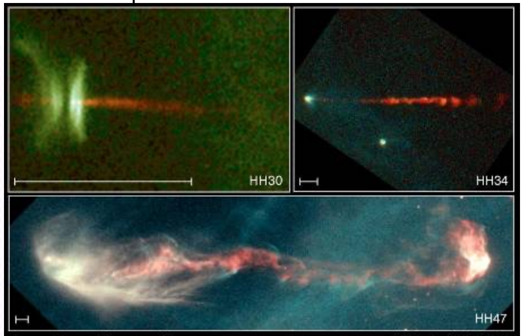
1 billion years

13.7 billion years

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

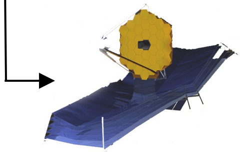
Birth of Stars and Planetary Systems
How stars form and chemical elements are produced



Jets from Young Stars HST • WFPC2
PRC95-24a • ST ScI OPO • June 6, 1995
C. Burrows (ST ScI), J. Hester (AZ State U.), J. Morse (ST ScI), NASA

WMAP

COBE



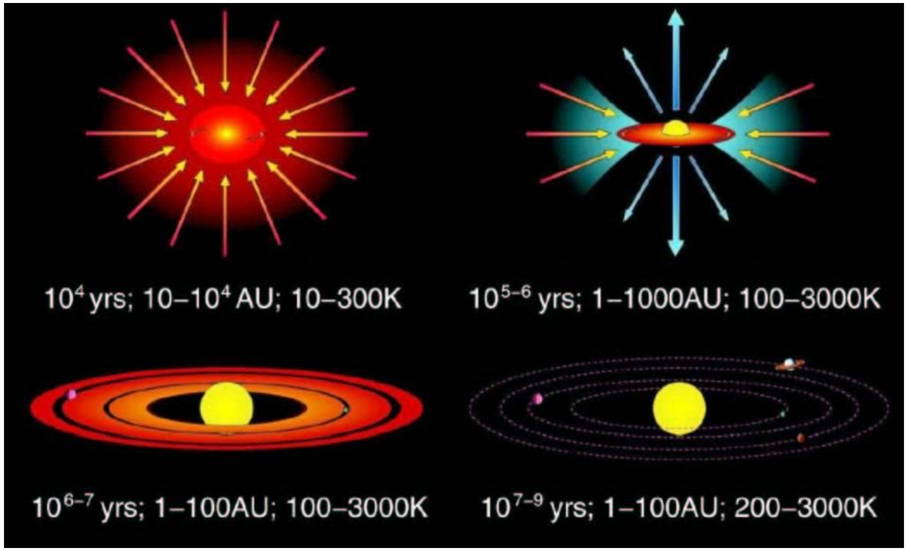
JWST

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?

Deeply embedded protostar

Circumstellar disk



Agglomeration & planetesimals

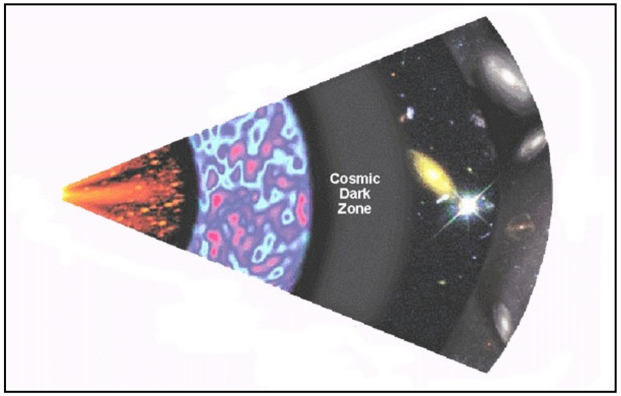
Mature planetary system

The Eagle Nebula as seen in the near-infrared

Key Enabling Design Requirments:

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

JWST will observe how planetary systems form and evolve

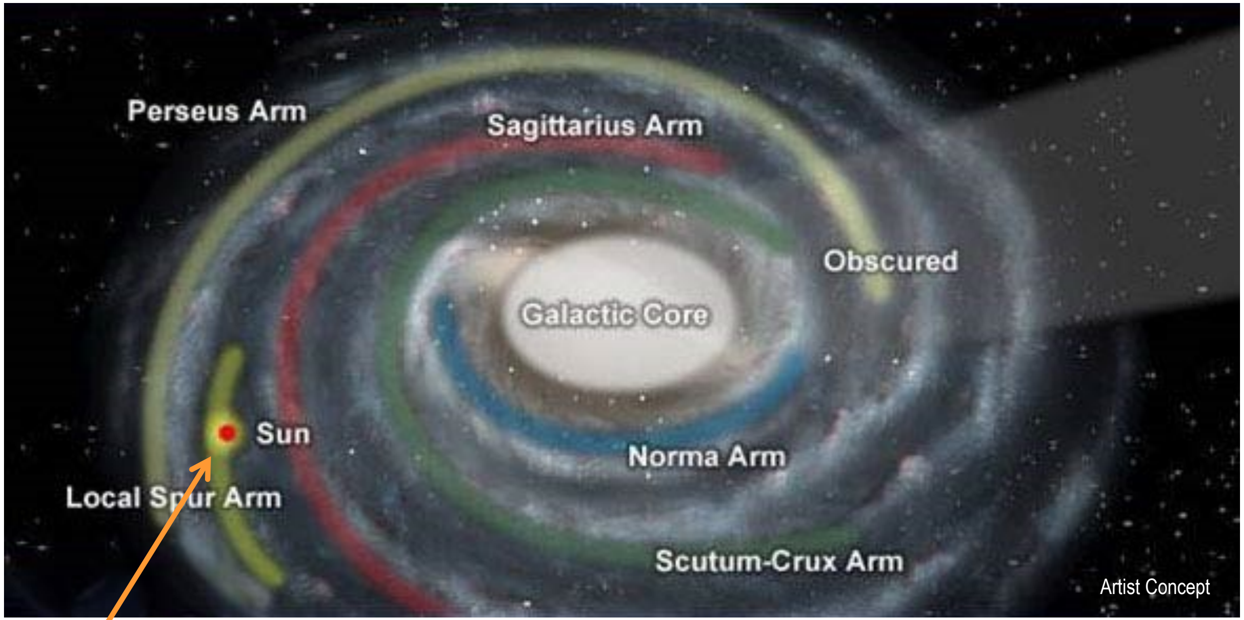


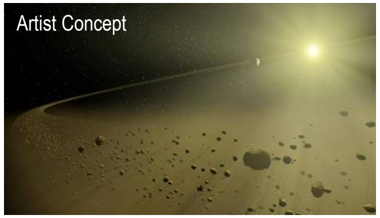
First Light (After the Big Bang)
First luminous objects, proto-galaxies, supernovae, black holes

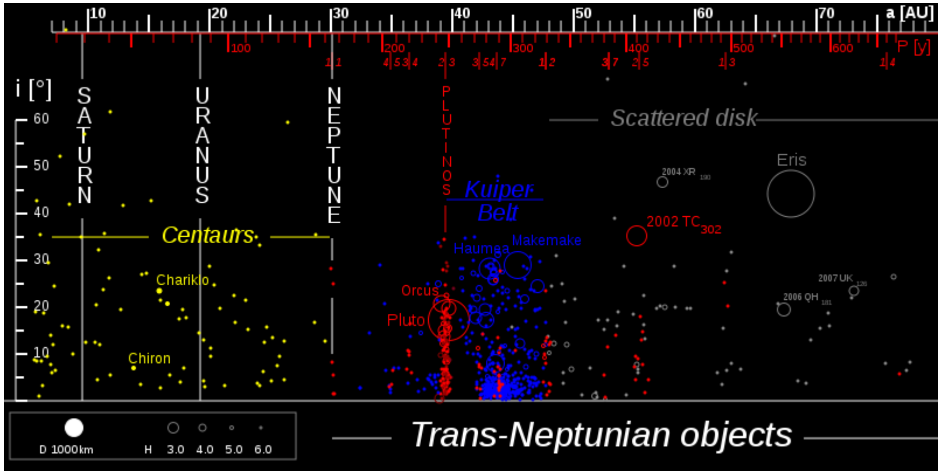
Assembly of Galaxies
Merging of proto-galaxies, effects of black holes, history of star formation

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

Planetary Systems & Origins of Life
Formation of planets

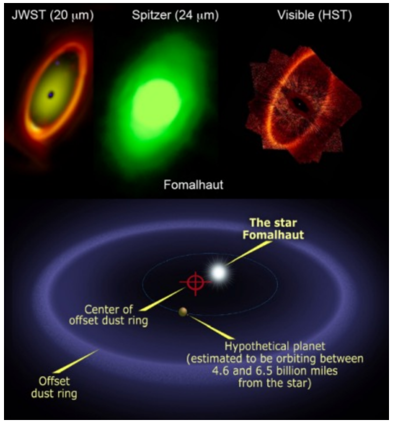




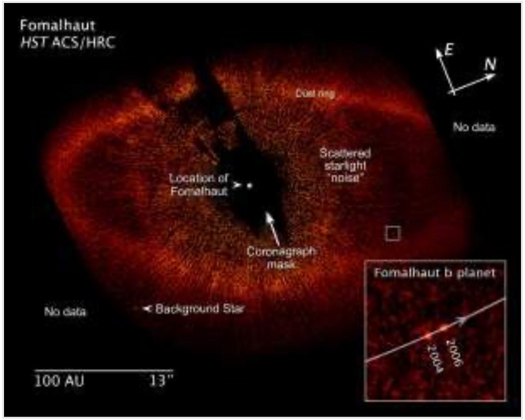


Key questions about planet formation:

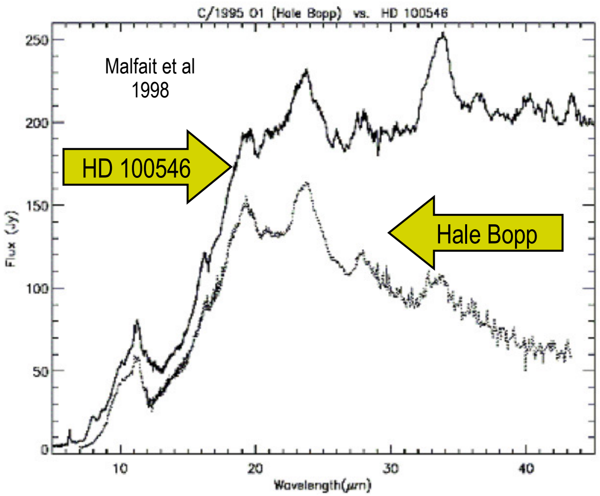
- How do planets form?
- How are circumstellar disks like our Solar System?
- How are habitable zones established?



Kalas, Graham & Clampin 2005

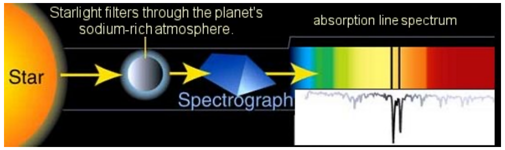


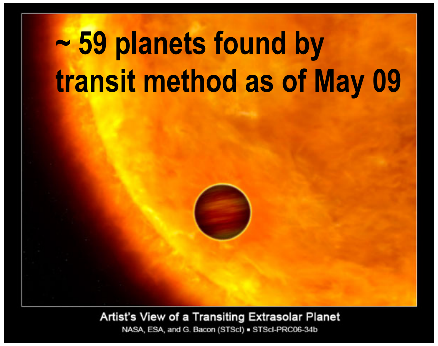
Kalas et al 2008

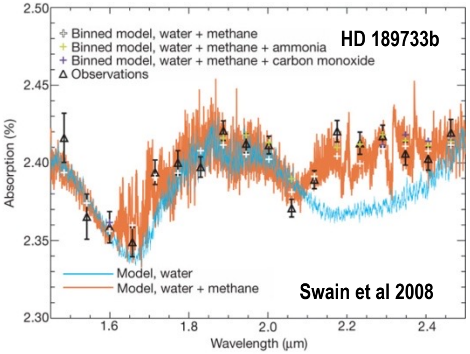


Key Enabling Design Requirements:

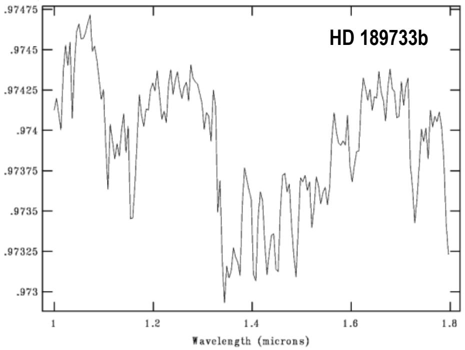
- Near- and mid-IR coronagraphic imagery
- Near- and mid-IR spectroscopy
- High cadence sub-array imagery & spectroscopy

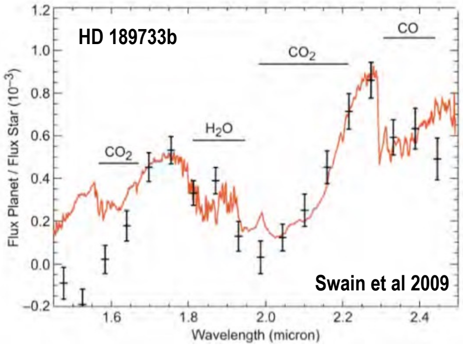






JWST simulation: Greene 2009





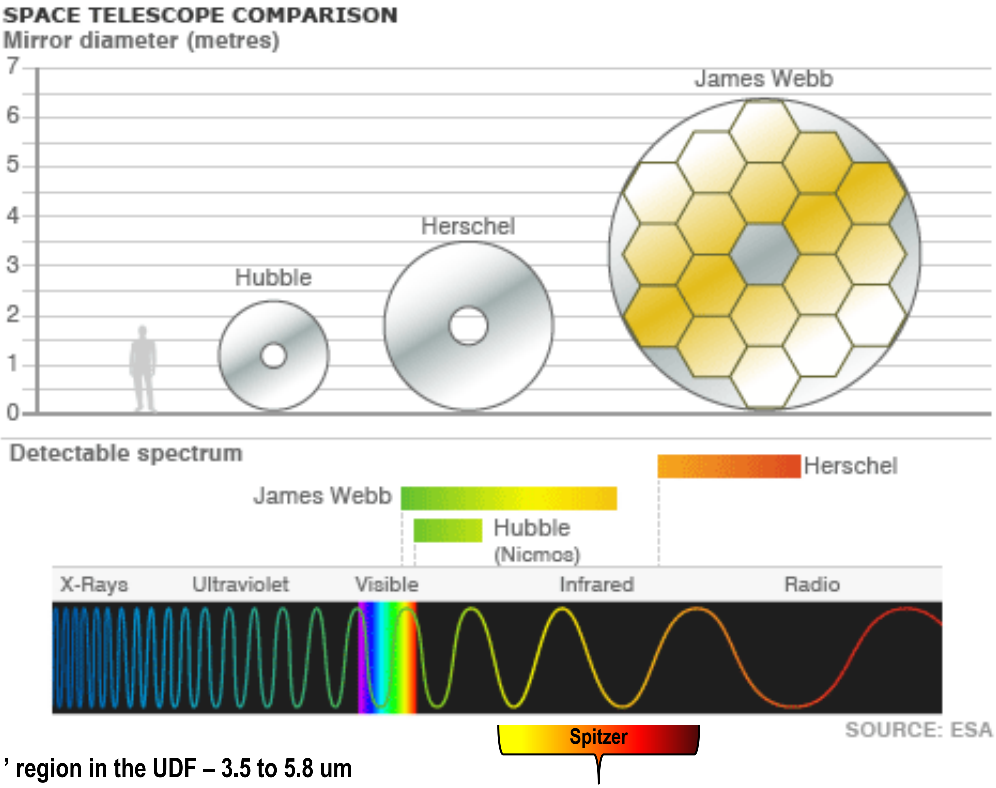
JWST requires the largest cryogenic telescope ever constructed

To observe the early universe, the JWST mission requires:

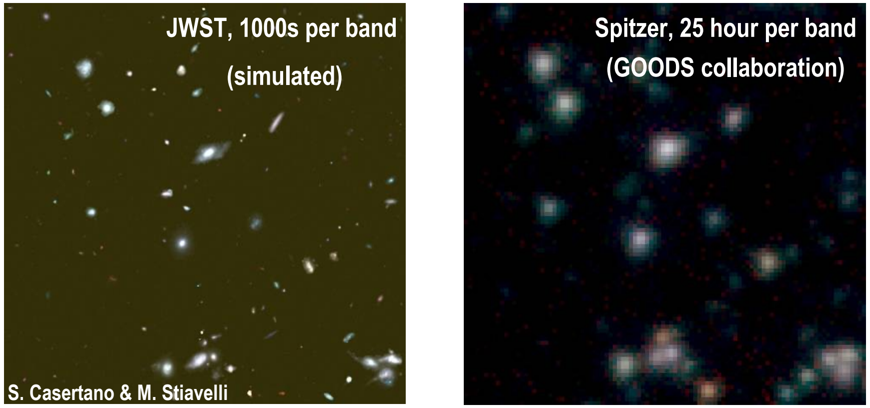
- 7X the light gathering capability of the Hubble Space Telescope
- similar angular resolution in the near-infrared spectrum
- wavelength coverage spanning the optical to mid-infrared spectrum

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

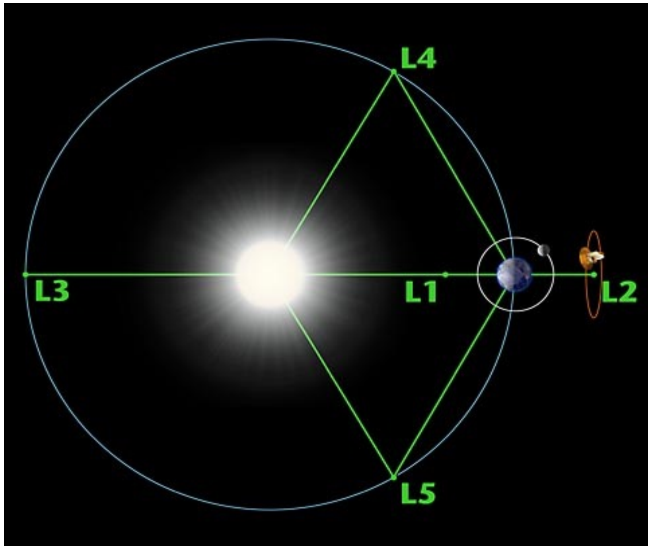


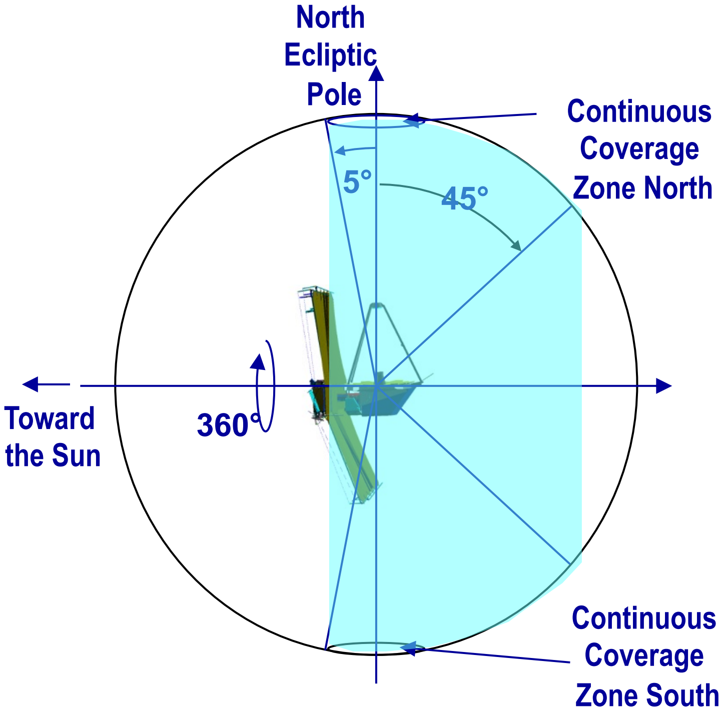
1'x1' region in the UDF – 3.5 to 5.8 um



JWST will be placed in orbit around the Sun-Earth L2 point: ~ 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 ~ 93 m/s)



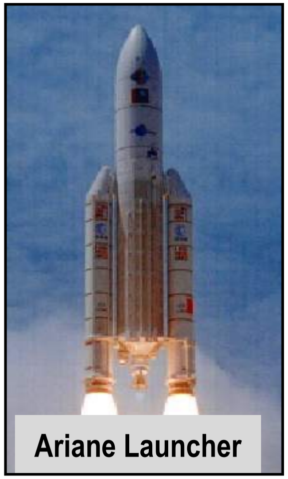


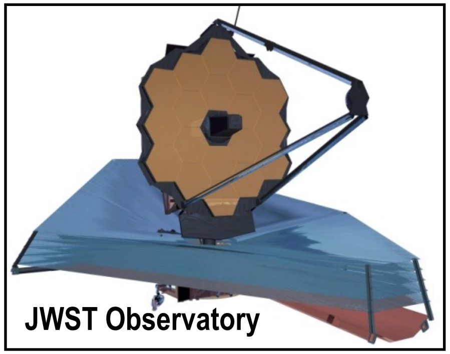
- The JWST can observe the whole sky while remaining continuously in the shadow of its sunshield
  - Field of Regard is an annulus covering 35% of the sky
  - The whole sky is covered each year with small continuous viewing zones at the Ecliptic poles

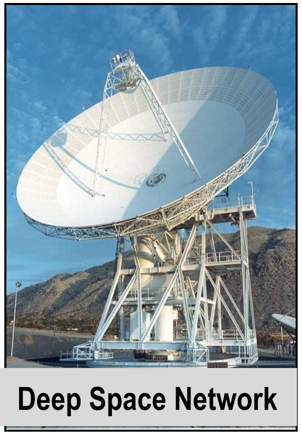
The JWST program is a multi-agency partnership

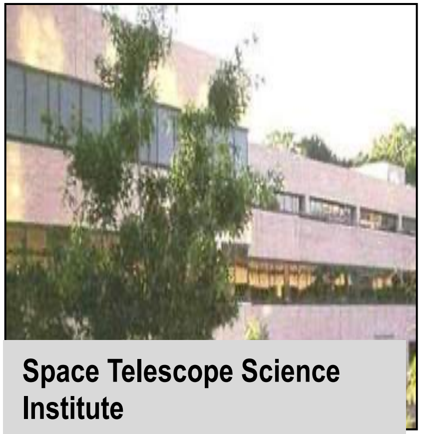
James Webb Space Telescope System

- 🟦 Launch Segment
  - 🟦 Launch Vehicle
  - 🟦 Payload Adapter
  - 🟦 Launch Site Services
- 🟩 Observatory Segment
  - 🟩 Optical Telescope Element (OTE)
  - 🟩 Integrated Science Instrument Module (ISIM)
    - 🟩 NIRCam
    - 🟩🟦 MIRI
    - 🟦 NIRSpec
    - 🟨 FGS
  - 🟩 Spacecraft Element (SE)
    - 🟩 Spacecraft Bus
    - 🟩 Sunshield
- 🟩 Ground Segment
  - 🟩 Science and Operations Center (SOC)
  - 🟩 Common Systems


Ariane Launcher


JWST Observatory


Deep Space Network


Space Telescope Science Institute

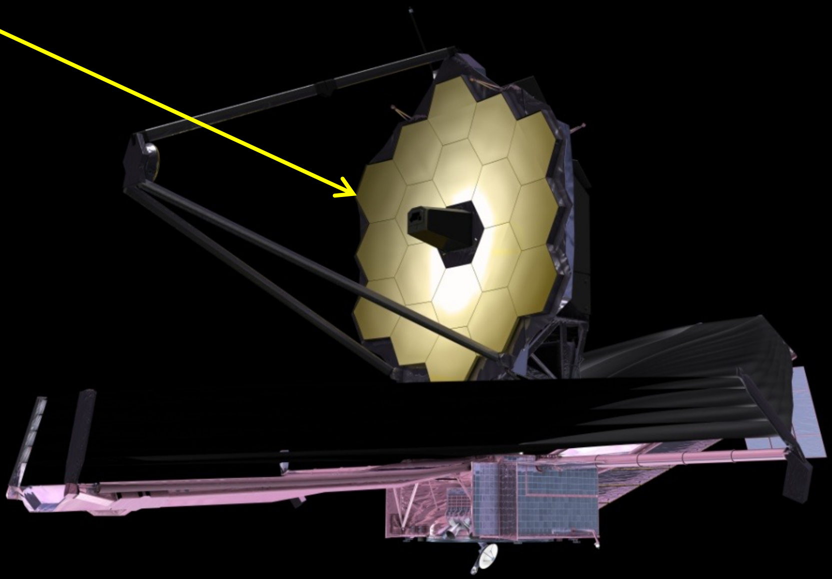
🟩 Provided by NASA
🟦 Provided by ESA
🟨 Provided by CSA

The observatory segment consists of three main 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



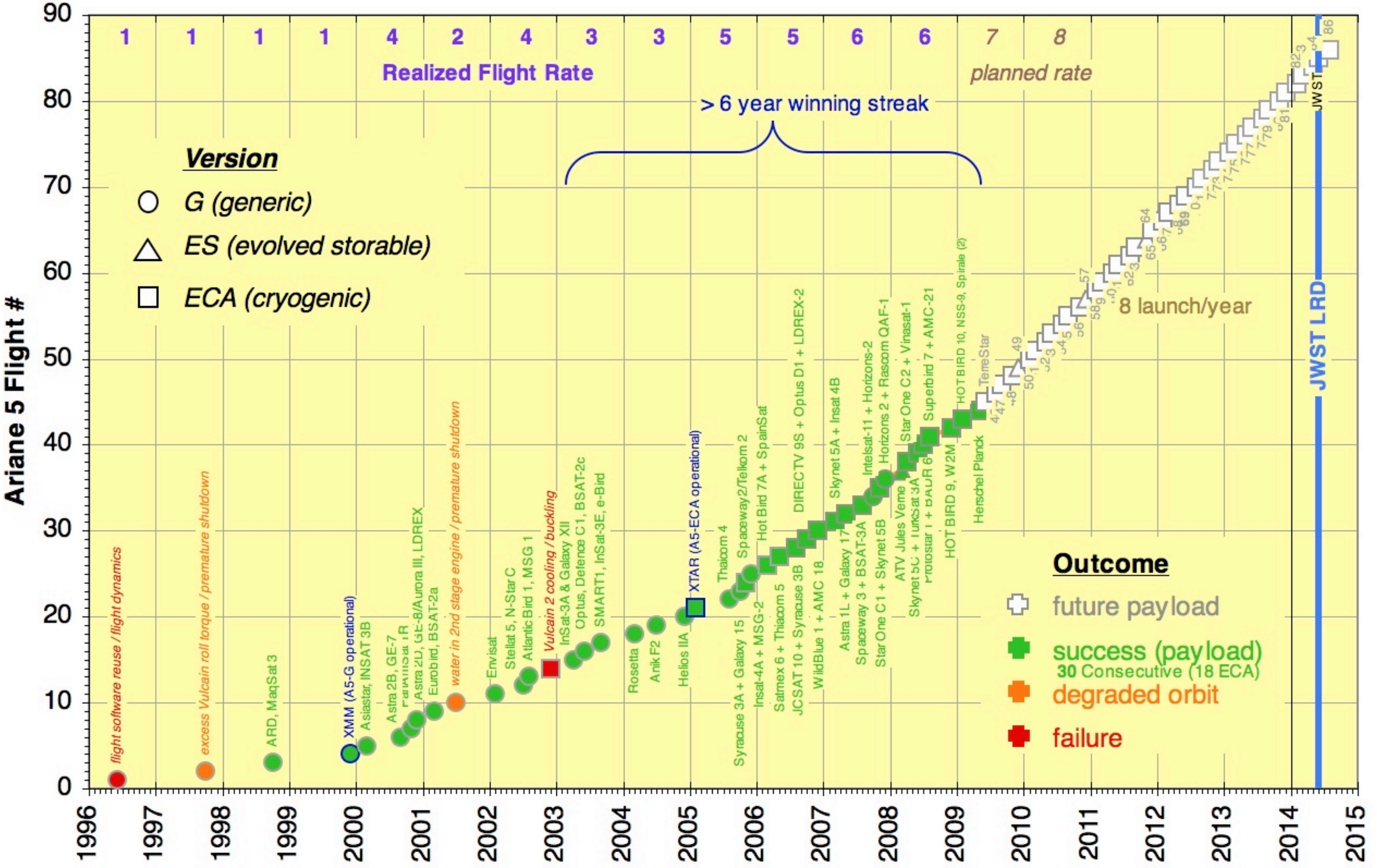
JWST requires a segmented deployable primary mirror

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

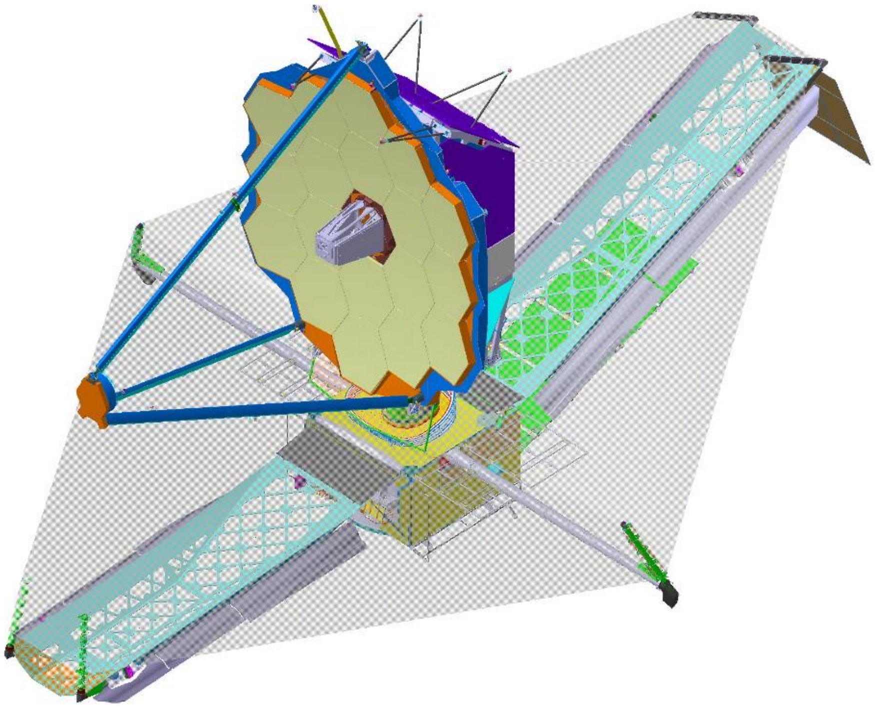
Ariane 5 ECA configuration is mature and reliable

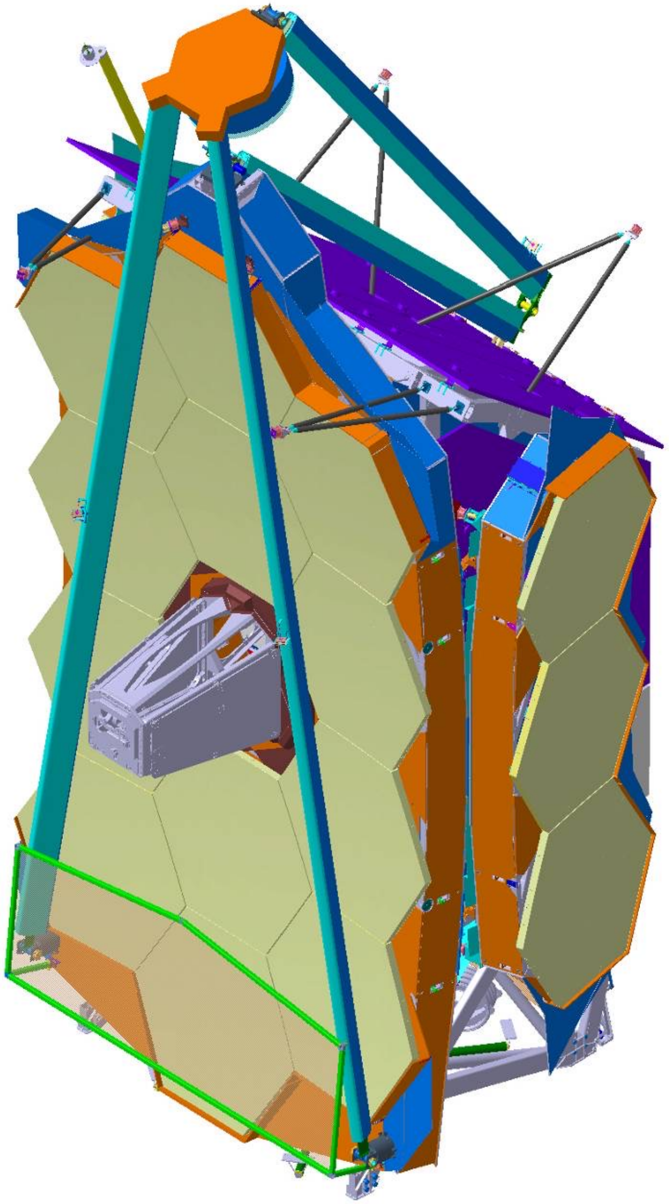
Status as of: 5/31/09



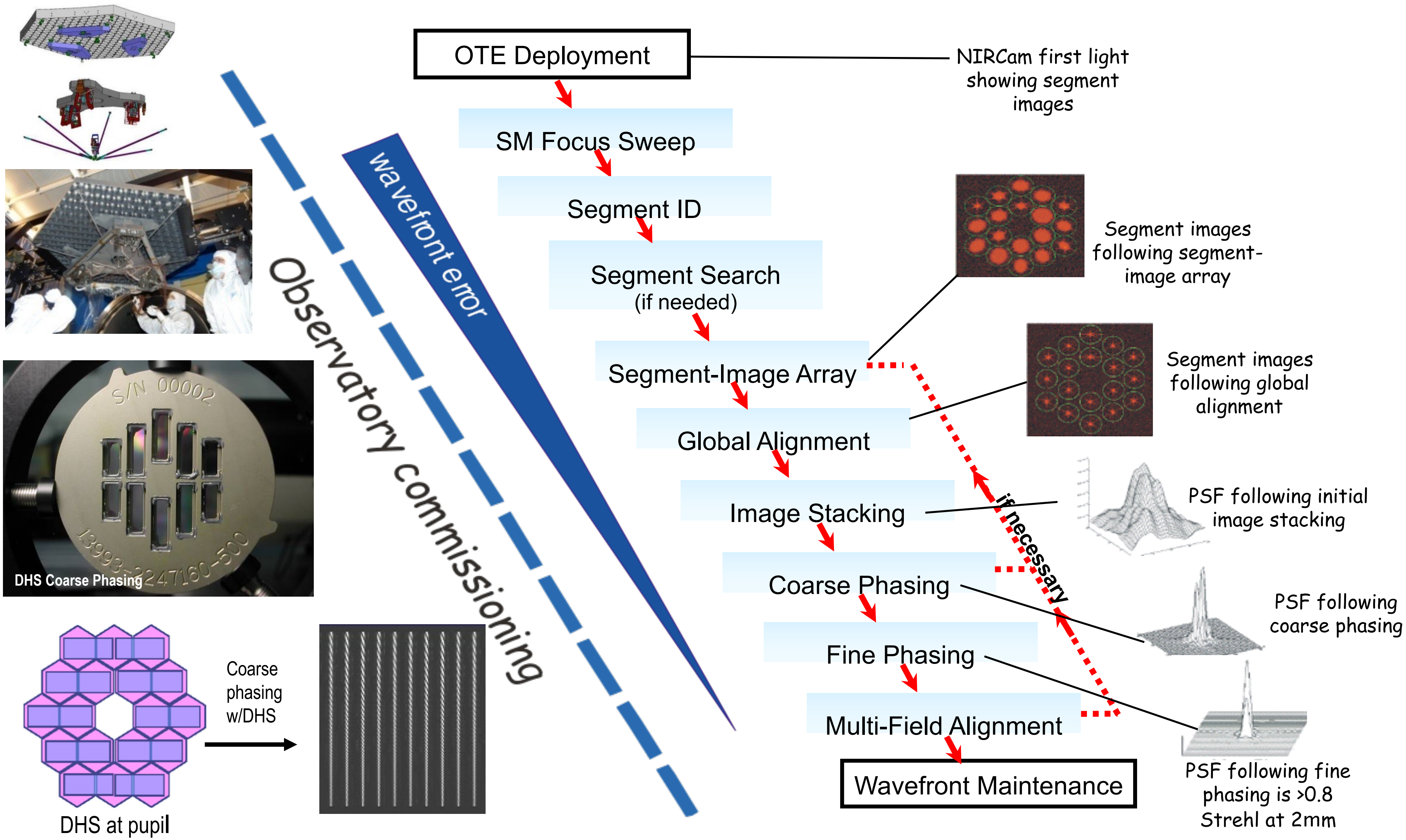
Deployment Sequence Overview

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.



OTE Deployment

SM Focus Sweep

Segment ID

Segment Search
(if needed)

Segment-Image Array

Global Alignment

Image Stacking

Coarse Phasing

Fine Phasing

Multi-Field Alignment

Wavefront Maintenance

wavefront error

Observatory commissioning

if necessary

NIRCam first light showing segment images

Segment images following segment-image array

Segment images following global alignment

PSF following initial image stacking

PSF following coarse phasing

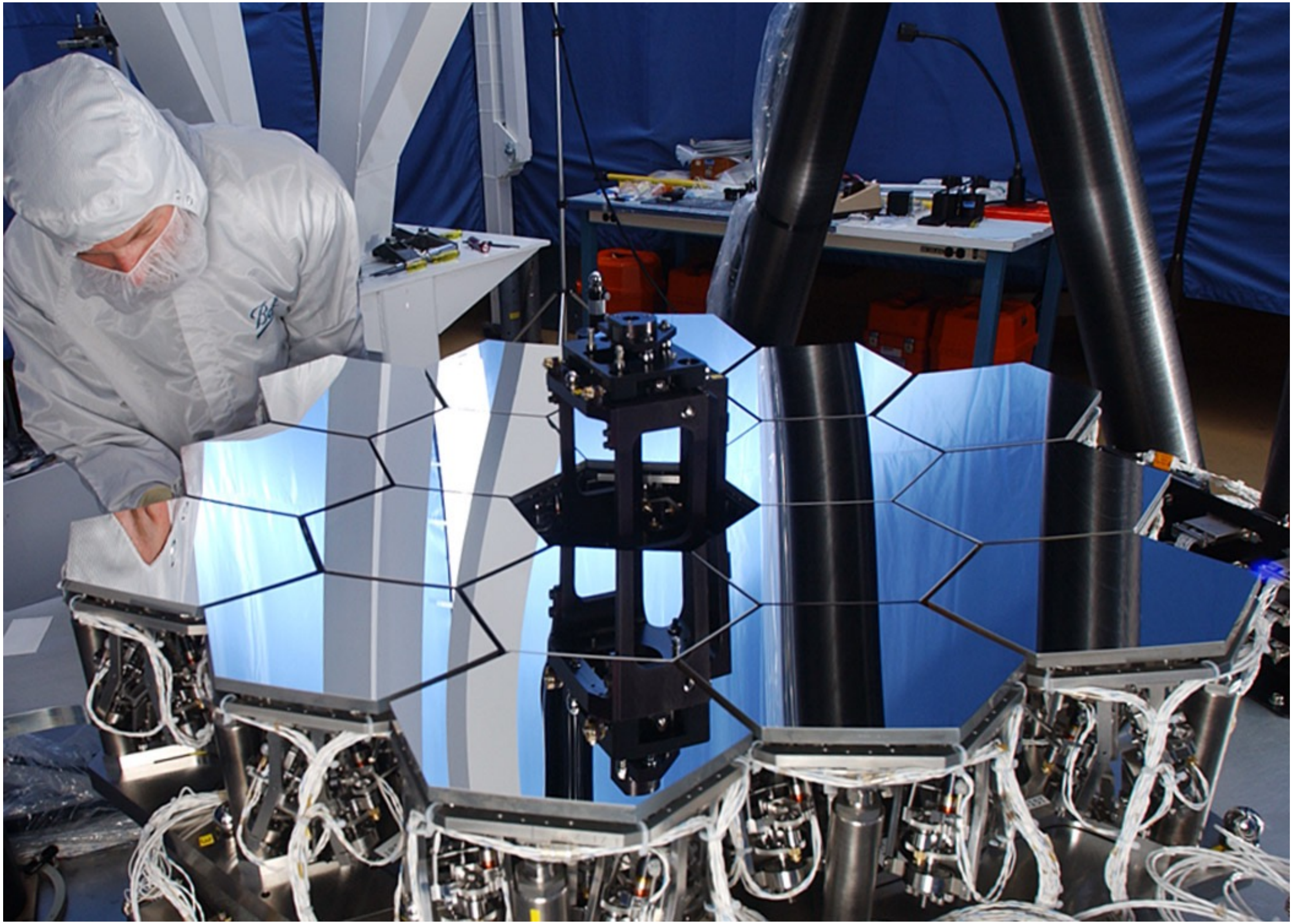
PSF following fine phasing is >0.8 Strehl at 2mm

DHS Coarse Phasing

Coarse phasing w/DHS

DHS at pupil

The mirror segment control process has been developed using a 1/6 scale fully functional telescope model



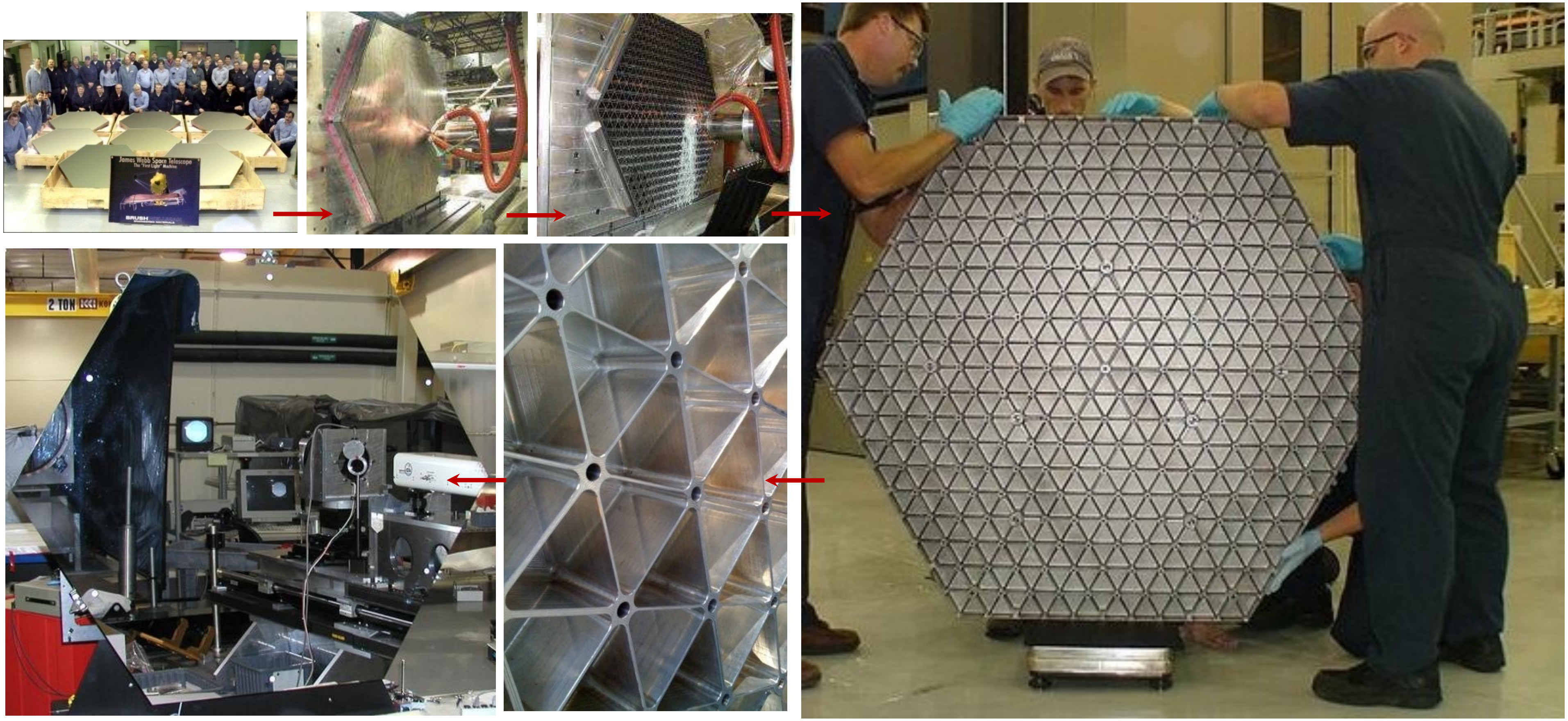
The telescope mirrors are fabricated from Beryllium

Key physical properties of Beryllium:

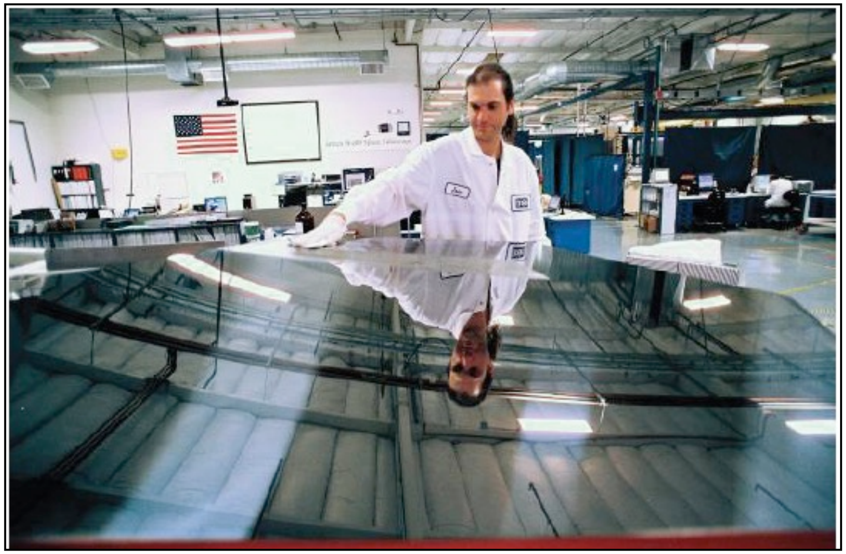
  - low coefficient of thermal expansion at 50 K
  - high thermal conductivity
  - high stiffness to mass ratio
- Type O-30 spherical powder
  - uniform CTE, high packing density, low oxide content

Primary mirror mass properties

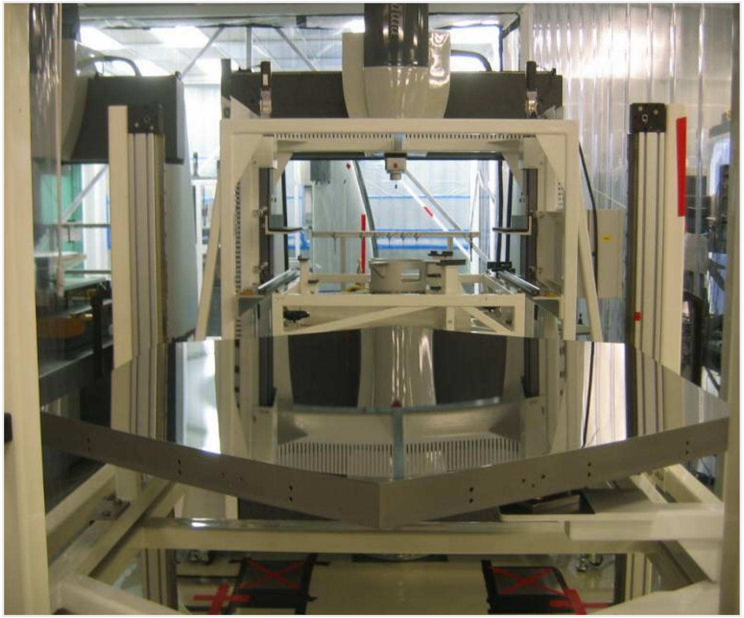
- substrate: 21.8 kg
- segment assembly: 39.4 kg
- OTE area density: ~28 kg m^{-2}
  - HST (ULE) ~ 180 kg m^{-2}
  - Keck (Zerodur) ~ 2000 kg m^{-2}

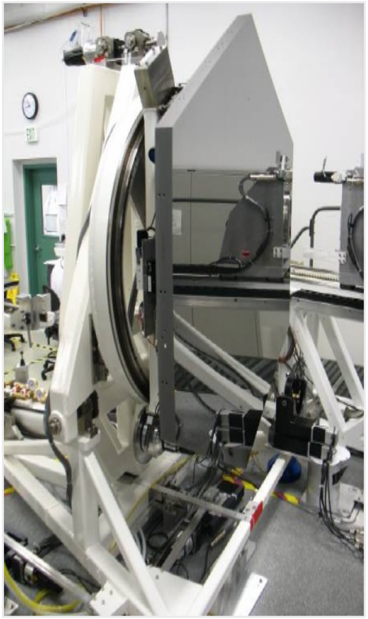


Telescope mirror polishing is underway



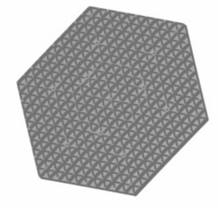
PMSA EDU



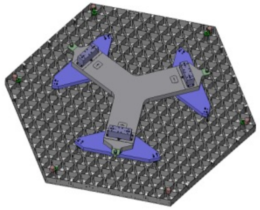


Cryogenic polishing is required to produce the JWST mirrors

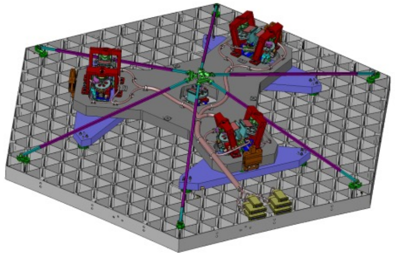
Config 1

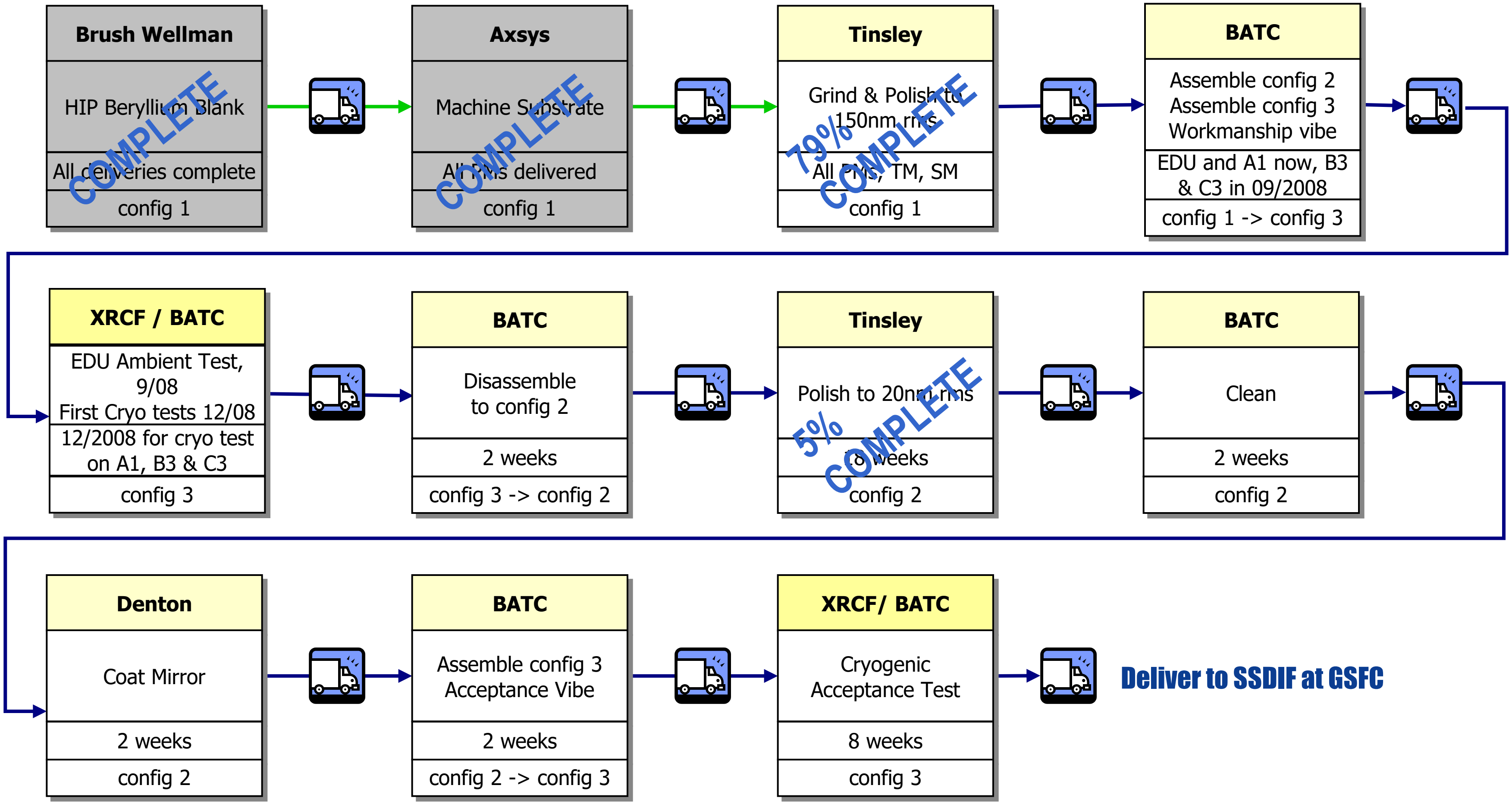


Config 2



Config 3





Brush Wellman
HIP Beryllium Blank
All deliveries complete
config 1
COMPLETE

Axsys
Machine Substrate
All PMs delivered
config 1
COMPLETE

Tinsley
Grind & Polish to 150nm rms
All PMs, TM, SM
config 1
79% COMPLETE

BATC
Assemble config 2
Assemble config 3
Workmanship vibe
EDU and A1 now, B3 & C3 in 09/2008
config 1 -> config 3

XRCF / BATC
EDU Ambient Test, 9/08
First Cryo tests 12/08
12/2008 for cryo test on A1, B3 & C3
config 3

BATC
Disassemble to config 2
2 weeks
config 3 -> config 2

Tinsley
Polish to 20nm rms
18 weeks
config 2
5% COMPLETE

BATC
Clean
2 weeks
config 2

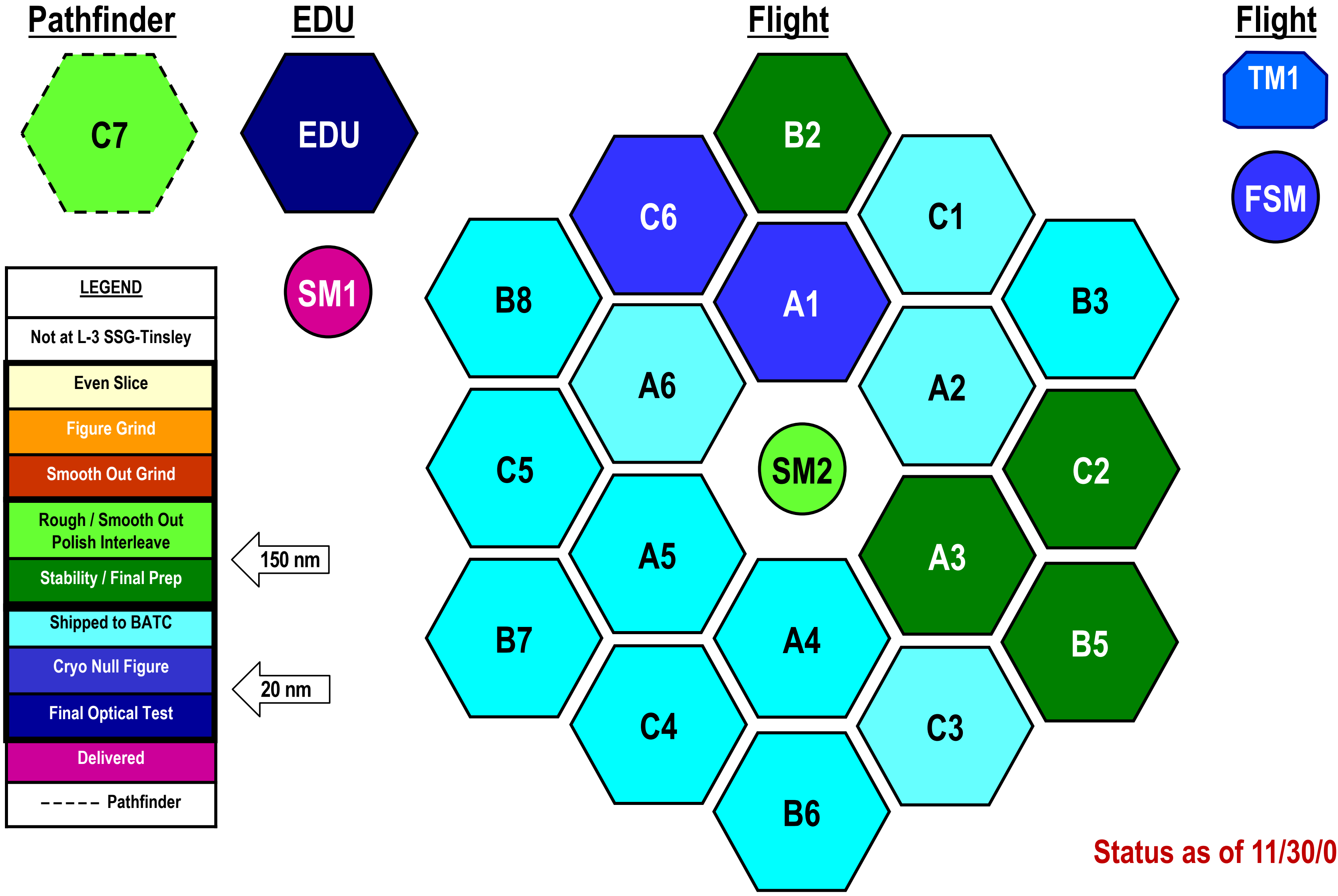
Denton
Coat Mirror
2 weeks
config 2

BATC
Assemble config 3
Acceptance Vibe
2 weeks
config 2 -> config 3

XRCF/ BATC
Cryogenic Acceptance Test
8 weeks
config 3

Deliver to SSDIF at GSFC

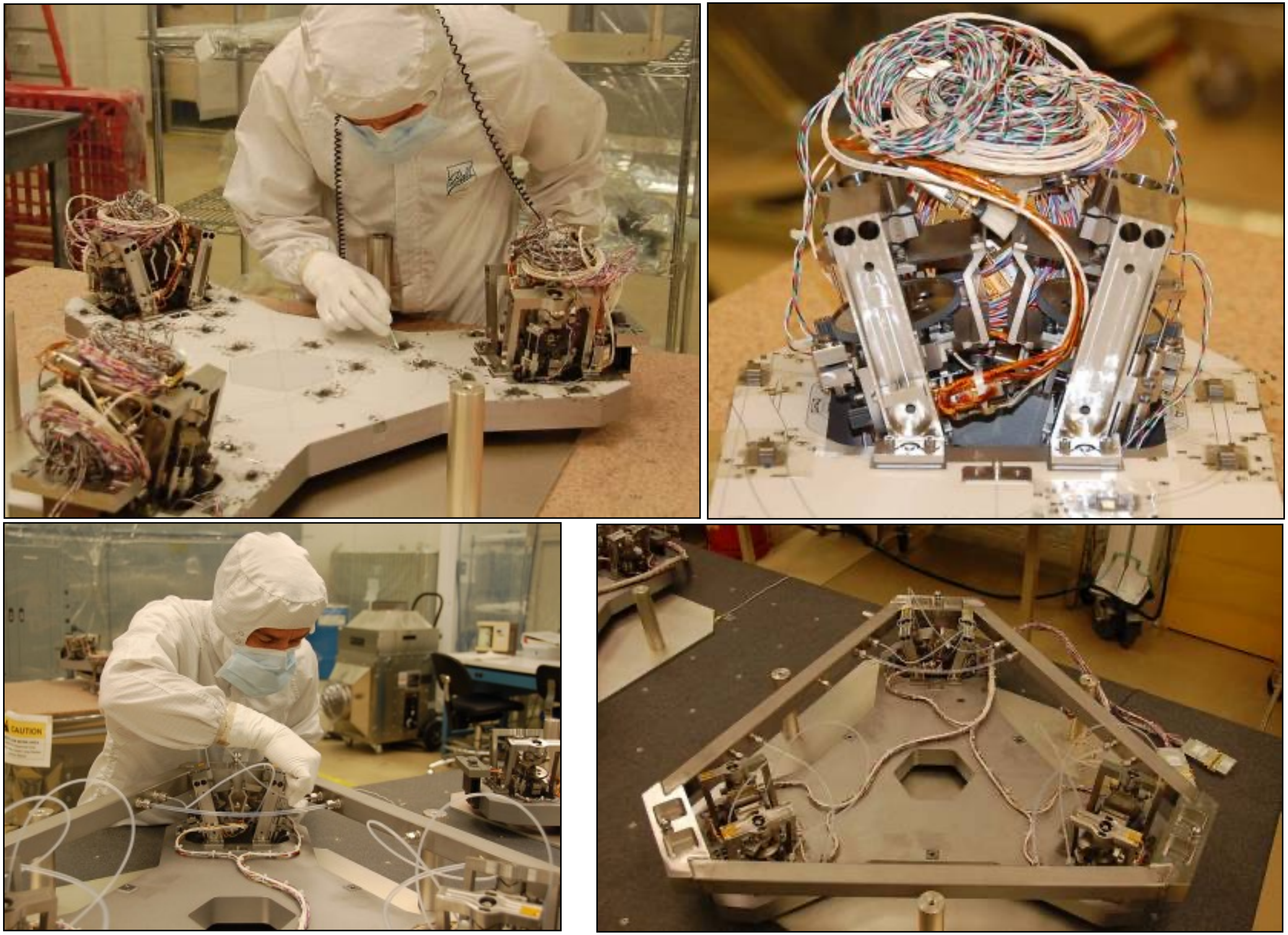
All flight mirrors are nearing final stages of polishing



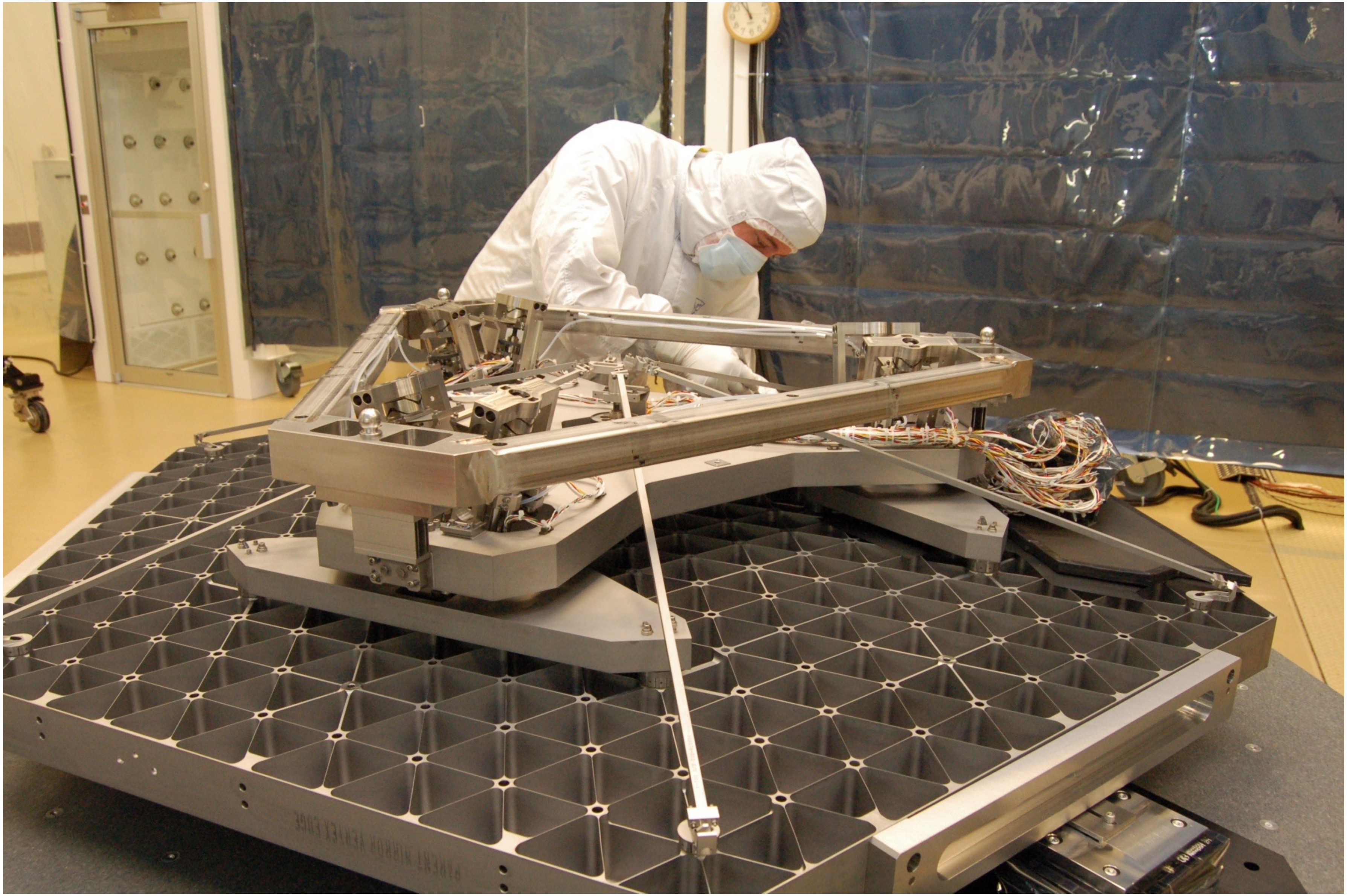
LEGEND
- Not at L-3 SSG-Tinsley
- Even Slice
- Figure Grind
- Smooth Out Grind
- Rough / Smooth Out Polish Interleave
- Stability / Final Prep
- Shipped to BATC
- Cryo Null Figure
- Final Optical Test
- Delivered
- ----- Pathfinder

Status as of 11/30/09

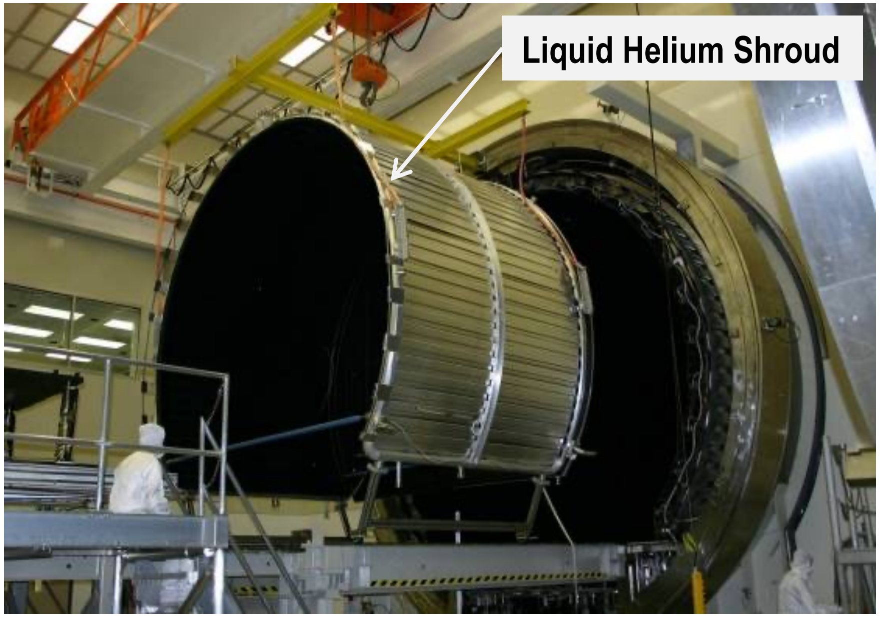
Hexapod assemblies are in manufacturing and on schedule

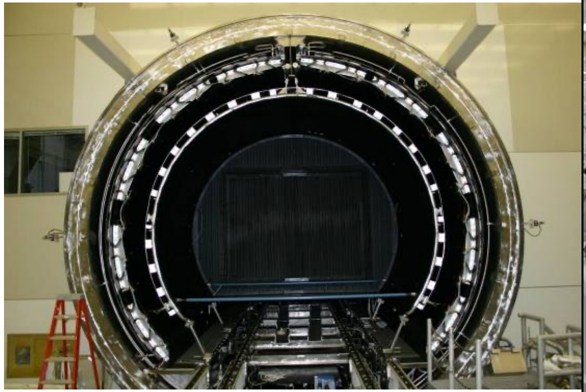


PMSA assembly in operational configuration

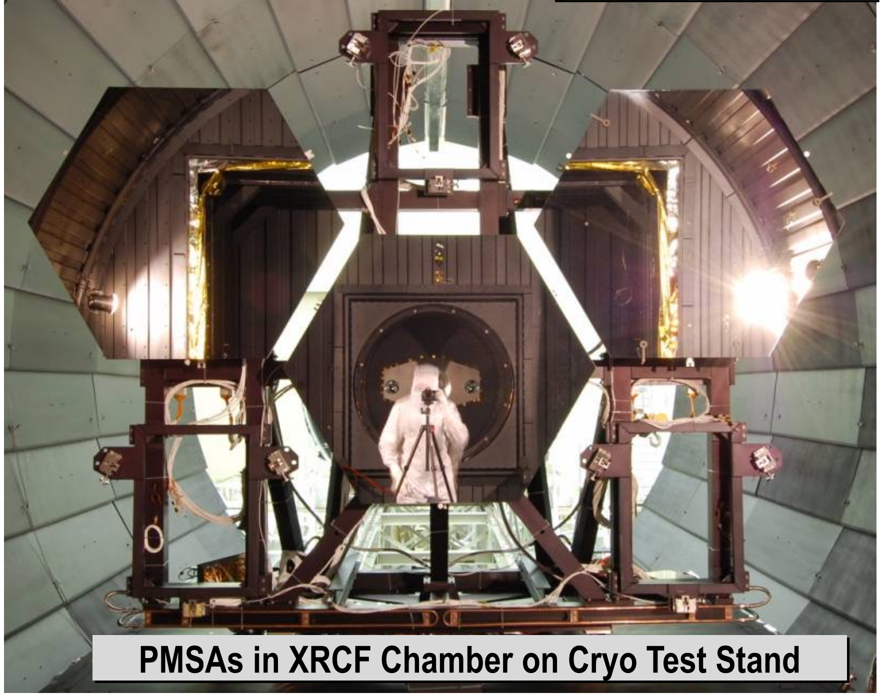


A large vacuum chamber at MSFC will be used to optically test the mirror segments at 50 K (-225 ◦C, -370 ◦F) after polishing

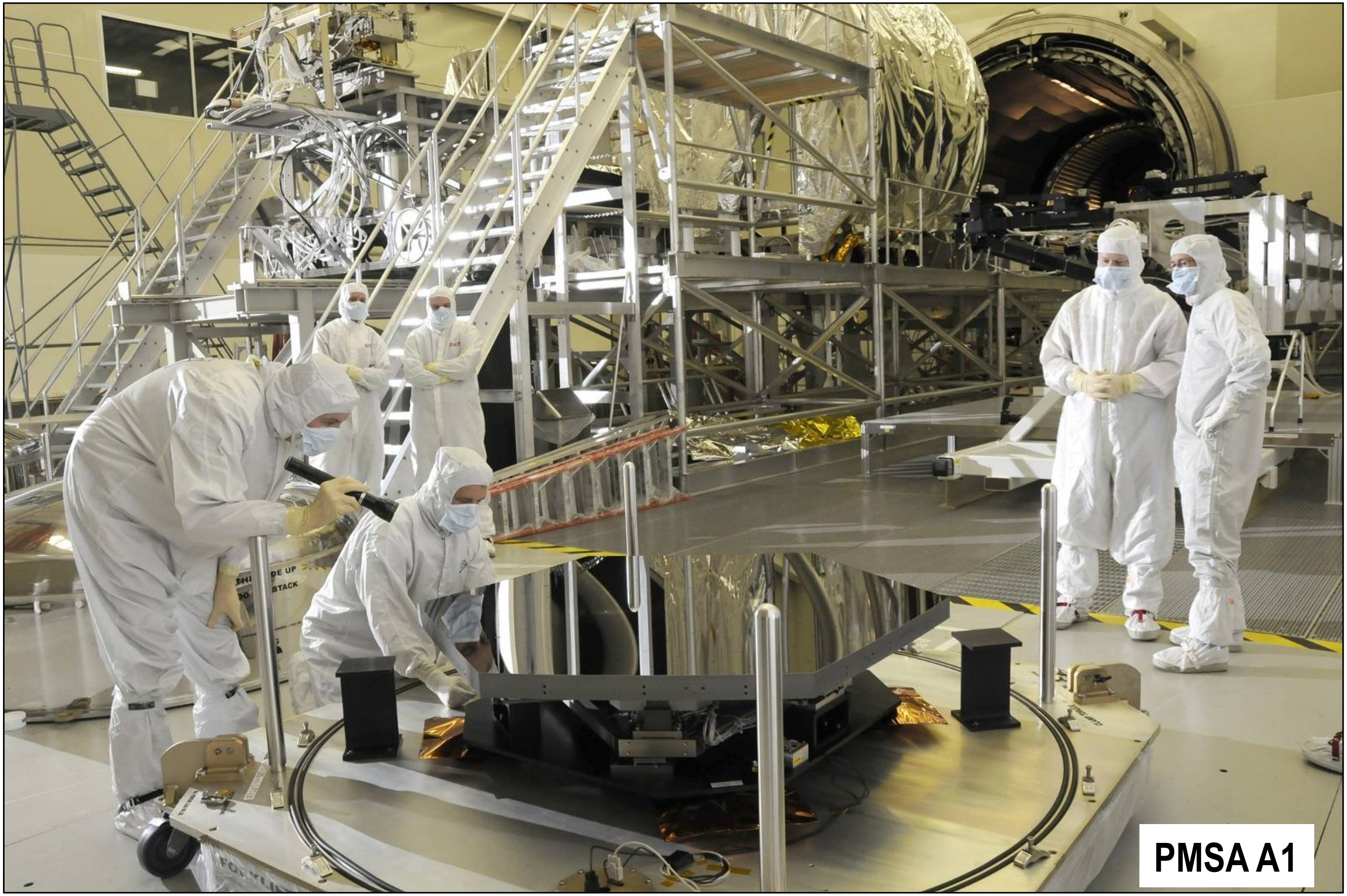




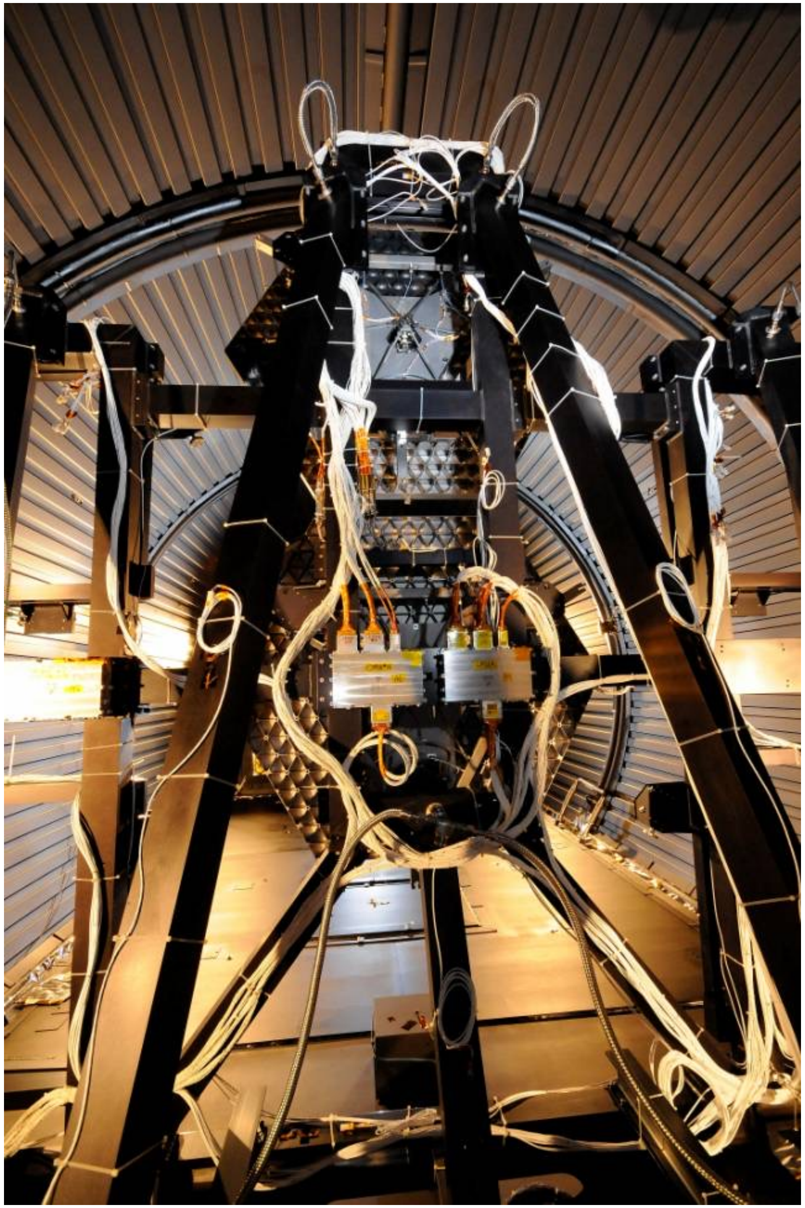

PMSA Integration onto XRCF Cryo Test Stand


PMSAs in XRCF Chamber on Cryo Test Stand

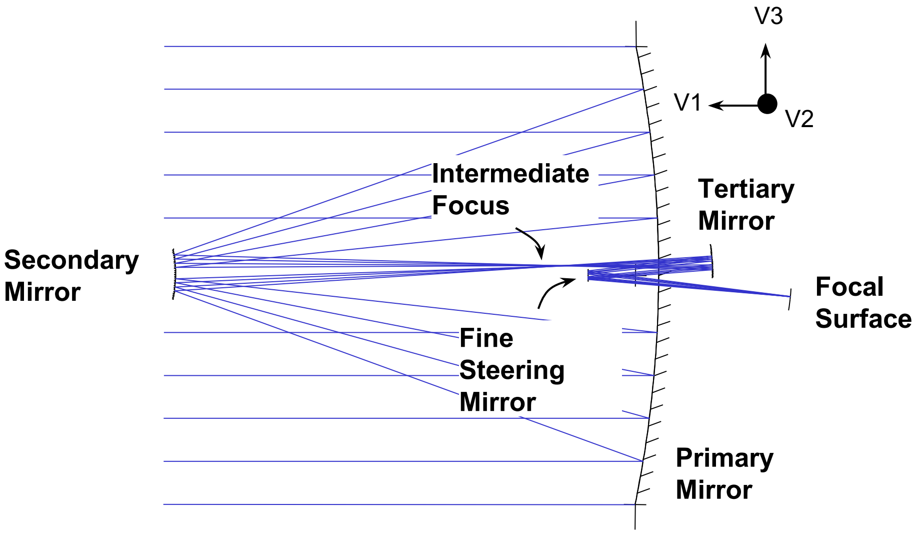
The first flight mirror segment at the XRCF at MSFC

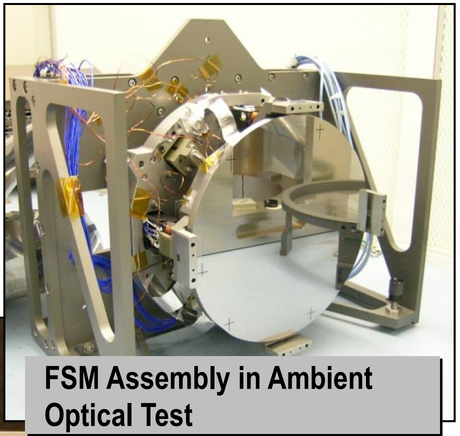


EDU and A1 PMSAs in the XRCF chamber at MSFC



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



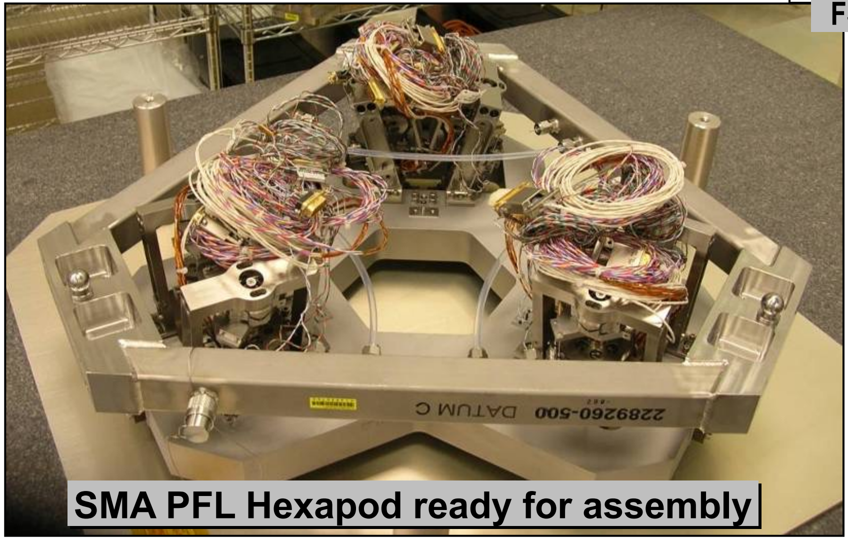


FSM Assembly in Ambient Optical Test

TMA in Ambient Test

FSM configuration 1

SM Configuration 1 (Substrate)

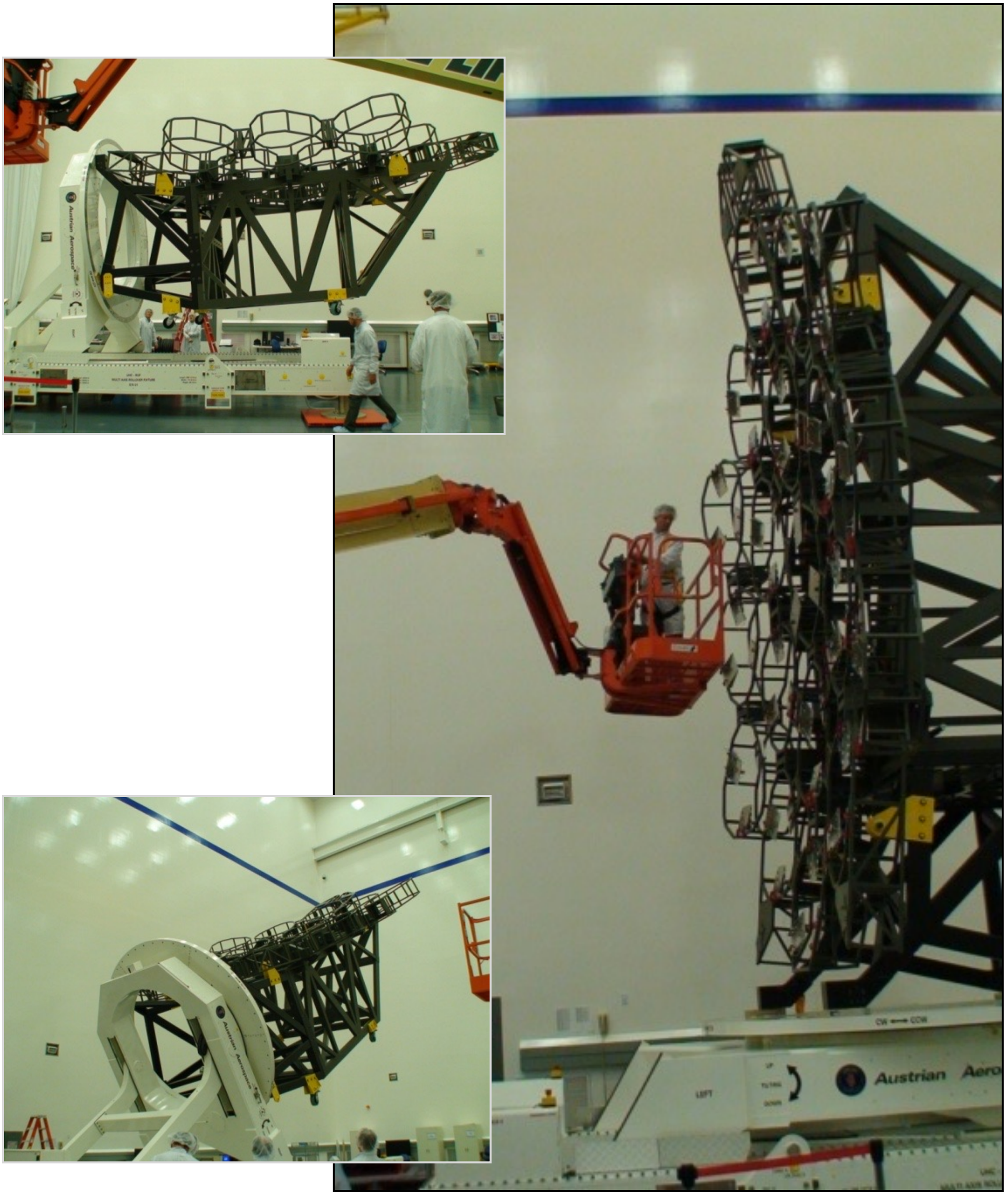


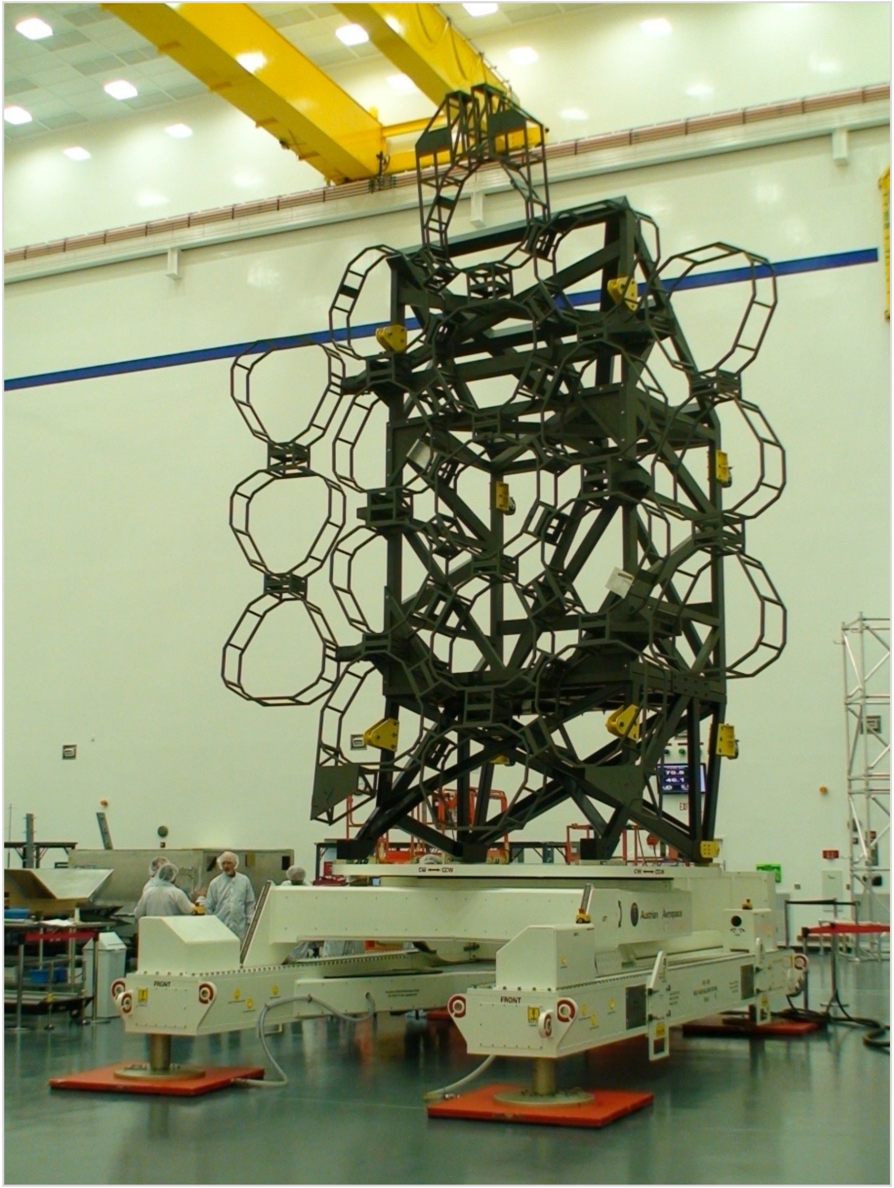
SMA PFL Hexapod ready for assembly

Buildup of telescope flight structure underway at ATK

Assembly consists of ~3,200 bonded composite piece parts

Full scale OTE mockup in handling test at NGAS

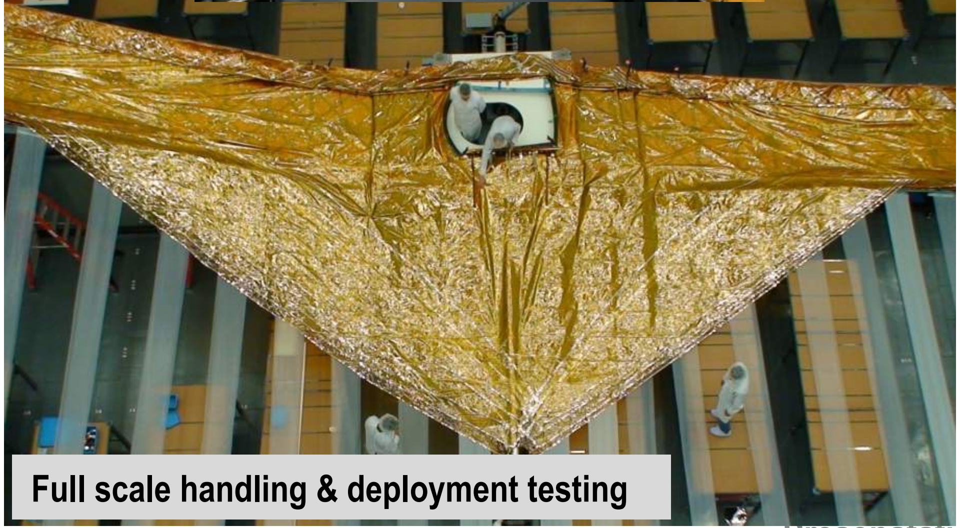




Sunshield development ready for CDR January 2010


OTE mockup


1/3 scale cryo test article


Full scale handling & deployment testing

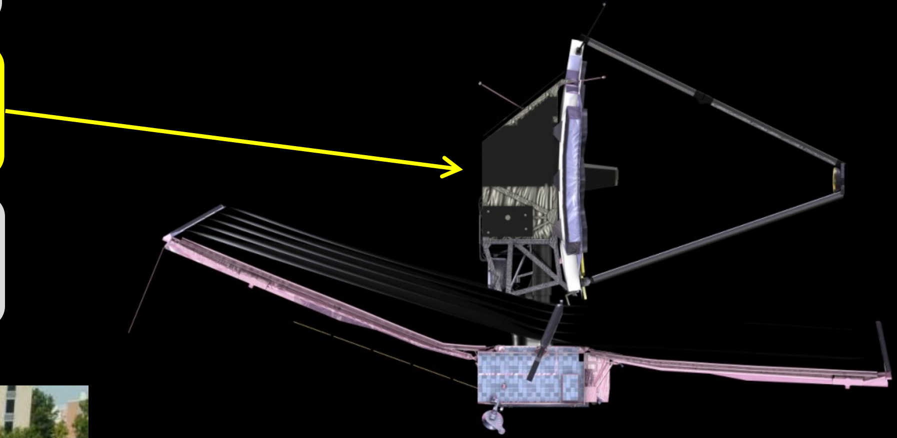

1/3 scale cryo test article

The observatory segment consists of three main elements

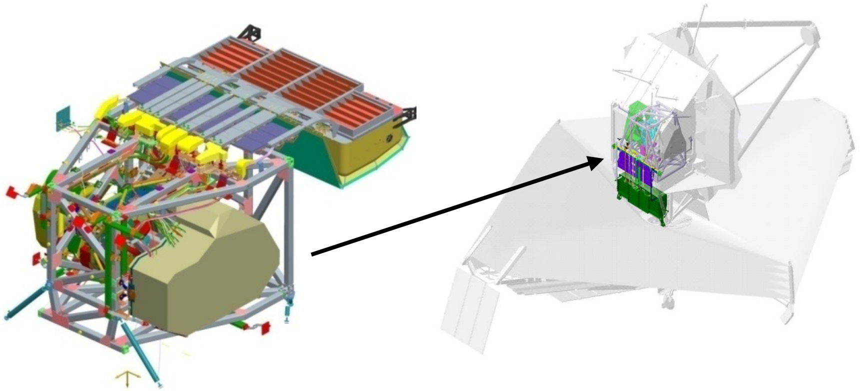
Optical Telescope Element (OTE)
Collects star light from distant objects

Integrated Science Instrument Module (ISIM)
Extracts physics information from star light

Spacecraft
Attitude control, telecom, power & other systems

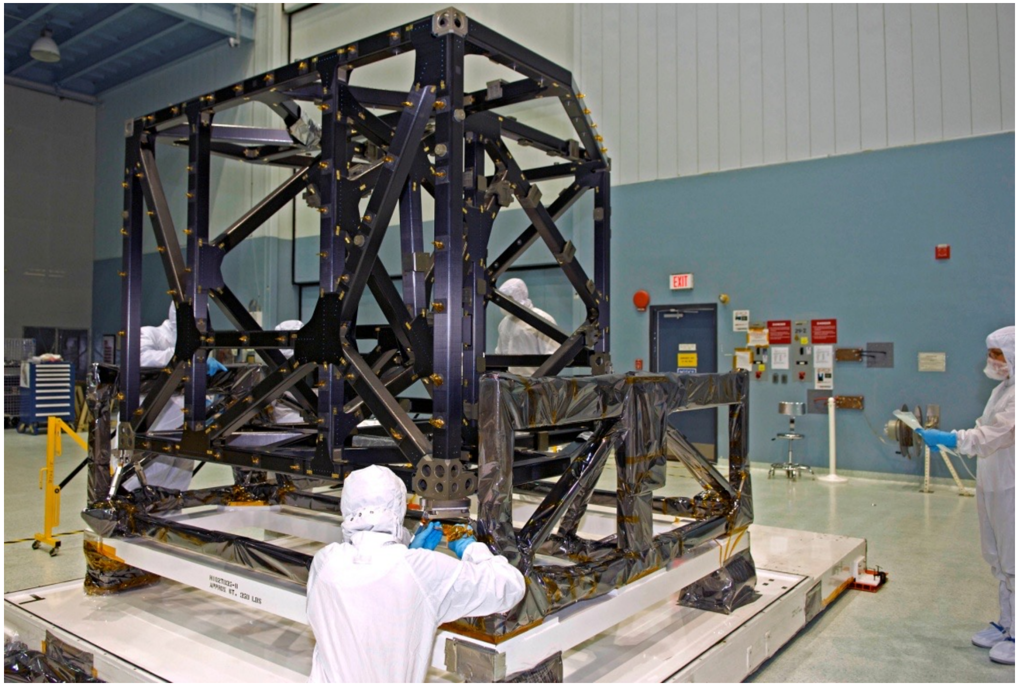


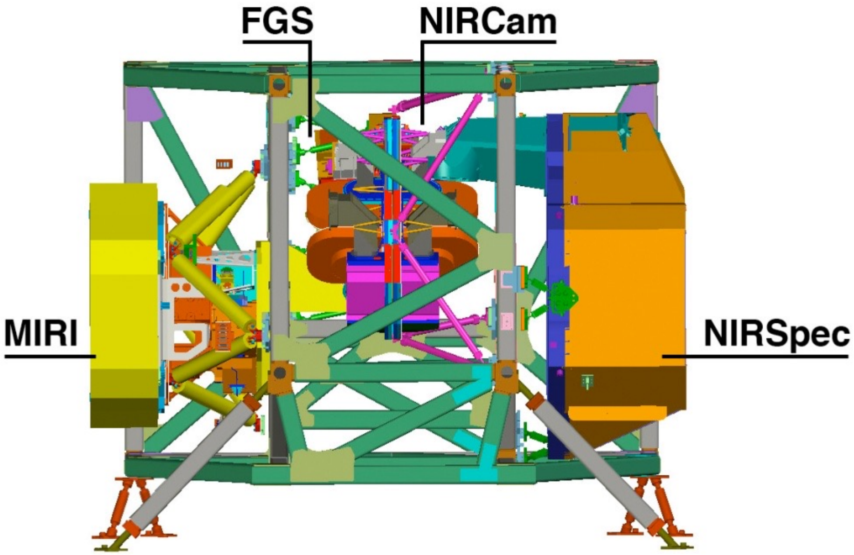
The JWST science instrument payload completed CDR during March 2009



Integrated Science Instrument Module (ISIM) contains:

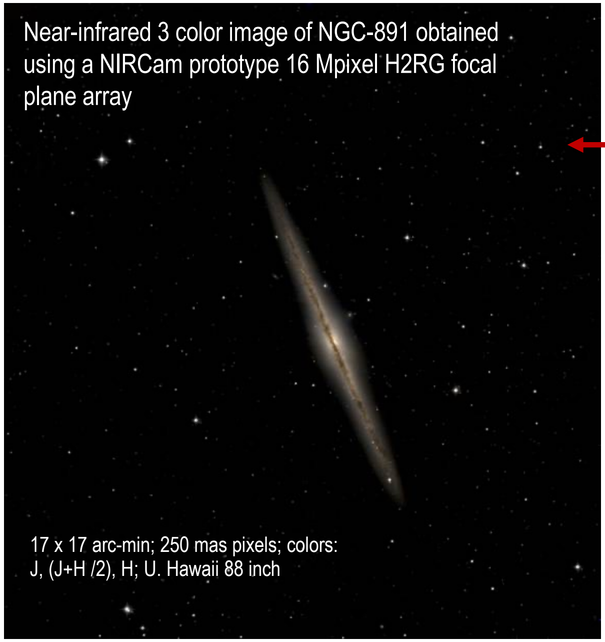
- Four science instruments
- Command and data handling system
- Flight software system
- Passive cryogenic thermal control system
- Optical metering structure system
- Science instrument control electronics
- Electrical harness system





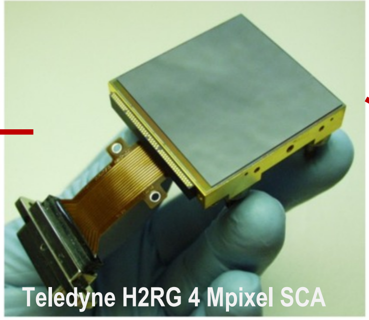
Detector development has met performance objectives

All flight detectors have been delivered

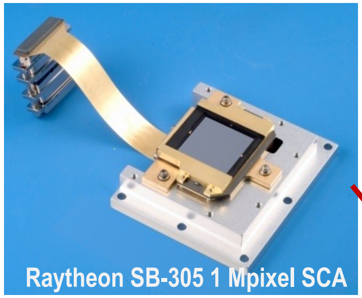


Near-infrared 3 color image of NGC-891 obtained using a NIRCam prototype 16 Mpixel H2RG focal plane array

17 x 17 arc-min; 250 mas pixels; colors: J, (J+H /2), H; U. Hawaii 88 inch



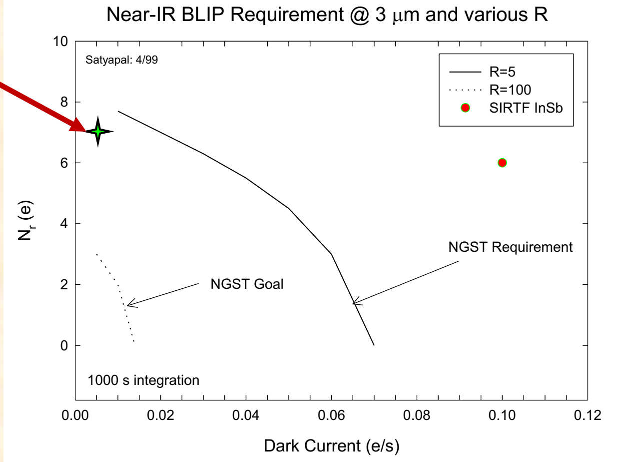
Teledyne H2RG 4 Mpixel SCA



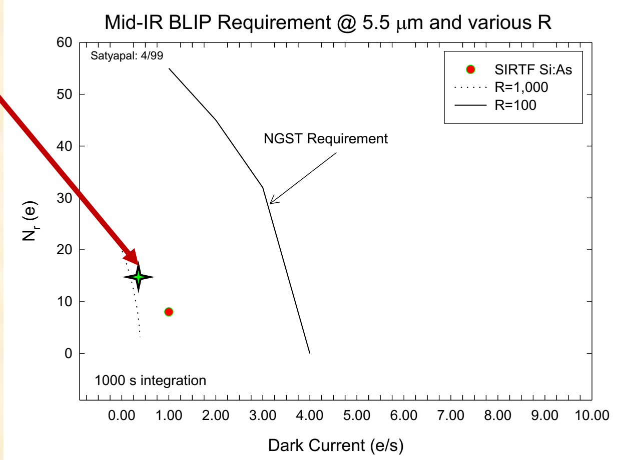
Raytheon SB-305 1 Mpixel SCA

	SWIR	MWIR
Spitzer	256 x 256 InSb	256 x 256 Si:As
JWST	2048 x 2048 HgCdTe	1024 x 1024 Si:As

Mission Requirements Circa 1999



Near-IR BLIP Requirement @ 3 μm and various R

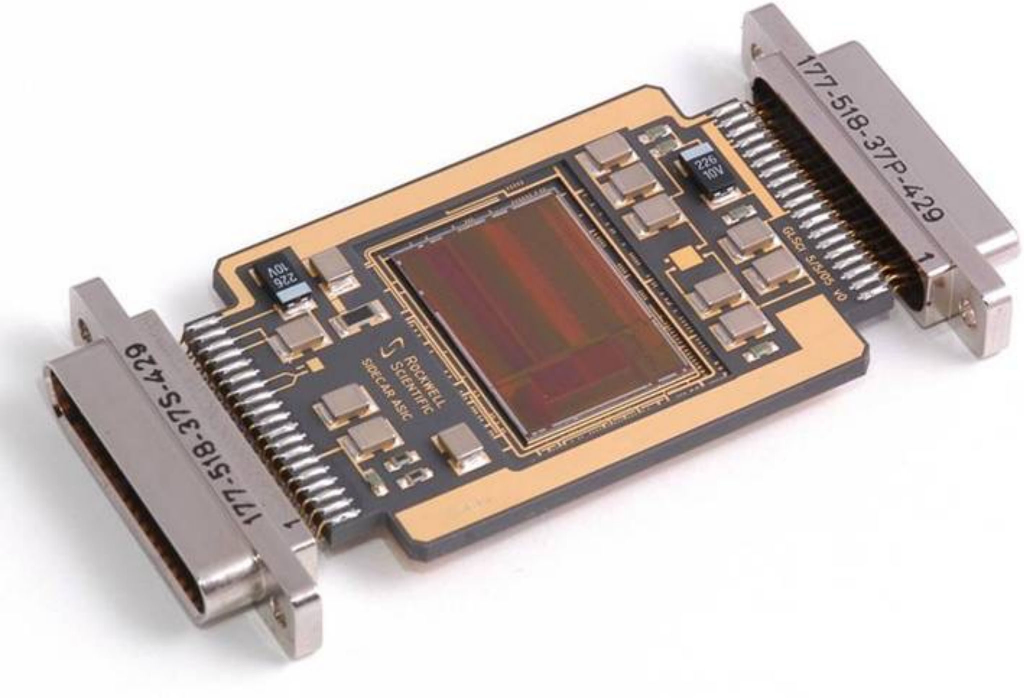


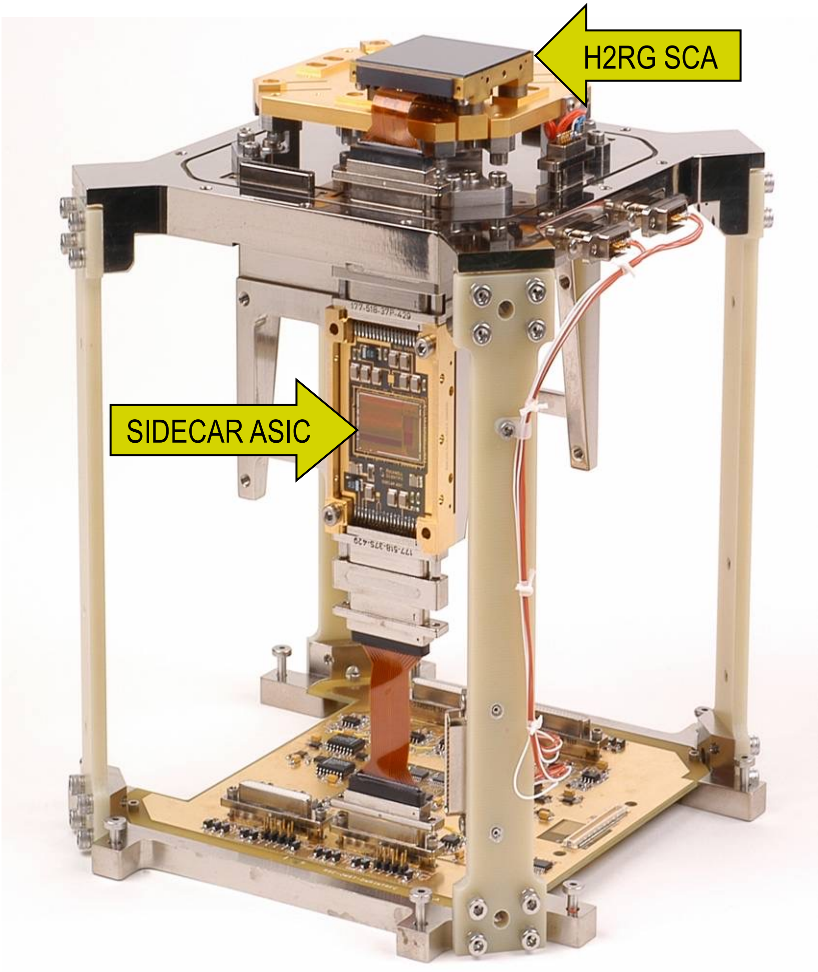
Mid-IR BLIP Requirement @ 5.5 μm and various R

Cryo-ASIC development fully successful and in flight production

TRL-9: In flight on HST/SM4

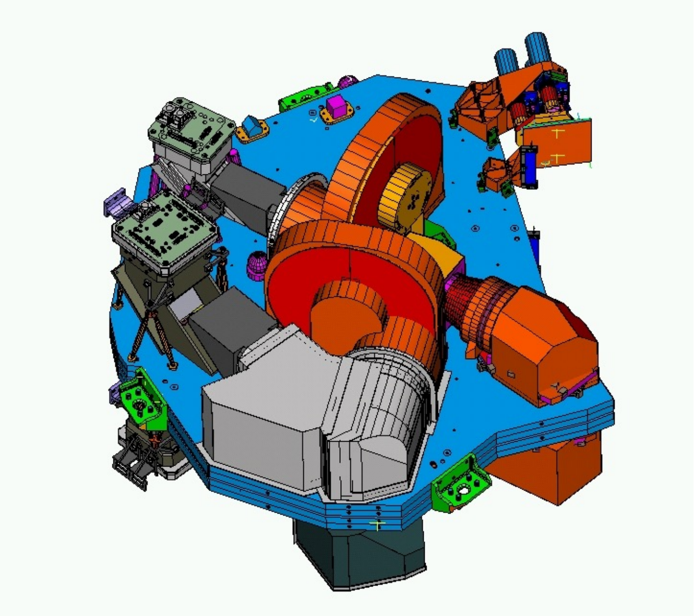
- Key to enabling ISIM 63 Mpixel near-infrared pixel compliment within mass and power constraints
- Provides complete control and data conversion functionality for operation of H2RG SCA
  - 37 K operation with < 20 mW dissipation
  - In-flight controllable software
  - 16 bit resolution

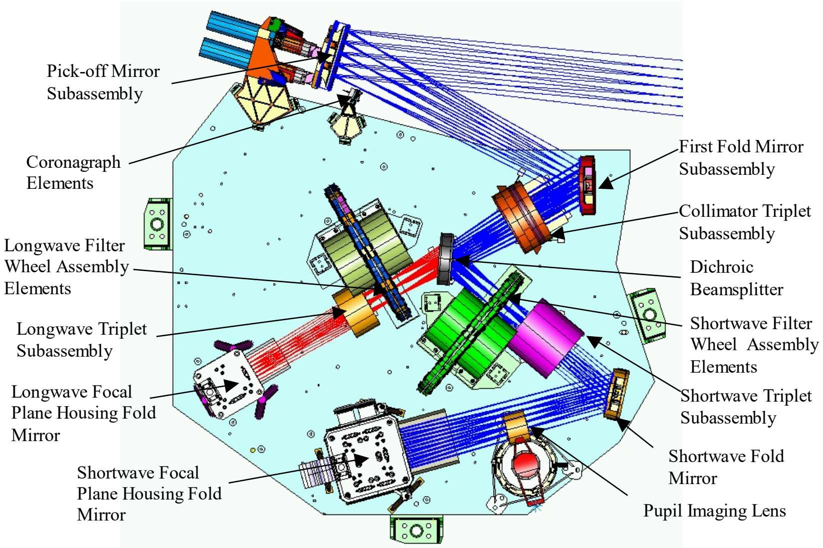




ASIC Cryogenic Test Assembly

The NIRCam instrument will image large portions of the sky identifying primeval galaxy targets for the other instruments

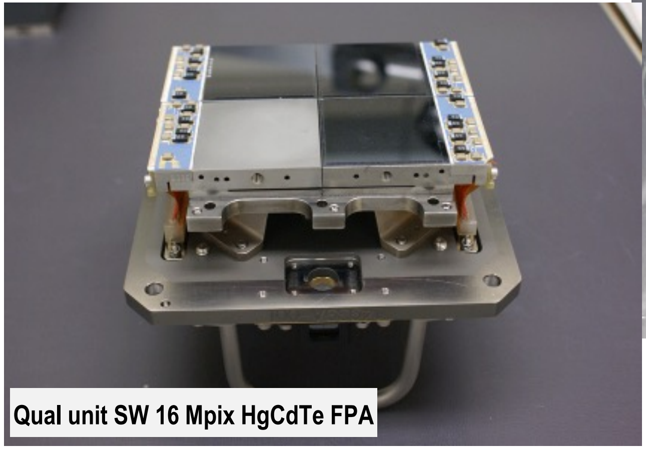




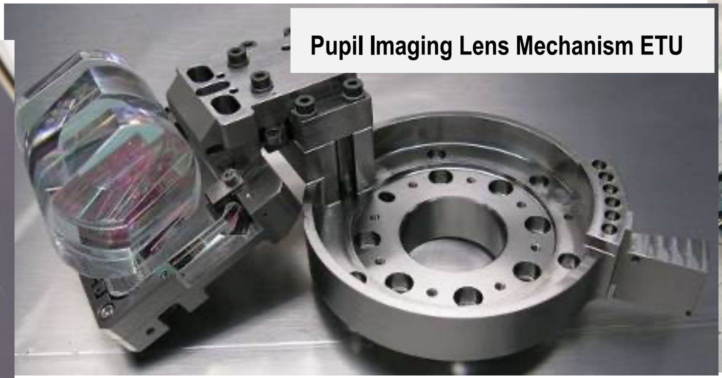
- Developed by the University of Arizona with Lockheed Martin ATC
  - Operating wavelength: 0.6 – 5.0 microns
  - Spectral resolution: 4, 10, 100
  - Field of view: 2.2 x 4.4 arc minutes
  - Angular resolution (1 pixel): 32 mas < 2.3 microns, 65 mas > 2.4 microns
  - Detector type: HgCdTe, 2048 x 2048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

NIRCam ETU in integration now

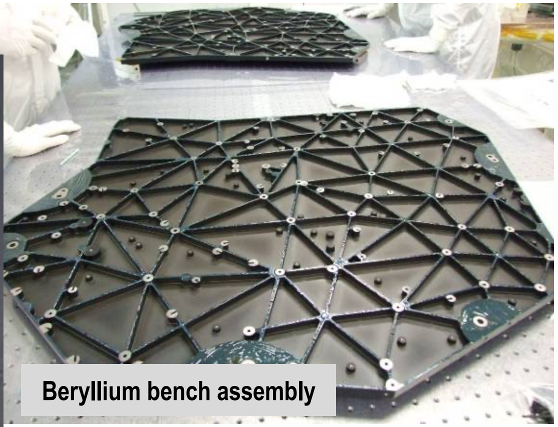
NIRCam is on schedule for delivery during March 2011



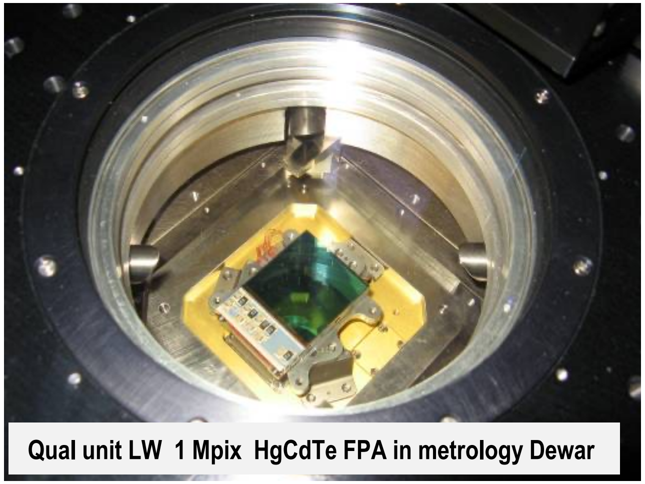
Qual unit SW 16 Mpix HgCdTe FPA



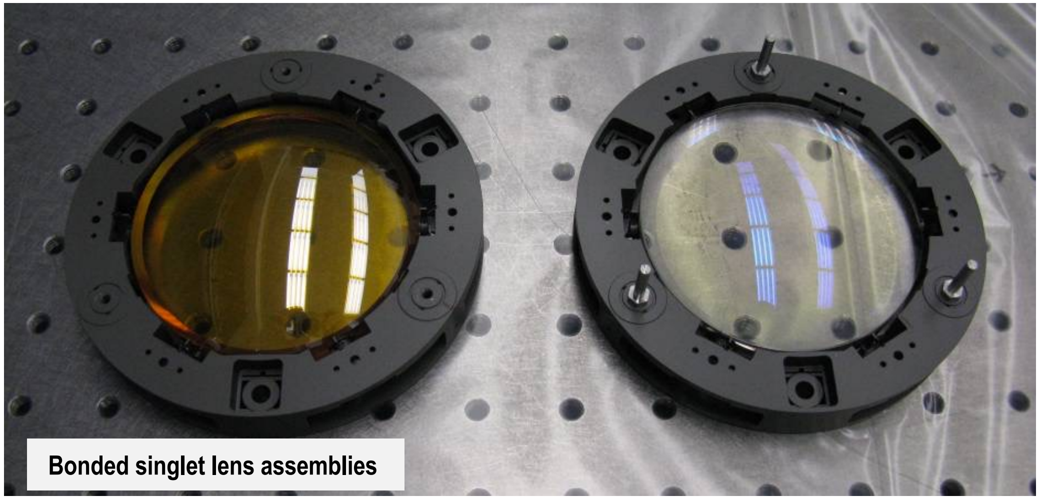
Pupil Imaging Lens Mechanism ETU



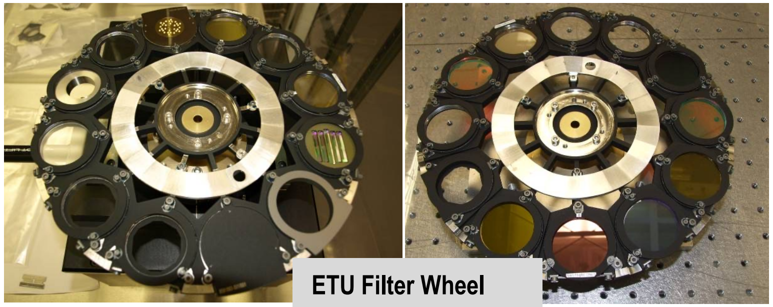
Beryllium bench assembly



Qual unit LW 1 Mpix HgCdTe FPA in metrology Dewar

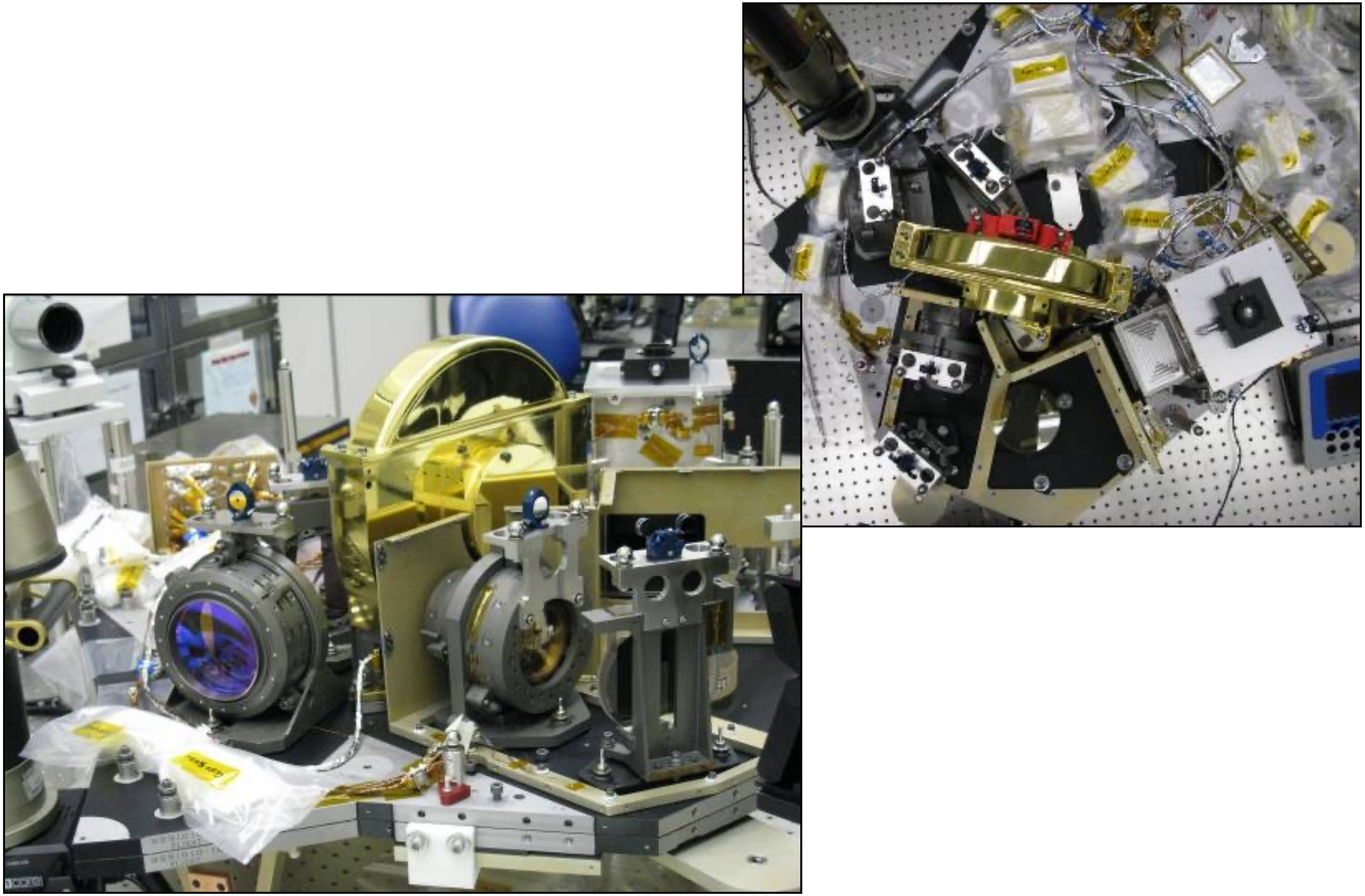


Bonded singlet lens assemblies

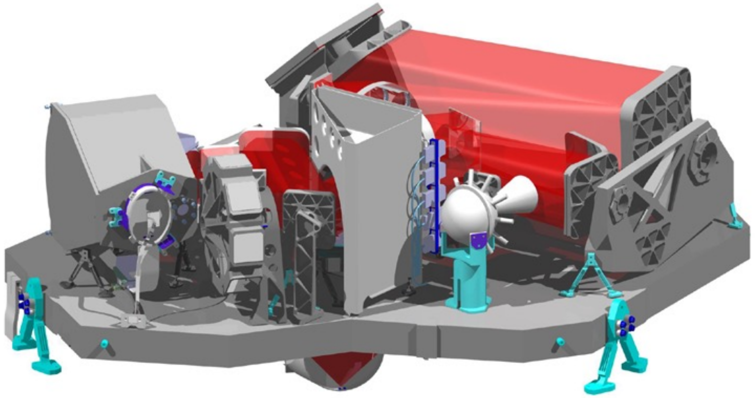


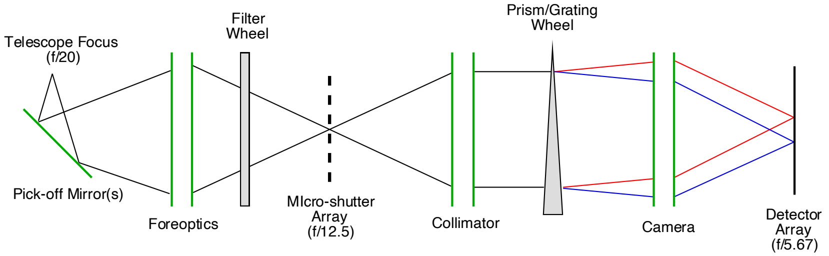
ETU Filter Wheel

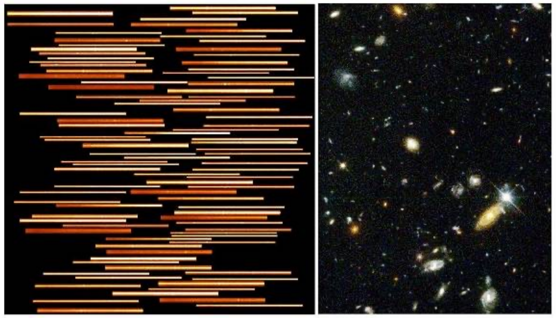
The NIRCam ETU is in integration & test



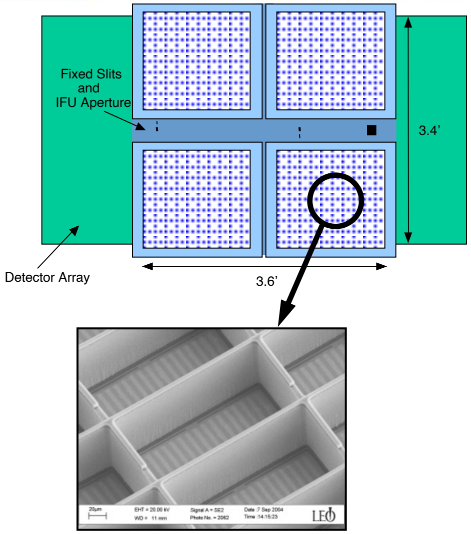
The NIRSpec will produce spectra of up to 100 galaxies in a single exposure





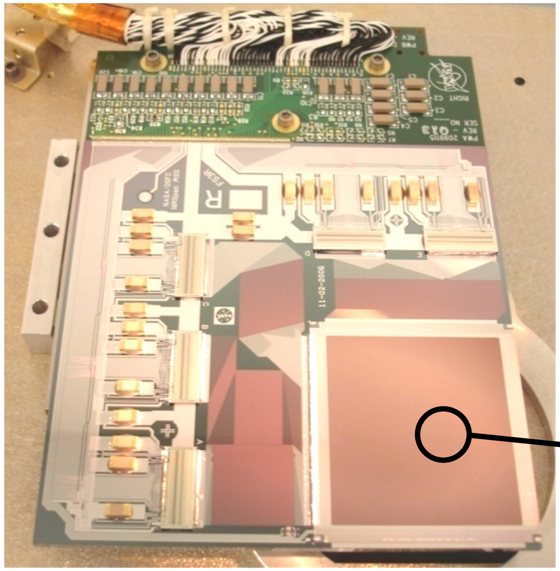


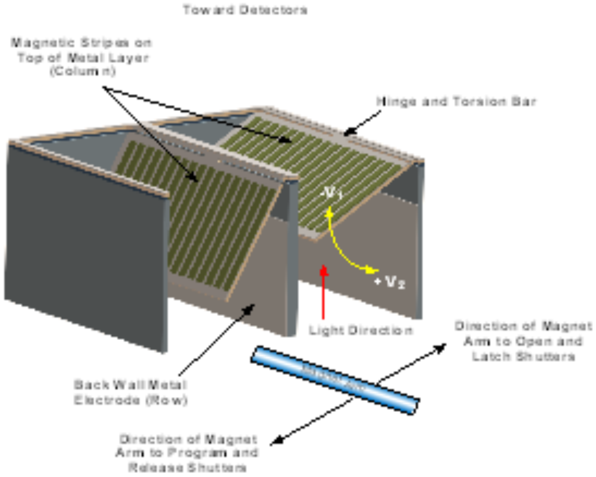
- Developed by the European Space Technology Center (ESTEC) with Astrium GmbH and Goddard Space Flight Ctr
  - Operating wavelength: 0.6 – 5.0 microns
  - Spectral resolution: 100, 1000, 3000
  - Field of view: 3.4 x 3.4 arc minutes
    - Aperture control: programmable micro-shutters, 250,000 pixels
    - Angular resolution: shutter open area 203 x 463 mas, pitch 267 x 528 mas
  - Detector type: HgCdTe, 2048 x 2048 pixel format, 2 detectors, 37 K passive cooling
  - Reflective optics, SiC structure and optics

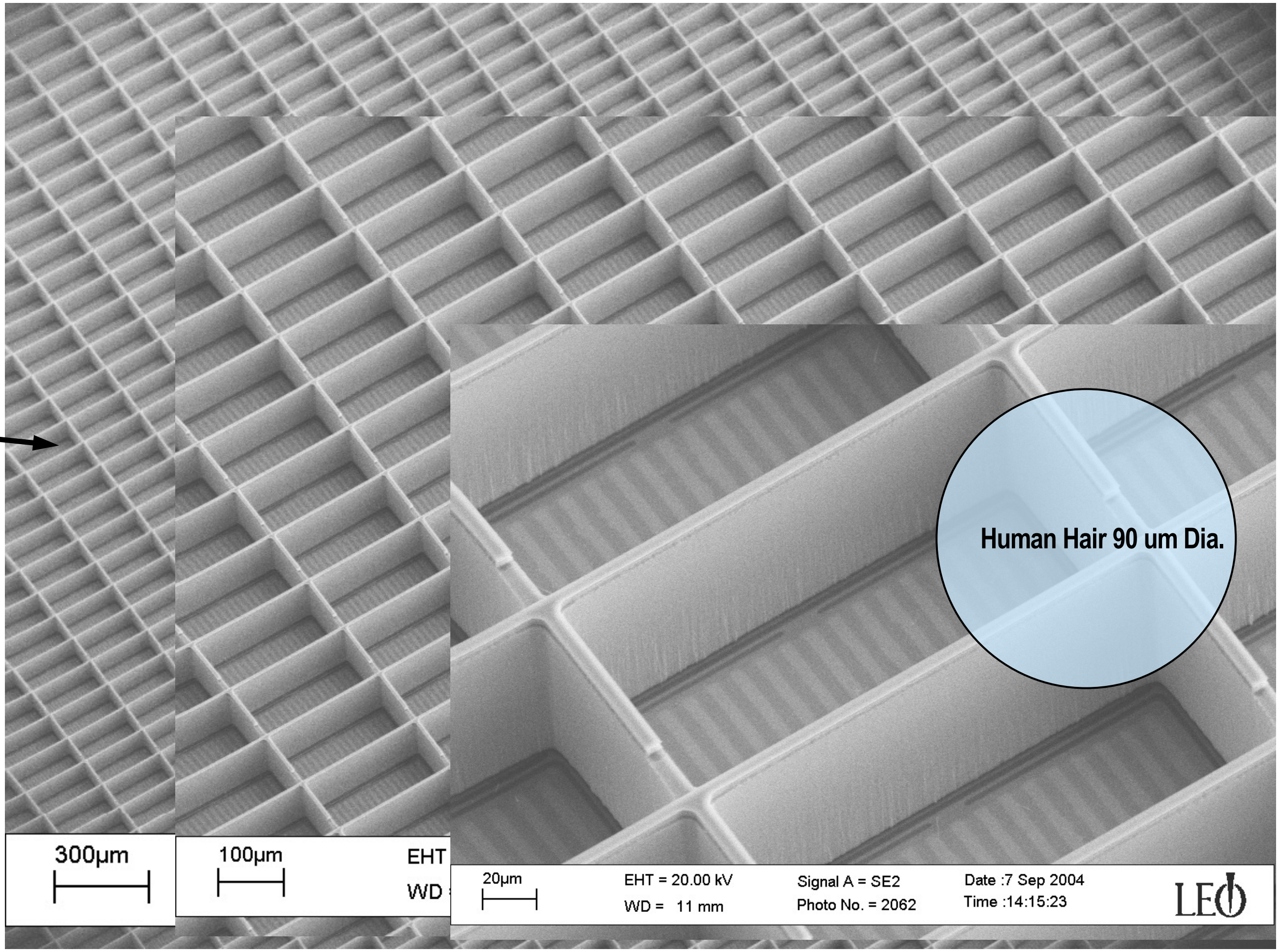


ETU Testing Completed Oct 09
Flight Model in Integration Now

250 thousand pixel cryogenic microshutter array system is on schedule for delivery during Feb 2010







203 x 463 mas shutter pixel clear aperture, 267 x 528 mas pitch, 4 x 171 x 365 array

NIRSpec is on schedule for delivery during Nov 2010

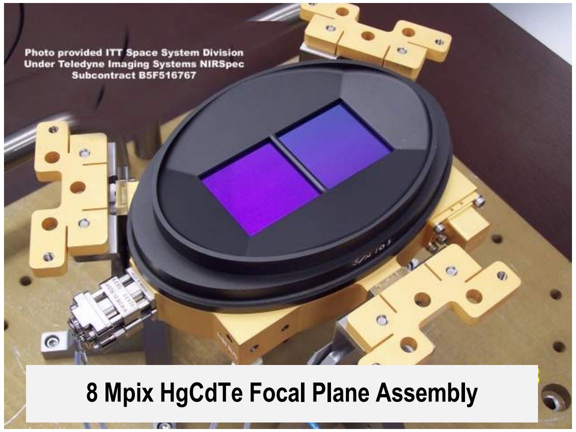
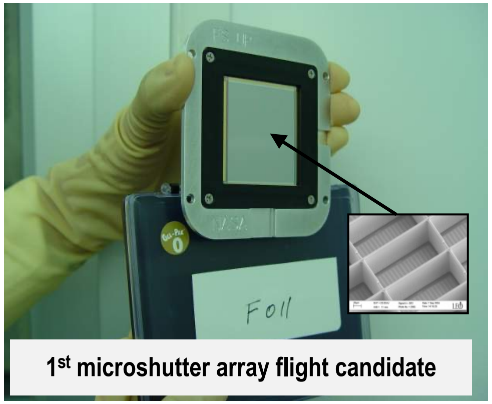
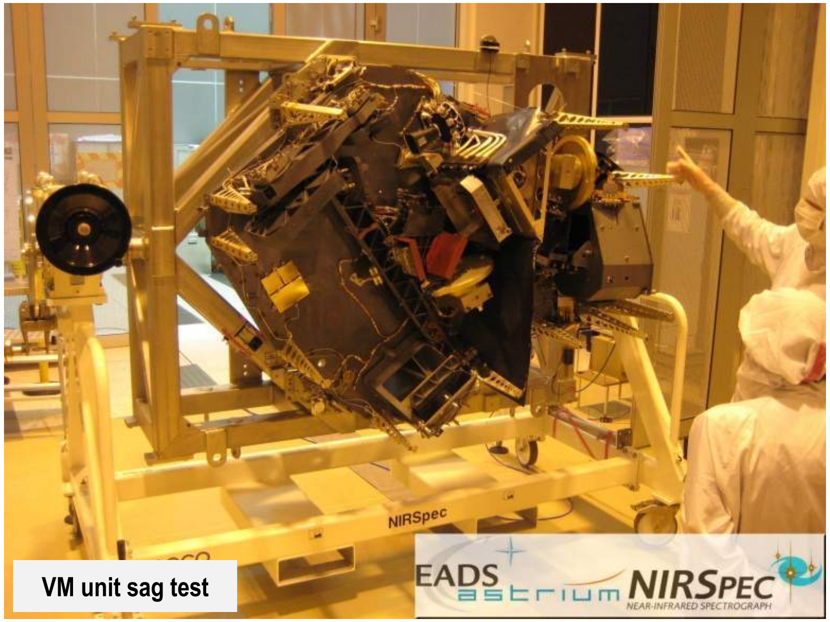


Photo provided ITT Space System Division
Under Teledyne Imaging Systems NIRSpec
Subcontract B5F516767

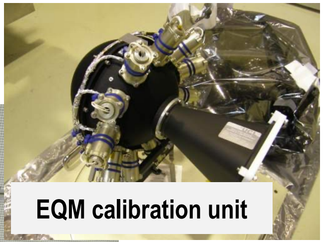
8 Mpix HgCdTe Focal Plane Assembly

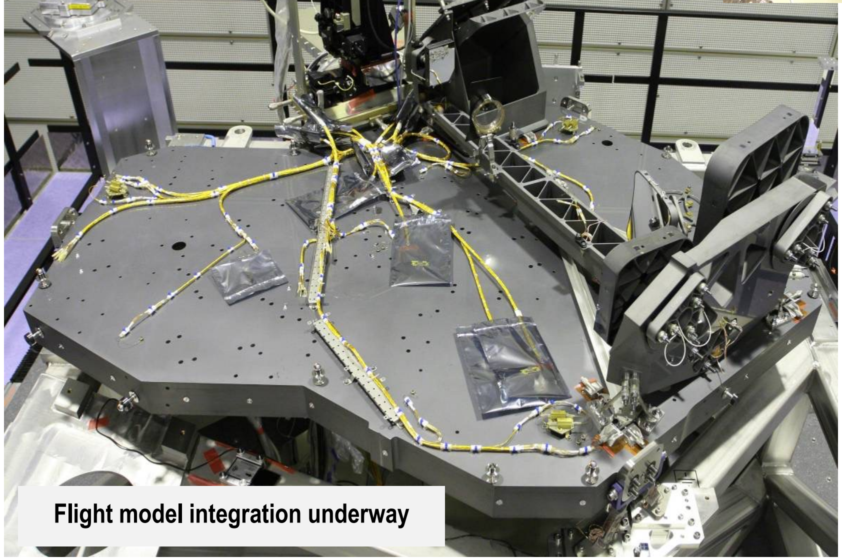


1st microshutter array flight candidate

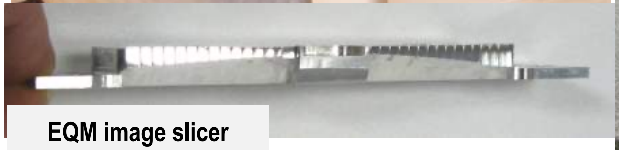


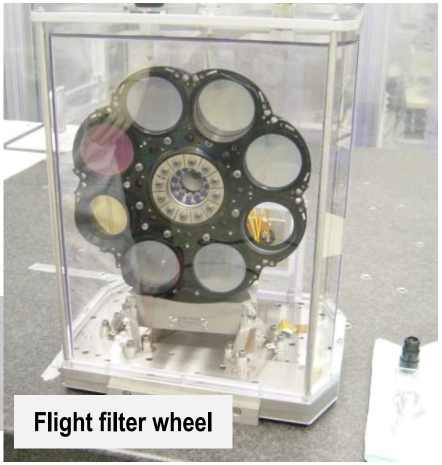
VM unit sag test


EQM calibration unit

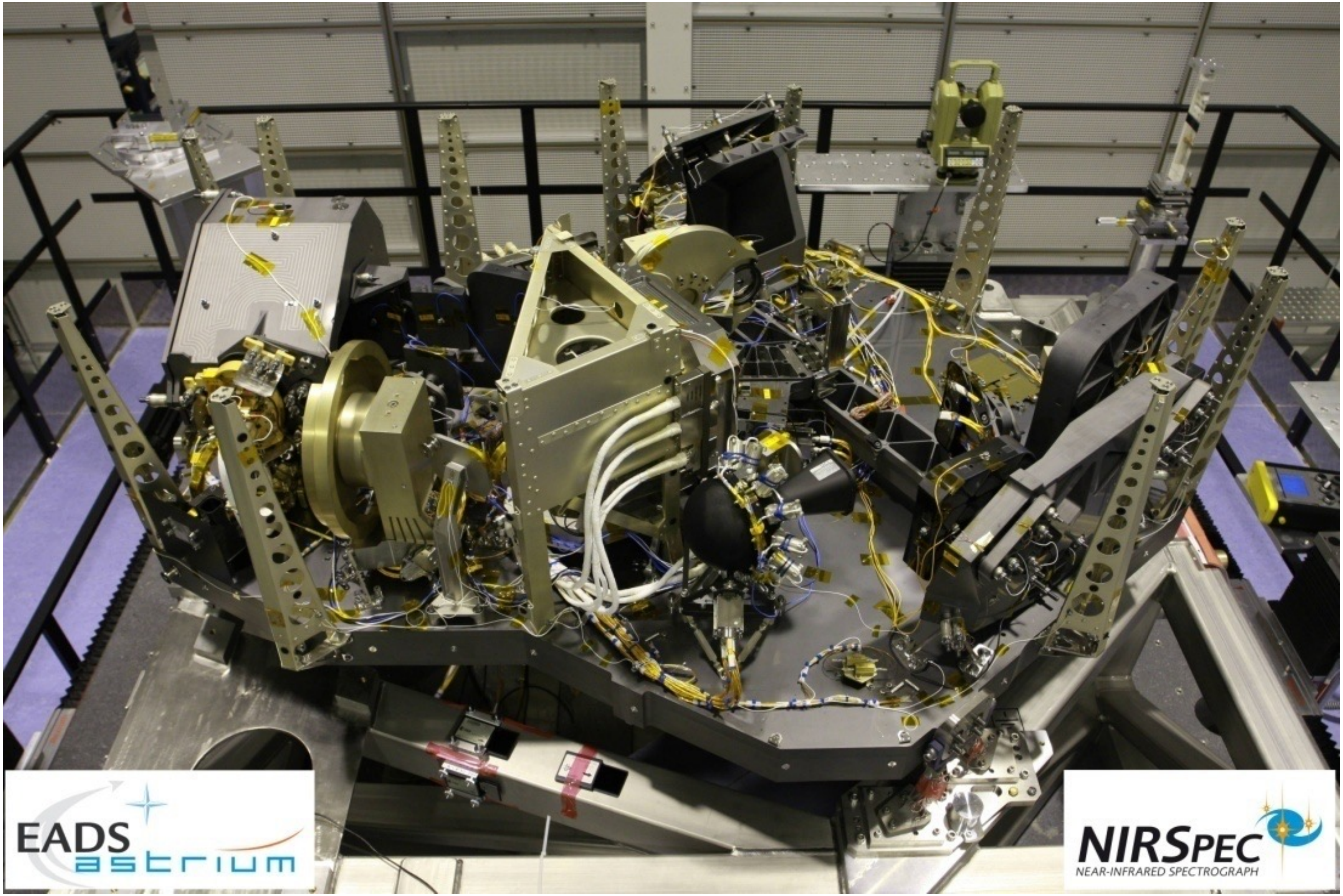

Flight model integration underway


EQM IFU assembly

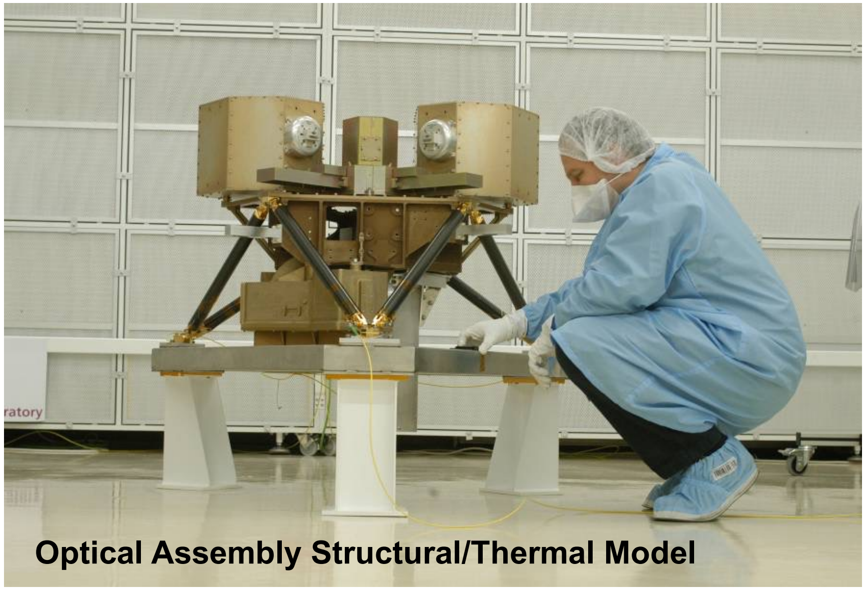

EQM image slicer


Flight filter wheel

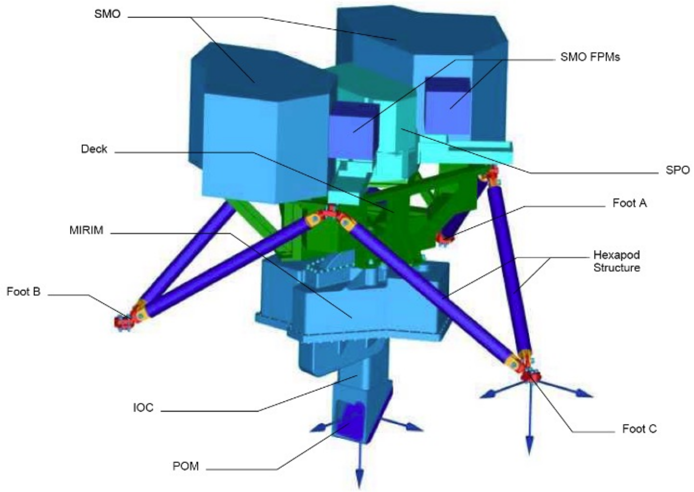
NIRSpec verification model testing was completed during October 2009



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



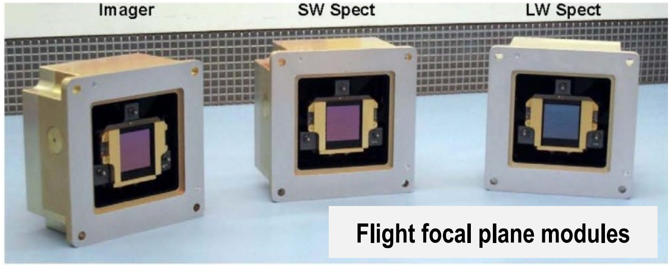
Optical Assembly Structural/Thermal Model



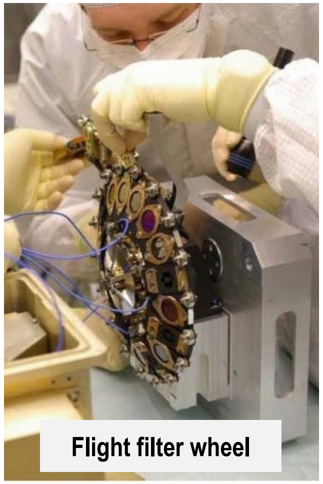
- Developed by the United Kingdom Advanced Technology Center and JPL
  - Operating wavelength: 5 - 29 microns
  - Spectral resolution: 5, 100, 2000
  - Field of view: 1.9 x 1.4 arc minutes broad-band imagery
    - R100 spectroscopy 5 x 0.2 arc sec slit
    - R2000 spectroscopy 3.5 x 3.5 and 7 x 7 arc sec integral field units
  - Detector type: Si:As, 1024 x 1024 pixel format, 3 detectors, 7 K cryo-cooler
  - Reflective optics, Aluminum structure and optics

ETU Testing Completed Dec 08
Flight Model in Integration Now

MIRI is on schedule for delivery during Oct 2010

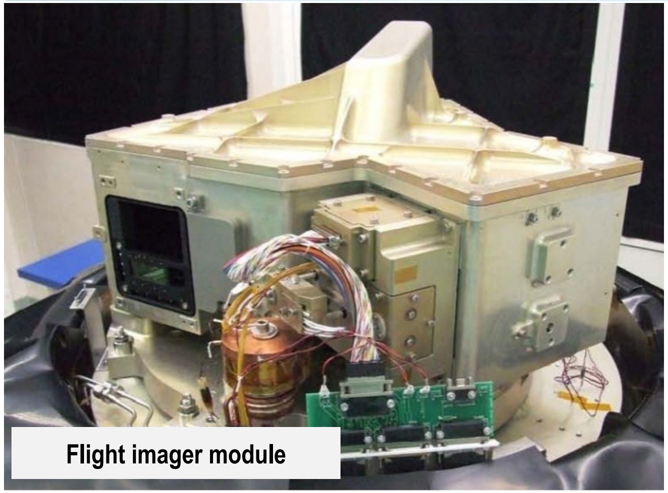


Flight focal plane modules

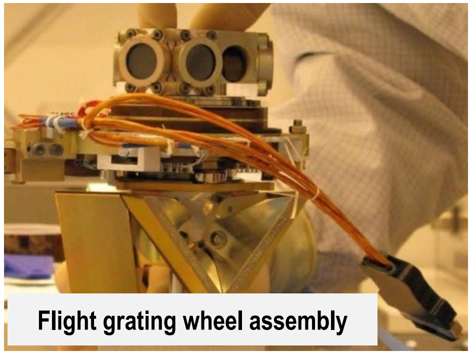


Flight filter wheel

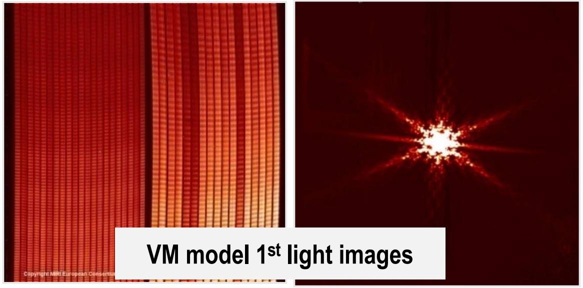
Flight filter wheel mechanism in vibration testing



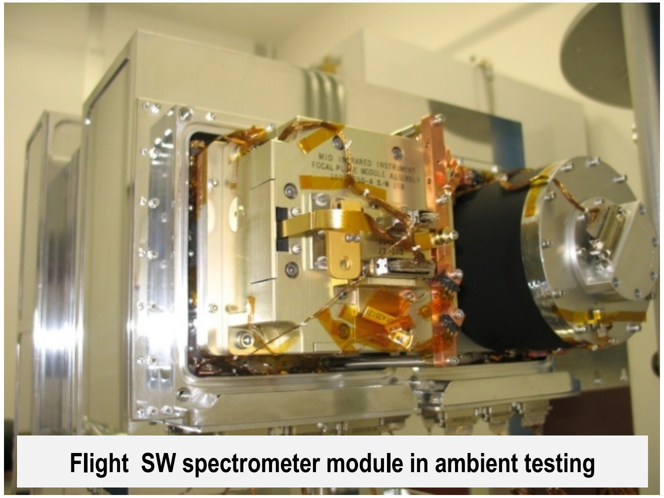
Flight imager module



Flight grating wheel assembly

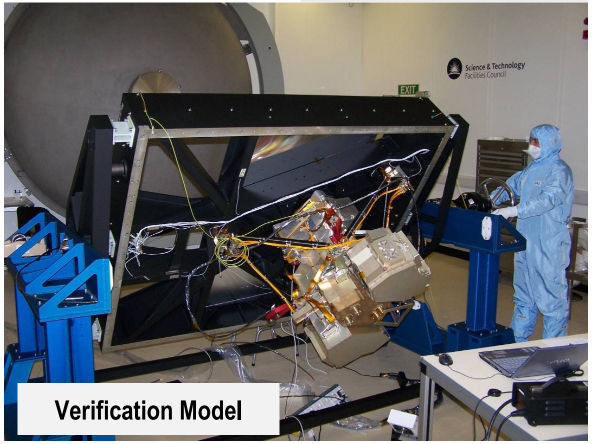


VM model 1st light images



Flight SW spectrometer module in ambient testing

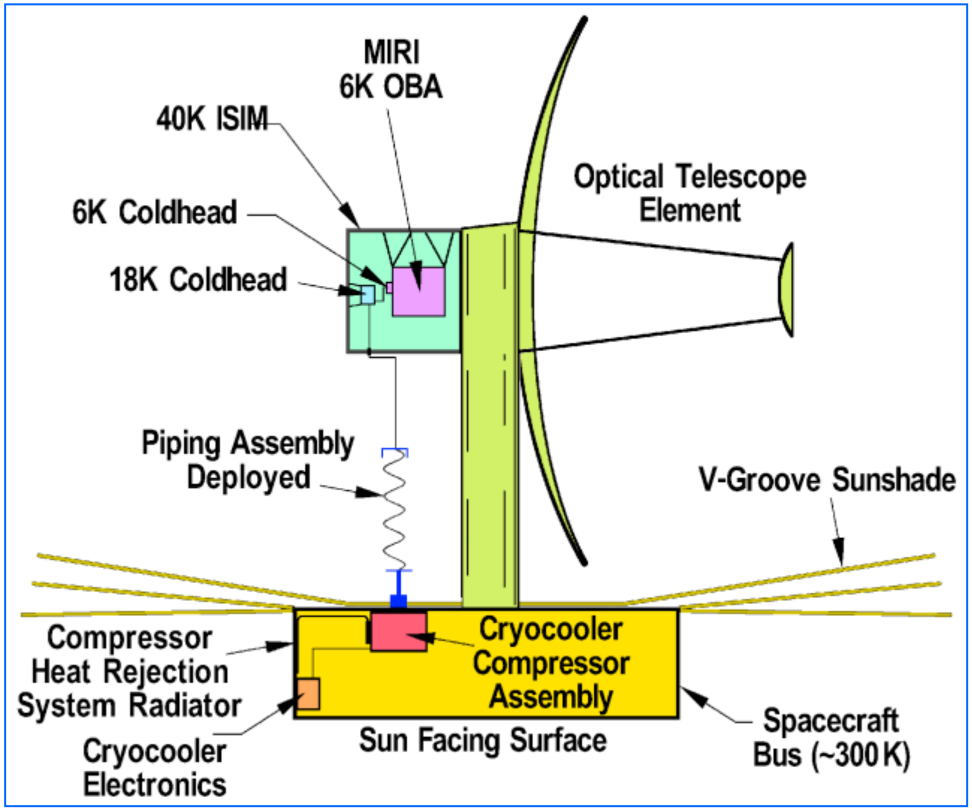
Flight ICE in vibration test

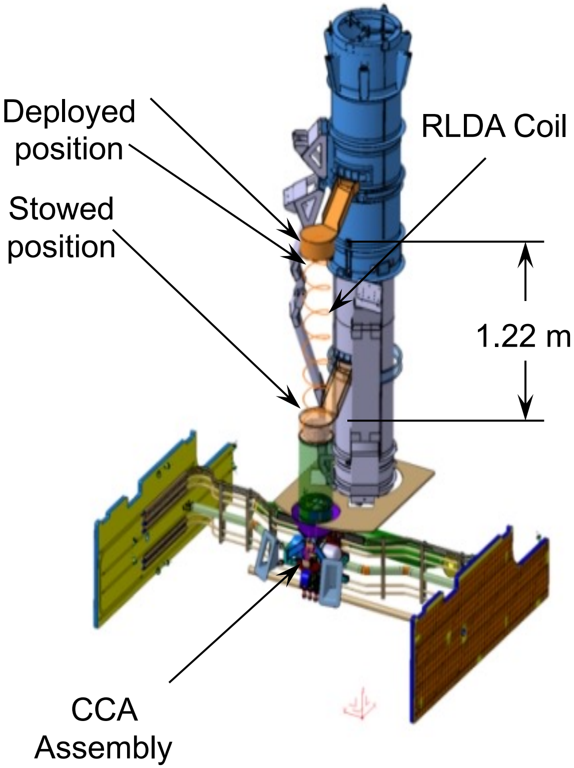


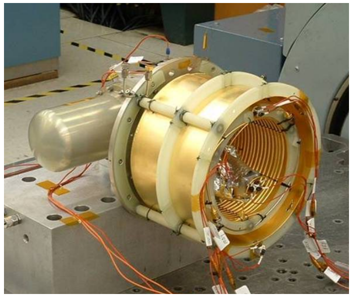
Verification Model

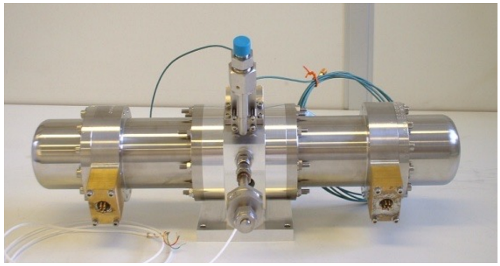
MIRI requires active cooling to 7 K

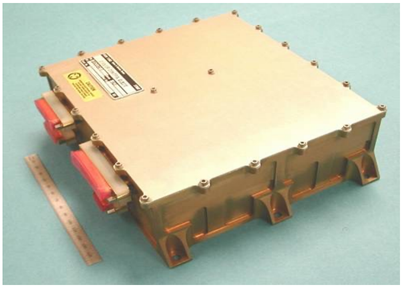
- **A two stage mechanical cooler is used to cool the MIRI below the nominal 40 K ISIM environment that is achieved by passive radiative cooling.**
  - The MIRI Cooler will be the first long life, 7K mechanical cooler for space flight
  - Developed by NGAS and JPL



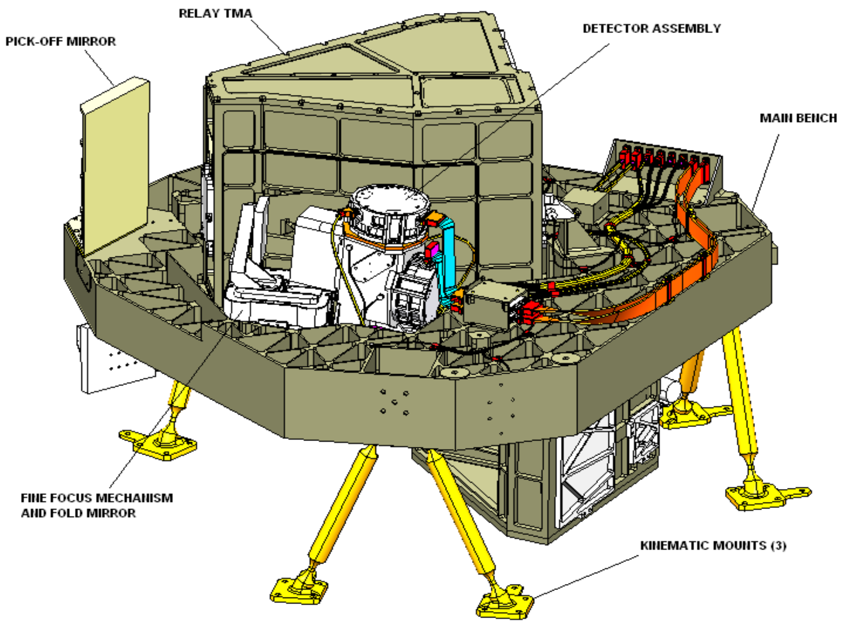


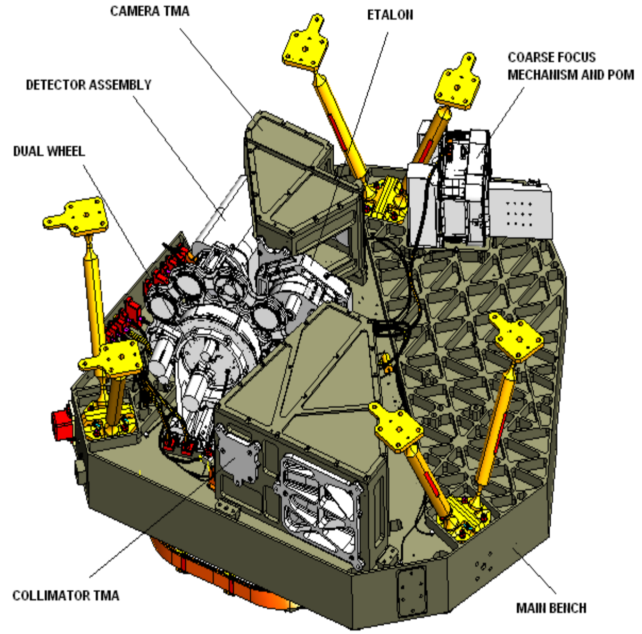

DM Pre-Cooler


Test JT compressor


JT-CCE (ACE)

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

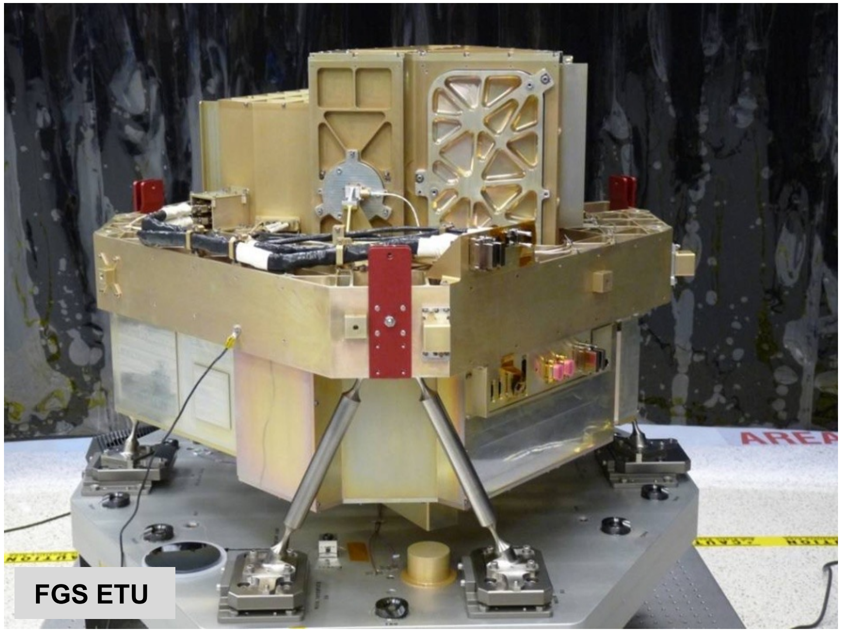




- Developed by the Canadian Space Agency with ComDev
  - Operating wavelength: 0.8 – 4.8 microns
  - Spectral resolution: Broad-band guider and R=100 science imagery
  - Field of view: 2.3 x 2.3 arc minutes
    - R=100 imagery with Fabry-Perot tunable filter and coronagraph
  - Angular resolution (1 pixel): 68 mas
  - Detector type: HgCdTe, 2048 x 2048 pixel format, 3 detectors, 40 K passive cooling
  - Reflective optics, Aluminum structure and optics

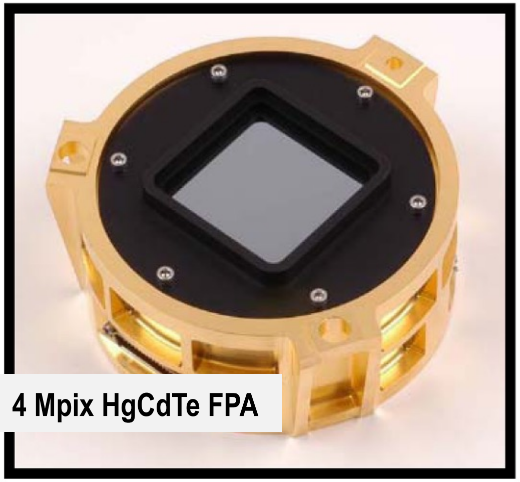
FGS ETU in Test Now

FGS is on schedule for delivery during Nov 2010



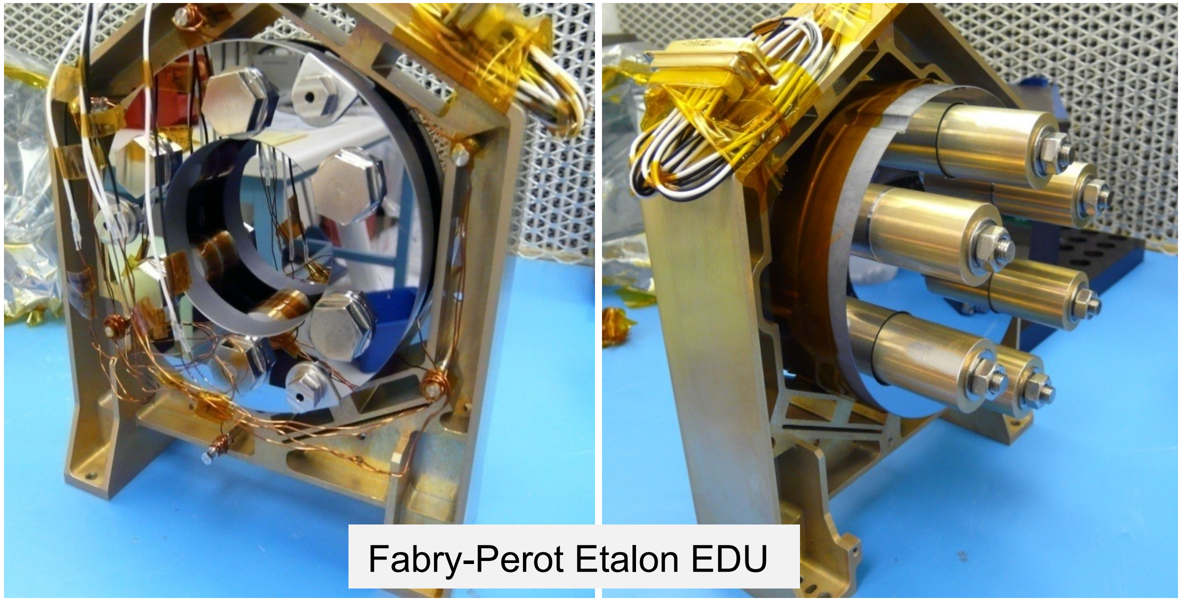
FGS ETU

FPA - Backside - Cover Removed

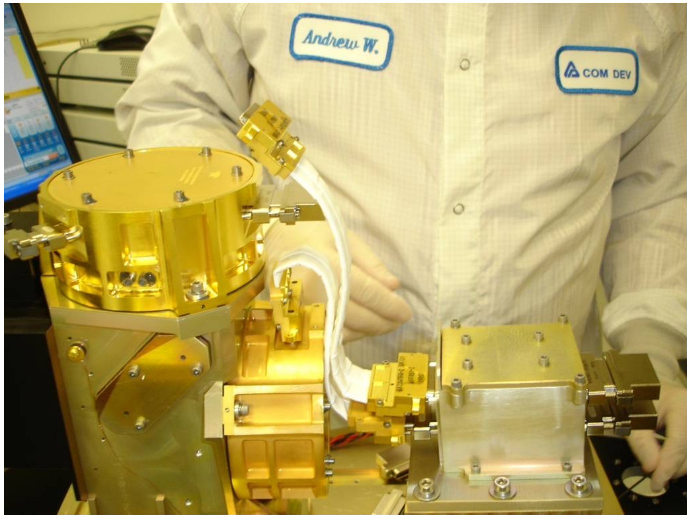


4 Mpix HgCdTe FPA

Light Facing Side - Scene



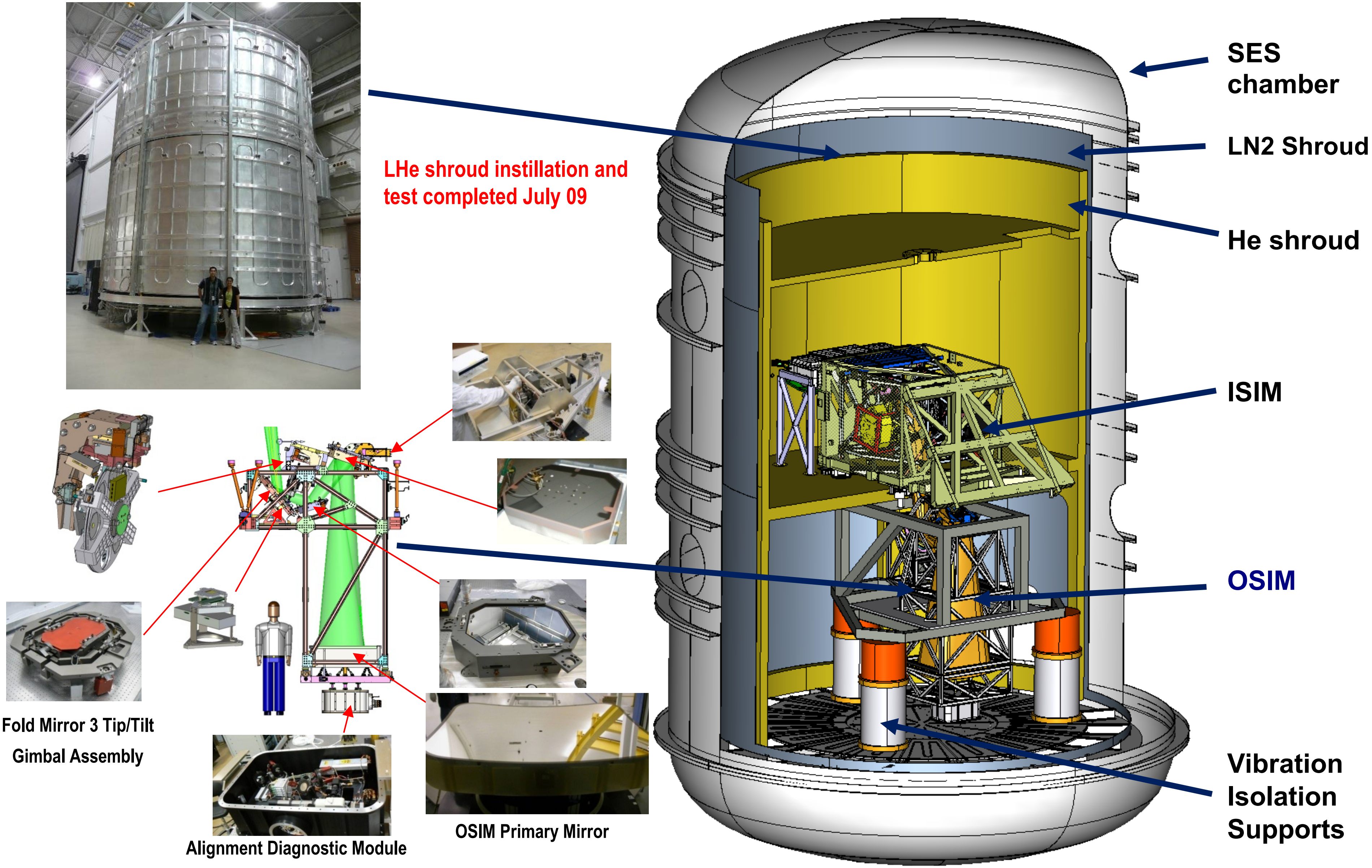
Fabry-Perot Etalon EDU



FPA – ASIC testing

FGS engineering test unit in space simulation chamber

ISIM will be tested in the GSFC SES chamber using an Optical Telescope Simulator (OSIM)



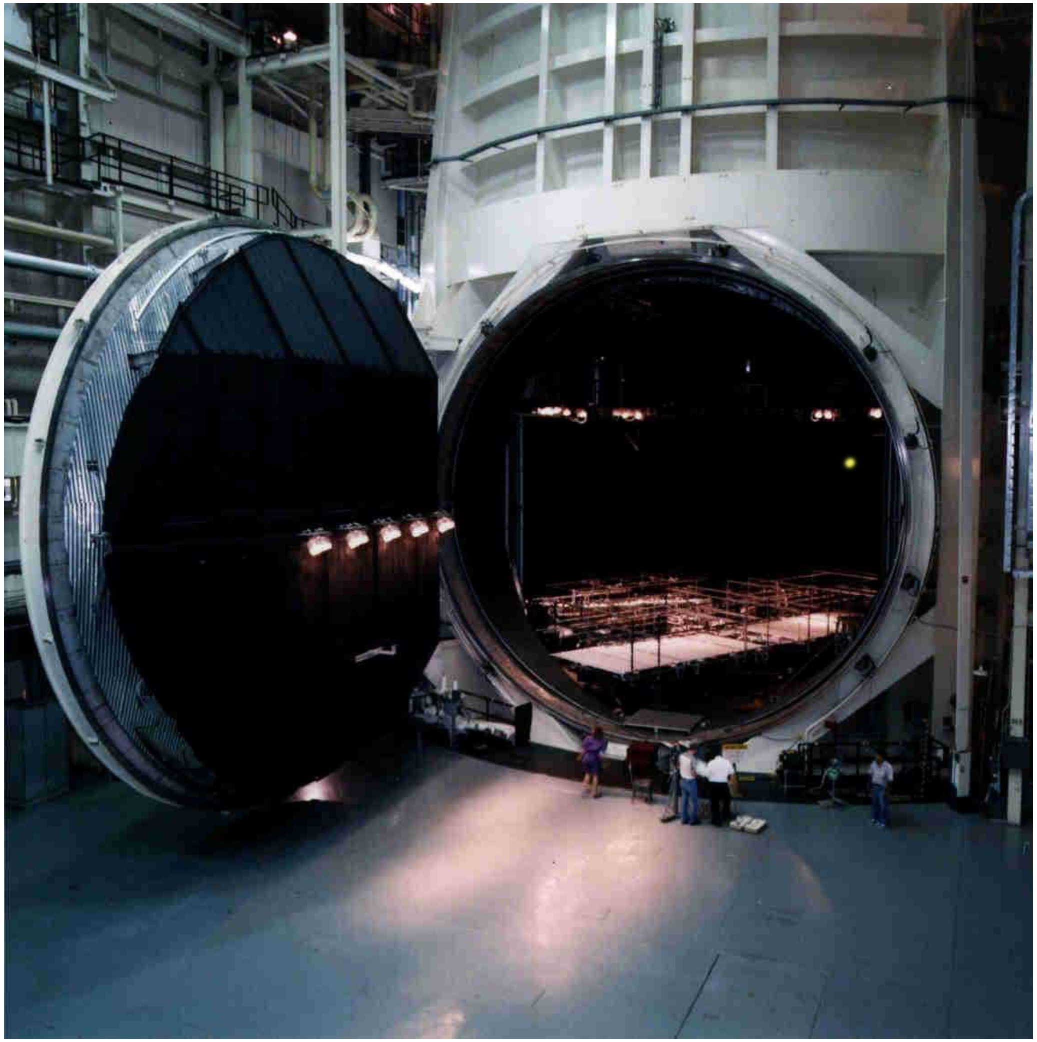
LHe shroud instillation and test completed July 09

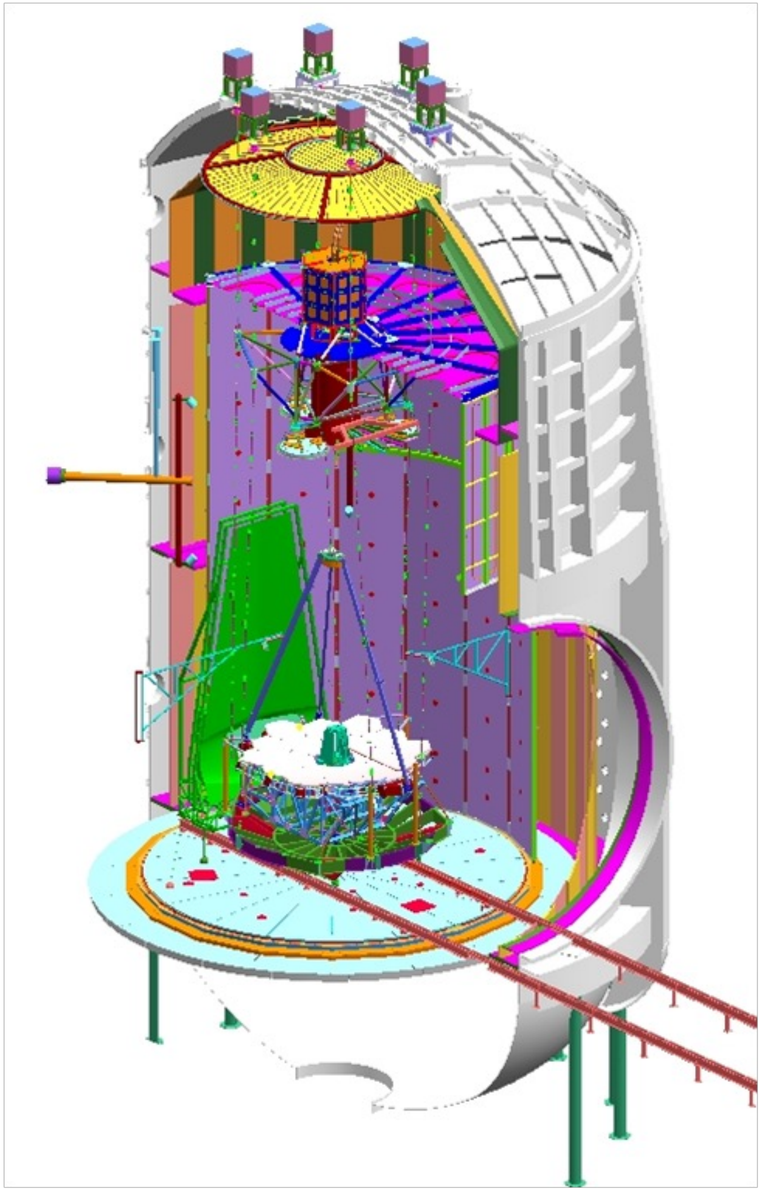
Fold Mirror 3 Tip/Tilt Gimbal Assembly

Alignment Diagnostic Module

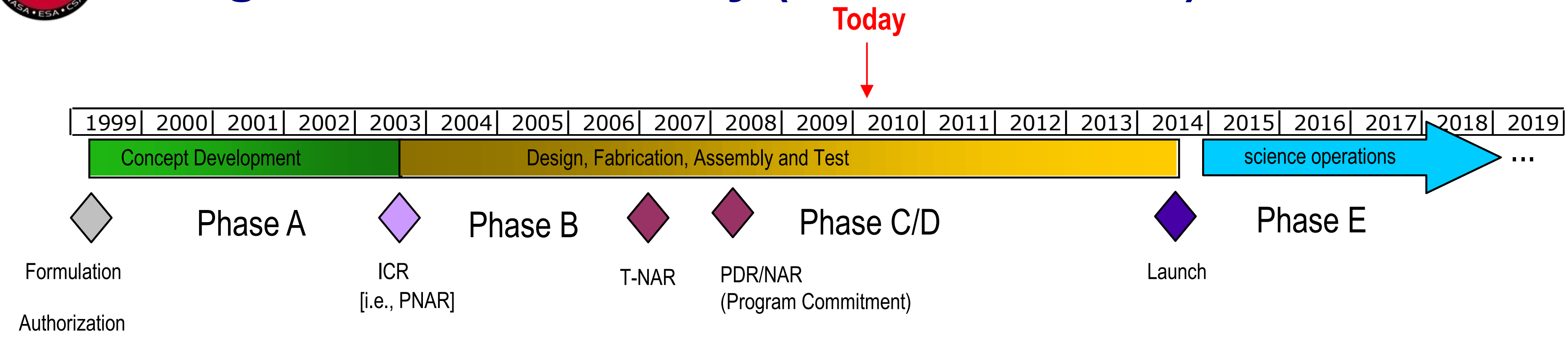
OSIM Primary Mirror

Then …. The OTE + ISIM will be tested in a larger space simulation chamber at JSC





Programmatic Summary (December 2009)



- **Successfully passed Confirmation Review (PDR/NAR) 2008**
  - **Launch Readiness Date moved to June 2014**
- **ISIM CDR passed March 09**
  - **All science instruments have passed CDR**
- **OTE CDR completed Oct 09; Sunshield CDR upcoming during January 2010**
- **Science instrument verification models completing integration & test now**
  - **They will be delivered to the GSFC over the next several months**
  - **Integration of the flight instruments is underway**
- **Continuing to make good progress on critical path items**
- **Getting ready for our Mission CDR April 2010**
- **Approximately 59% of Phase A through D cost invested so far**
  - **Pacing items (mirrors, instruments, etc) in flight production**

Learn more at: www.jwst.nasa.gov

- **The JWST will enable the first observations of the period in the history of the universe in which the first stars and galaxies formed**

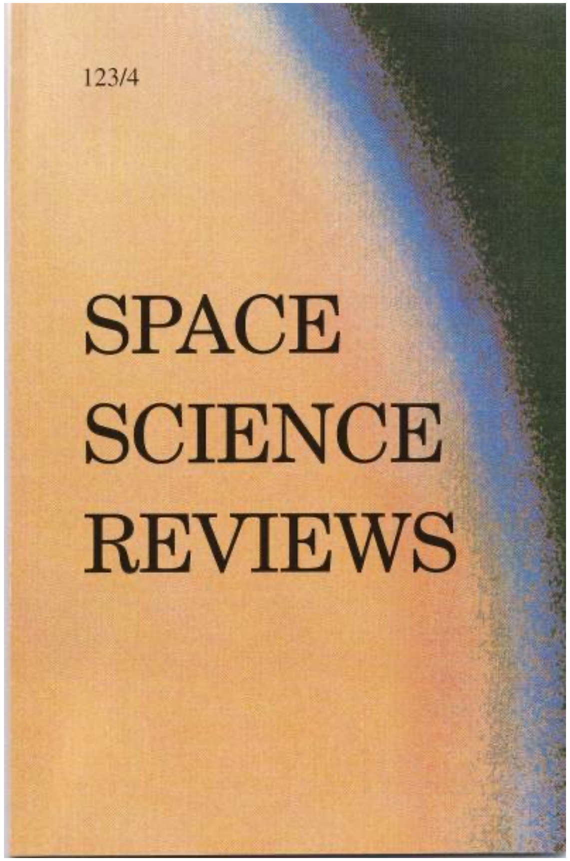
- **It is a versatile tool that will revolutionize understanding in other important areas:**
  - How the first galaxies evolved to produce the diversity of that exists today
  - How stars form and produce circumstellar debris from which planets are formed
  - How planetary systems form and evolve

- **The observatory is on schedule and on budget for launch during 2014**

- **Sun centered orbit at Sun-Earth L2 point**
- **5 year baseline mission with propellant to enable 10 year goal**
- **6.5 m class infrared cryogenic telescope, four science instruments**
  - 0.6 -29 micron wavelength coverage, imagery, spectroscopy, coronagraphy

- **Partnership with European and Canadian space agencies**
- **Mission Lead: Goddard Space Flight Center**
- **Prime Contractor: Northrop Grumman Aerospace Systems**

Learn more about JWST science ….



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SPACE SCIENCE REVIEWS

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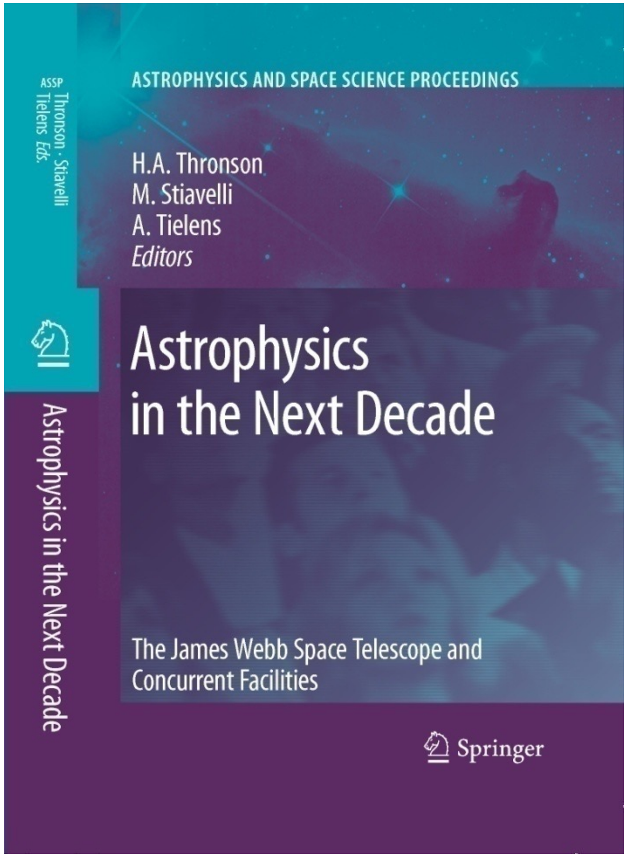
jwst.gsfc.nasa.gov

New



ASSP Thronson · Stiavelli Tielens *Eds.*

Astrophysics in the Next Decade

ASTROPHYSICS AND SPACE SCIENCE PROCEEDINGS

H.A. Thronson
M. Stiavelli
A. Tielens
Editors

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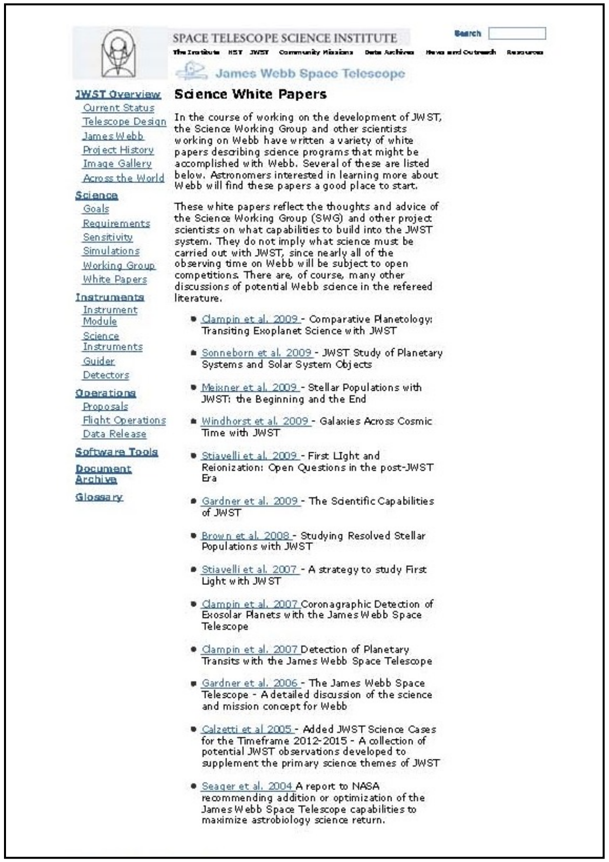


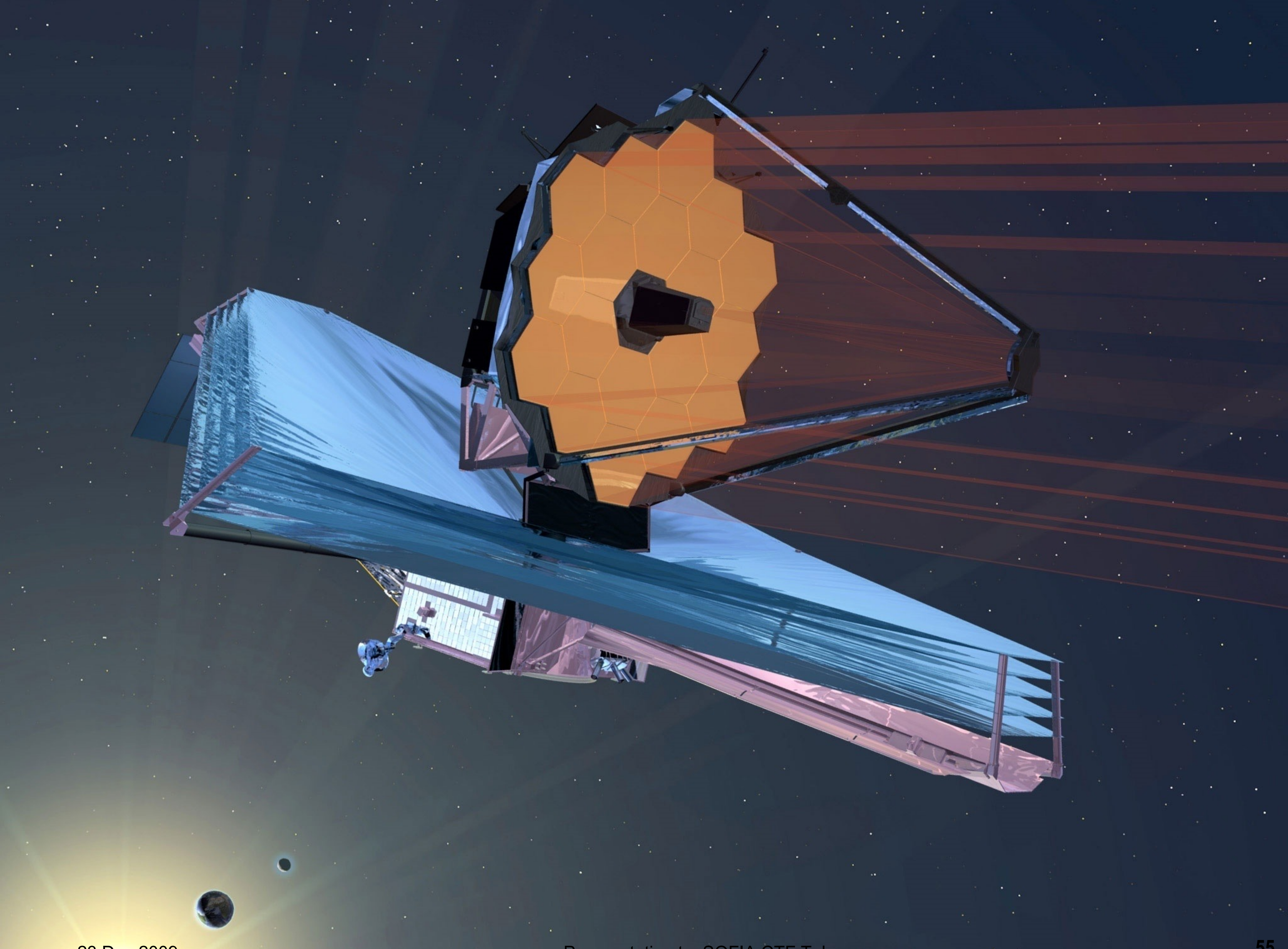
Science White Papers

In the course of working on the development of JWST, the Science Working Group and other scientists working on Webb have written a variety of white papers describing science programs that might be accomplished with Webb. Several of these are listed below. Astronomers interested in learning more about Webb will find these papers a good place to start.

These white papers reflect the thoughts and advice of the Science Working Group (SWG) and other project scientists on what capabilities to build into the JWST system. They do not imply what science must be carried out with JWST, since nearly all of the observing time on Webb will be subject to open competitions. There are, of course, many other discussions of potential Webb science in the refereed literature.

- Clampin et al. 2009 - Comparative Planetology: Transiting Exoplanet Science with JWST
- Sonneborn et al. 2009 - JWST Study of Planetary Systems and Solar System Objects
- Meixner et al. 2009 - Stellar Populations with JWST: the Beginning and the End
- Windhorst et al. 2009 - Galaxies Across Cosmic Time with JWST
- Stiavelli et al. 2009 - First LIght and Reionization: Open Questions in the post-JWST Era
- Gardner et al. 2009 - The Scientific Capabilities of JWST
- Brown et al. 2008 - Studying Resolved Stellar Populations with JWST
- Stiavelli et al. 2007 - A strategy to study First Light with JWST
- Clampin et al. 2007 Coronagraphic Detection of Exosolar Planets with the James Webb Space Telescope
- Clampin et al. 2007 Detection of Planetary Transits with the James Webb Space Telescope
- Gardner et al. 2006 - The James Webb Space Telescope - A detailed discussion of the science and mission concept for Webb
- Calzetti et al 2005 - Added JWST Science Cases for the Timeframe 2012-2015 - A collection of potential JWST observations developed to supplement the primary science themes of JWST
- Seager et al. 2004 A report to NASA recommending addition or optimization of the James Webb Space Telescope capabilities to maximize astrobiology science return.

www.stsci.edu/jwst/science/whitepapers/



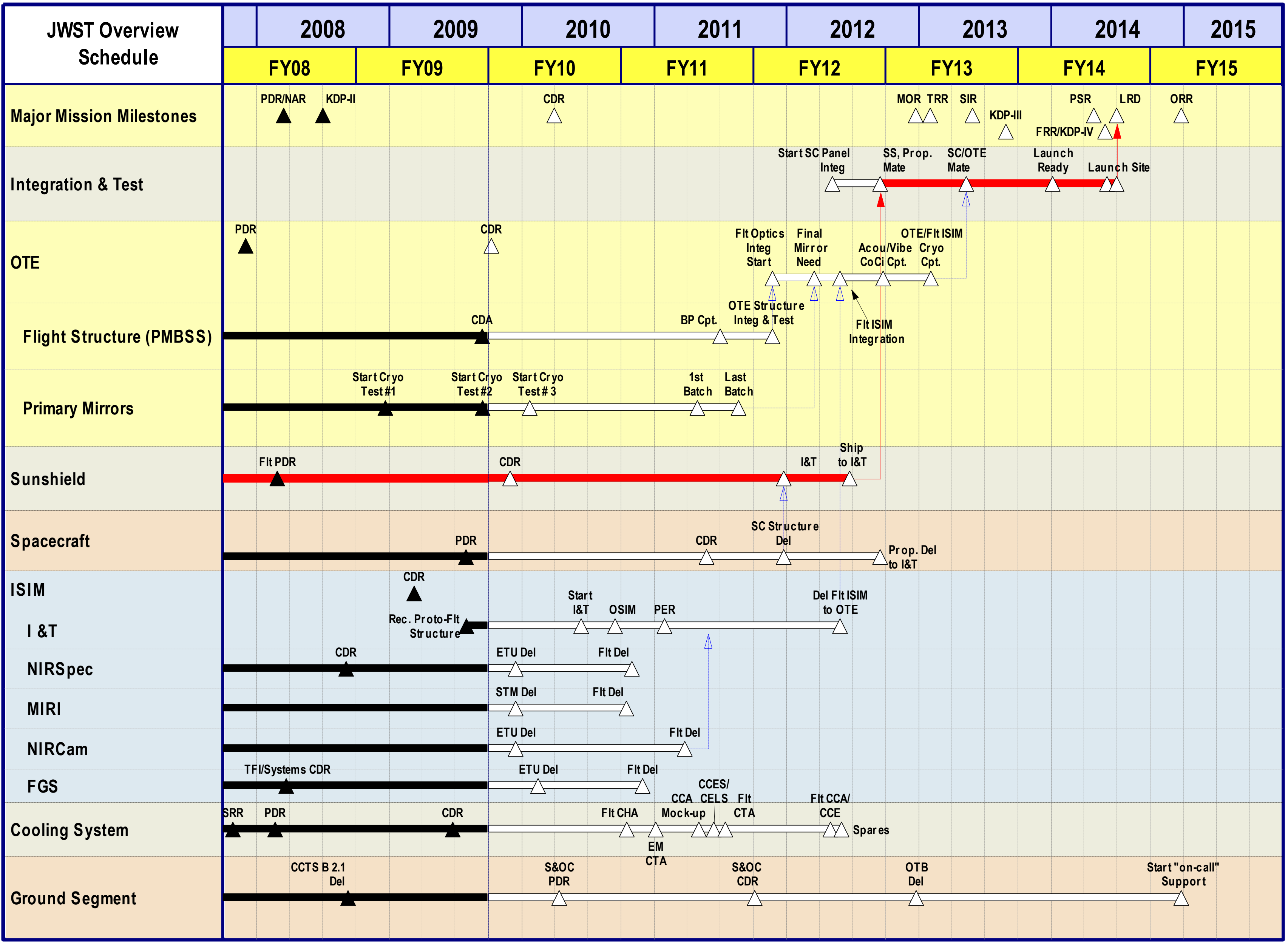
Backup Charts

ISIM Instrument characteristics wallet card

Key Instrument Characteristics (as of Mar 06)

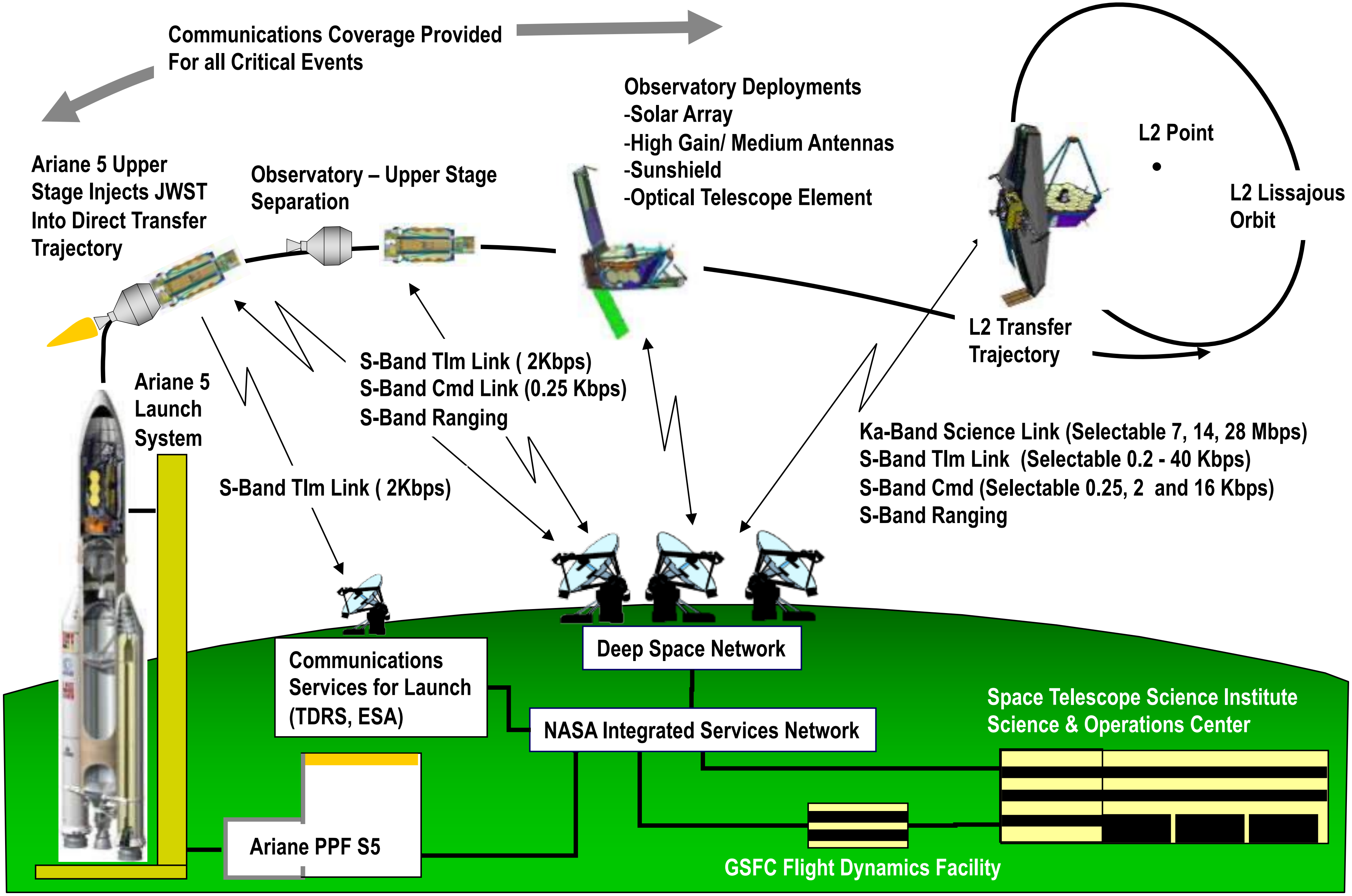
Instrument	Channel/Mode	Wavelength (microns)	Typical Spectral Resolution (λ/Δλ)	FOV	Angular Resolution (arc sec)	Number of Sensor Chip Arrays	Mega Pixels	Detector Type / Format NIR=18 um pixels MIR=25 um pixels	Detector Temp (K)
NIRCam	Shortwave	0.6 - 2.3	4,10,100	2.2' x 2.2' each of 2 modules	0.032 / pixel	8	34	HgCdTe / 2048 x 2048	40
	Longwave	2.4 - 5.0	4,10,100	2.2' x 2.2' each of 2 modules	0.065 / pixel	2	8	HgCdTe / 2048 x 2048	40
NIRSpec	Multi-Object Spec	1.0 - 5.0 0.6 - 5.0	1000 100	203 x 463 mas clear shutter aperture, 267 x 528 mas pitch, 4 x 171 x 365 shutter array format, 9.7 sq arcmin mulit-object targetable solid angle	see FOV	2	8	HgCdTe / 2048 x 2048	37
	Long Slits (5)	1.0 - 5.0	100, 1000, 2700	200 x 3500 mas x 3, 400 x 4000 mas, 100 x 2000 mas					
	IFU	0.7 - 5.0	2700	3 x 3 arc-sec	0.10 slice width				
MIRI	Imager	5 - 27	4-6	1.9' x 1.4'	0.11 / pixel	1	1	Si:As / 1024 x 1024	7
	Low Res Slit	5 - 11	100	5" x 0.6"	see FOV	1	1	Si:As / 1024 x 1024	7
	Med Res IFU	4.87 - 7.76	3000	3.7" x 3.7"	0.18 slice width	1	1	Si:As / 1024 x 1024	7
		7.45 - 11.87	3000	4.7" x 4.5"	0.28 slice width				
		11.47 - 18.24	3000	6.2" x 6.1"	0.39 slice width				
		17.54 - 28.82	2250	7.1" x 7.7"	0.65 slice width				
FGS-TF		1.6 - 2.5, 3.2 - 4.9	100	2.2' x 2.2'	0.065 / pixel	1	4	HgCdTe / 2048 x 2048	40
FGS-Guider		0.8 - 5.0	0.7	2.3' x 2.3' each of 2 modules	0.068 / pixel	2	8	HgCdTe / 2048 x 2048	40

JWST Overview Schedule



Rev-I DRAFT

JWST System Architecture



Communications Coverage Provided
For all Critical Events

Ariane 5 Upper
Stage Injects JWST
Into Direct Transfer
Trajectory

Observatory – Upper Stage
Separation

Observatory Deployments
-Solar Array
-High Gain/ Medium Antennas
-Sunshield
-Optical Telescope Element

L2 Point

L2 Lissajous
Orbit

L2 Transfer
Trajectory

Ariane 5
Launch
System

S-Band Tlm Link (2Kbps)
S-Band Cmd Link (0.25 Kbps)
S-Band Ranging

S-Band Tlm Link (2Kbps)

Ka-Band Science Link (Selectable 7, 14, 28 Mbps)
S-Band Tlm Link (Selectable 0.2 - 40 Kbps)
S-Band Cmd (Selectable 0.25, 2 and 16 Kbps)
S-Band Ranging

Communications
Services for Launch
(TDRS, ESA)

Deep Space Network

NASA Integrated Services Network

Space Telescope Science Institute
Science & Operations Center

Ariane PPF S5

GSFC Flight Dynamics Facility

Science Instrument FOV Layout on the Sky