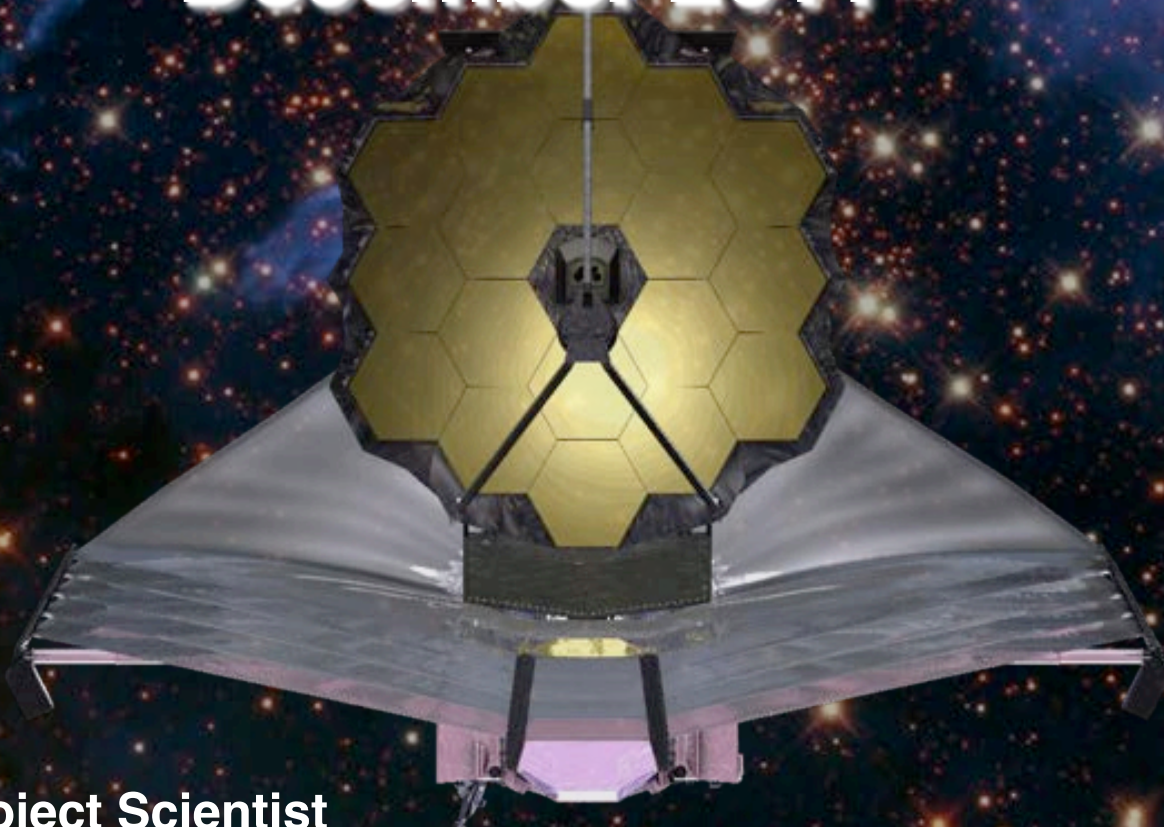
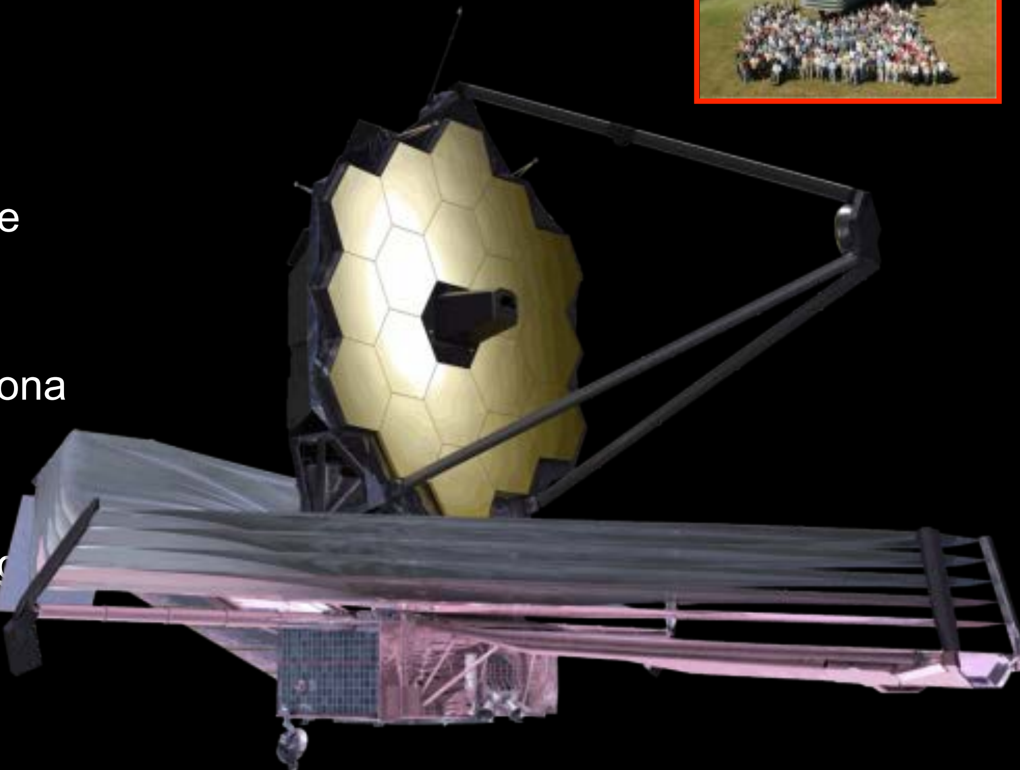
JWST Science and Status

December 2011



John Mather
JWST Senior Project Scientist
Goddard Space Flight Center

James Webb Space Telescope



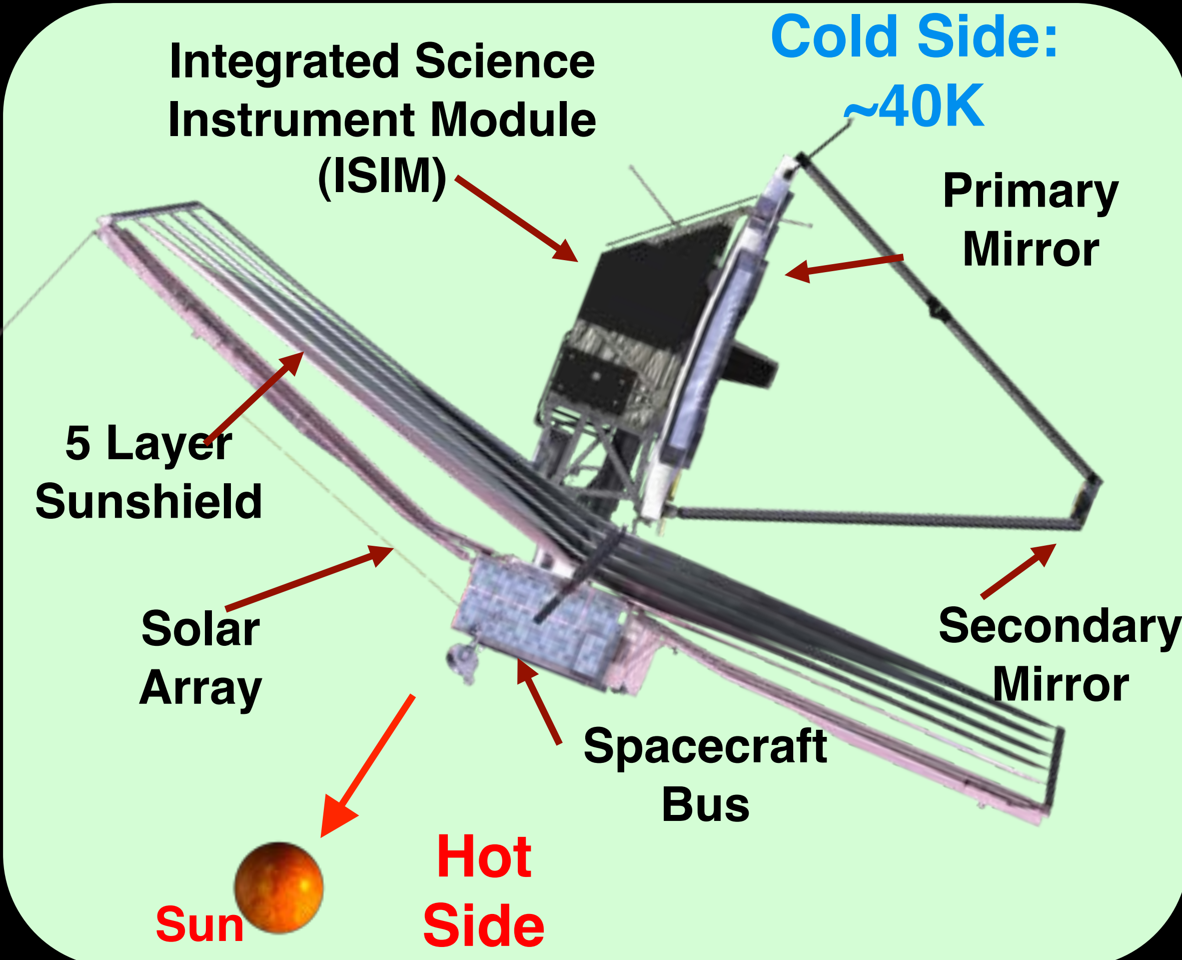
Organization

- **Mission Lead:** Goddard Space Flight Center
- **Senior Project Scientist:** Dr John Mather
- **International collaboration:** ESA & CSA
- **Prime Contractor:** Northrop Grumman Aerospace Systems
- **Instruments:**
  - Near Infrared Camera (NIRCam) – Univ. of Arizona
  - Near Infrared Spectrograph (NIRSpec) – ESA
  - Mid-Infrared Instrument (MIRI) – JPL/ESA
  - Fine Guidance Sensor (FGS) & Near IR Imaging Slitless Spectrometer – CSA
- **Operations:** Space Telescope Science Institute

Description

- Deployable infrared telescope with 6.5 meter diameter segmented adjustable primary mirror
- Cryogenic temperature telescope and instruments for infrared performance
- Launch on an ESA-supplied Ariane 5 rocket to Sun-Earth L2
- 5-year science mission requirement (10-year propellant lifetime)

HOW JWST WORKS

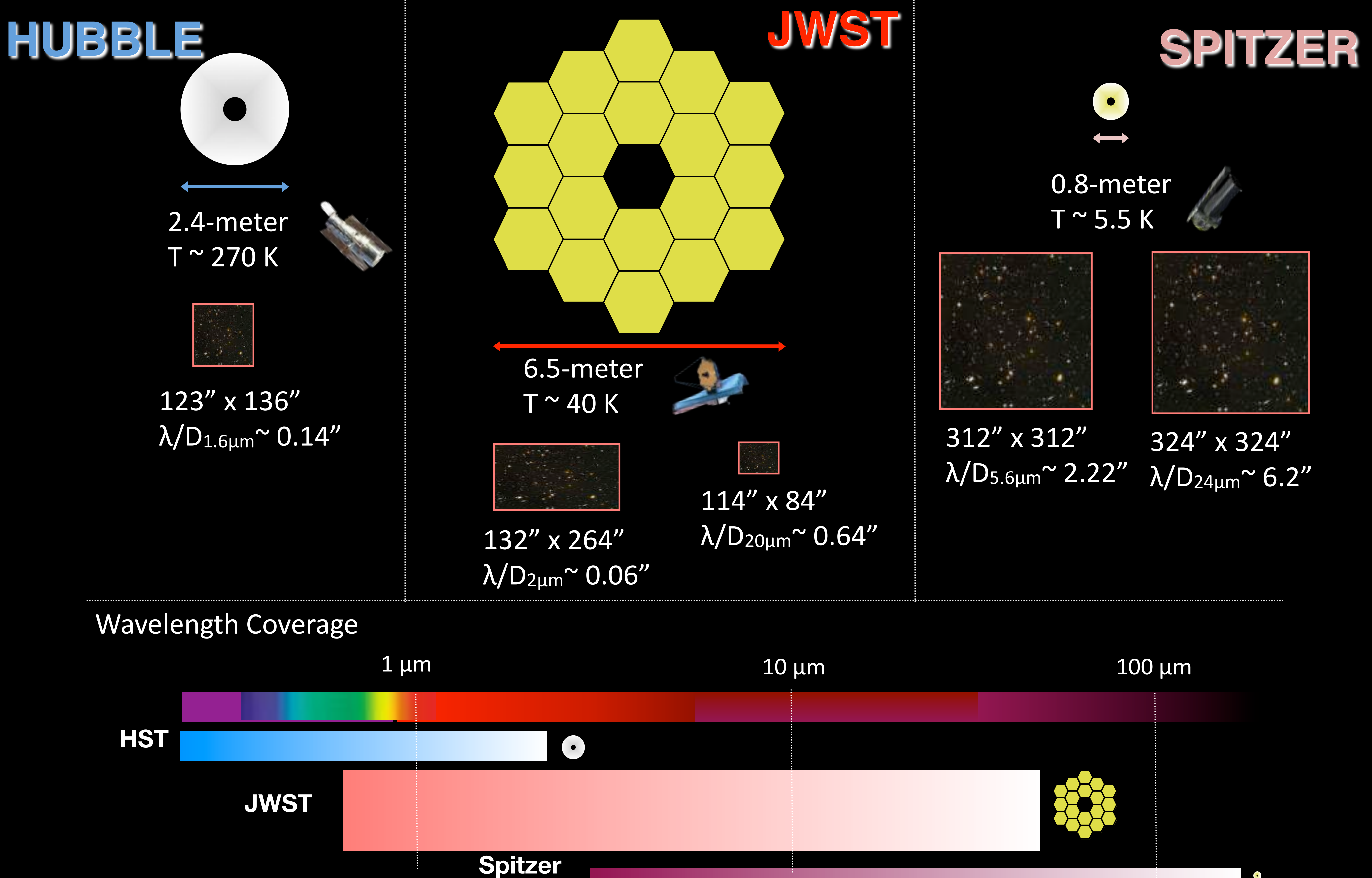


JWST is folded and stowed for launch

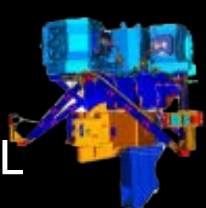
Observatory is deployed after launch

JWST Orbits the 2nd Lagrange Point (L2)

JWST and its Precursors

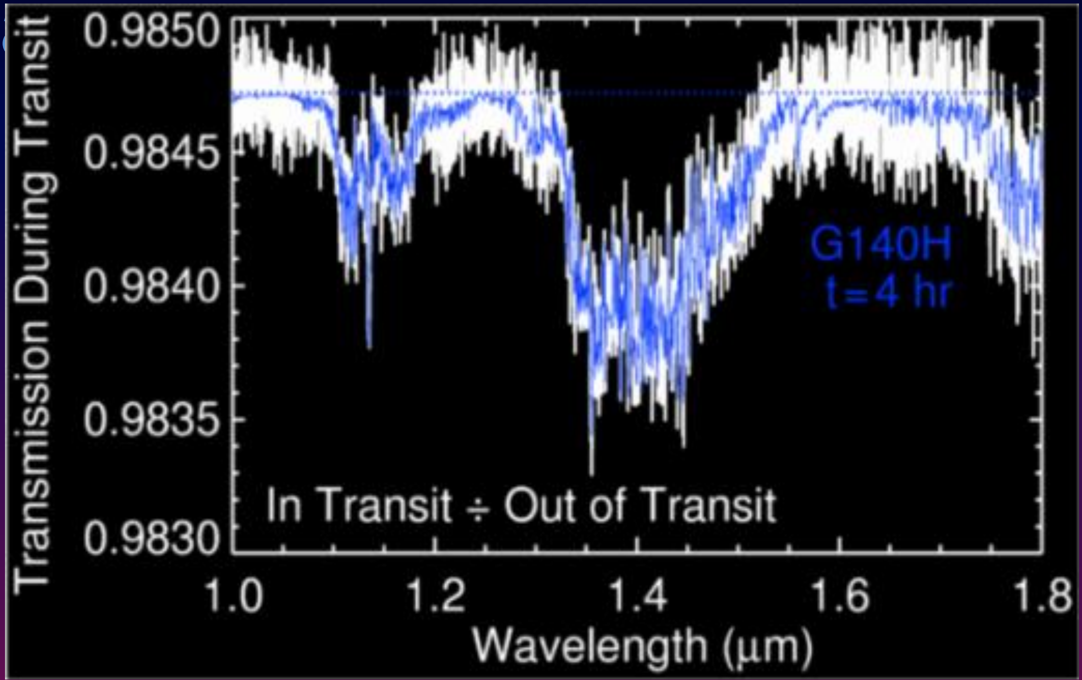


JWST Instrumentation

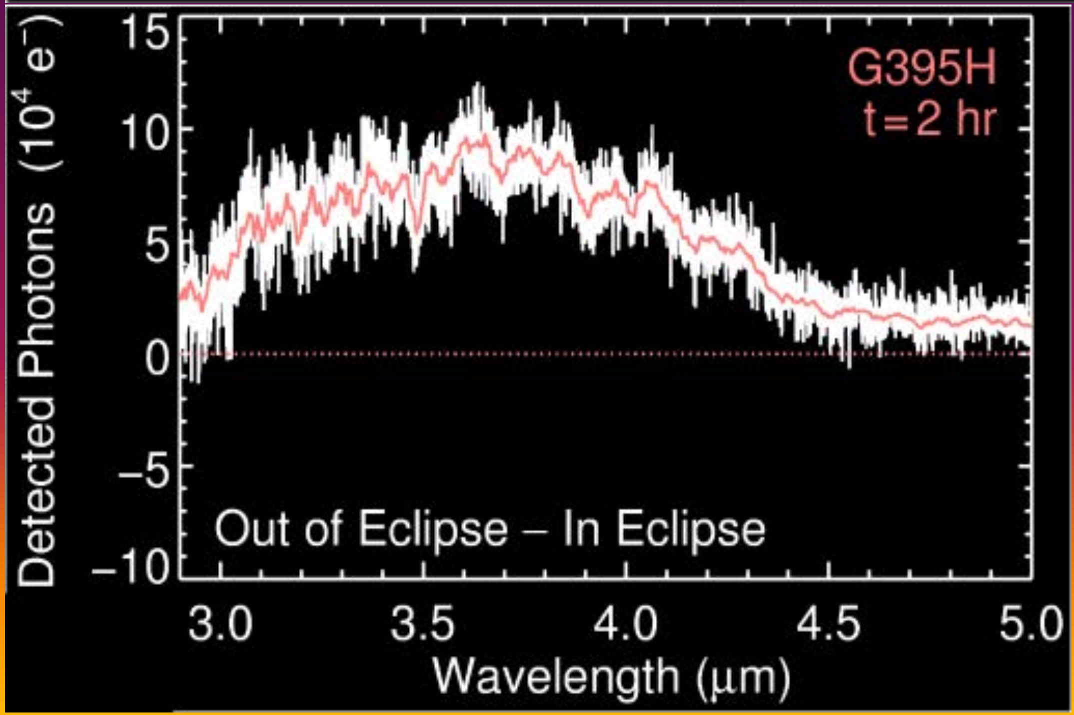
Instrument	Science Requirement	Capability
NIRCam Univ. Az/LMATC 	Wide field, deep imaging ‣0.6 µm - 2.3 µm (SW) ‣2.4 µm - 5.0 µm (LW)	Two 2.2’ x 2.2’ SW Two 2.2’ x 2.2’ LW Coronagraph
NIRSpec ESA/Astrium 	Multi-object spectroscopy ‣0.6 µm - 5.0 µm	9.7 Sq arcmin Ω + IFU + slits 100 selectable targets: MSA R=100, 1000, 3000
MIRI ESA/UKATC/JPL 	Mid-infrared imaging ‣ 5 µm - 27 µm Mid-infrared spectroscopy ‣ 4.9 µm - 28.8 µm	1.9’ x1.4’ with coronagraph 3.7”x3.7” – 7.1”x7.7” IFU R=3000 - 2250
FGS/TFI CSA 	Fine Guidance Sensor 0.8 µm - 5.0 µm Near IR Imaging Slitless Spectrometer, ‣1.6 µm - 4.9 µm	Two 2.3’ x 2.3’ 2.2’ x 2.2’ R=100 with coronagraph

Simulated Webb/NIRSpec Transit Data

Atmospheric Transmission Spectrum (4 hr) for HD209458-like Kepler source using NIRSpec R~3000 grating. These data are not smoothed.



Atmospheric Emission Spectrum (2 hr) for Kepler source



Simulations by Jeff Valenti, STScI.

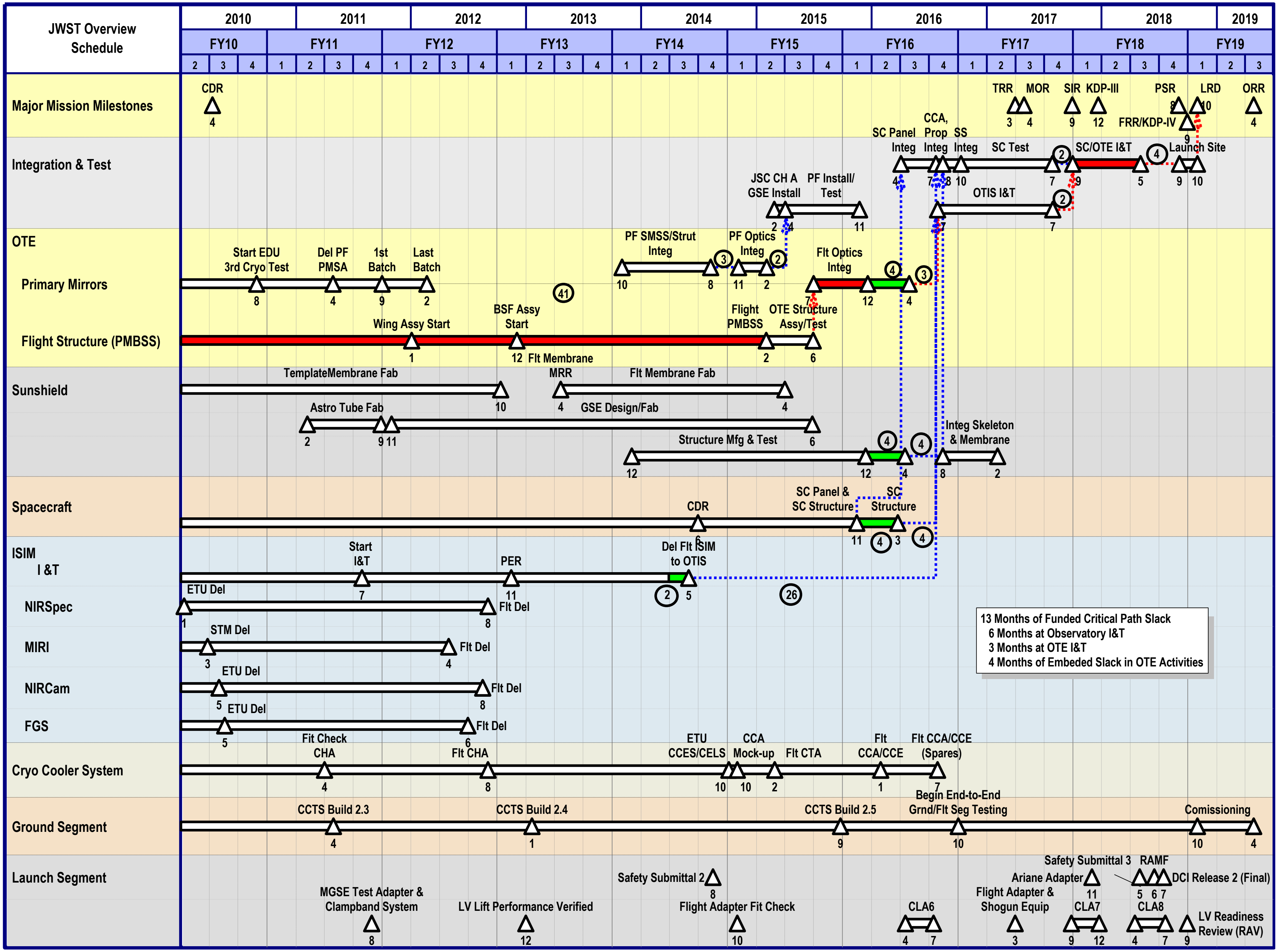
JWST has the capability to discover -in transit - an habitable super Earth

JWST on a new path

- **NASA has made significant changes in the management of JWST**
  - Response to ICRP report (http://www.ngst.nasa.gov/resources/JamesWebbSpaceTelescopeIndependentComprehensiveReviewPanelReport.pdf)
- **Communications have greatly improved between HQ, Centers and contractors, especially at senior management levels**
  - Open and honest dialogue, quick identification of issues and agreement on fixes
- **Assessment of alternatives completed**
- **Completed a replan (9/23/2011) with an October 2018 launch date**
  - Plan has adequate cost and schedule reserves consistent with an 80% confidence level
  - Replan is on track to support the FY13 budget process

JWST made great progress in FY2011, achieving milestones within cost and schedule

JWST Master Schedule



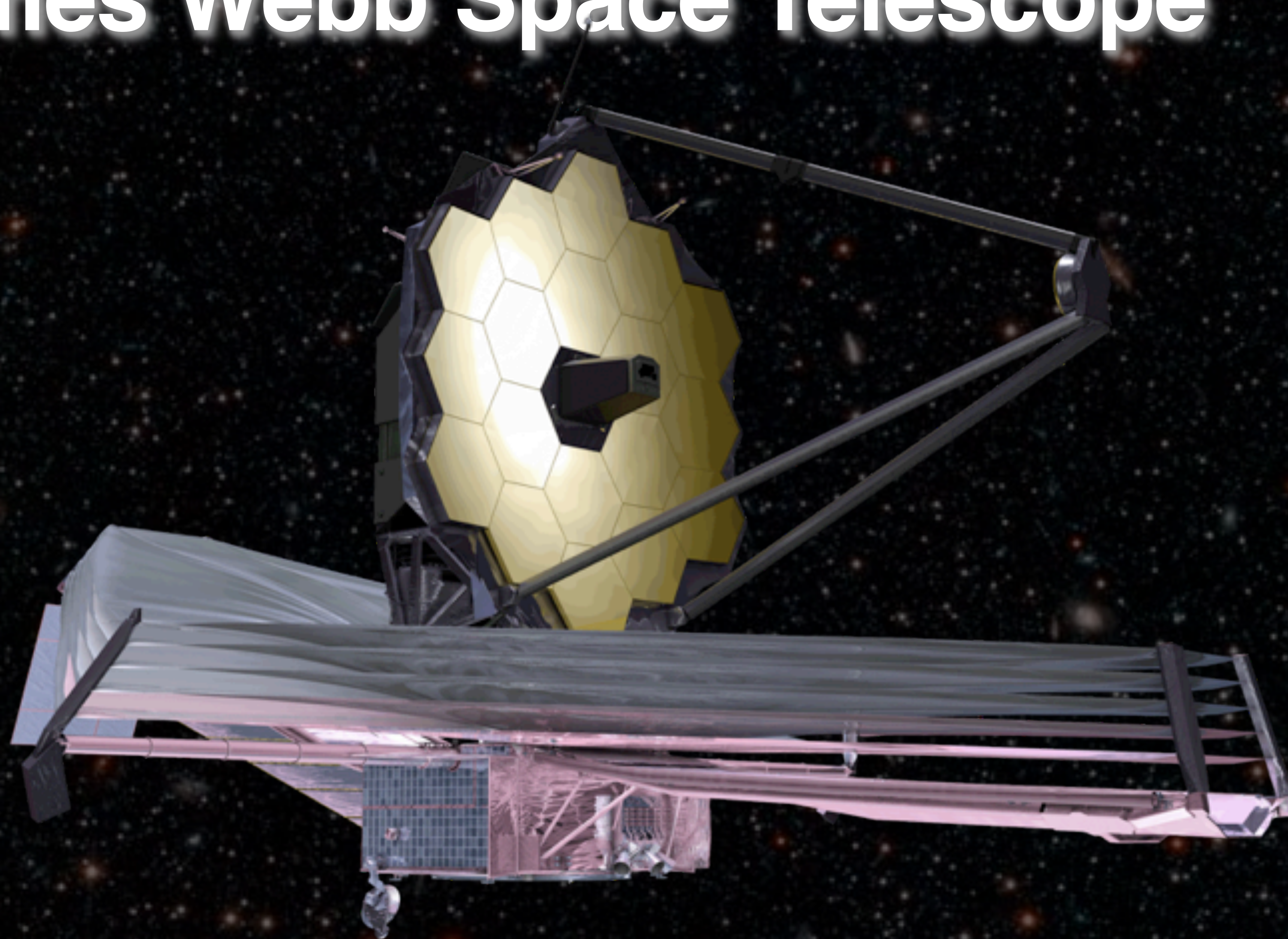
NASA's Proposed Offsets to support JWST 2018 Replan

Total additional funds required FY2012-2016: $1208 M

- **FY2012 additional requirement: $156M**
  - 50% from the Science Mission Directorate (SMD)
    - No funds from Earth Science
  - 50% from Agency's institutional support budget

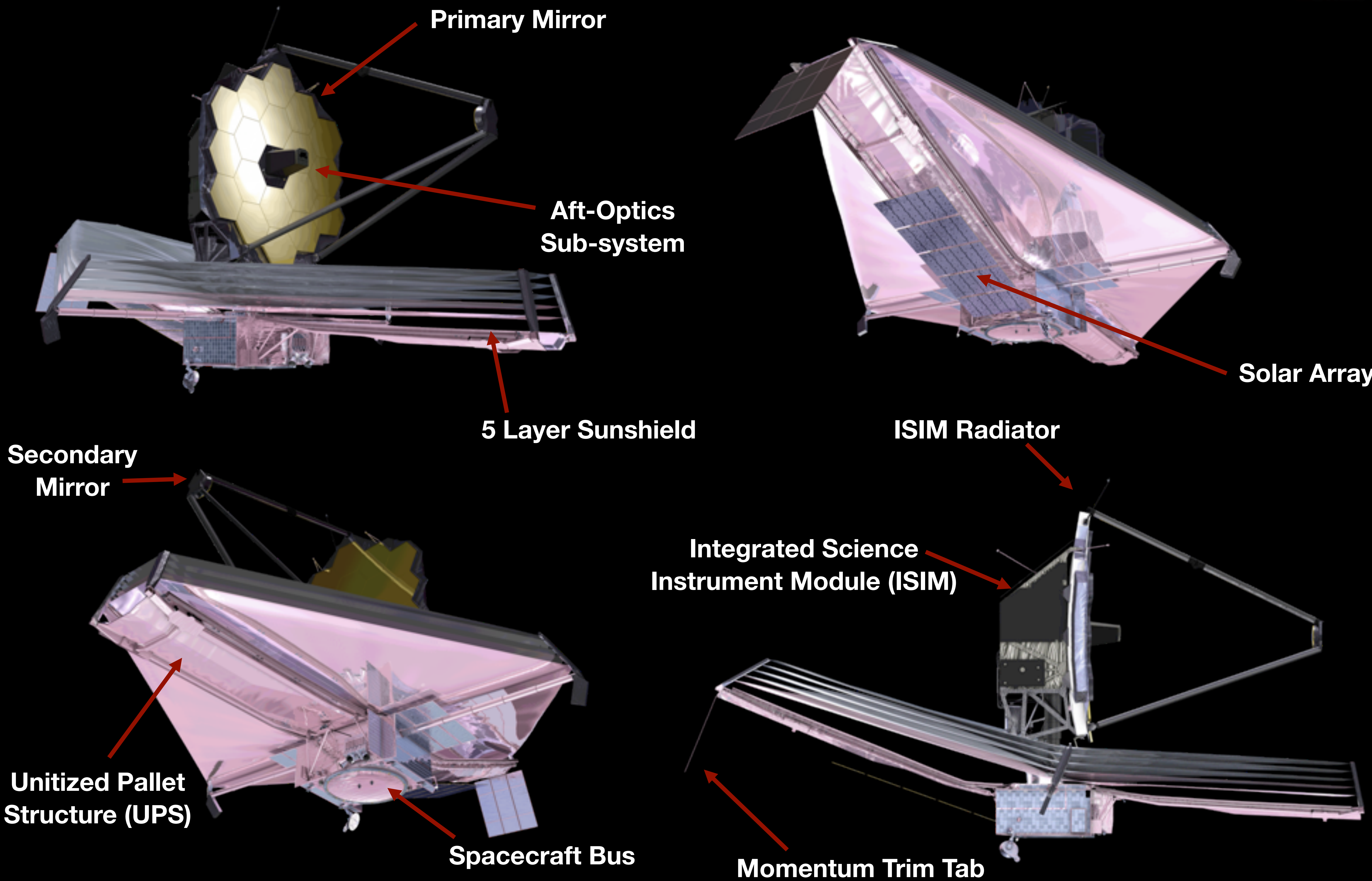
- **FY2013-2016 additional requirement: $1055M**
  - Details still being assessed

Overview of the James Webb Space Telescope

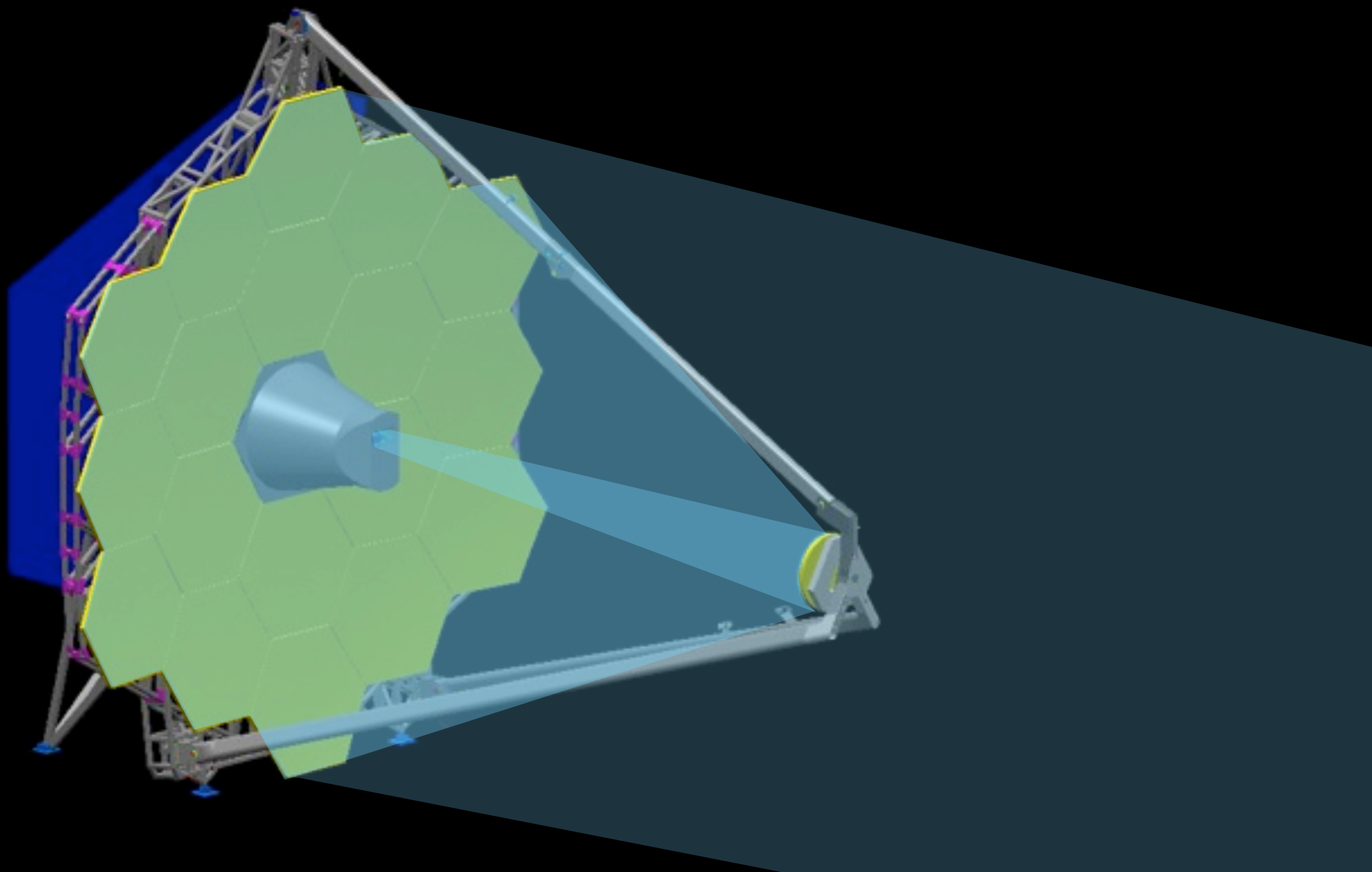


Mark Clampin - JWST Observatory Project Scientist
mark.clampin@nasa.gov
Goddard Space Flight Center

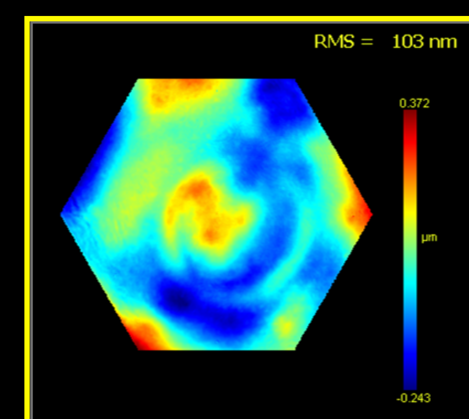
JWST Design: Key Features



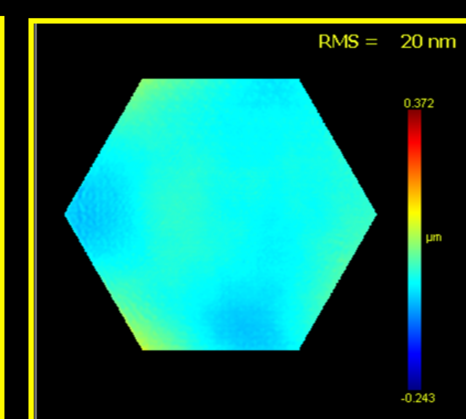
JWST's Telescope Design



- ➡ 18 primary mirror segments
- ➡ 6 degrees of freedom + ROC
- ➡ Beryllium mirrors
  - ➡ 40 K operation
  - ➡ <u>Cryo-polishing required</u>
  - ➡ Long lead time fabrication



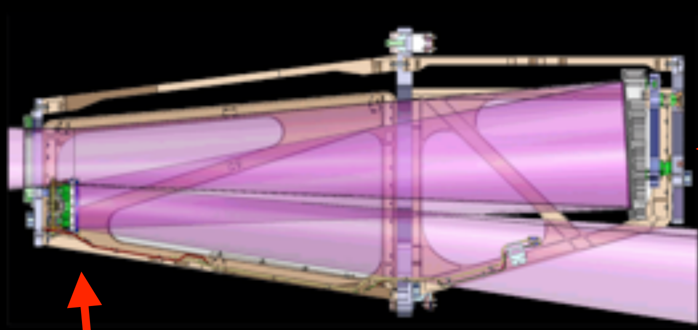
Ambient Surface

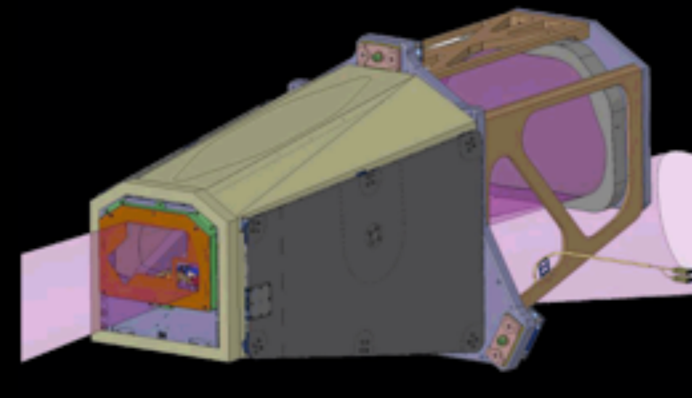


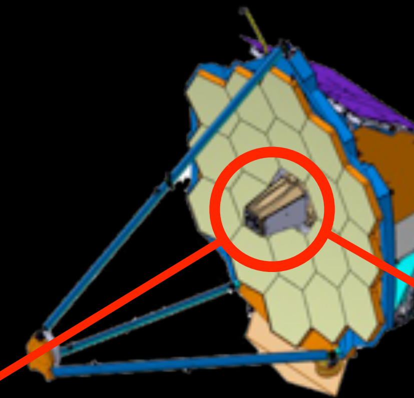
Cryo Surface

- ➡ ***Elliptical*** **f/1.2 Primary Mirror (PM)**
- ➡ ***Hyperbolic*** **Secondary Mirror (SM)**
- ➡ ***Elliptical*** **Tertiary Mirror (TM) images pupil at** ***Flat*** **Fine Steering Mirror (FSM)**
- ➡ **Diffraction-limited imaging at ≥ 2 *µm* [150 nm WFE @ NIRCam focal plane]**

Aft-Optical System Optics Complete

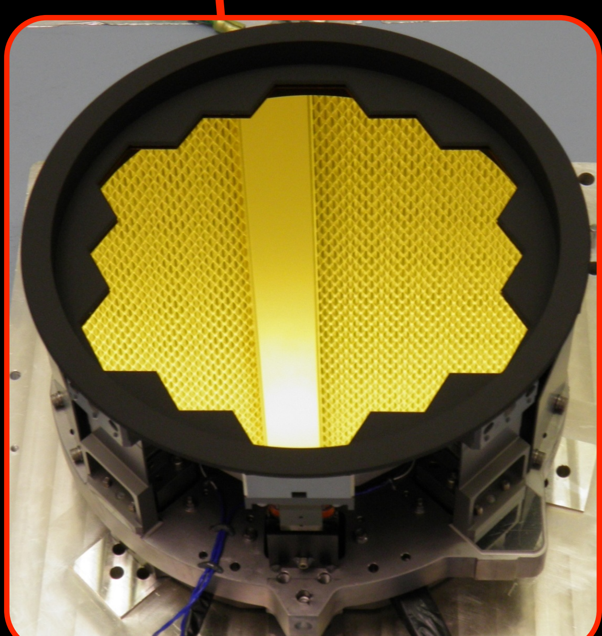






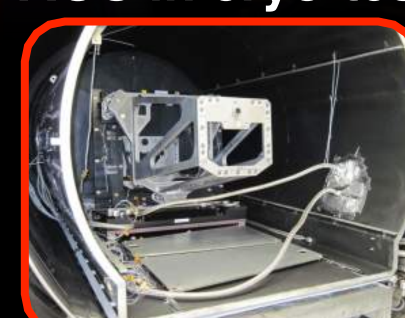
Aft optics and optical bench complete

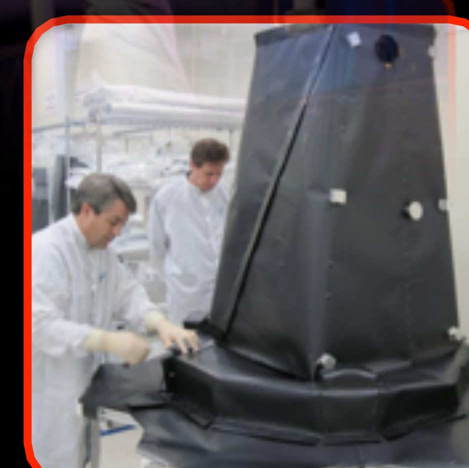
Tertiary Mirror



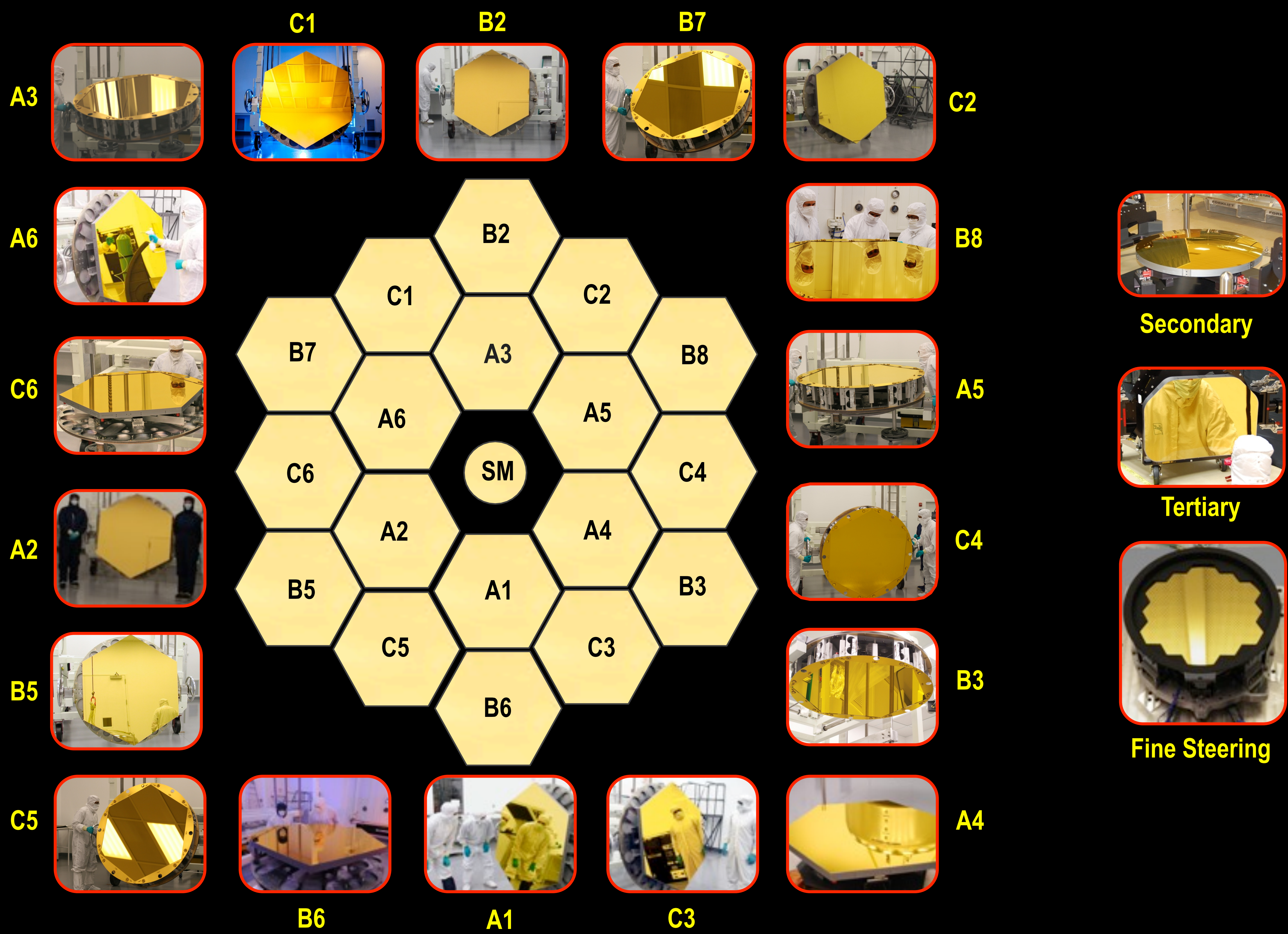
Fine Steering Mirror

AOS in cryo-test



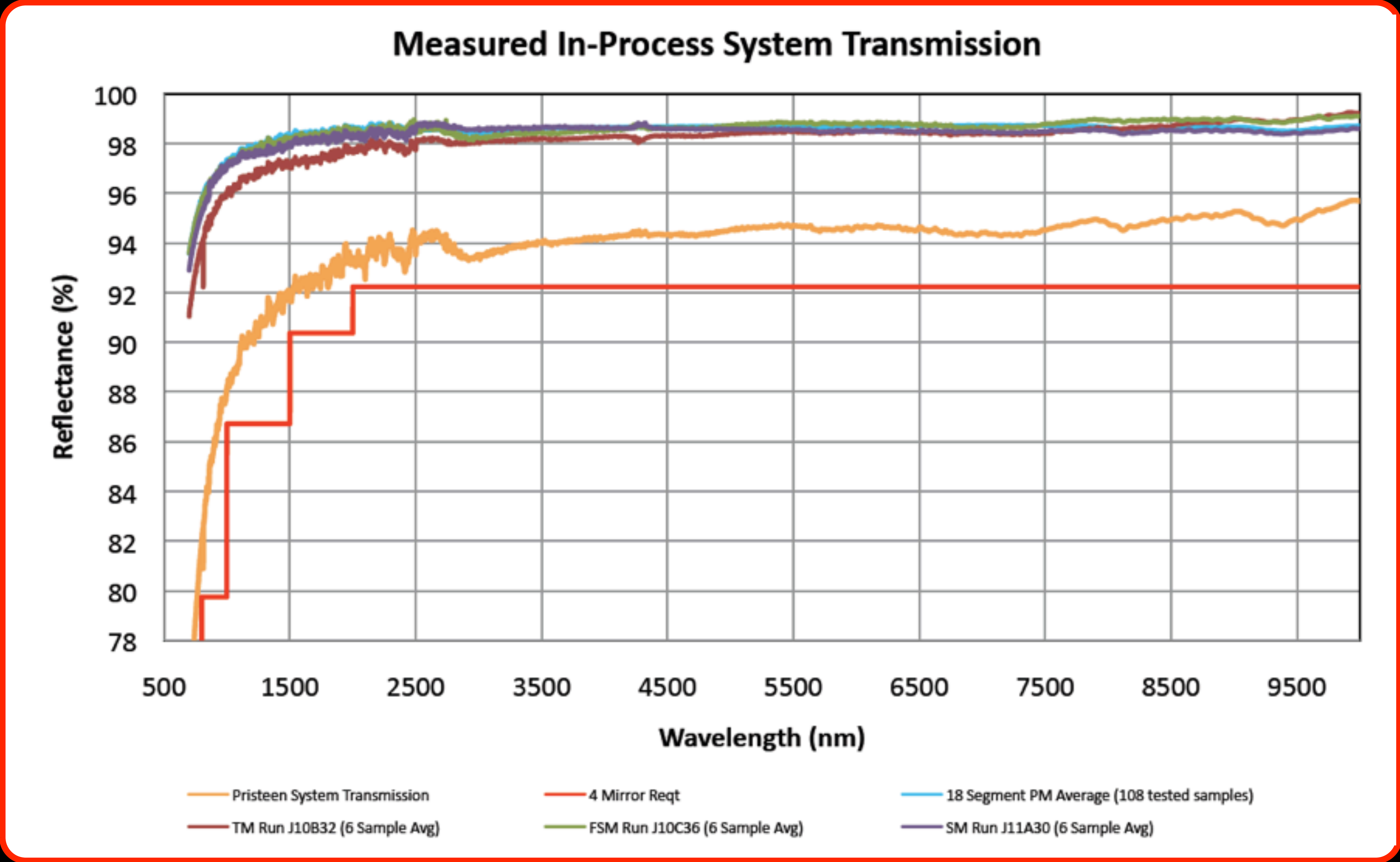


Telescope Mirrors Gold Coated



Mirror Reflectivity

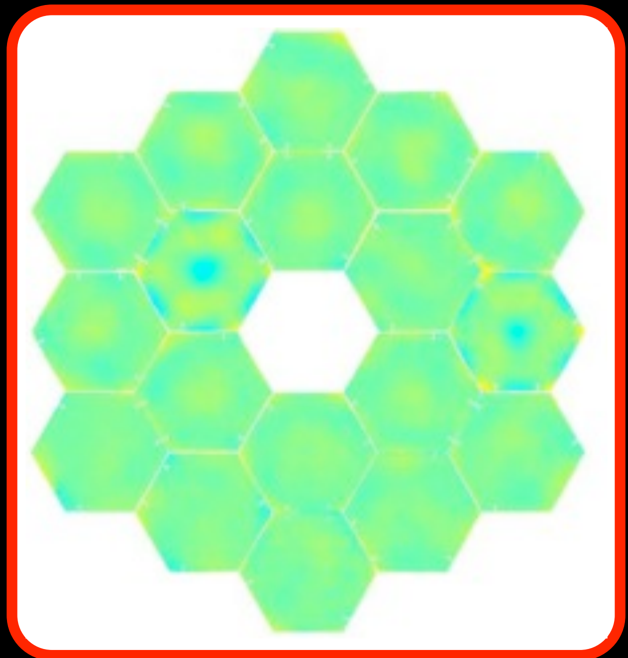
- Measured reflectivity of newly coated mirrors (i.e. pristine)



Flight Mirrors: Cryo-Performance

- **Preliminary Surface Figure Error (SFE) for OTE optical elements**
  - ➡ **Preliminary as-built cryo-measured surface figure error (SFE)**

Mirror	Measured (nm RMS SFE)	Uncertainty (nm RMS SFE)	Total (nm RMS SFE)	Requirement (nm RMS SFE)	Margin (nm RMS SFE)
18 Primary Mirrors (composite)	23.7	8.1	25.0	25.8	6.4
Secondary	14.5	14.9	20.8	23.5	10.9
Tertiary	17.5	9.4	19.9	23.3	11.9
Fine Steering	14.7	8.7	17.1	17.5	3.7

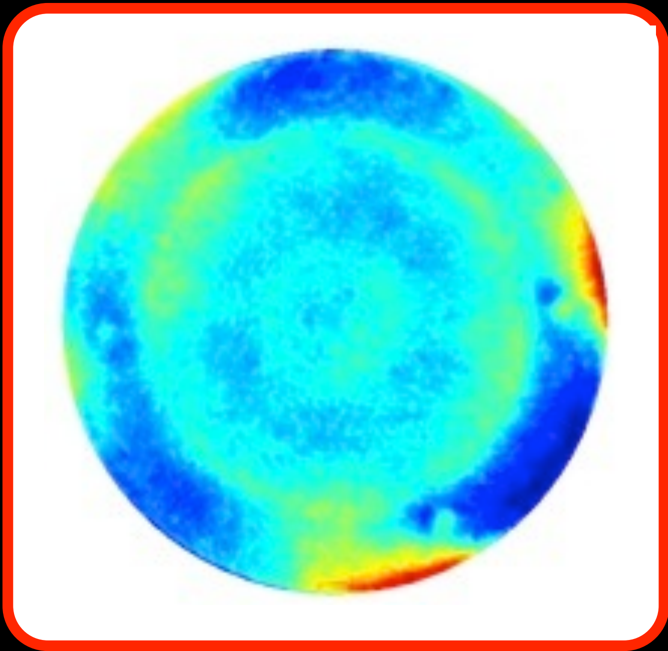


Primary Mirror

Flight Mirrors: Cryo-Performance

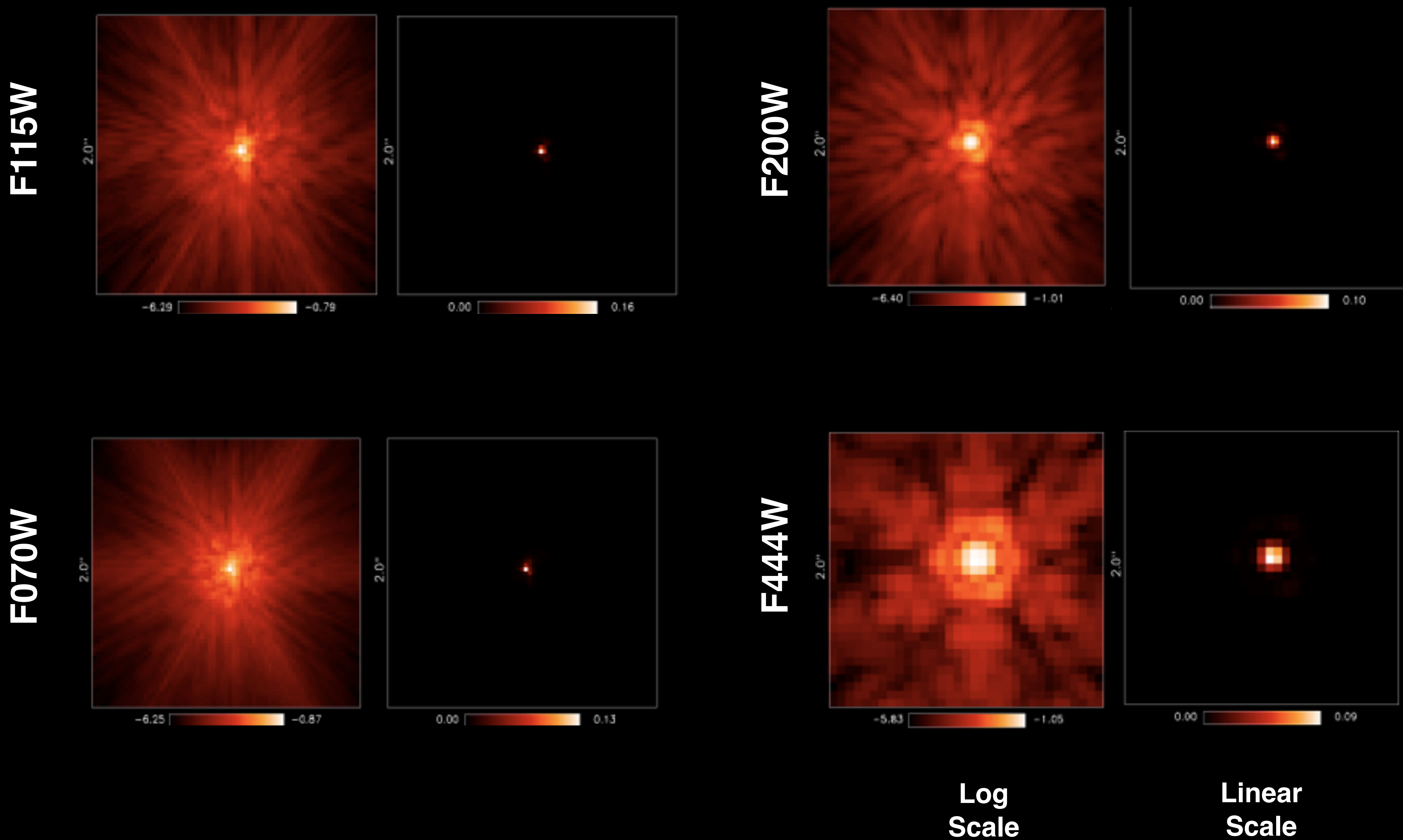
- Preliminary Surface Figure Error (SFE) for OTE optical elements
  - ➡ Preliminary as-built cryo-measured surface figure error (SFE)

Mirror	Measured (nm RMS SFE)	Uncertainty (nm RMS SFE)	Total (nm RMS SFE)	Requirement (nm RMS SFE)	Margin (nm RMS SFE)
18 Primary Mirrors (composite)	23.7	8.1	25.0	25.8	6.4
Secondary	14.5	14.9	20.8	23.5	10.9
Tertiary	17.5	9.4	19.9	23.3	11.9
Fine Steering	14.7	8.7	17.1	17.5	3.7



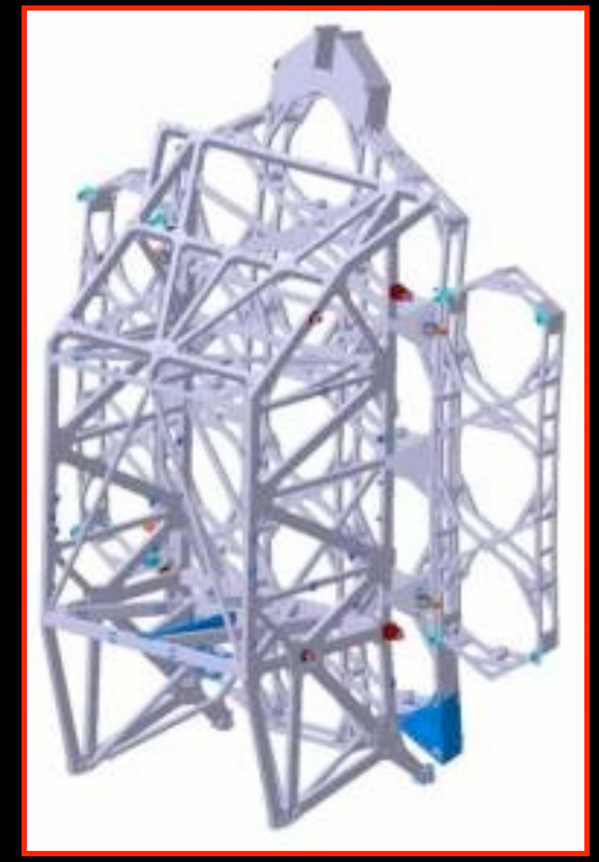
Secondary Mirror

Predicted Image Quality



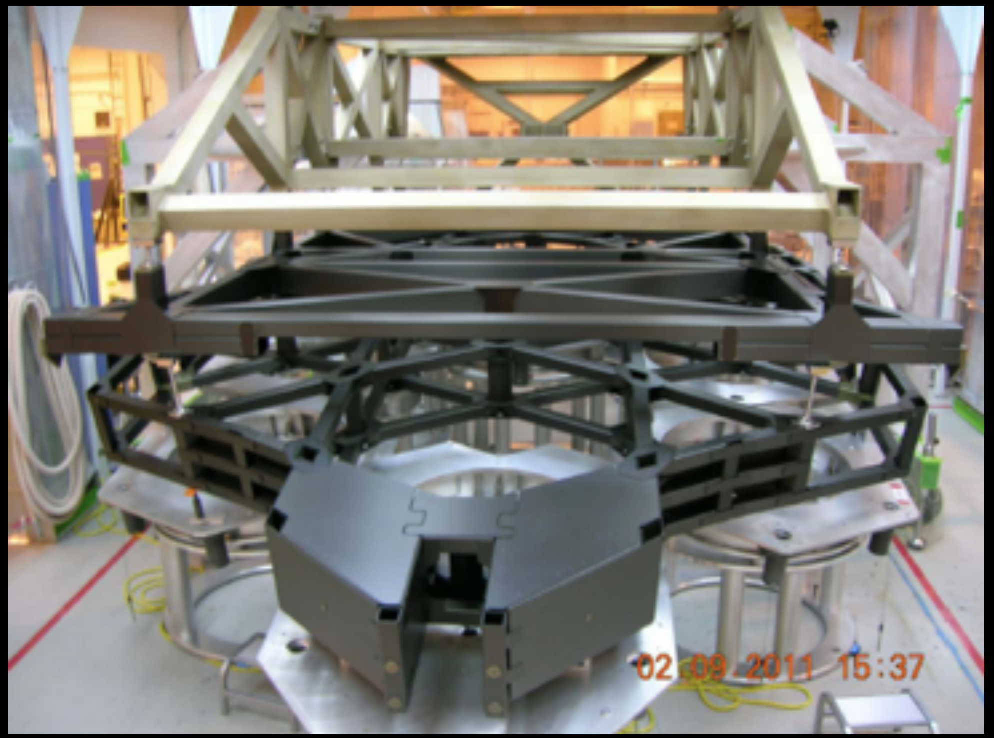
Primary Mirror Backplane

- Pathfinder backplane (central section) is complete
  - ➡ Primary use is verification of test procedures at JSC
- Flight Backplane under construction

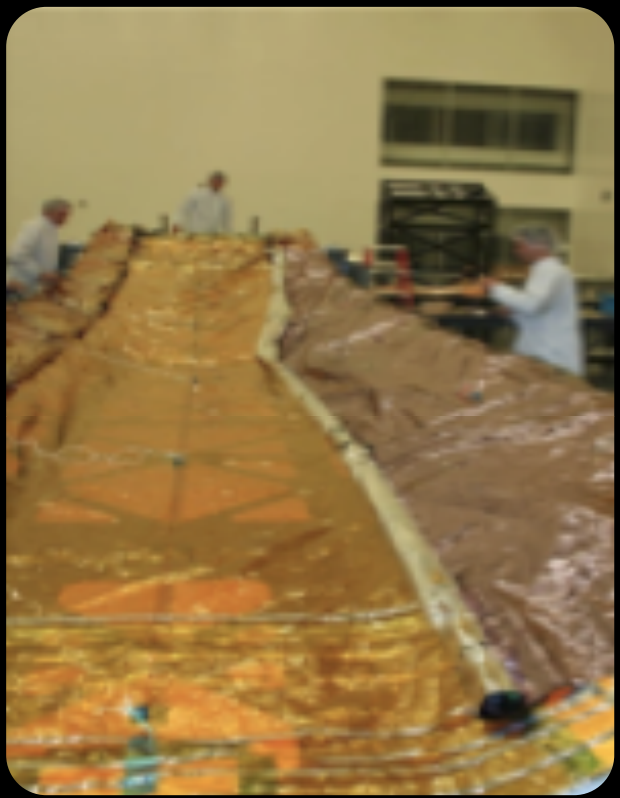


Flight backplane

Pathfinder



Sunshield Deployment



Sunshield cover test

1/3rd scale thermal test

UPS Deployment/clearance tests

Membrane fold tests

Sunshield alignment

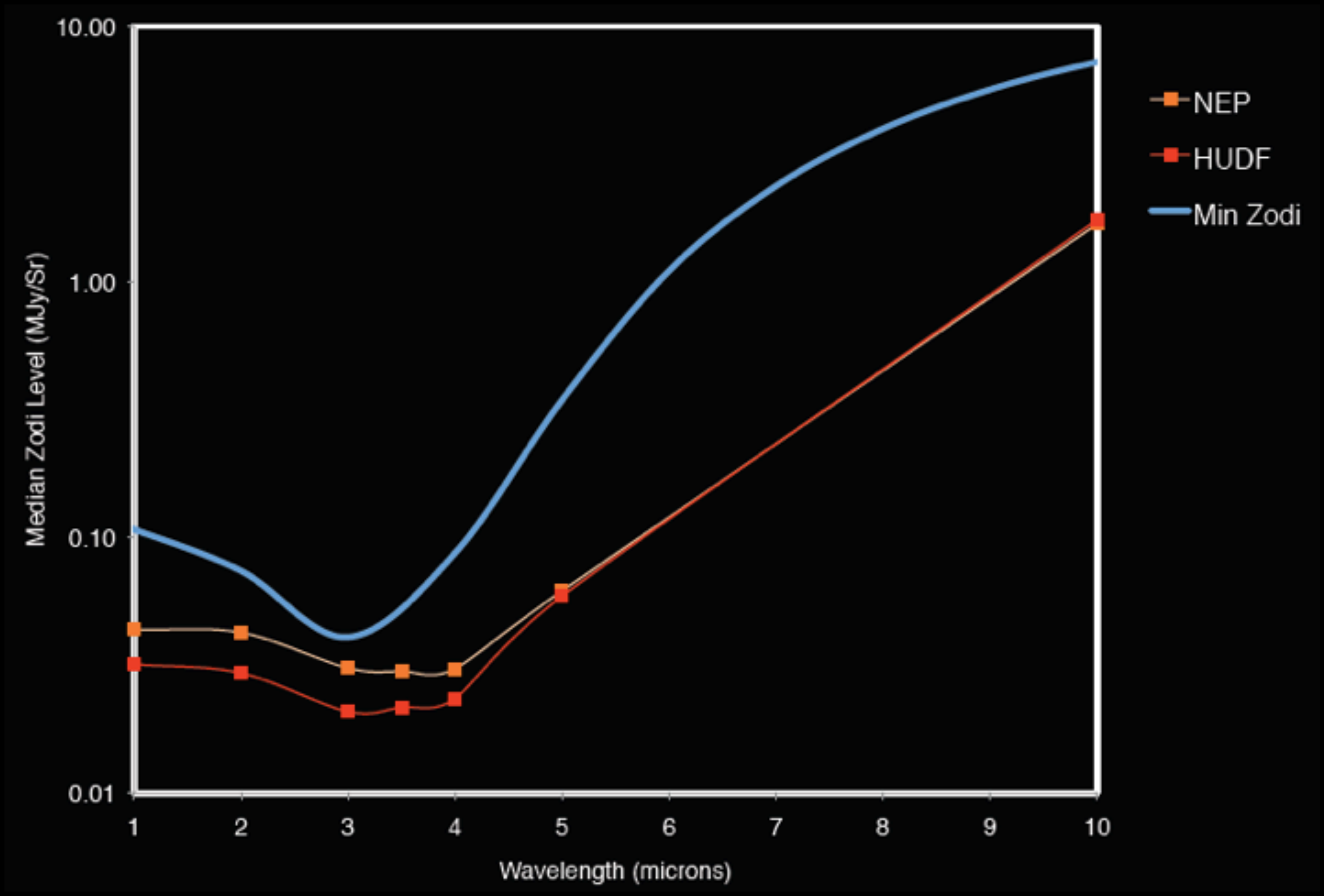
Sunshield deployment tests

3D Shape Measurement: Layer 3

- Layer 3 template membrane is being used to verify 3D shape and alignment tolerances: Layers, 5, 4, 2, and 1 will be tested next year
- Next step is hole-punching. Designed to verify release pin hole alignments on five folded membranes

Sky Background

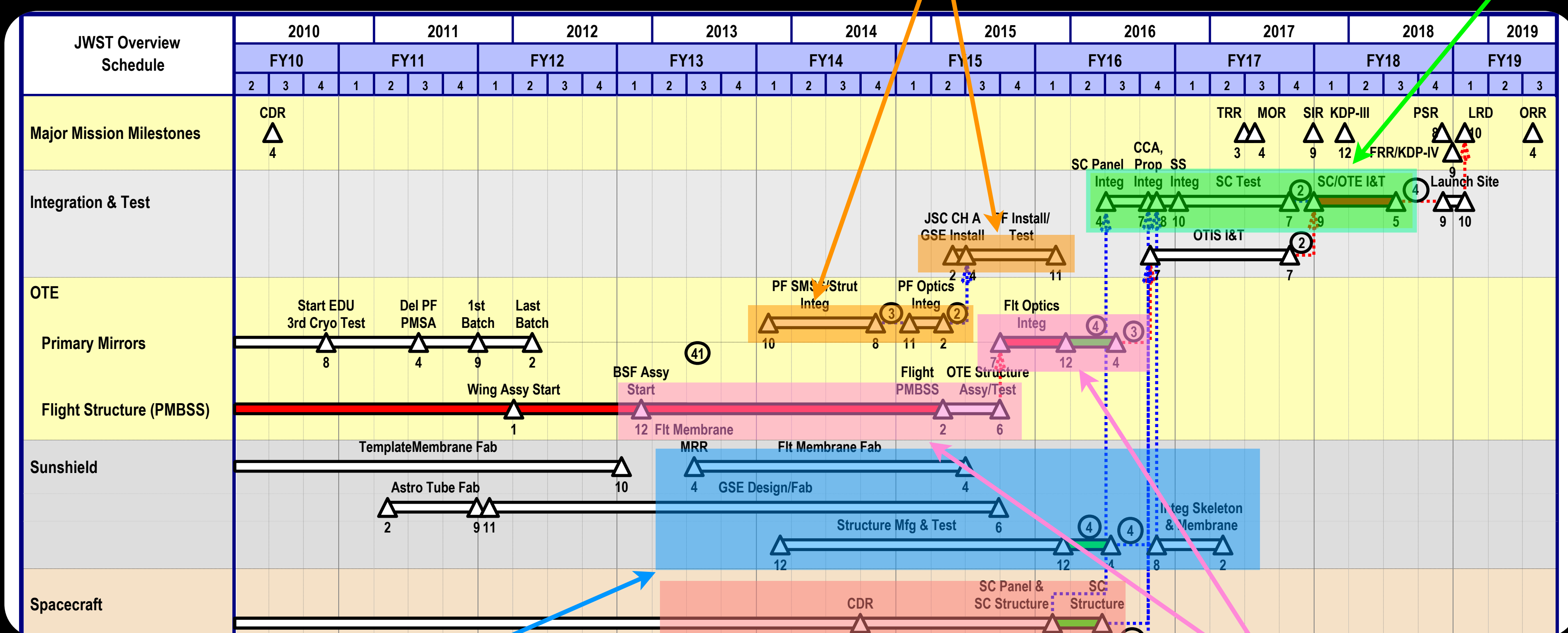
- JWST should be zodi-limited at $\lambda < 10\ \mu m$
- Background levels will include contribution from stray light



Observatory Schedule

Pathfinder backplane/SMSS
- integration & test

Telescope/Sunshield/Spacecraft
- integration & test



Sunshield Flight Membrane fabrication:
- Sunshield structure integration and test

Primary Mirror Support Structure:
- Assembly completion and cryo-test
- Mirror population

Spacecraft
- Design, fabrication & subsystem integration

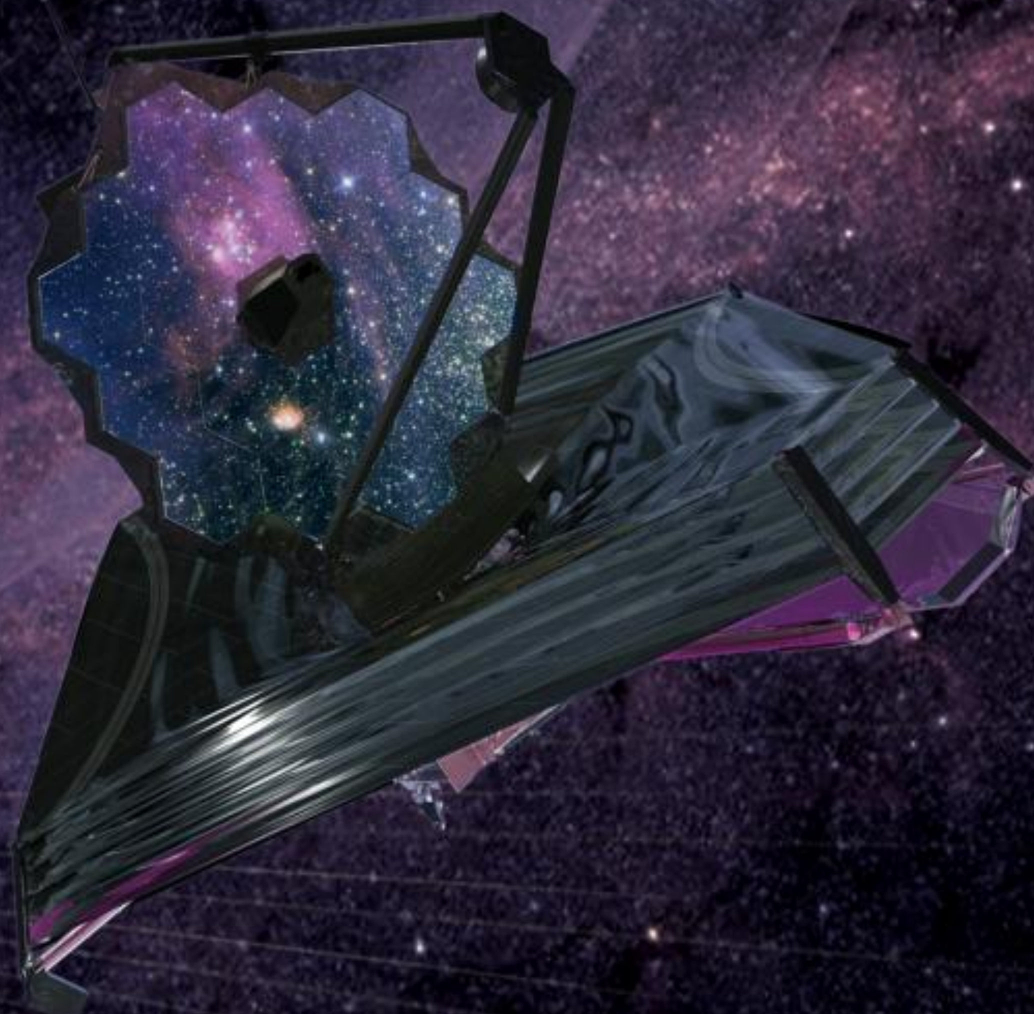
JWST Schedule

- **Key Events for 2012**

Month	Milestone	Comments
Oct '11	Begin construction of 140,000-lb robotic facility to build segmented main mirror at GSFC	Assembly began 10/4
Nov '11	Complete electronics simulator model for Integrated Science Instrument Module ("ISIM") Deliver tools for software development environment and verification	Completed 11/15 Completed 10/27
Dec '11	Install Helium shroud floor at Johnson Space Center thermal vacuum chamber ("JSC TVC") Determine root cause of NIRSpec optical bench flaw	Completed 10/26
Jan '12	Conduct Critical Design Review for Spacecraft-to-Optical Telescope Element vibration isolation system Finish building Center of Curvature Optical Assembly ("COCOA") for testing primary mirror in JSC TVC Review preliminary requirements for ground structure for spacecraft equipment panels Complete Aft Optic System integration and alignment Update Program Plan and Program Commitment Agreement to reflect replan	
Feb '12	Complete assembly and initial testing of main mirrors at Marshall Space Flight Center Install Helium shroud walls at JSC TVC	
Mar '12	Complete assessment of System Engineering Team thermal margins Deliver ISIM computer #2 to ISIM integration and testing Complete analysis of JSC TVC telescope testing equipment plans	
Apr '12	Receive Flight Mid-infrared Instrument (MIRI) from Europe, first of the telescope's four science instruments	

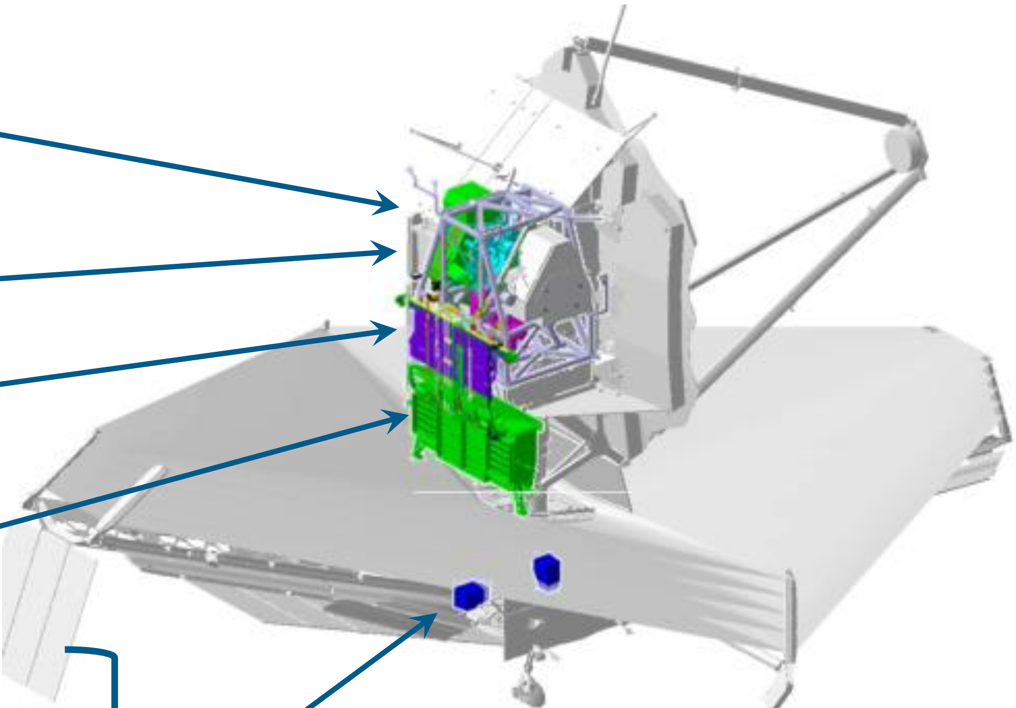
The JWST Science Instrument Module

Matt Greenhouse
JWST Project Office
NASA Goddard Space Flight Center
16 December 2011

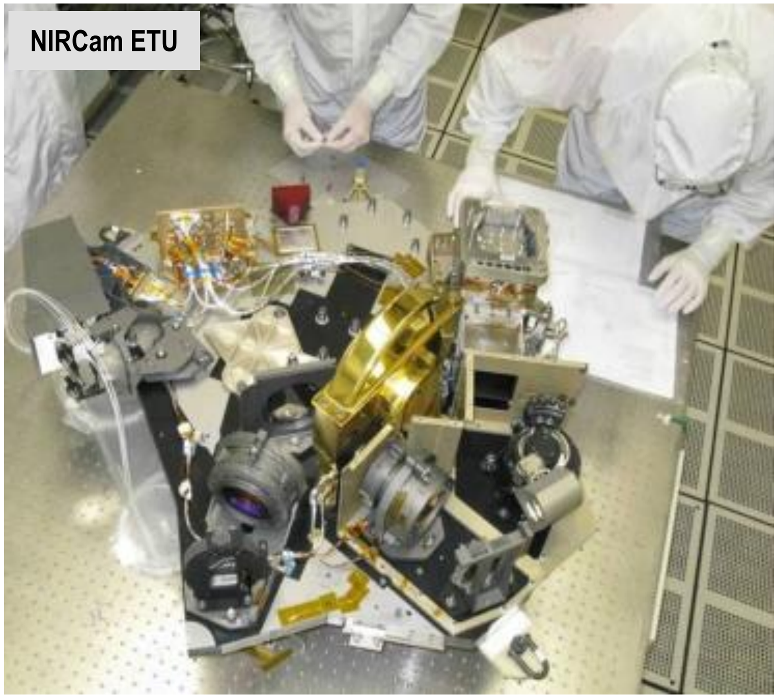


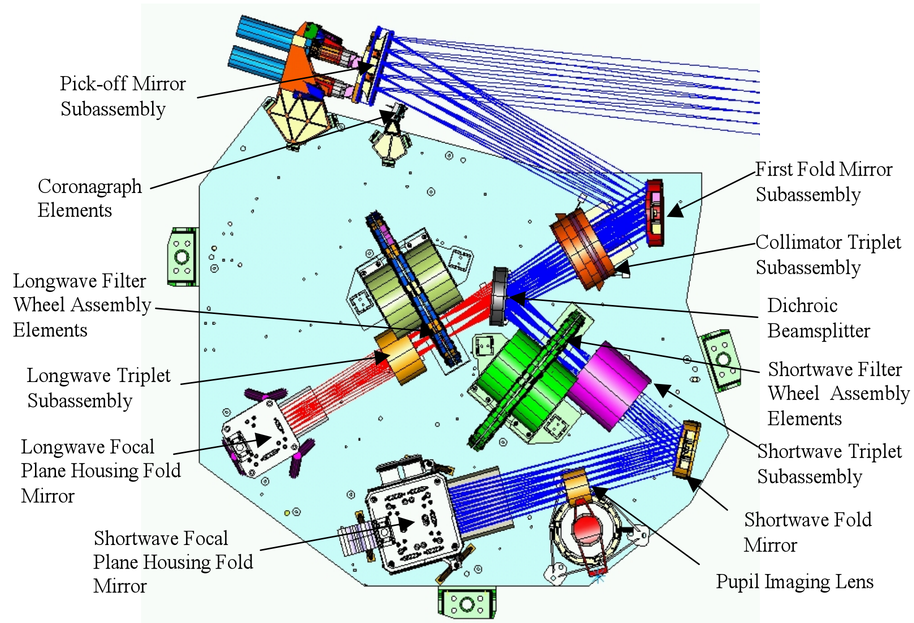
ISIM is the science instrument payload of the JWST

- **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



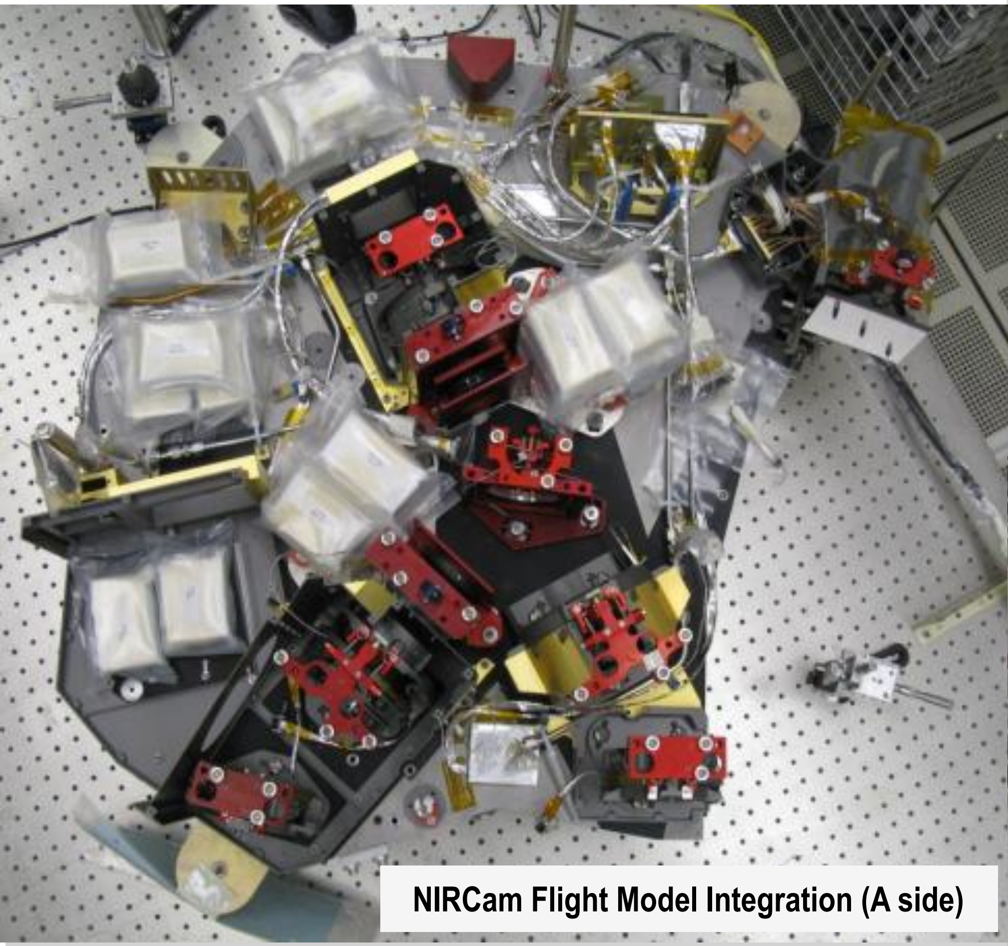
NIRCam will provide the deepest near-infrared images ever and will identify primeval galaxy targets for the NIRSpec





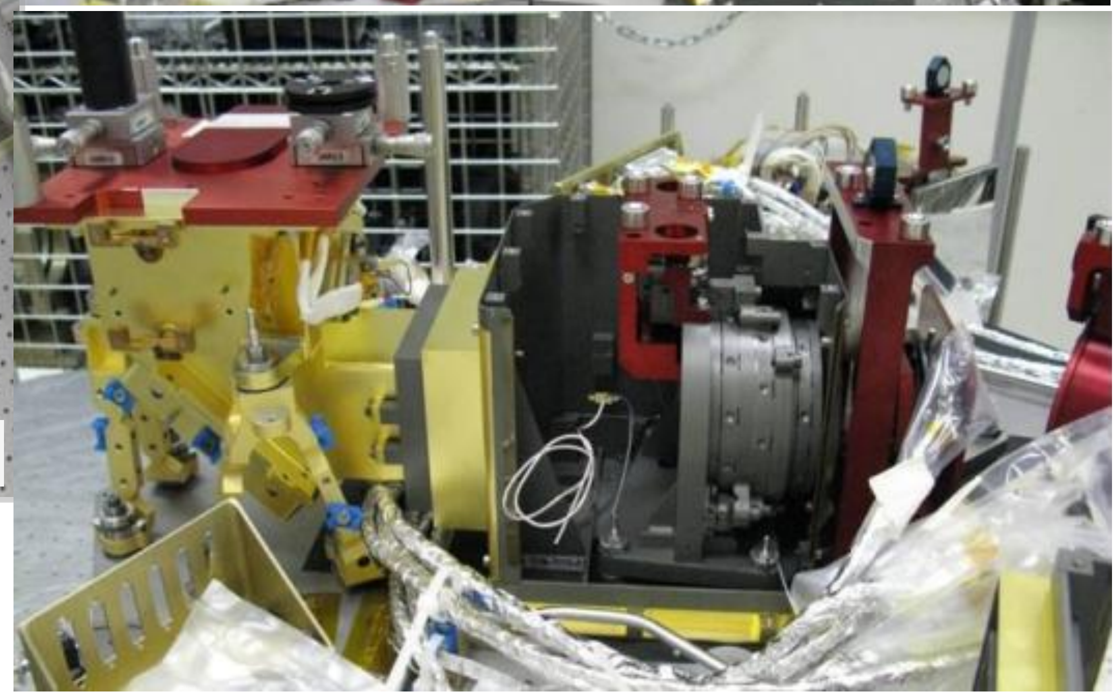
- Developed by the University of Arizona with Lockheed Martin ATC
  - Operating wavelength: 0.6 – 5.0 microns
  - Spectral resolution: 4, 10, 100 (filters + grism), coronagraph
  - Field of view: 2.2 x 4.4 arc minutes
  - Angular resolution (1 pixel): 32 mas < 2.3 microns, 65 mas > 2.4 microns, coronagraph
  - 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

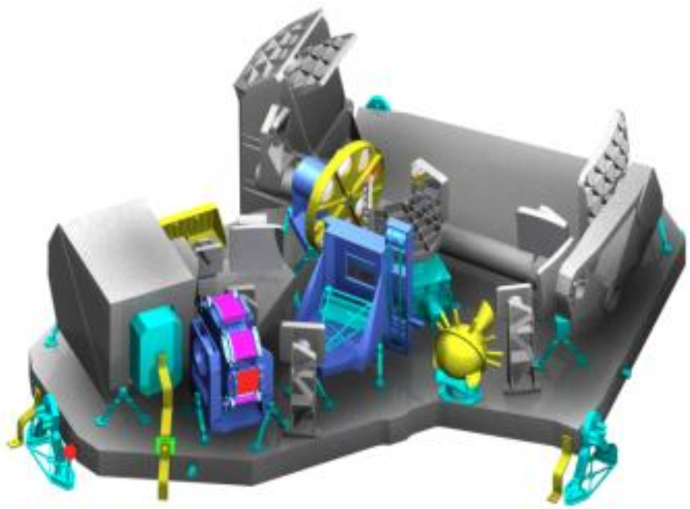


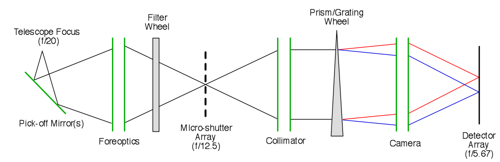
NIRCam Flight Model Integration (A side)

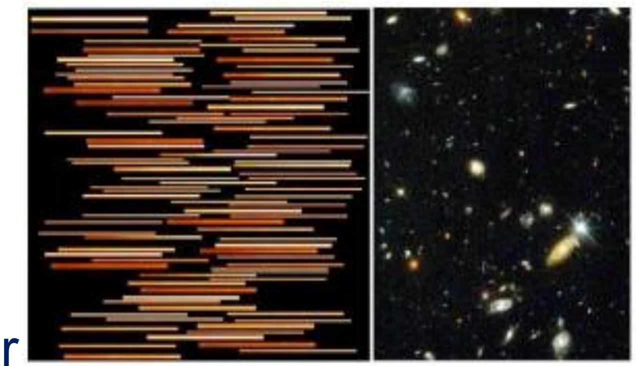
NIRCam Flight Model Integration (A side)



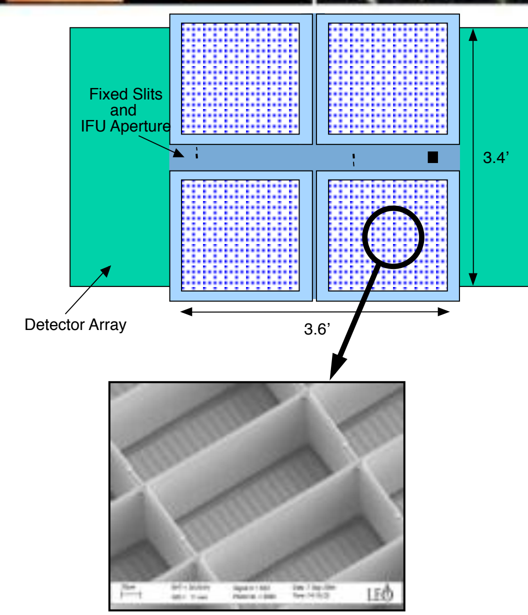
The NIRSpec will acquire spectra of up to 100 galaxies in a single exposure



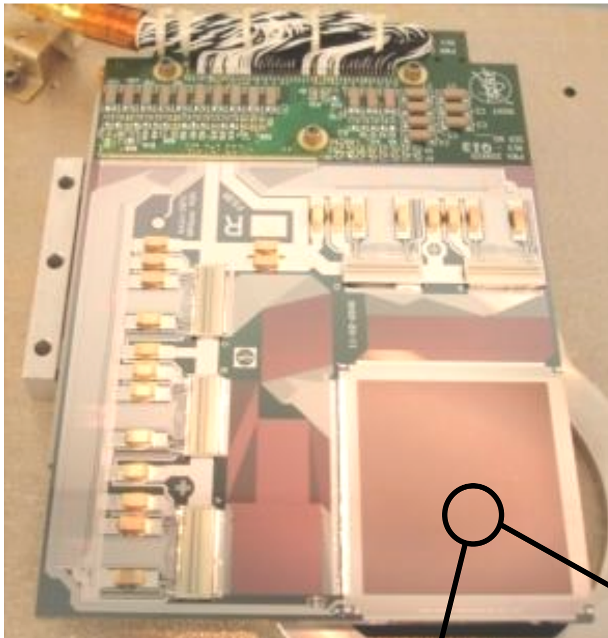


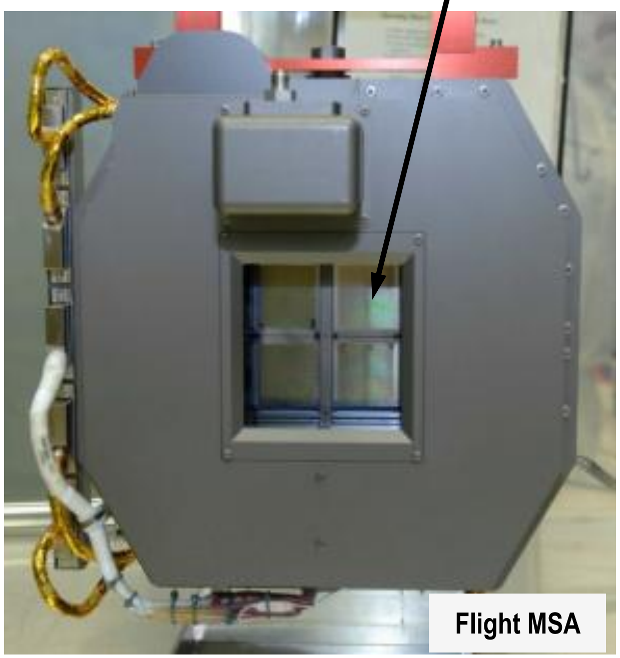


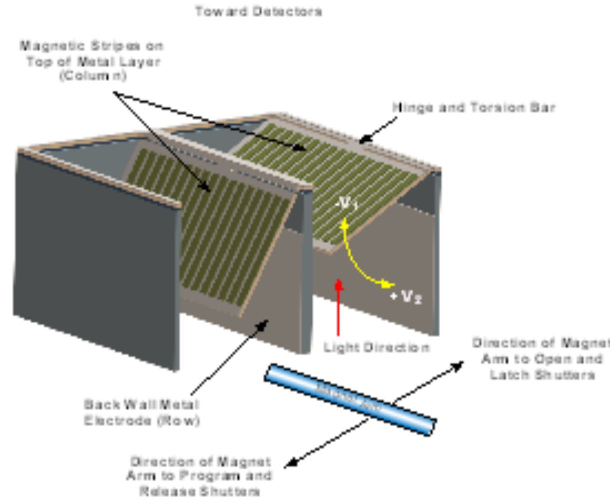
- Developed by the European Space Technology Center (ESTEC) with Astrium GmbH and Goddard Space Flight Ctr
  - Operating wavelength: 0.6 – 5.0 microns
  - Spectral resolution: 100, 1000, 3000
  - Field of view: 3.4 x 3.4 arc minutes
    - Aperture control:
      - Programmable micro-shutters, 250,000 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

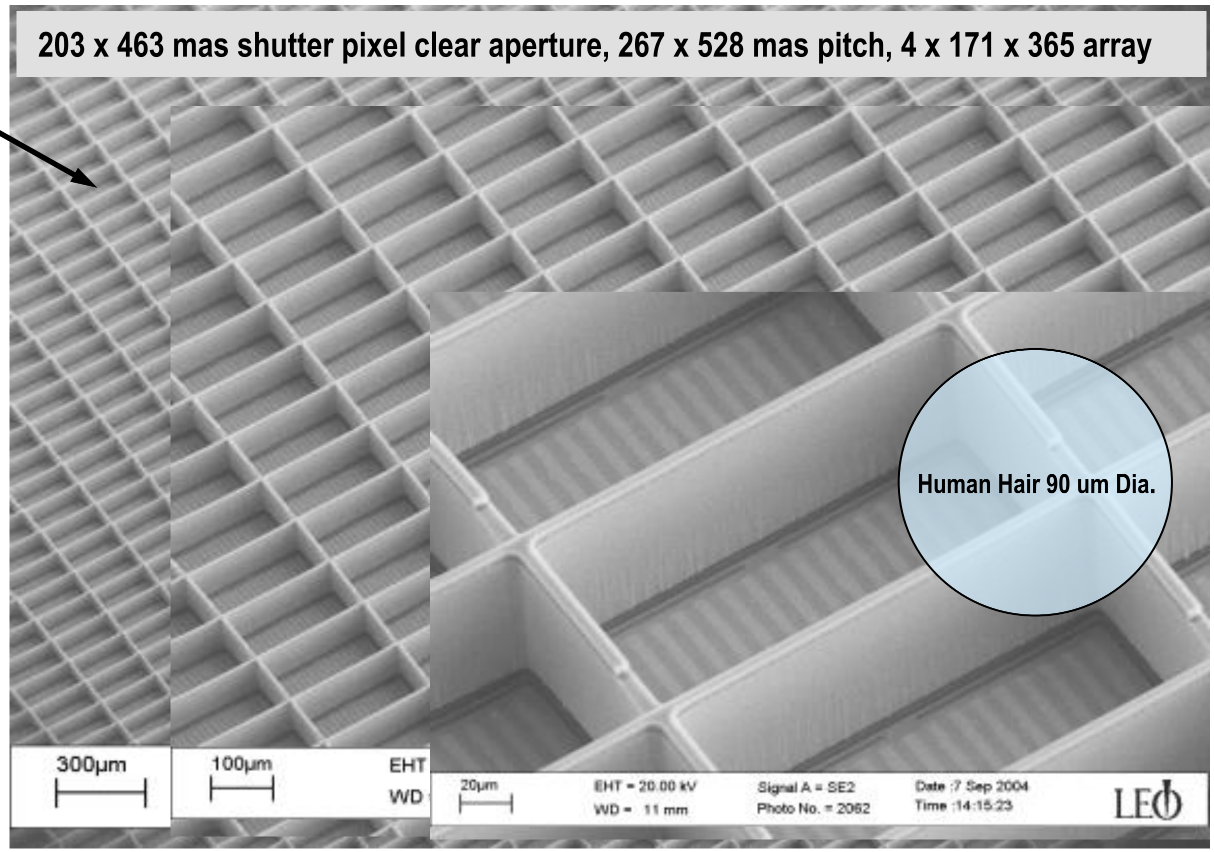


Aperture control: 250,000 programmable micro-shutters System at TRL-8 and delivered to ESA June 2010



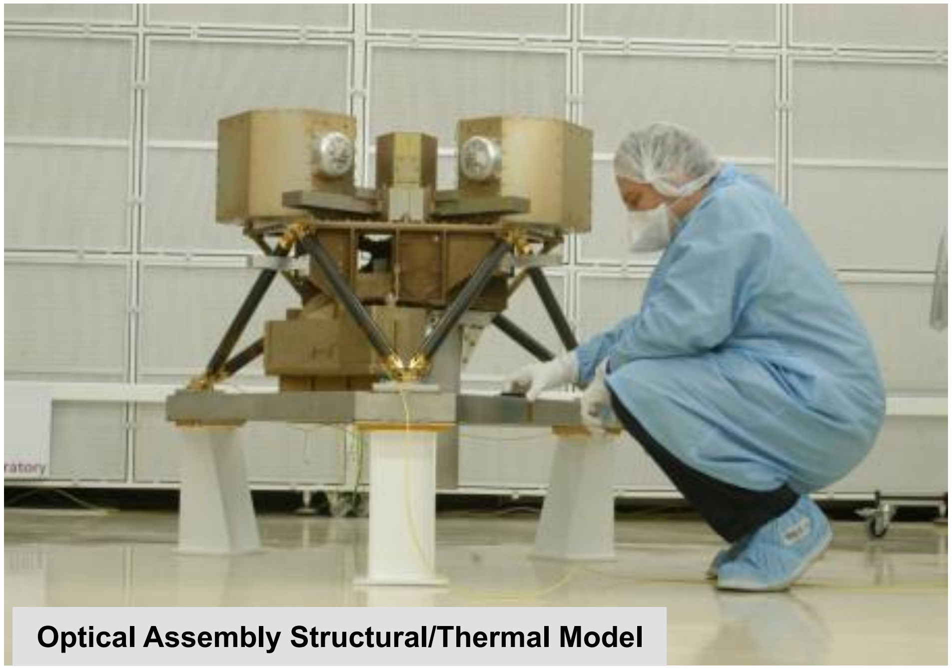


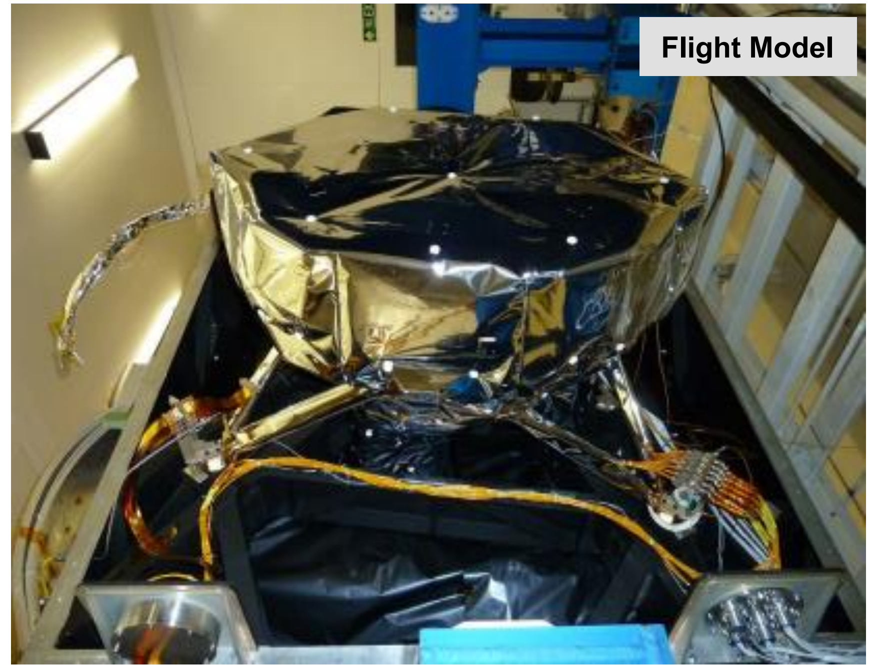




NIRSpec delivery expected during 2012

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

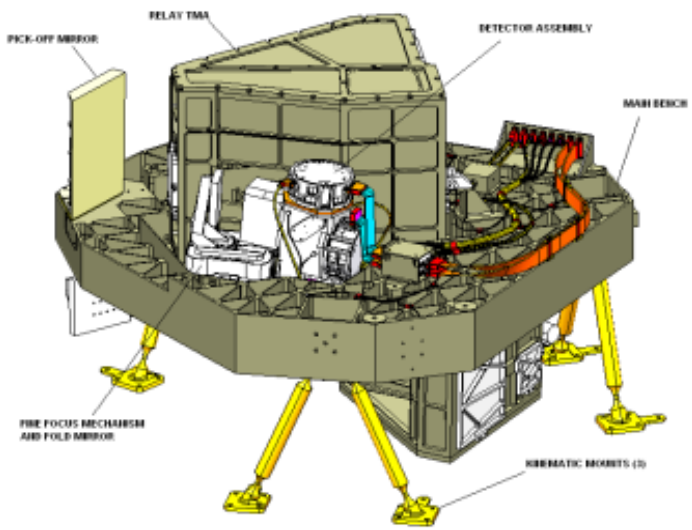
- Developed by a European Consortium and JPL
  - Operating wavelength: 5 - 29 microns
  - Spectral resolution: 5, 100, 2000
  - Broad-band imagery: 1.9 x 1.4 arc minutes FOV
  - Coronagraphic imagery
  - Spectroscopy:
    - R100 long slit spectroscopy 5 x 0.2 arc sec
    - R2000 spectroscopy 3.5 x 3.5 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

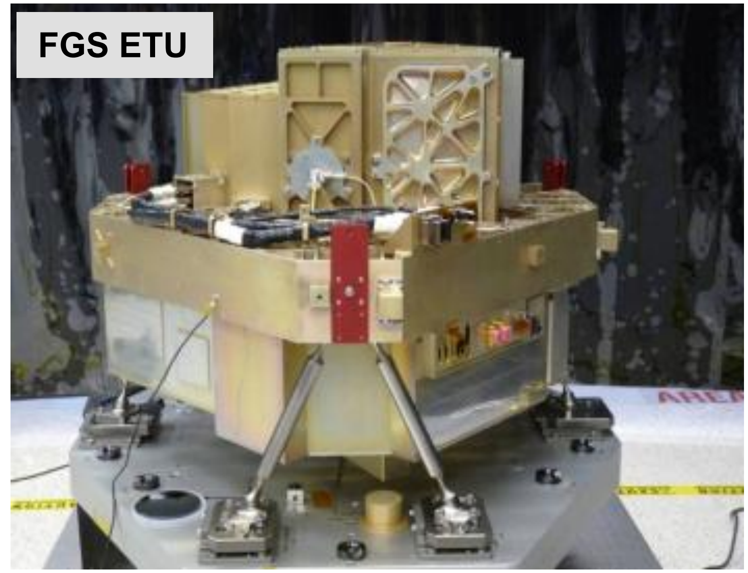
Flight unit cryo-vacuum testing successfully completed during July 2011

MIRI is on schedule for delivery during 2012

Flight MIRI on test fixture

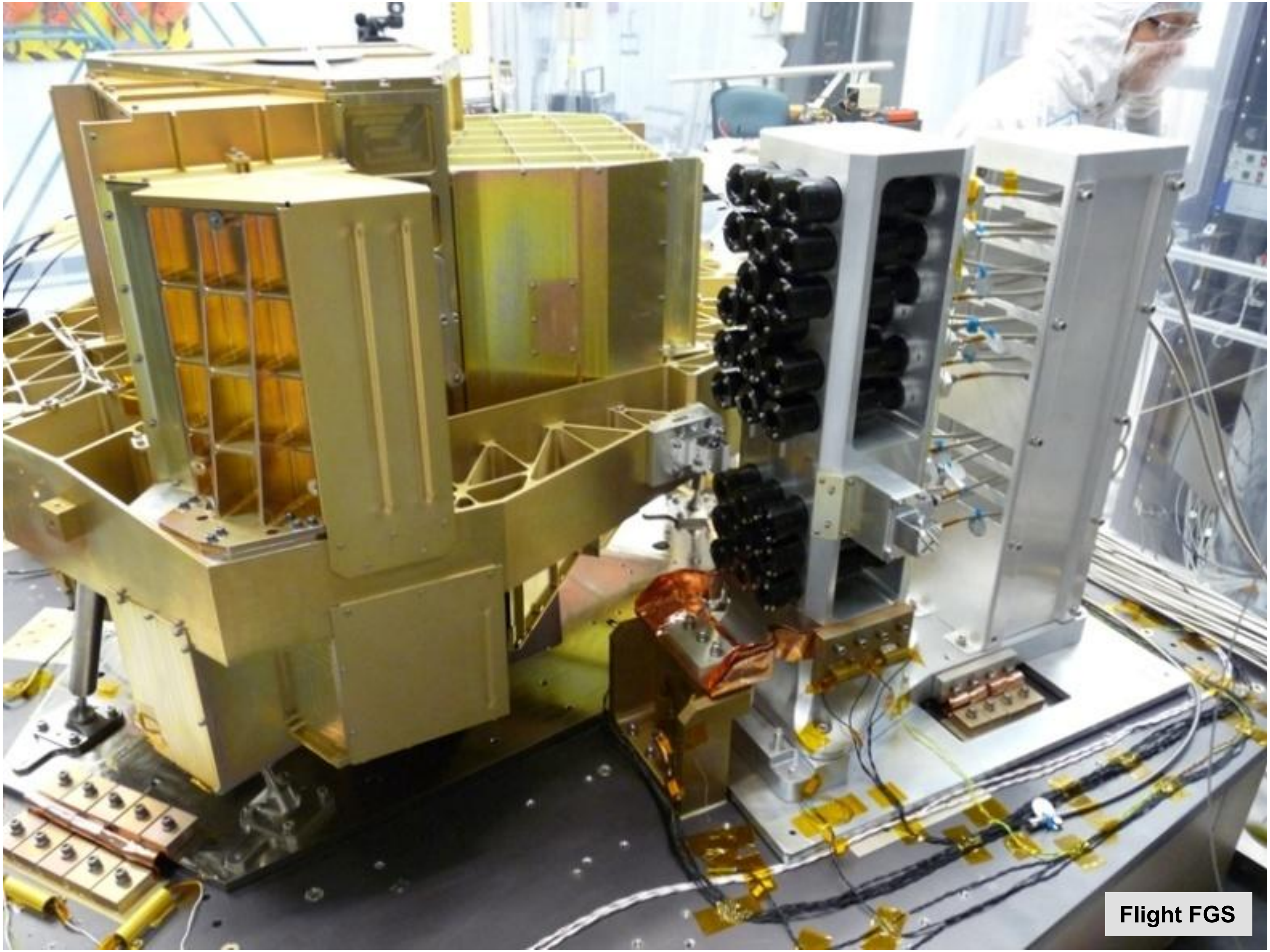
The FGS-Guider and -NIRSS provide imagery for telescope pointing control & spectroscopy for Ly-α galaxy surveys and extra-solar planet transits





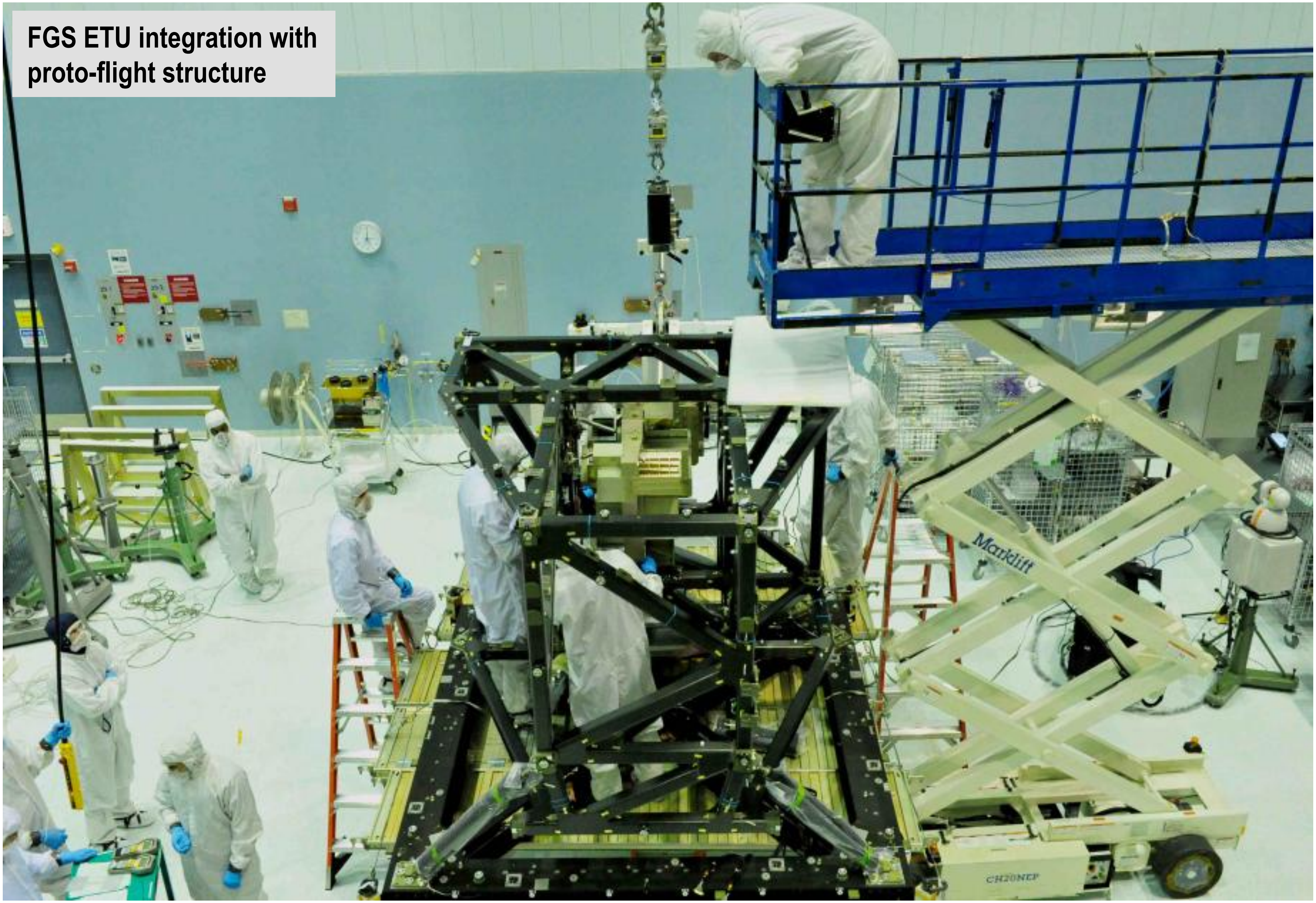
- Developed by the Canadian Space Agency with ComDev
  - Broad-band guider (0.6 – 5 microns)
  - Field of view: 2.3 x 2.3 arc minutes
  - Science imagery:
    - Slitless spectroscopic imagery (grism)
      - R ~ 150, 0.8 – 2.25 microns optimized for Ly alpha galaxy surveys
      - R ~ 700, 0.7 – 2.5 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

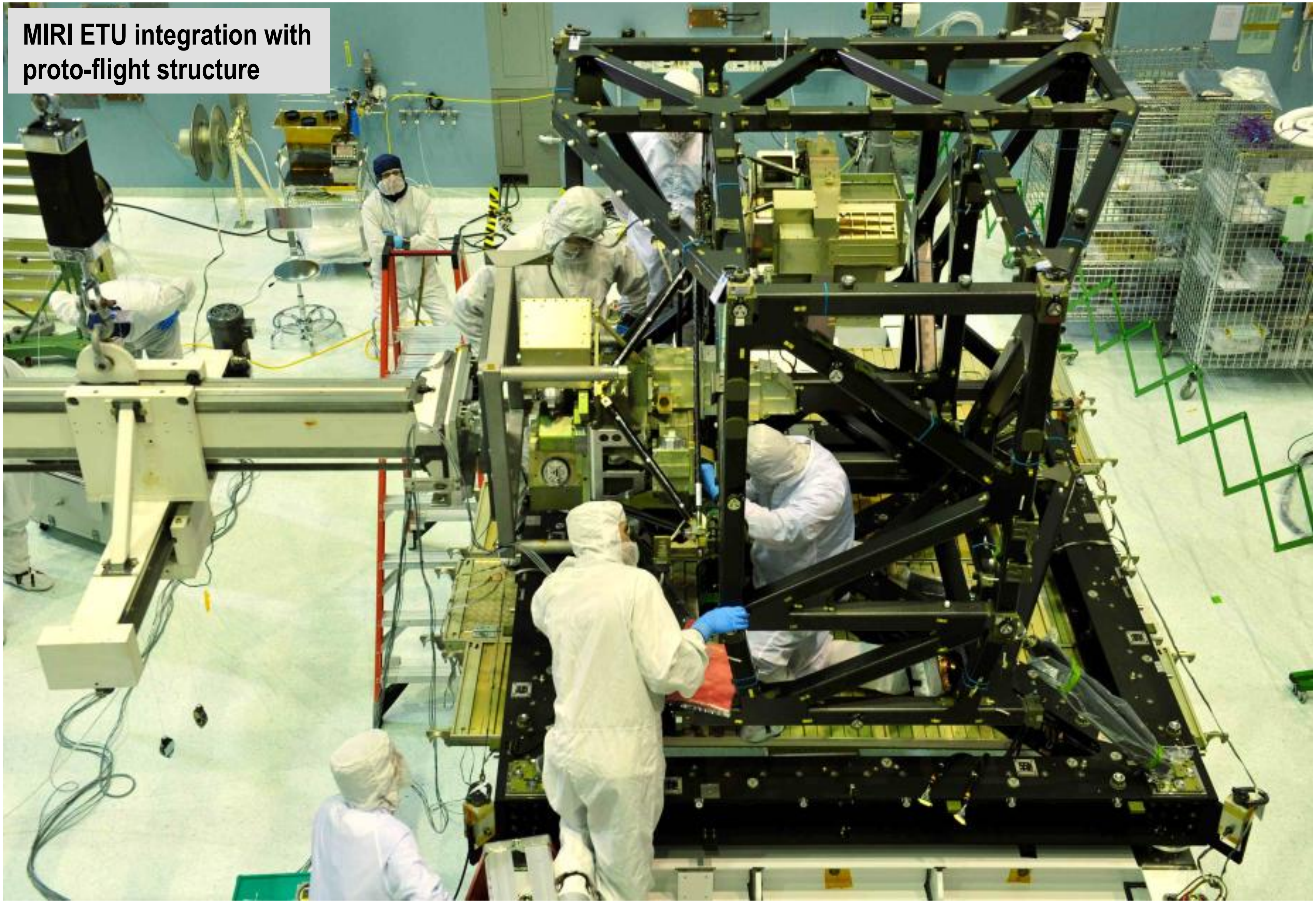


Flight FGS

ETU SI integration with ISIM structure proceeding well



ETU SI integration with ISIM structure proceeding well



MIRI ETU integration with proto-flight structure

ISIM issue and risk status as of November 2011

Current key issues:

- NIRSpec bench crack:
  - Root causes determined; installing flight spare bench
  - Not expected to delay ISIM delivery
- HgCdTe detector degradation:
  - Root cause determined; new design undergoing flight qualification
  - Cost and schedule to replace is incorporated into 2018 LRD re-plan

Risk focus:

- SES chamber thermal stray light:
  - Expected closure 3/13 CV1
- Achieving thermal model correlation during SES testing
  - Expected closure 3/13 CV1
- Damage to proto-flight structure during integration and test
  - Expected closure 7/15 ISIM delivery
- SES test setup fault tolerance
  - Expected closure 11/12 ISIM PER
- ISIM to SI interface verification
  - Expected closure 3/12 ICDH interface testing complete

- **Learn more about the ISIM science instruments at:**
  - http://www.jwst.nasa.gov/instruments.html
  - http://www.stsci.edu/jwst/instruments
- **Explore their capability relative to your science objectives at:**
  - http://jwstetc.stsci.edu/
- **Interact with GSFC scientists assigned to the JWST ISIM:**
  - **Matt Greenhouse**: ISIM Project Scientist
  - **Bernie Rauscher**: Deputy ISIM PS and NIRSpec detector system PI
  - **Harvey Moseley**: NIRSpec micro-shutter system PI
  - **Bob Hill**: Near-infrared detector fabrication

The James Webb Space Telescope Integration & Test Program

Randy Kimble
JWST Project Office
NASA Goddard Space Flight Center
16 December 2011

Integration and Test of the James Webb Space Telescope

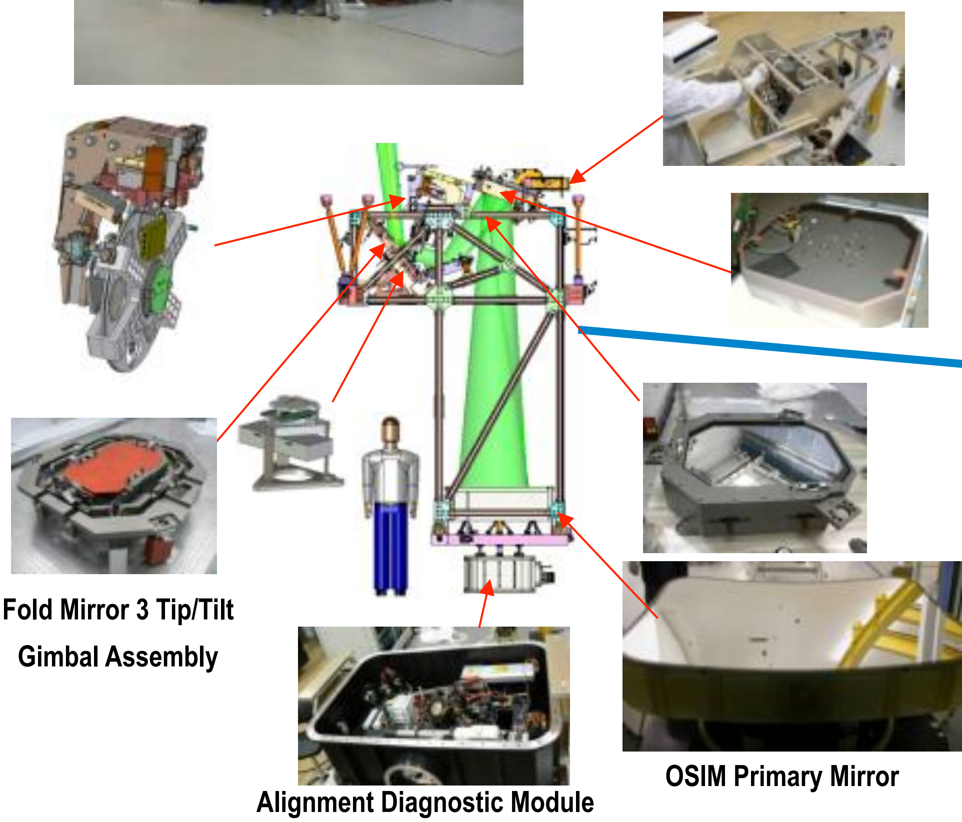
- **As is typically the case, I&T for JWST is a hierarchical process**
  - Lower level elements, developed and tested in parallel
  - Integrated into higher level assemblies and tested again
    - Subsystems → Science Instruments
    - Four Science Instruments + Electronics + Structure… → ISIM
    - ISIM + OTE → OTIS
    - OTIS + Spacecraft → Observatory
  - Verify performance requirements at the appropriate level of assembly
  - Try to catch problems at the lowest level possible (easiest to fix)
  - Provide independent cross-checks at the higher levels to confirm nothing went wrong in assembly
- **For an observatory as complex as JWST**
  - There's a lot of I….
  - There's a lot of T….
- ***Here are some highlights….***

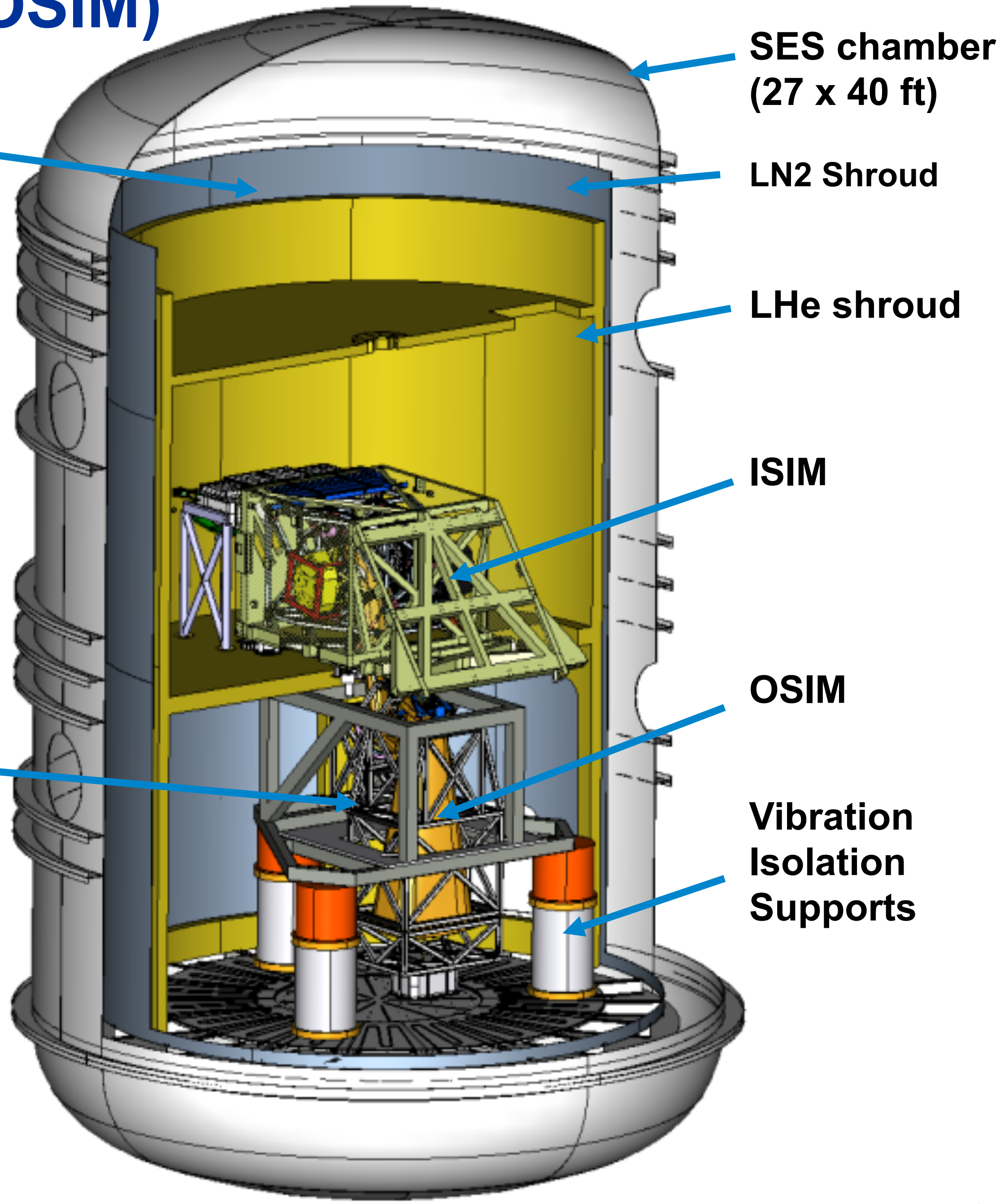
ISIM I&T has already begun; SI integration will be a highlight, starting with 1st delivery in the spring of 2012.

Test installation of MIRI Structural Thermal Model

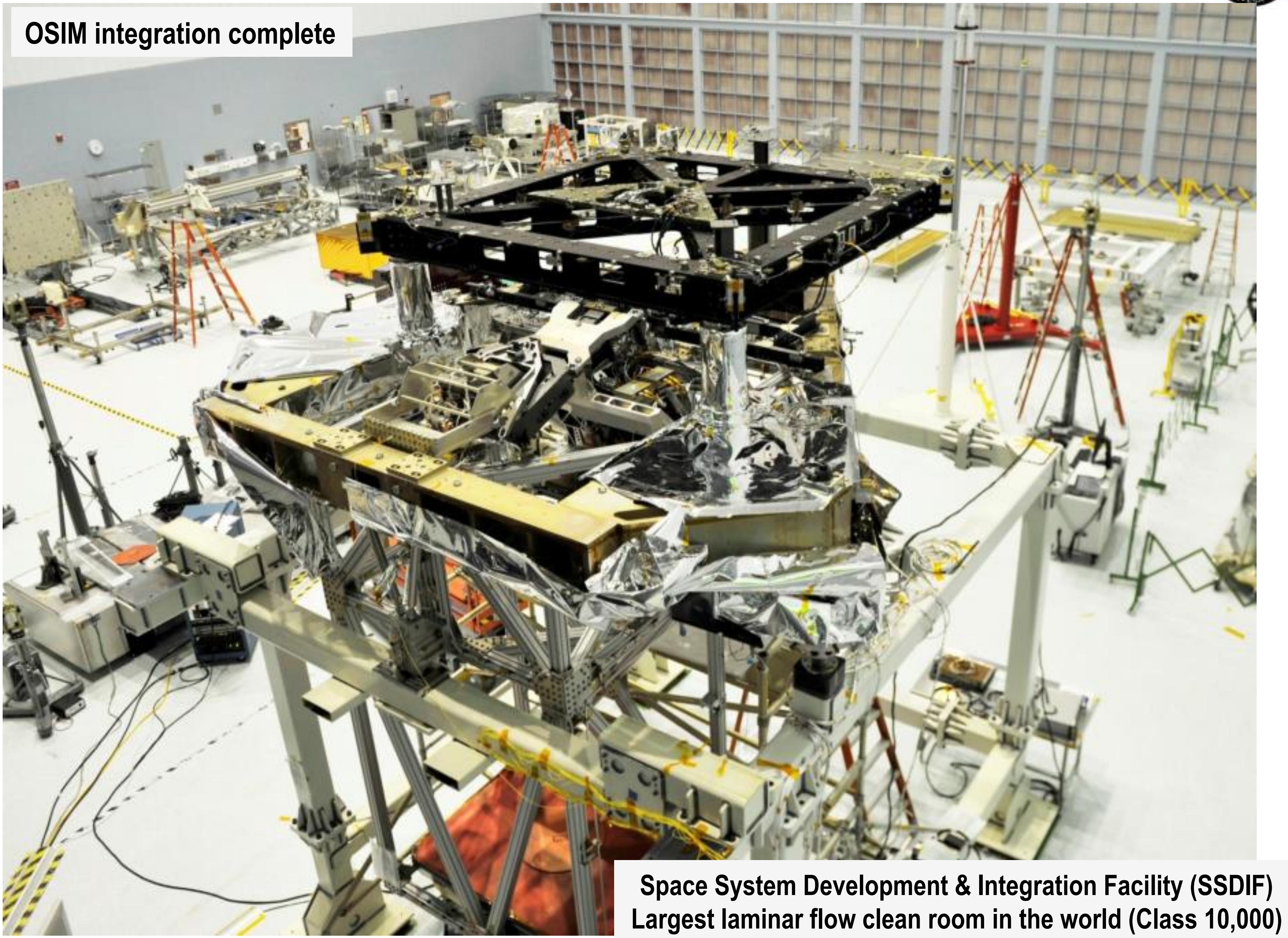
ISIM will be tested at ~35 K in the GSFC SES chamber using a cryogenic telescope simulator (OSIM)

LHe shroud installation and test completed July 09





OSIM on schedule for cryo-vac certification in 2012



Key Aspects of the ISIM Cryo-Vac Program

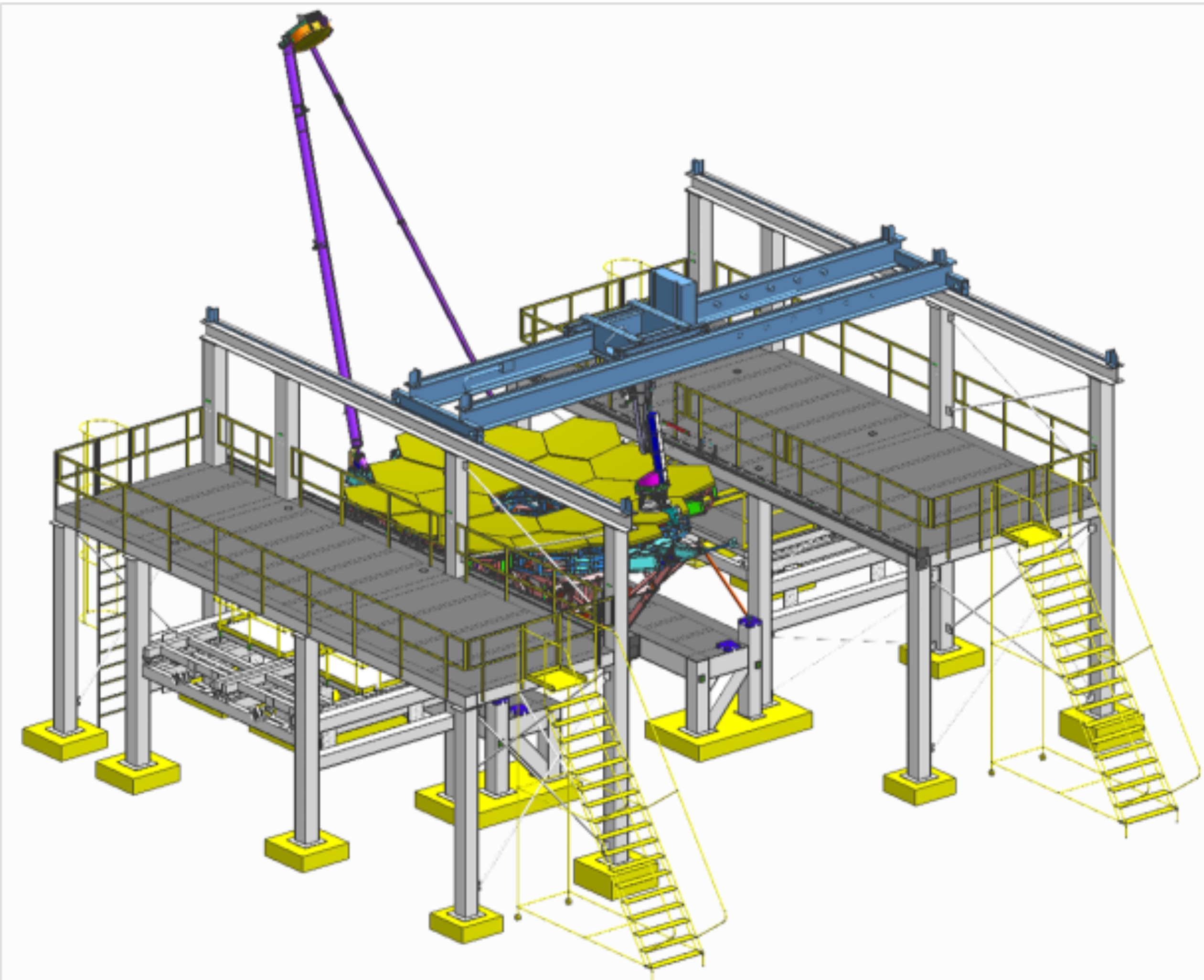
- **The principal goals**
  - Verify parfocality, coalignment, pupil alignment of SI's
  - Cross-check image quality against OSIM
  - Verify wavefront sensing capabilities of the SI's, obtain necessary calibrations
  - Validate thermal performance and correlate thermal model
  - Verify performance with ISIM electrical systems, non-interference of SI's with each other
  - Test some of the operational scenarios

- **At least two, and probably three ISIM cryo-vacs are planned**
  - Two bracketing the rest of the ISIM environmental test program to confirm optical and thermal stability of the system against vibe/acoustics
  - Regression cryo-vac after likely replacement of NIR detectors

- **First scheduled to begin in 2013**

Ambient Optical Alignment Stand for OTE & OTIS assembly recently installed in the SSDIF clean room

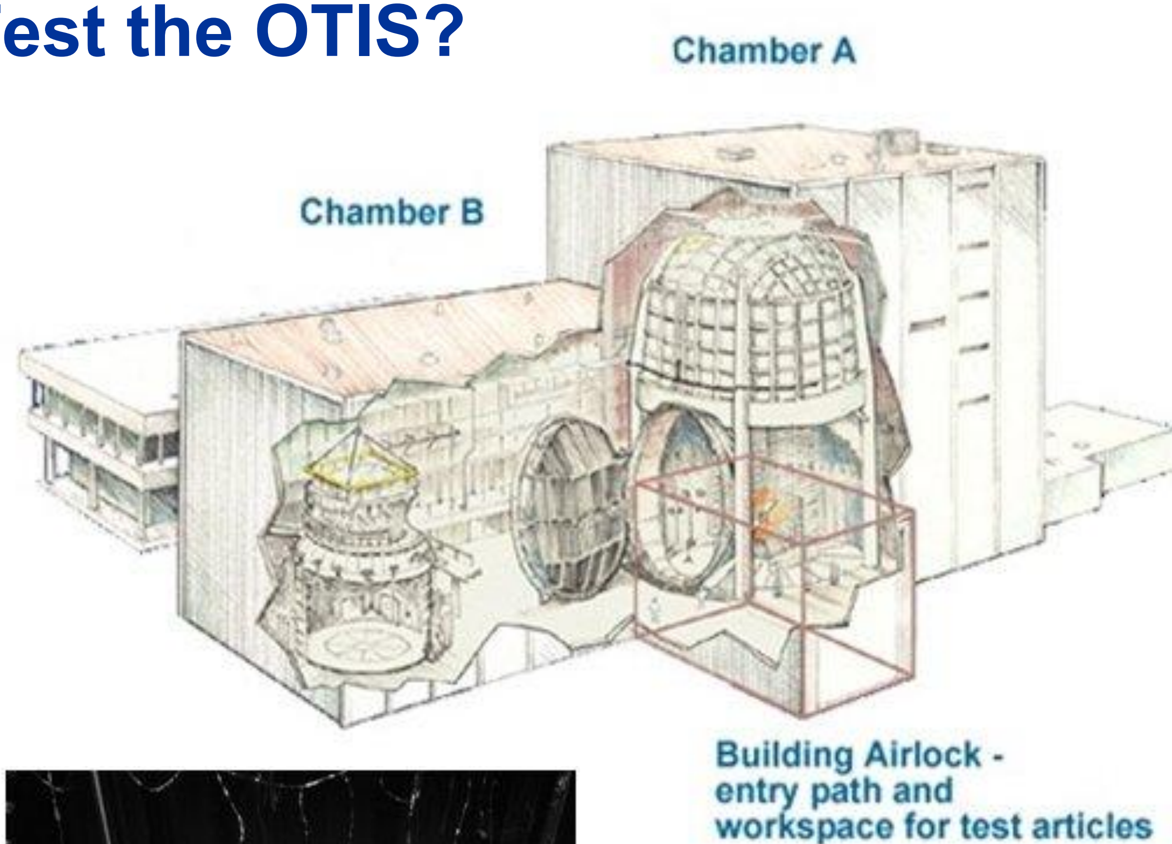
Optical Telescope Element will be integrated on this alignment stand using the machine at right for primary mirror segment installation

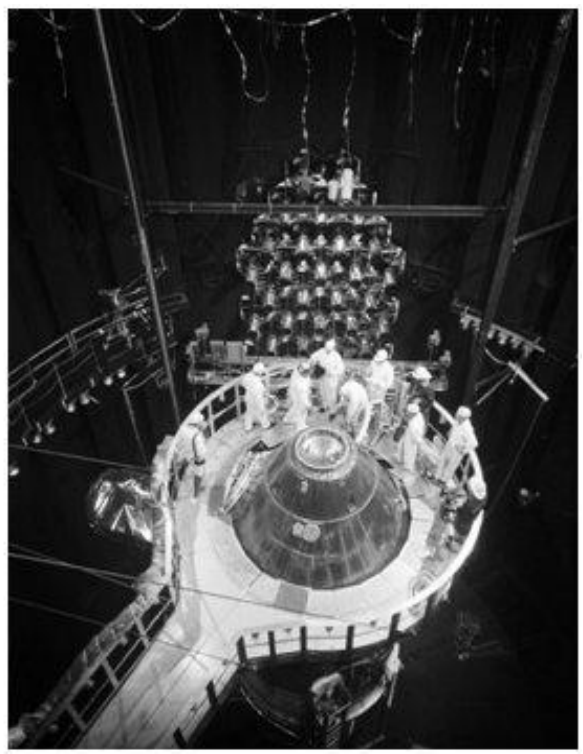


followed by attachment of the ISIM to make OTIS – scheduled for 2016

Where to Cryo-Test the OTIS?

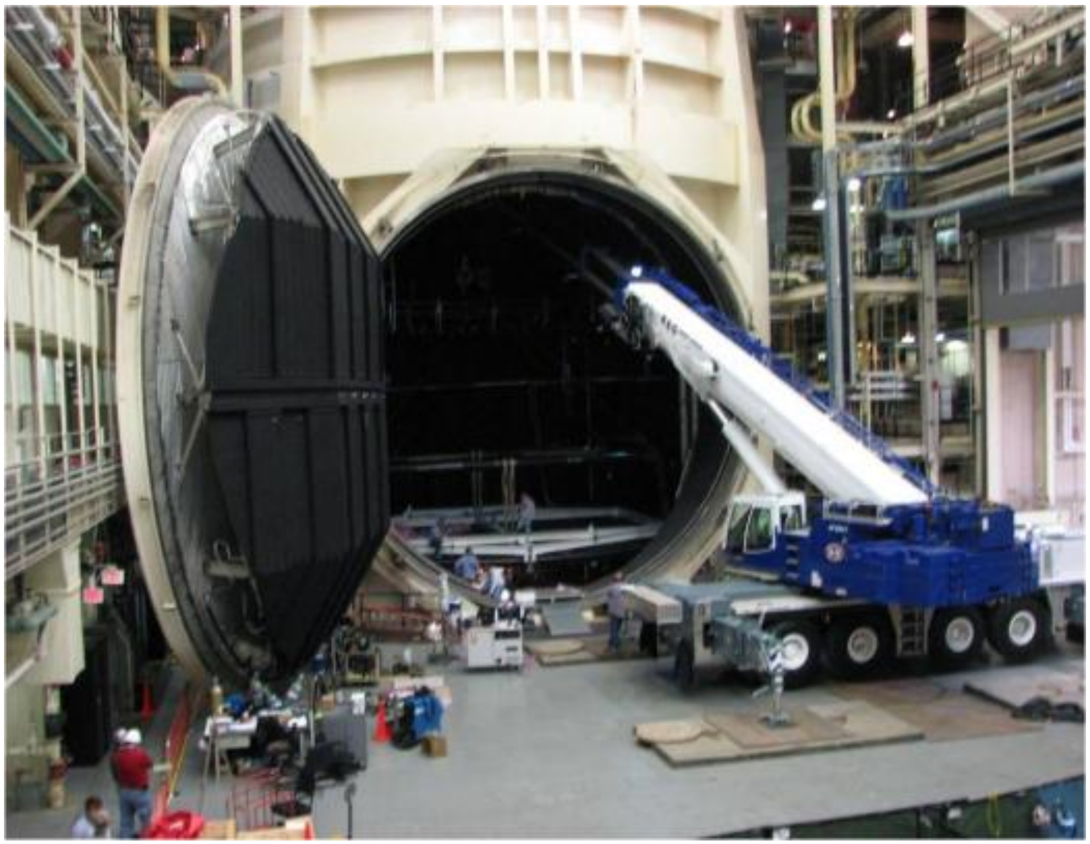
Off to JSC to a giant National Historic Landmark vacuum chamber from the Apollo era





JSC Upgrades Are Proceeding Rapidly

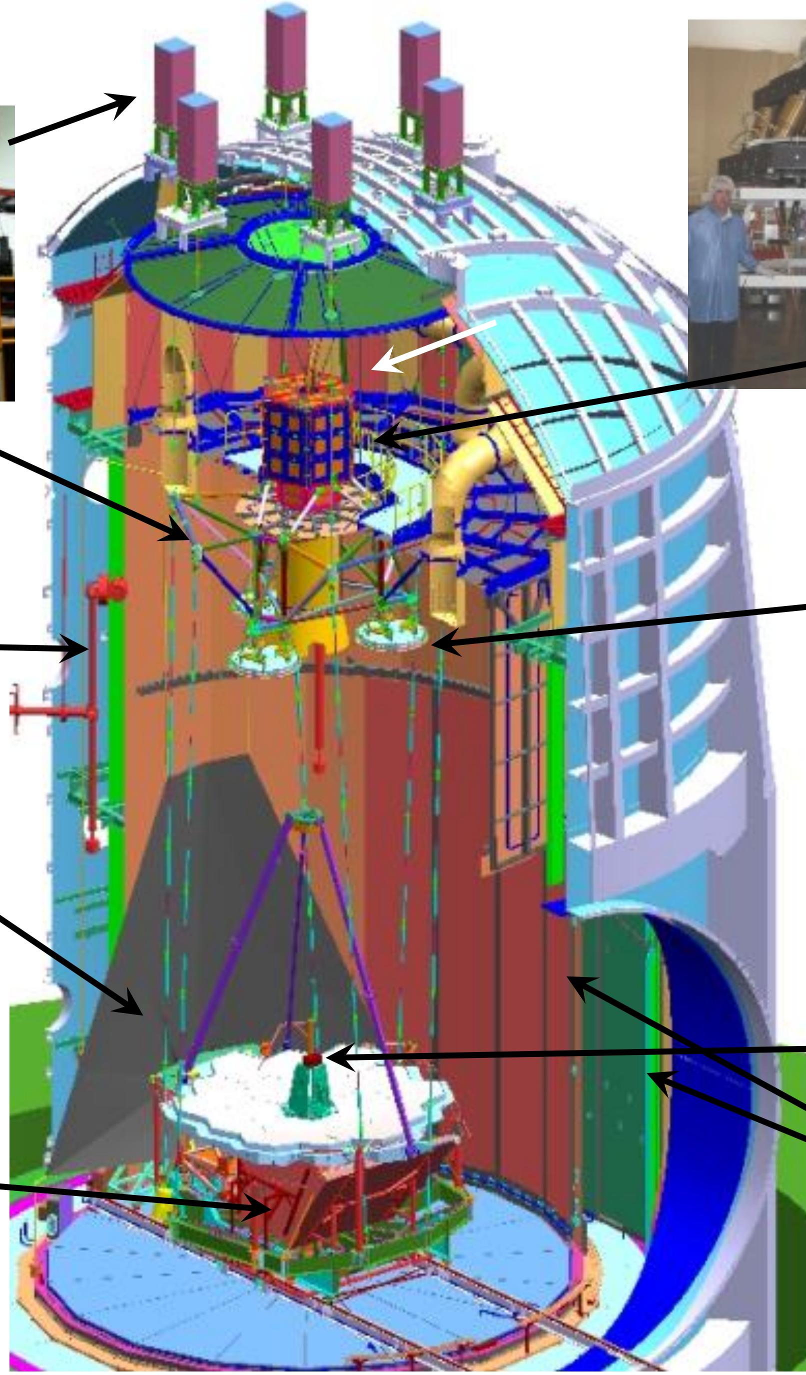
Refurbishment for deep cryogenic operation is well underway



Including the installation of the GHe shrouds and refrigeration system for taking JWST to its flight operating temperature

OTIS Test Architecture is Well Defined

Chamber Isolation
1st unit tested



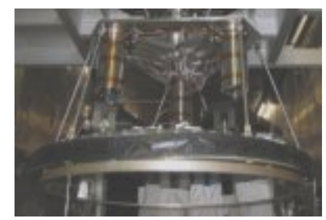
Center of Curvature Optical Assembly (COCOA)
Well into its I&T

Suspension Subsystem

3 Autocollimating Flat Mirrors
1st unit complete.
Units 2 & 3 polished

Photogrammetry Windmills

Space Vehicle Thermal Simulator (SVTS) w/ cryo-cooler and electronics



AOS Source Plate

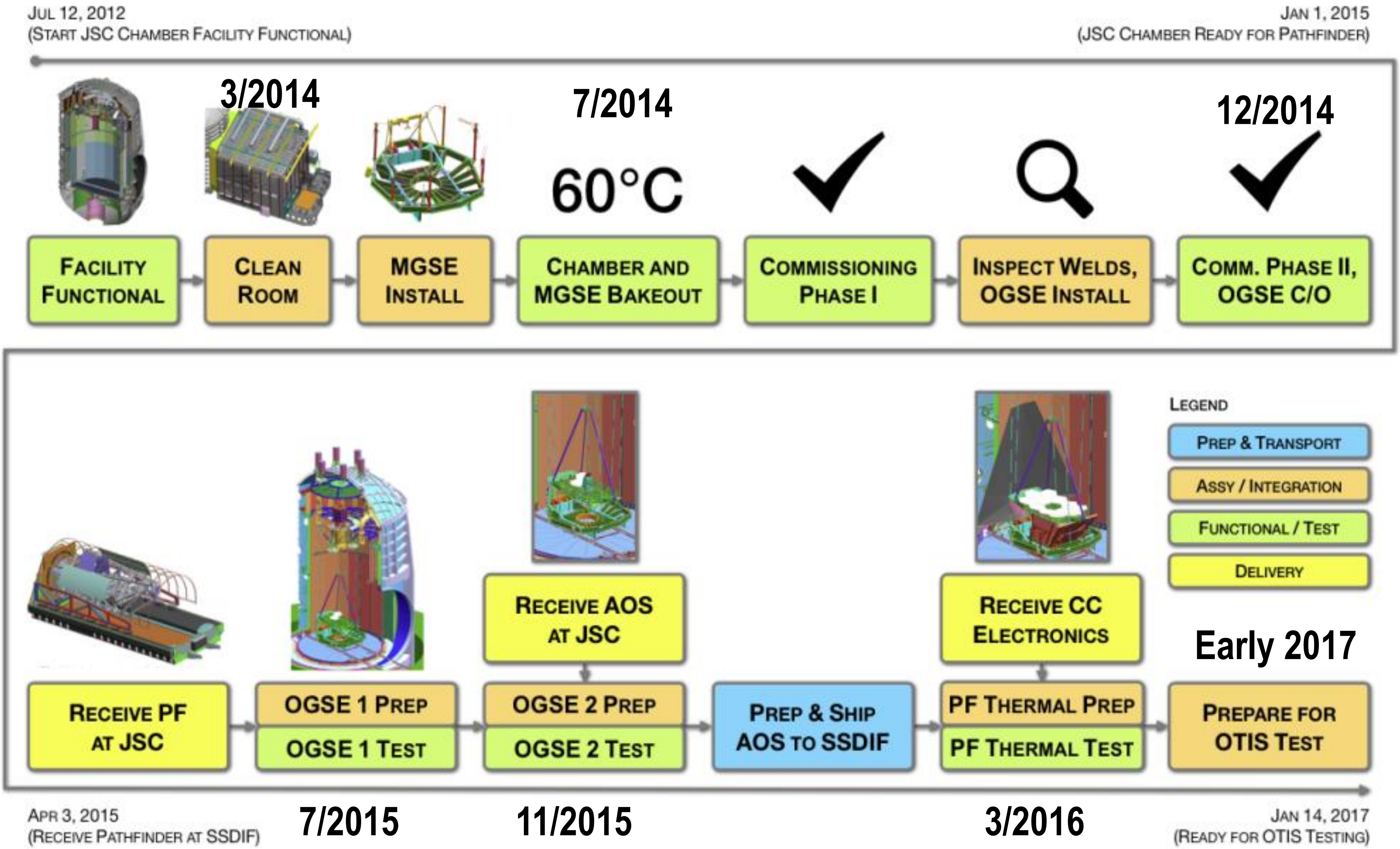
Hardpoint Offloader Support System

LN2 and Helium Cryogenic Shrouds and "barn door"

Key Aspects of the JSC OTIS Cryo-Vac Program

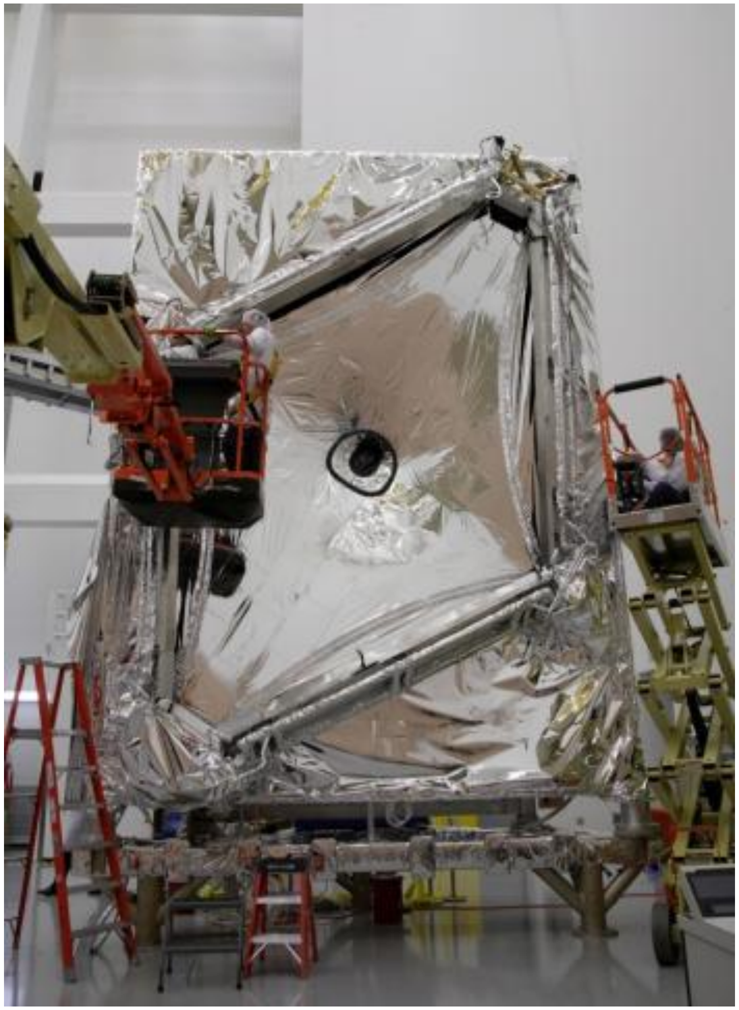
- **Optical goals**
  - Verify critical fixed alignments – ISIM to AOS
  - Verify co-alignment to within budgeted actuation range for active primary and secondary mirror
  - Verify optical performance stability against expected thermal transients
  - Cross-checks of lower level testing
- **Thermal goals**
  - Provide the thermal conditions required to perform electro-optical-mechanical and thermal hardware verification
  - Collect thermal balance point data that is used to correlate and validate the OTE/ ISIM thermal flight model (highly sensitive to workmanship)
- **Electrical, operational goals**
  - Proper electrical operation of flight systems, cross-strapping, redundancy
  - Demonstration of key operations, e.g. Wavefront Sensing & Control, parity checks of guiding functions
  - Day-in-the-life operational script testing
- **A critical overall goal is model validation**

JSC Test Facilities, GSE, Procedures Validated w/Many Activities Before Flight OTIS Arrives



Sunshield and Rest of Spacecraft Progress On Their Own I&T Path

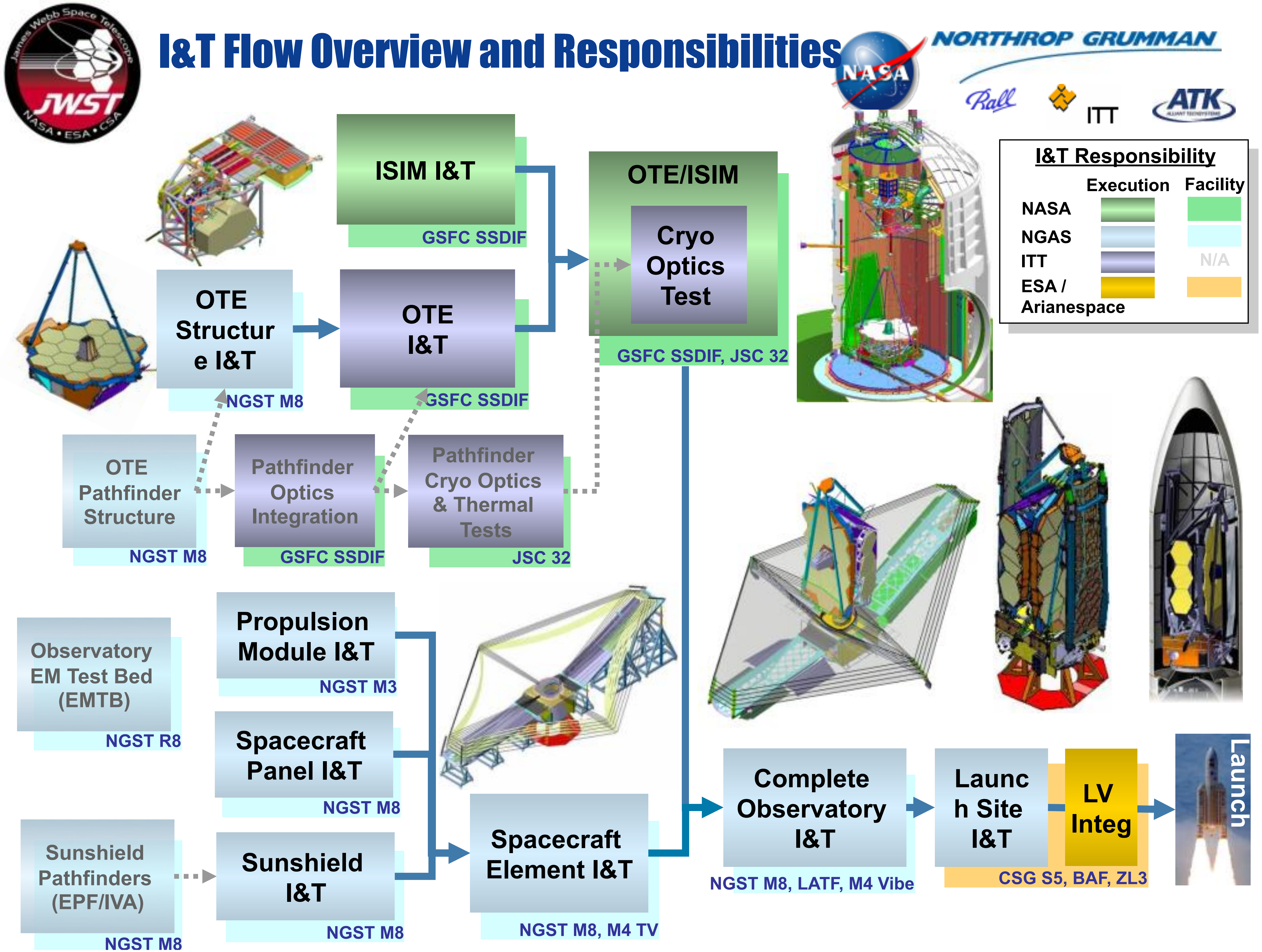
- 1/3rd scale sunshield test completed successfully for thermal model validation



- Template sunshield membranes currently in work

- *Everything meets up at NGAS a year before launch for Observatory I&T*

I&T Flow Overview and Responsibilities



Want to Learn More about JWST?


THE JAMES WEBB SPACE TELESCOPE

Gardner et al. 2006,
Space Science Reviews, 123/4, 485
http://jwst.nasa.gov/scientists.html

2011 Conference
Webcast and Charts
http://webcast.stsci.edu
"Webcast Archives"

White Papers:

JWST in Decadal Survey
- Solar System Objects
- Dark Energy
- Transiting Planets
- Coronagraphy
- Planetary Systems
- Stellar Pops
- Star Formation
- Galaxy Assembly
- First Light
- Astrobiology
- Scientific Capabilities
- Observation Planning

Science White Papers
http://www.stsci.edu/jwst/science/whitepapers/

JWST FAQ for Scientists: http://jwst.gsfc.nasa.gov/faq_scientists.html