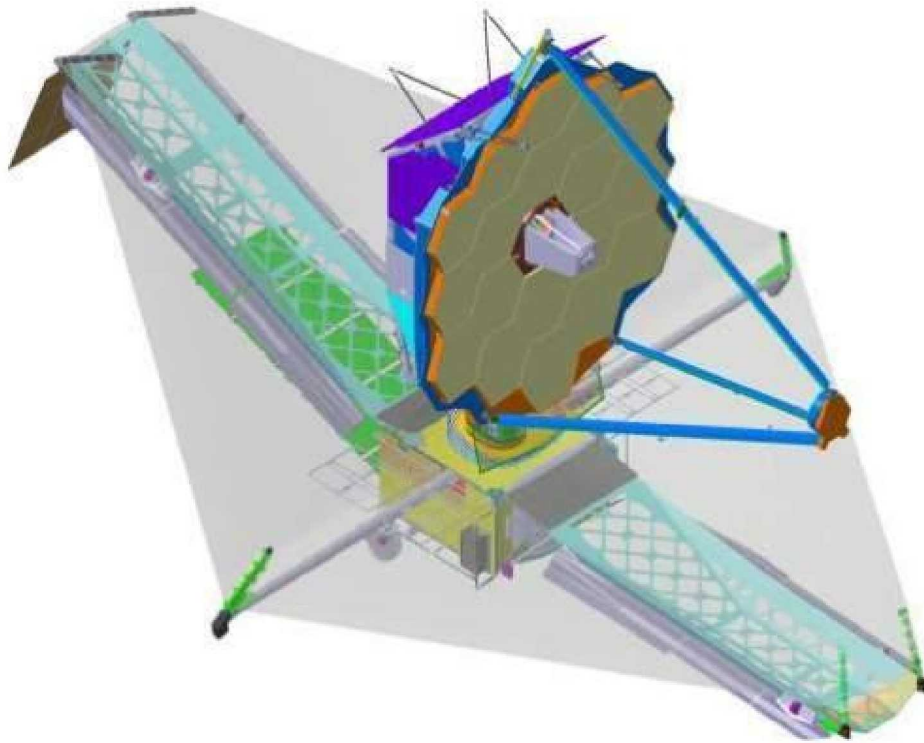




James Webb Space Telescope Project Overview and Status for the SPIE Conference Paper Number 7731-8



**Phil Sabelhaus
JWST Program Manager
June 27, 2010**



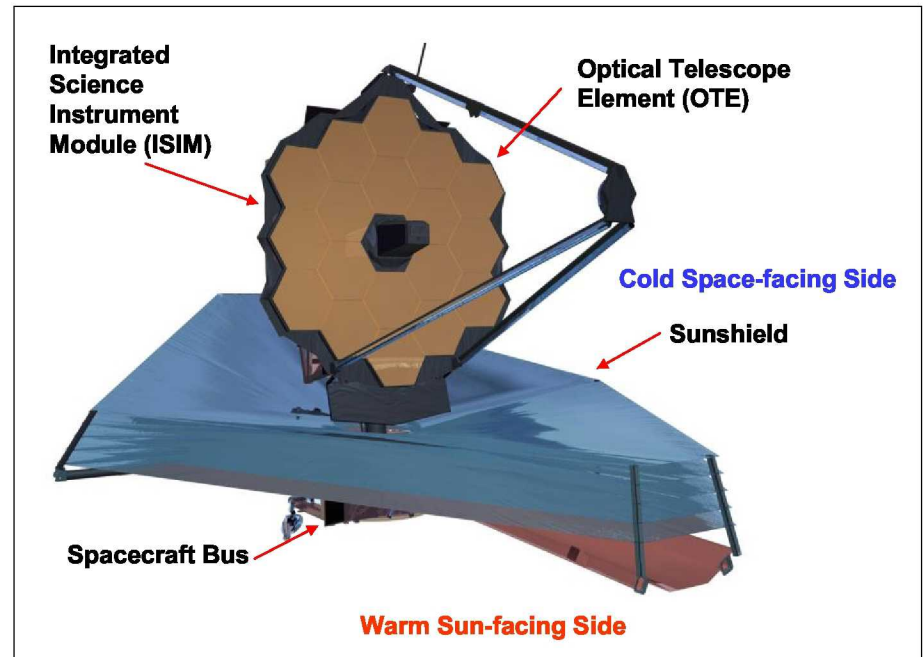
James Webb Space Telescope (JWST)

Organization

- Mission Lead: Goddard Space Flight Center
- International collaboration with 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) – 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 June 2014 on an ESA-supplied Ariane 5 rocket to Sun-Earth L2
- 5-year science mission (10-year goal)



JWST Science Themes



End of the dark ages: First light and reionization



The assembly of galaxies



Birth of stars and proto-planetary systems



Planetary systems and the origin of life



JWST Full Scale Model at the GSFC





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

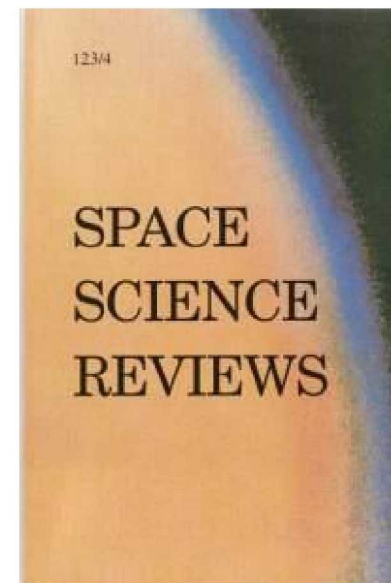
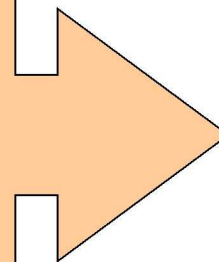
- **Often described as the successor to the Hubble Space Telescope, the JWST will serve astronomers world-wide in much the same way:**
 - Science & mission operations managed by the Space Telescope Science Institute
- **The science investigations performed by the JWST will be determined by the General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

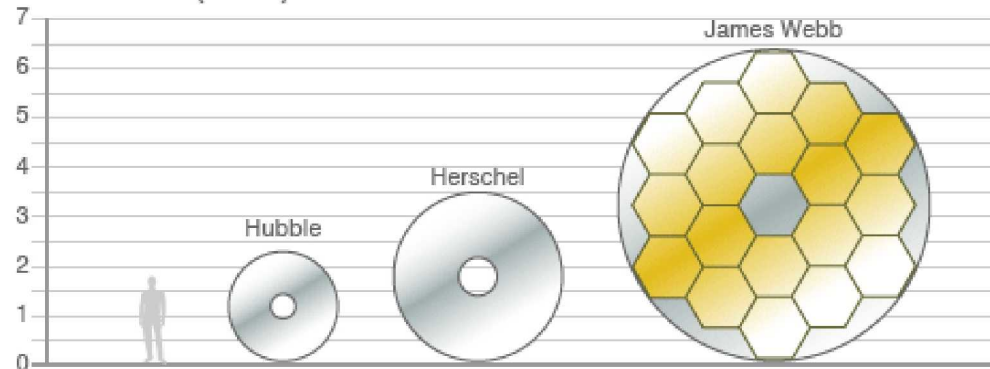
As a consequence, the observatory requires:

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

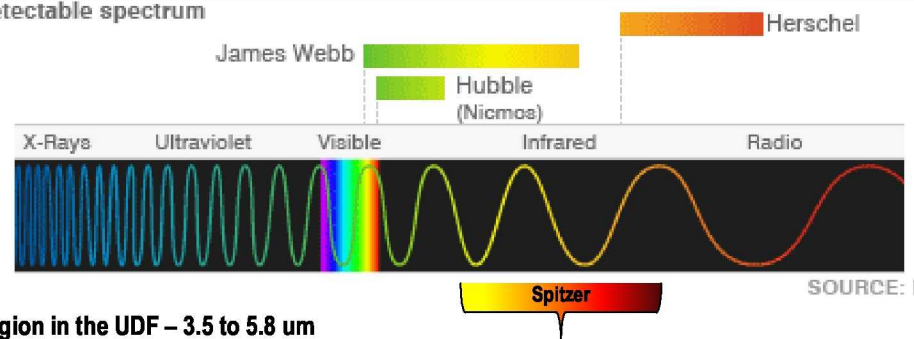
a high stability 40-50K cryogenic operating temperature

SPACE TELESCOPE COMPARISON

Mirror diameter (metres)

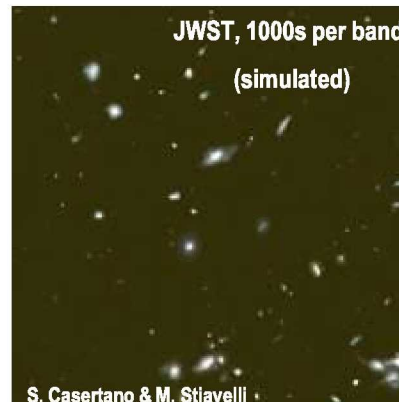


Detectable spectrum



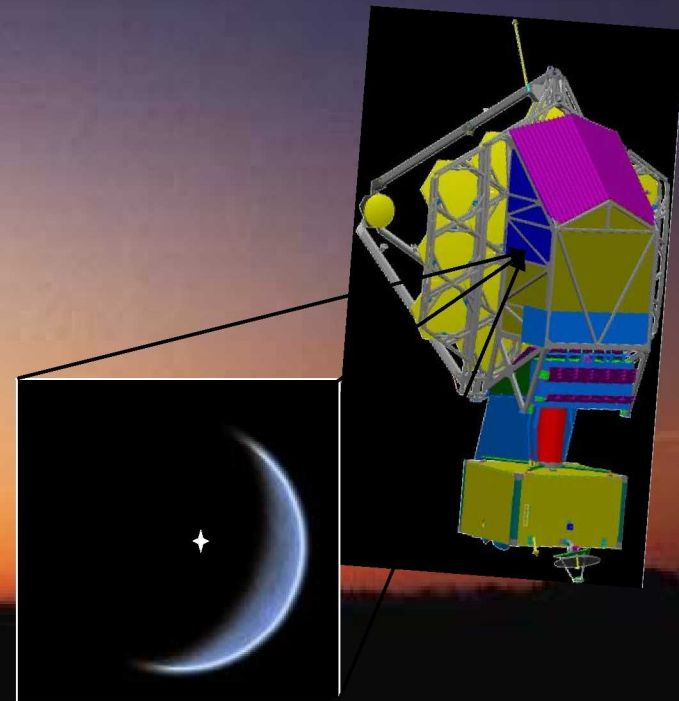
SOURCE: ESA

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



Fun Facts – Detector/Sensing Capability

- If the JWST observatory were sitting on the surface of the earth looking at the moon and a night light* were turned on or a candle+ were lit on the dark side of the moon the observatory would detect it**!



Notes:

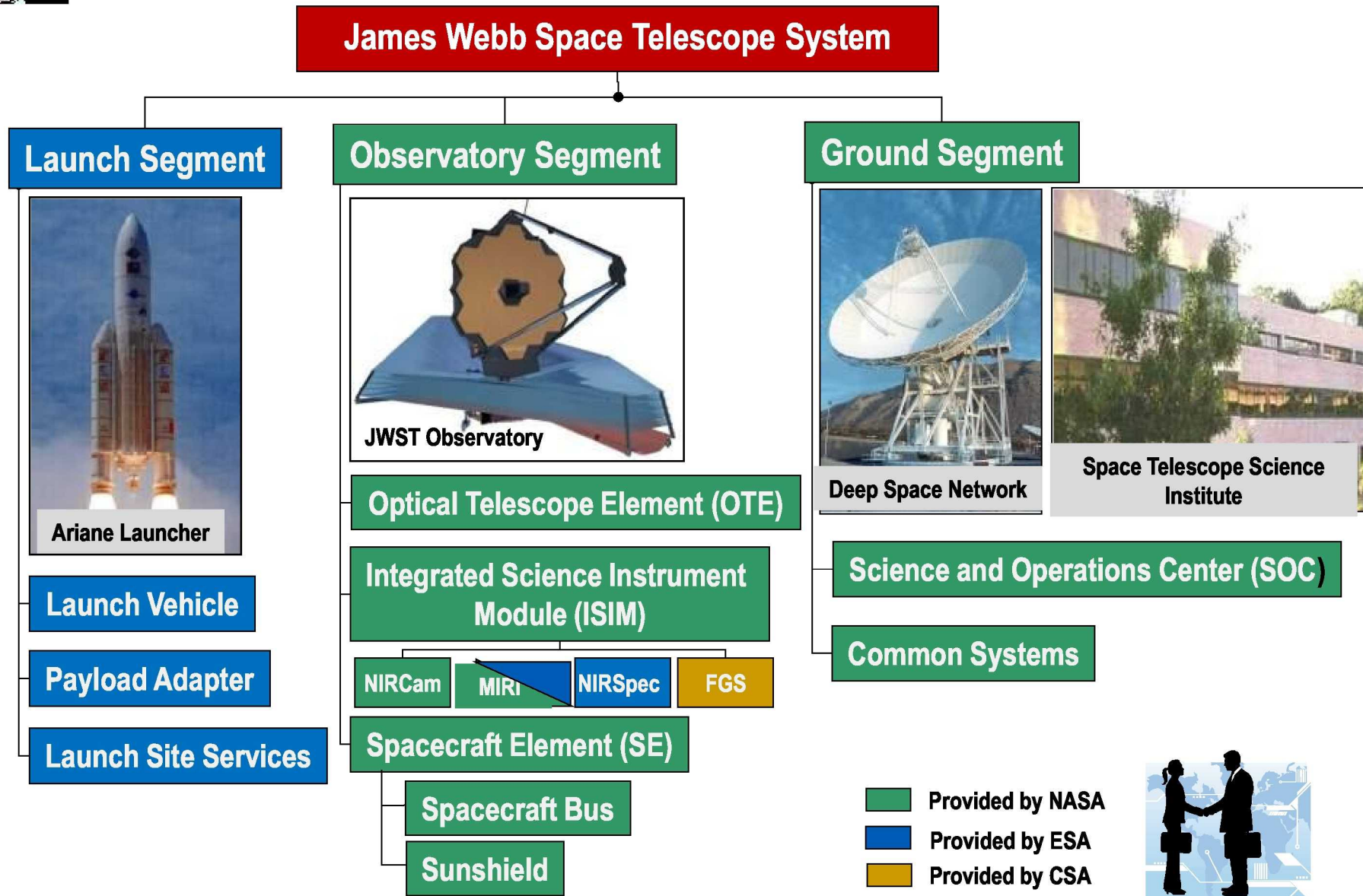
- + assumes acts like a grey body emitter
- * assumes a 5W bulb
- ** not factoring in atmospheric effects



JWST System Overview



The JWST Program is a Multi-Agency Partnership





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

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



Ariane 5 Launch Vehicle



Ariane 5 ECA



- JWST is designed for launch on an Ariane 5 launch vehicle with a 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





JWST Team and Responsibilities

Integrated Science Instrument Module (ISIM) – GSFC

- Structure – GSFC/ATK
- MIRI- JPL & ESA/European Consortium
- NIRSpec- ESA/Astrium
- NIRCam – U of Arizona/LMATC
- FGS/TFI – CSA/COM DEV

ISIM Radiators- NGAS/Ball

Optical Telescope Element (OTE) – NGAS/Ball

Backplane Structure – NGAS/ATK

ISIM Electronics Compartment (IEC)- GSFC

Deployment Tower - NGAS

Sunshield – NGAS

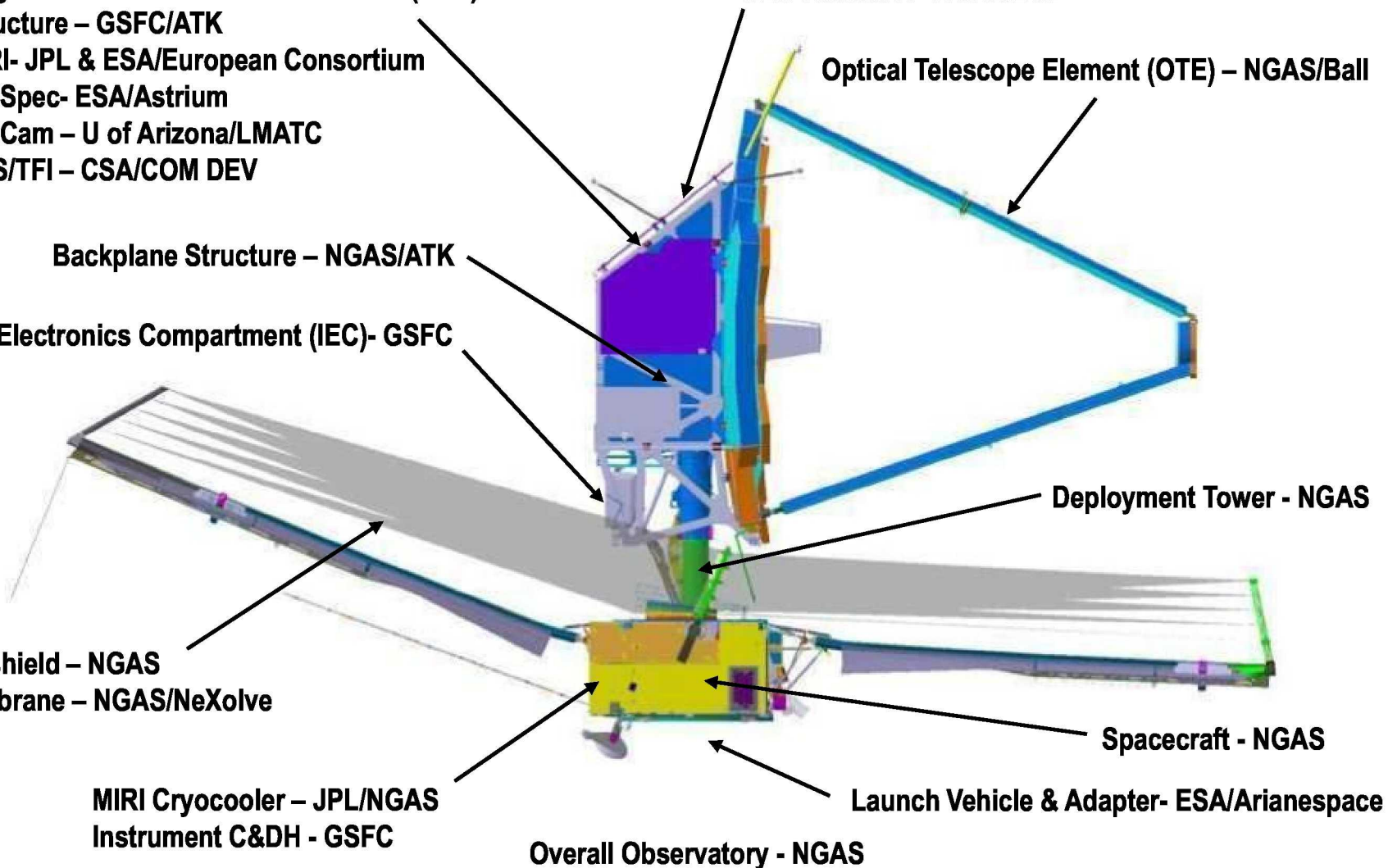
Membrane – NGAS/NeXolve

Spacecraft - NGAS

MIRI Cryocooler – JPL/NGAS
Instrument C&DH - GSFC

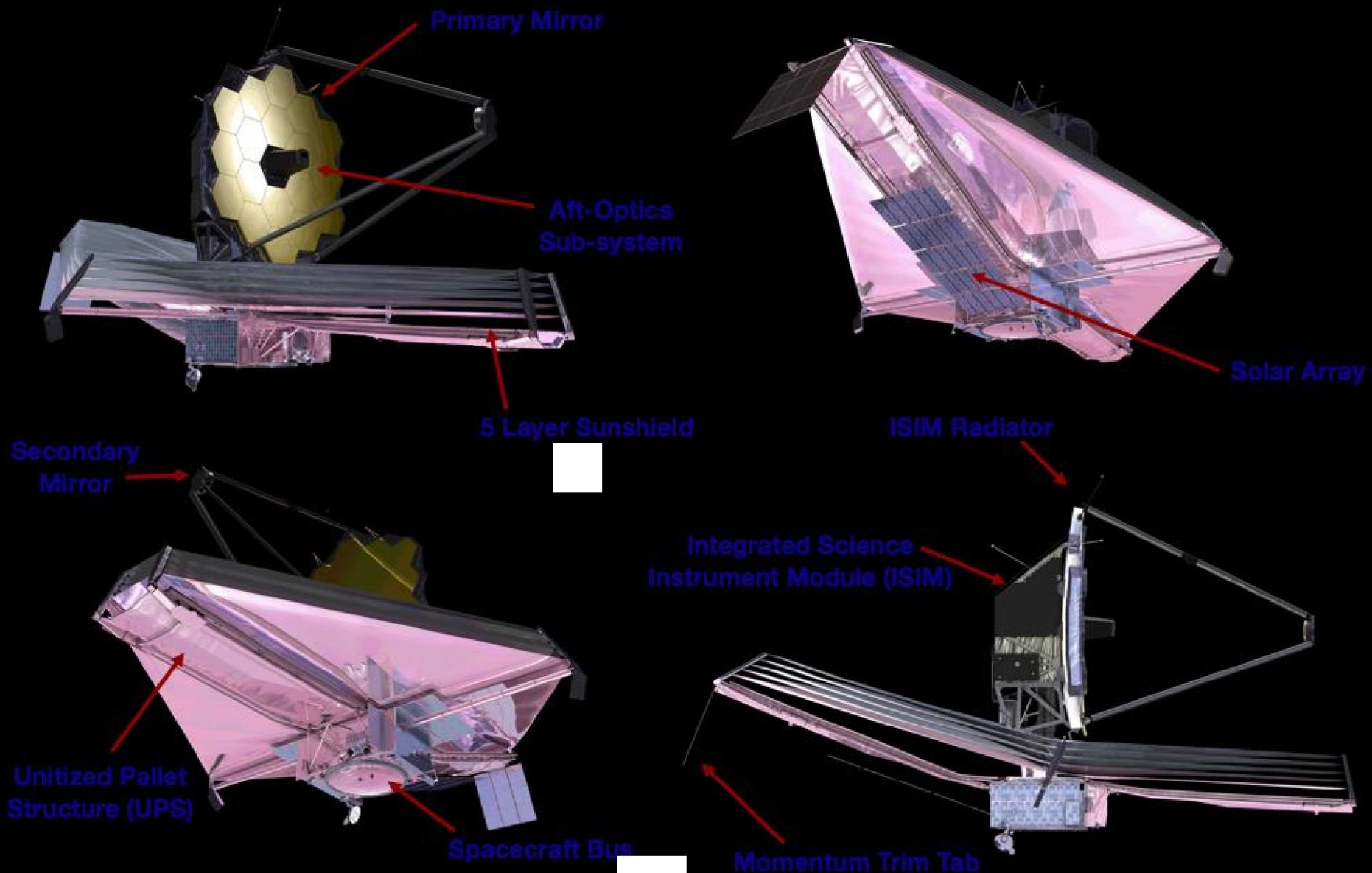
Launch Vehicle & Adapter- ESA/Arianespace

Overall Observatory - NGAS





JWST Architecture





Telescope mirrors are fabricated from Beryllium

Key physical properties of beryllium (Be):

- 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) $\sim 2000 \text{ kg m}^{-2}$

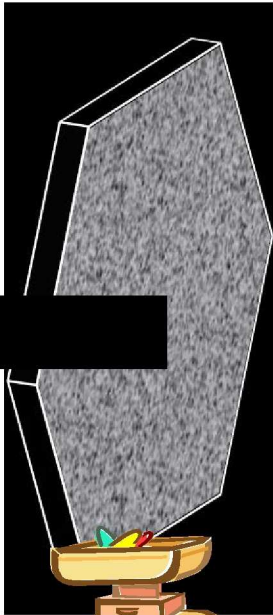




Fun Facts ± Mirror Manufacturing

Before

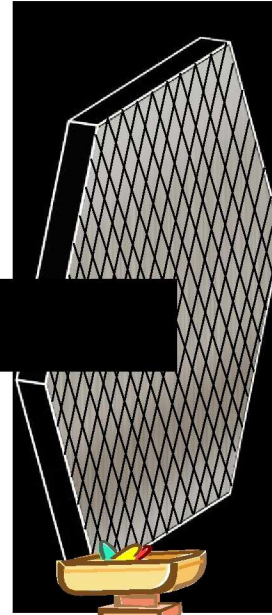
Be Billet



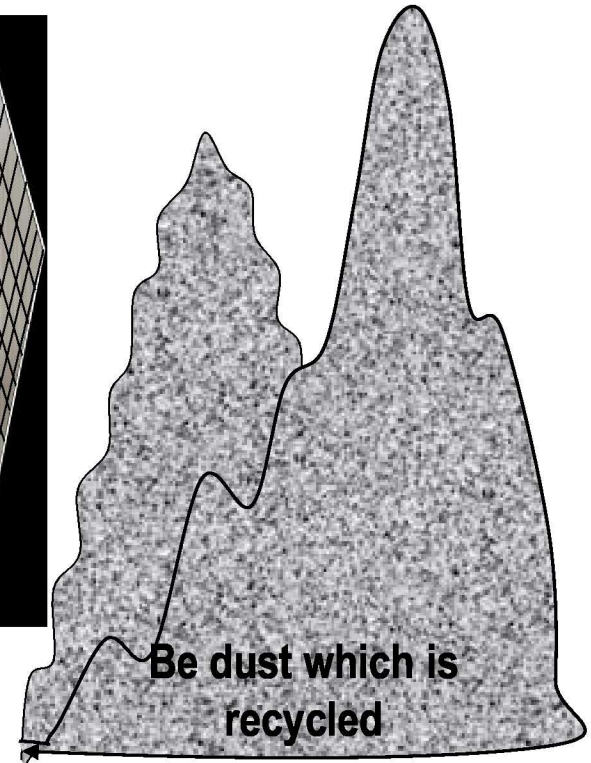
250 kgs

After

Finished
Mirror
Segment



21 kgs



Be dust which is
recycled

Over 90% of material is removed to make each mirror segment – want a little mirror with your Be dust?

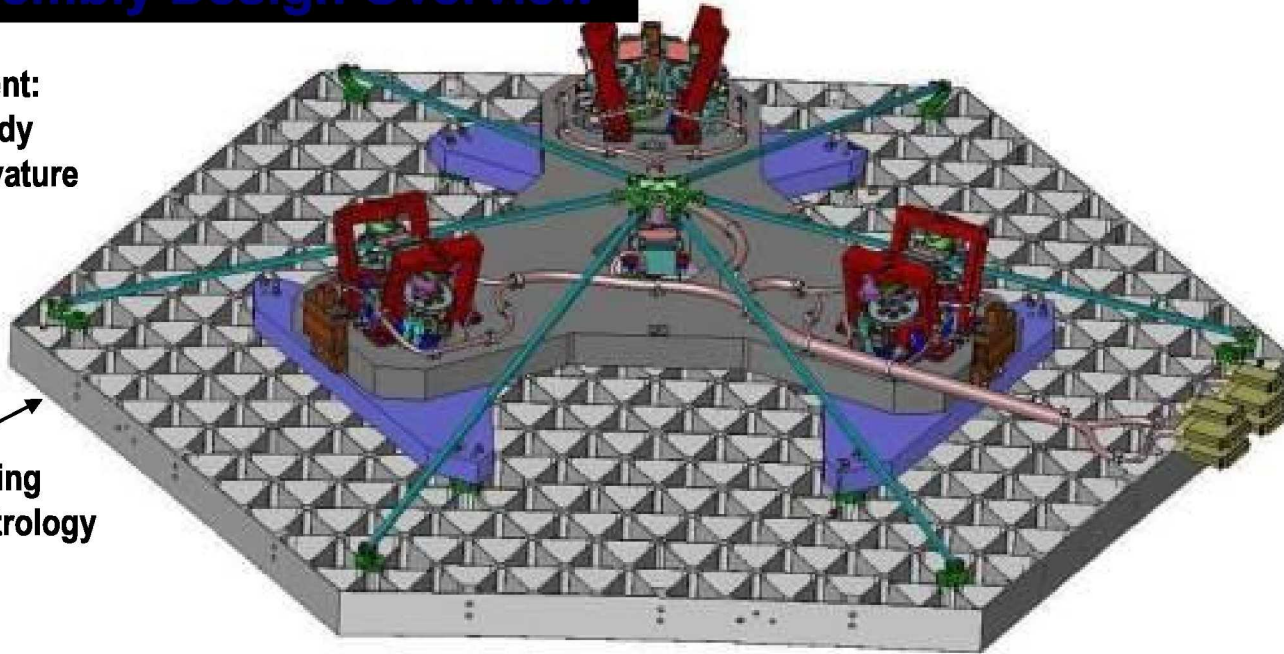


Primary Mirror Segment Assembly and Secondary Mirror Assembly Design Overview

PMSA Adjustment:

- 6 DOF rigid body
- Radius of Curvature

Inserts for tooling
ball alignment metrology



Primary Mirror Segment Assembly

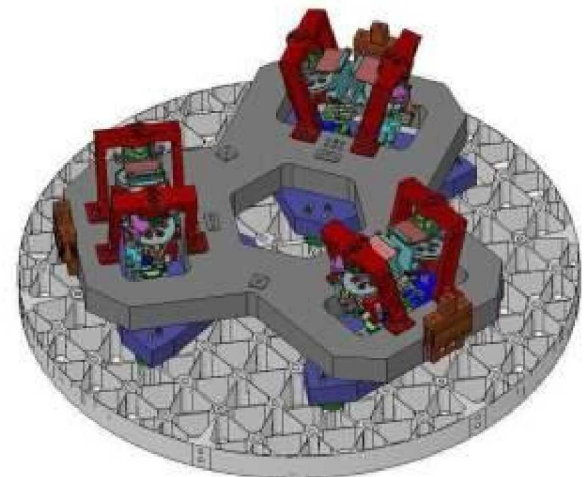
Common Design Features



Bipod Actuator

SMA Adjustment:

- 6 DOF rigid body

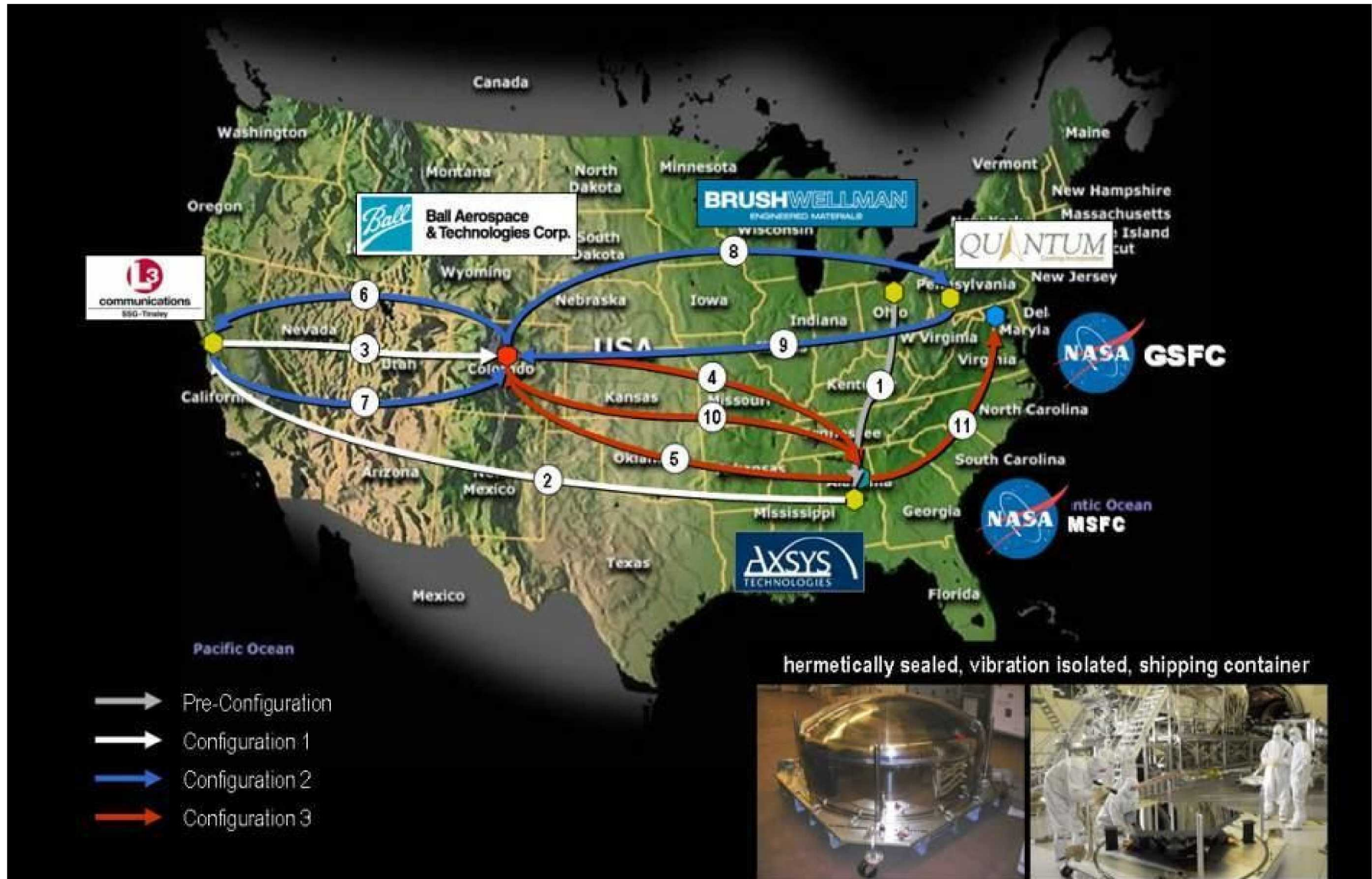


Secondary Mirror Assembly



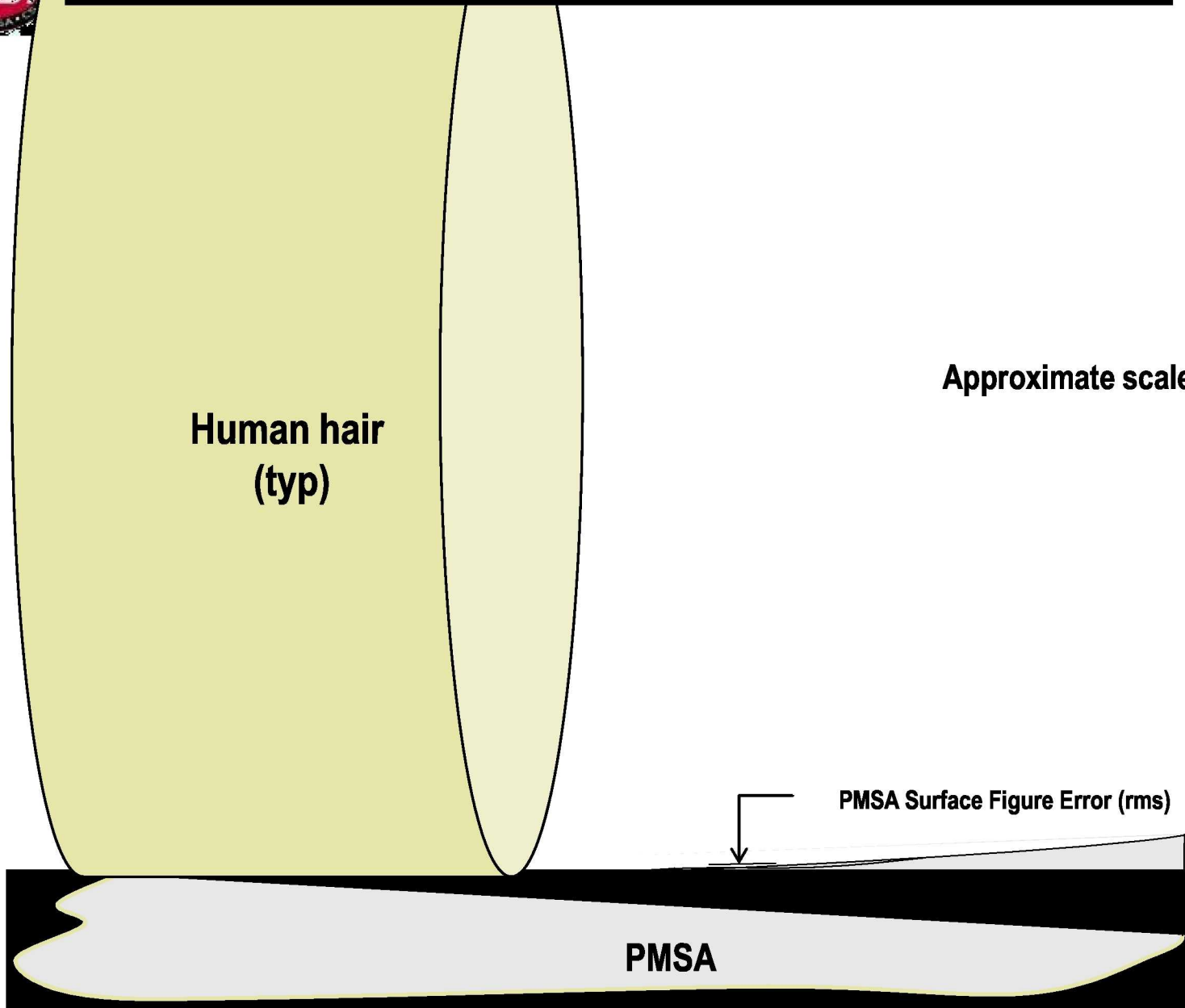
Flight Primary Mirror Assembly Travel Itinerary

Each mirror segment crisscrosses the country on 11 trips, traveling ~15,000 miles, before being integrated with the telescope at GSFC



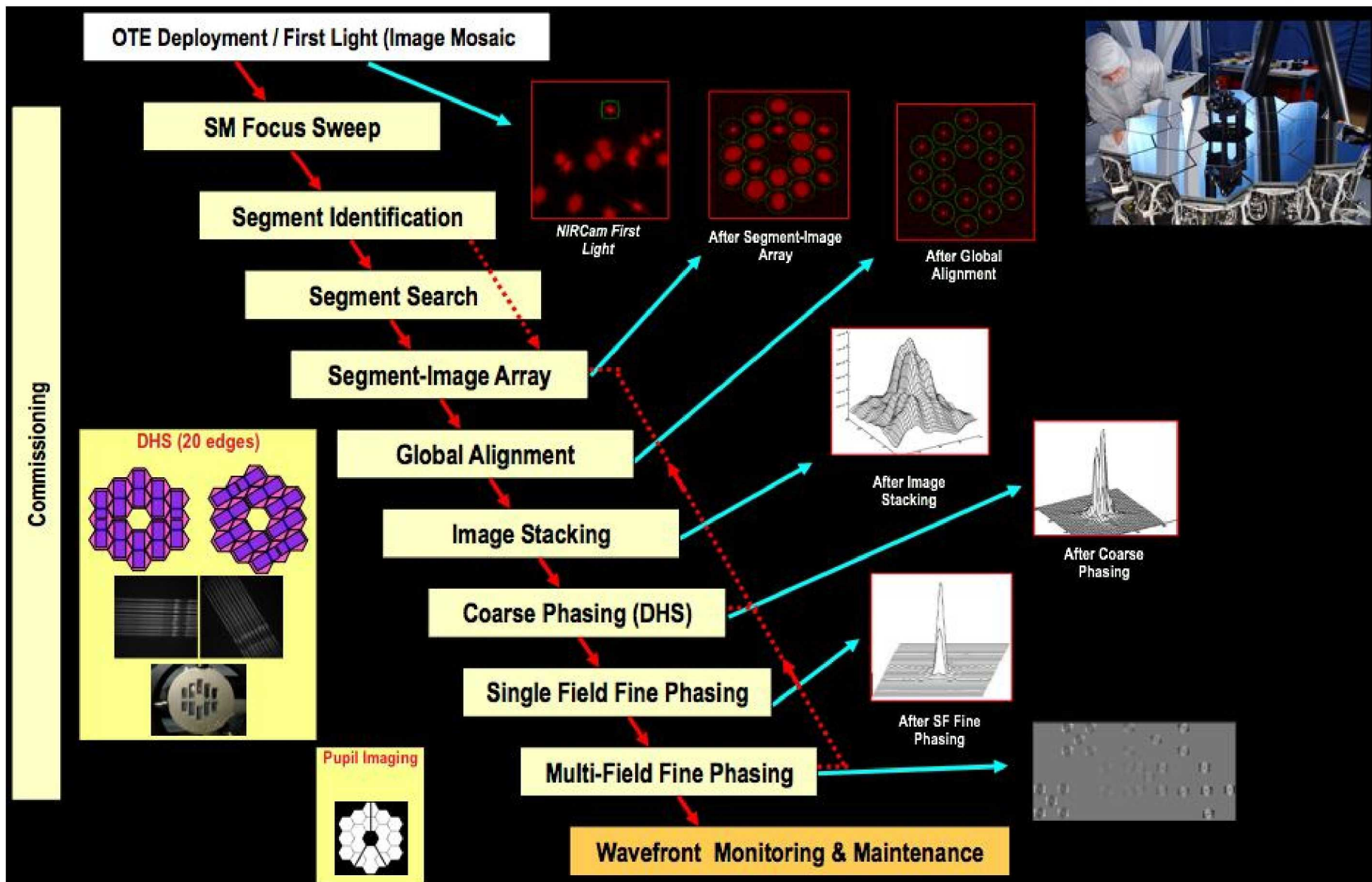


Fun Fact $\pm$ Mirror Surface Tolerance





JWST Wavefront Sensing and Control

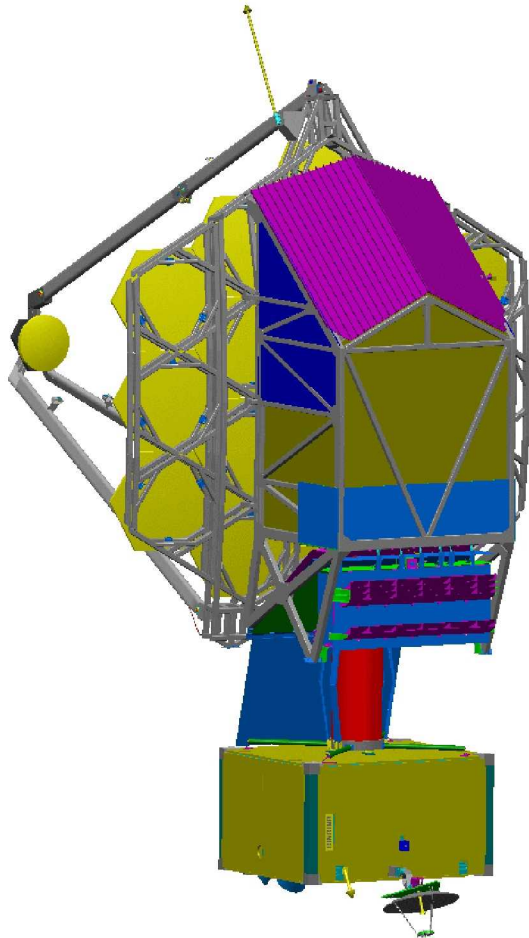




ISIM Overview

ISIM is:

- The JWST Science Instruments
- Associated Infrastructure: Structure, Thermal Subsystem, C&DH, & FSW



Region 1:

Science Instrument Optics Assemblies

*Near Infrared Camera (NIRCam)
Near Infrared Spectrograph (NIRSpec)
Mid Infrared Instrument (MIRI)
Fine Guidance Sensor w/Tunable Filter (FGS/TF)*

Optical Bench Structure

Radiators and support structure (NGAS-supplied)

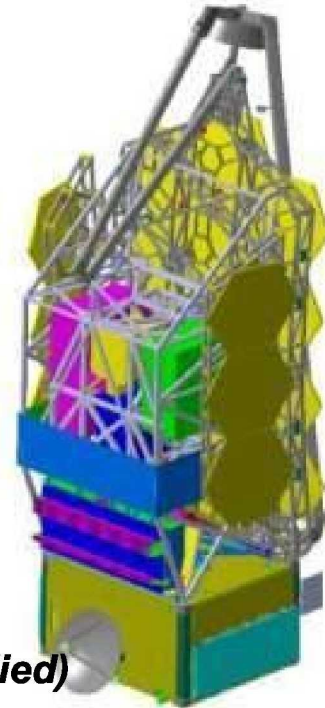
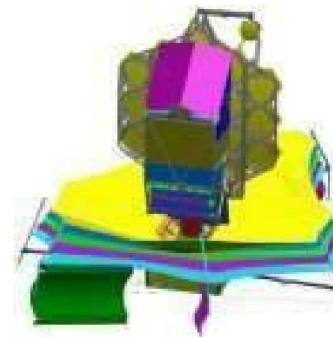
Region 2:

ISIM Electronics Compartment

*Focal Plane Electronics (FPE)
Instrument Control Electronics (ICE, MCE)
ISIM Remote Services Unit (IRSU)*

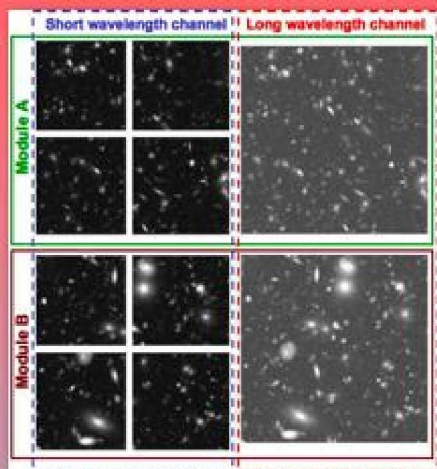
Region 3

ISIM Command & Data Handling (C&DH) Electronics



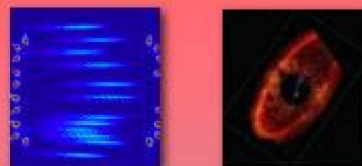


JWST Science Instruments



Deep, wide field broadband-imaging

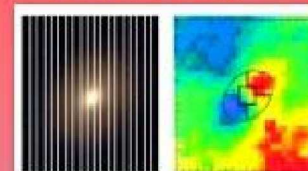
Wavefront Sensing & Coronagraphic Imaging (WFSC)



Multi-Object, IR spectroscopy



IFU spectroscopy



NIRCam



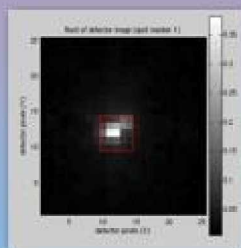
NIRSpec



Long Slit spectroscopy



Fine Guidance Sensor



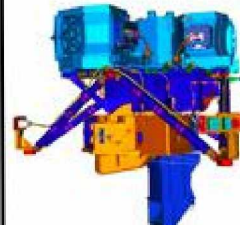
Moving Target Support



FGS/TF



MIRI



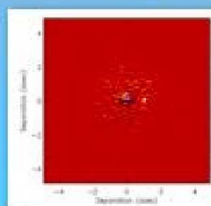
Mid-Infrared, wide field Imaging



R=100 Narrowband Imaging



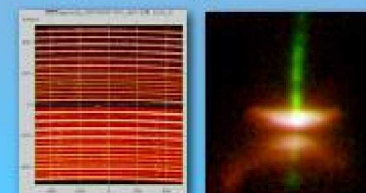
Coronagraphic Imaging R~100



Mid-IR Coronagraphic Imaging



IFU spectroscopy

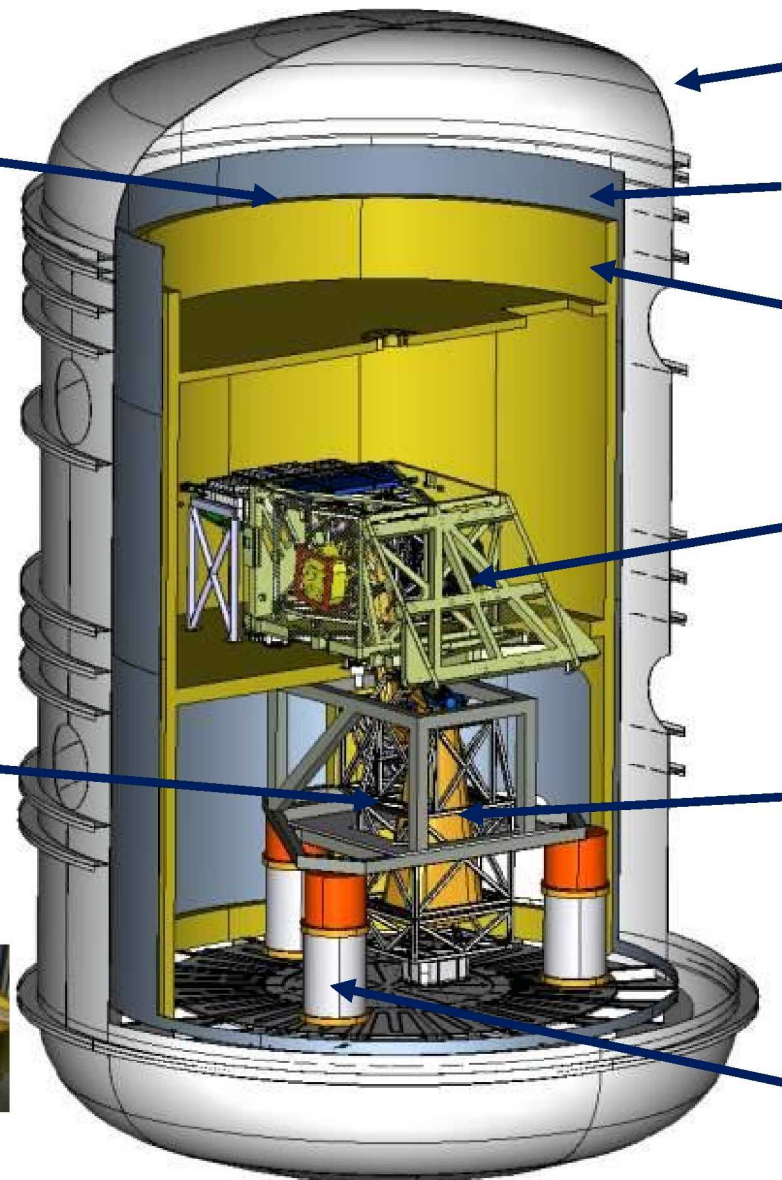




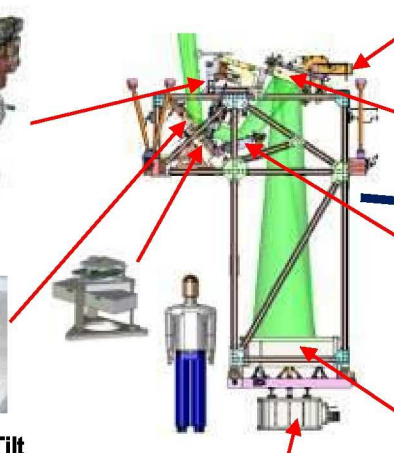
ISIM will be tested in the GSFC SES chamber using an Optical Telescope Element Simulator (OSIM)



GHe shroud instillation and test completed July 09



OSIM Primary Mirror



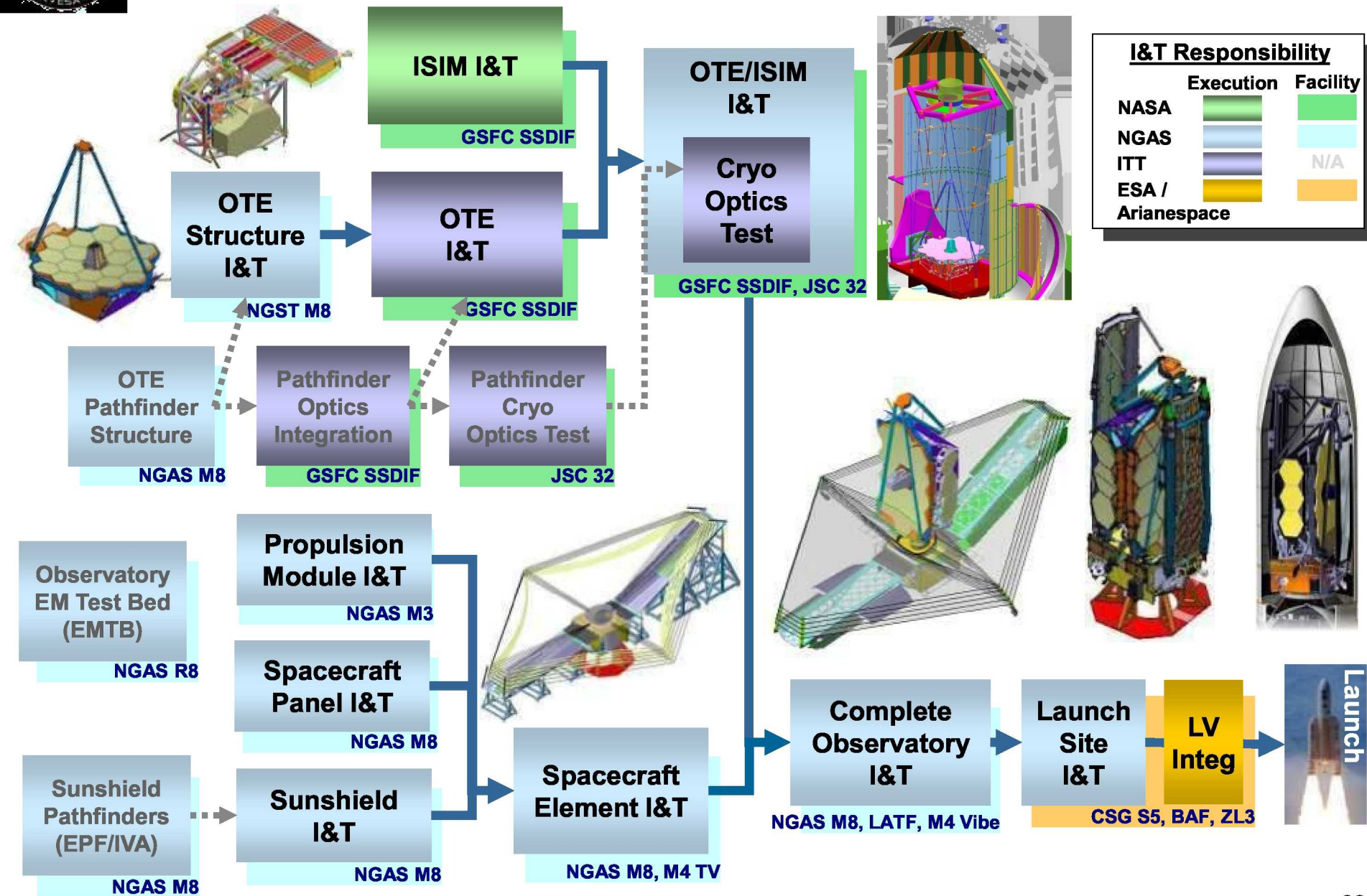
Alignment Diagnostic Module



Fold Mirror 3 Tip/Tilt Gimbal Assembly

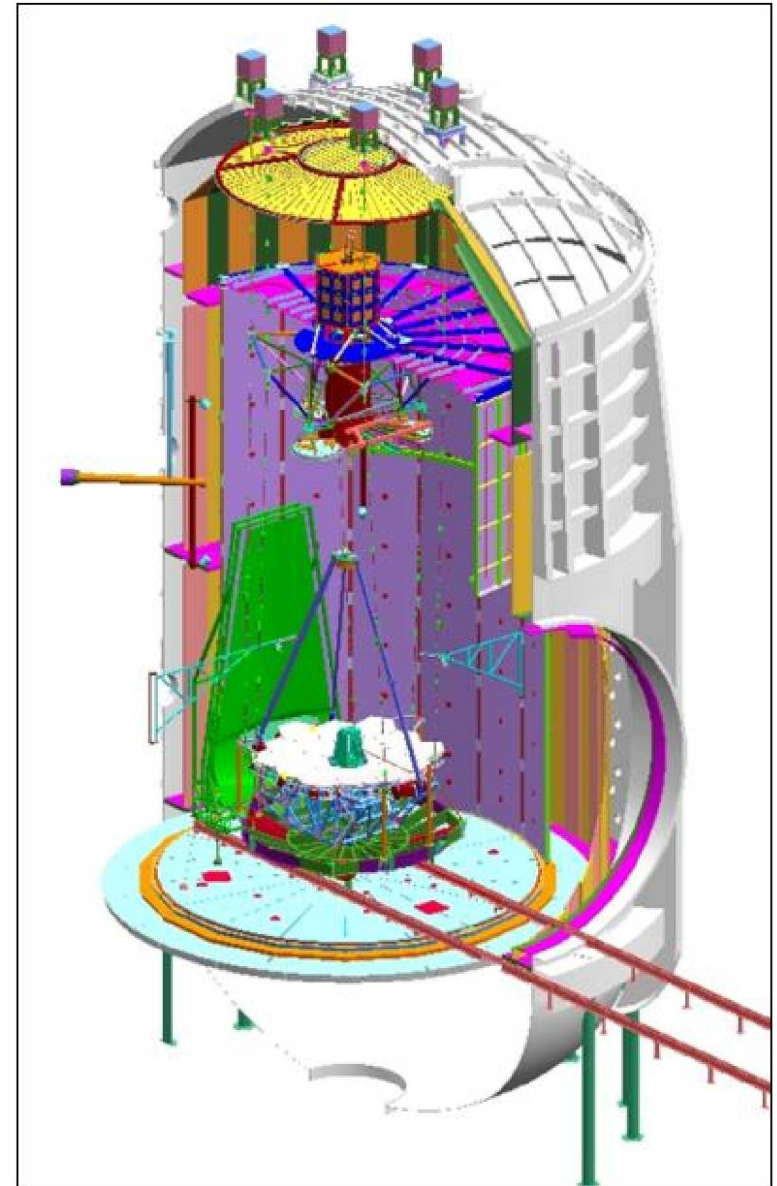
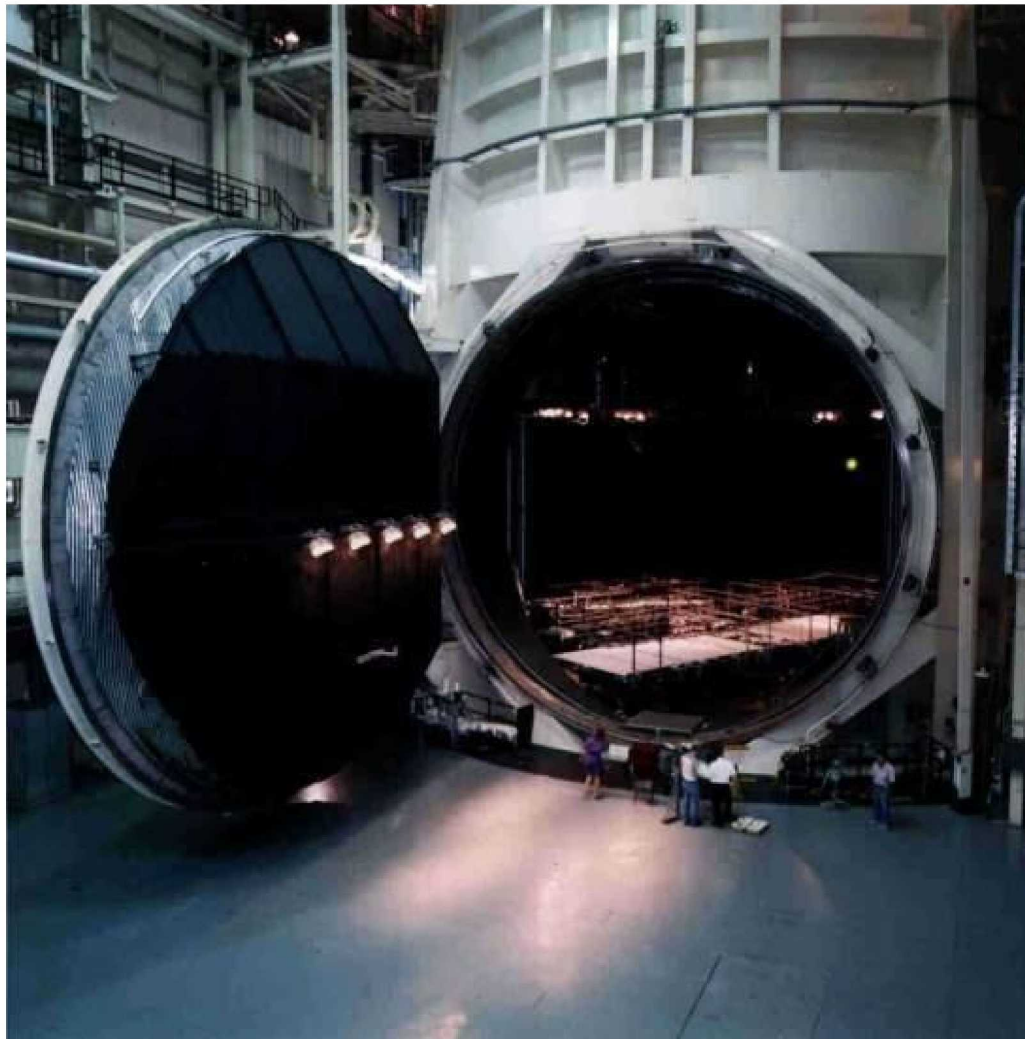


Integration & Test Flow Overview





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

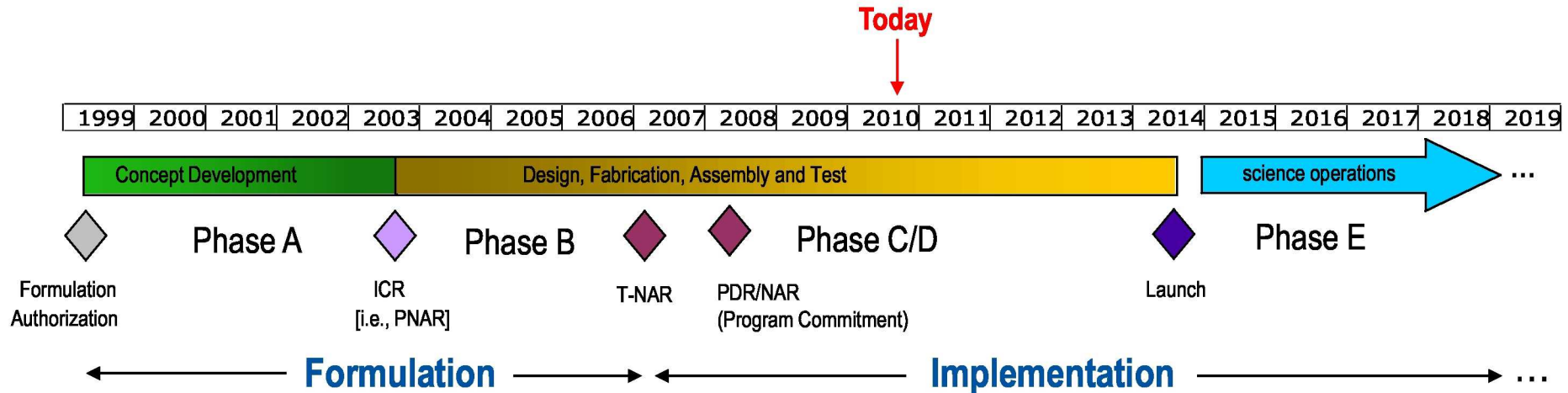




JWST Status



Program Phases

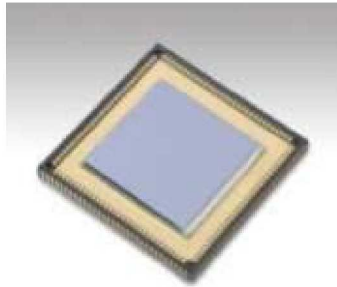


- **Mission PDR/Non-Advocate Review (NAR) completed in Spring 2008**
 - Confirmation Review successfully held in July 2008
- **Mission Critical Design Review (MCDR) held in April 2010**
 - Currently in Implementation (Phase D)
- **Early emphasis on vigorous technology development to retire risk**
 - Greater than 50% of Phase A through D total invested so far
 - Pacing items (mirrors, detectors, instruments, etc) in flight production or complete
 - Successful Technology-Non Advocate Review (T-NAR) in January 2007

Near IR Detectors



Mid IR Detectors



Heat Switch



Sunshield Membrane



**SIDECAR
ASIC**



**Stable Large Cryogenic Structures
Backplane Stability Test Article (BSTA)**



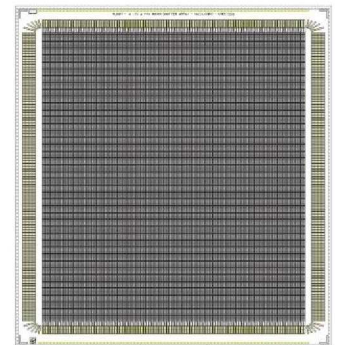
**Wavefront Sensing & Control
Test Bed Telescope**



MIRI Cryocooler



Micro Shutter



Primary Mirror





Accomplishments since KDP-C in July 2008

(About the time of the SPIE Conference in France)

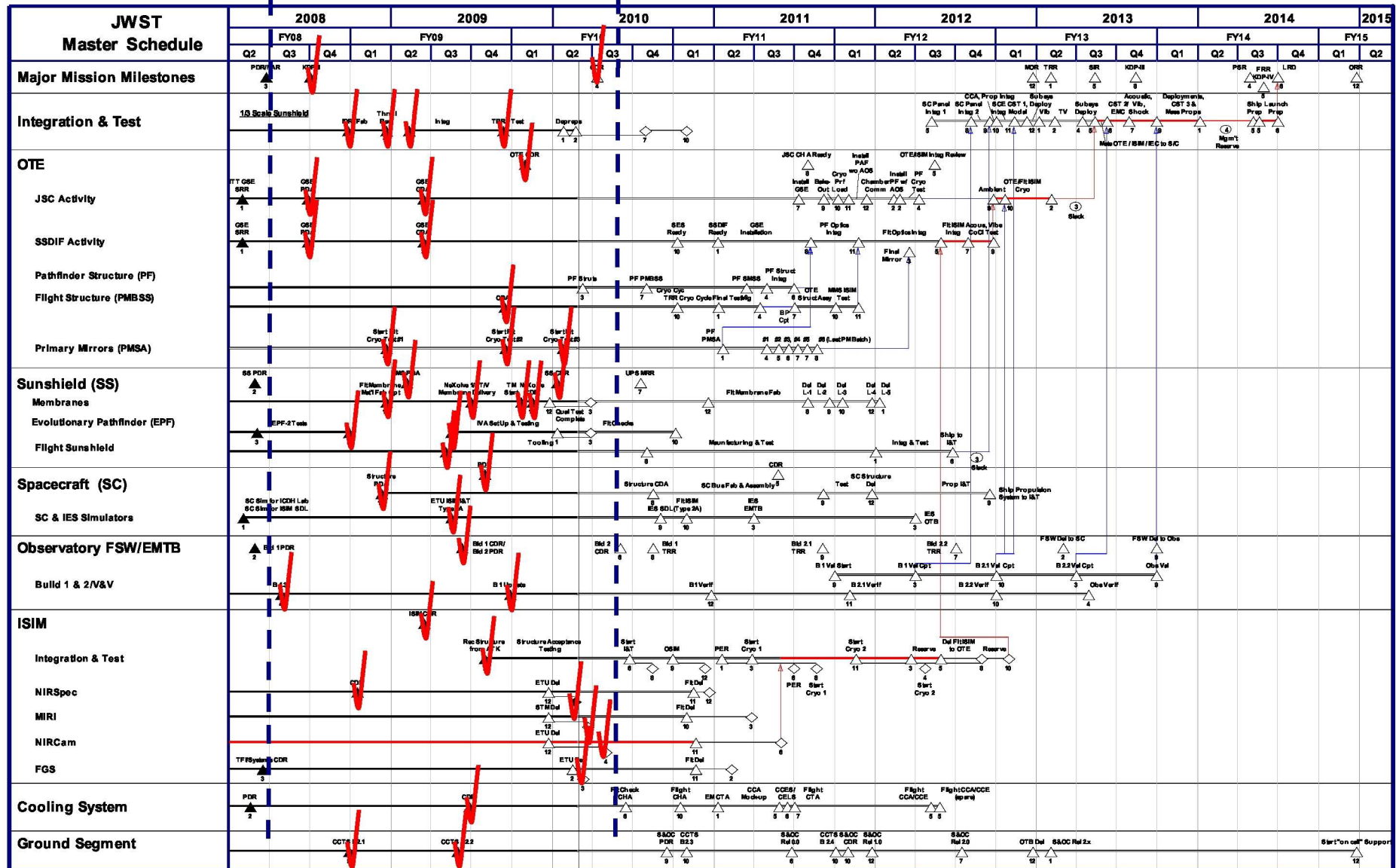


JWST Progress Since KDP-C

PDR/NAR

As of 5/31/10

2/28/10





Accomplishments since KDP-C

- **General:**

- Launch Readiness Date is June 2014

- **Reviews:**

- As of now, the Science Instruments, ISIM, OTE , Sunshield and Mission have all successfully completed their CDR's
- Spacecraft element CDR scheduled for Spring 2011

- **Observatory:**

- Completed Full Scale Core Test Article cryo vacuum testing in May 2009
- Completed the 1/3 Scale Sunshield cryo vacuum testing in December 2009

- **Ground Segment:**

- All DSN 32-meter antennas have been upgraded to support Ka-band for JWST
- All SIDU, SITS and ITS deployments complete; Common Command and Telemetry System (CCTS) being used at 32 Project facilities worldwide to support ISIM, science instrument and spacecraft flight software development and integration and test activities



Core Test Article Completed Testing in May 2009

Core Test Article



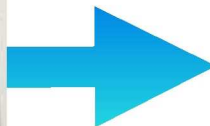
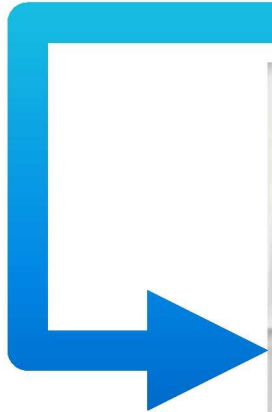
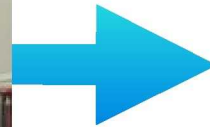
Installation on Chamber Lid



He Shroud Installation

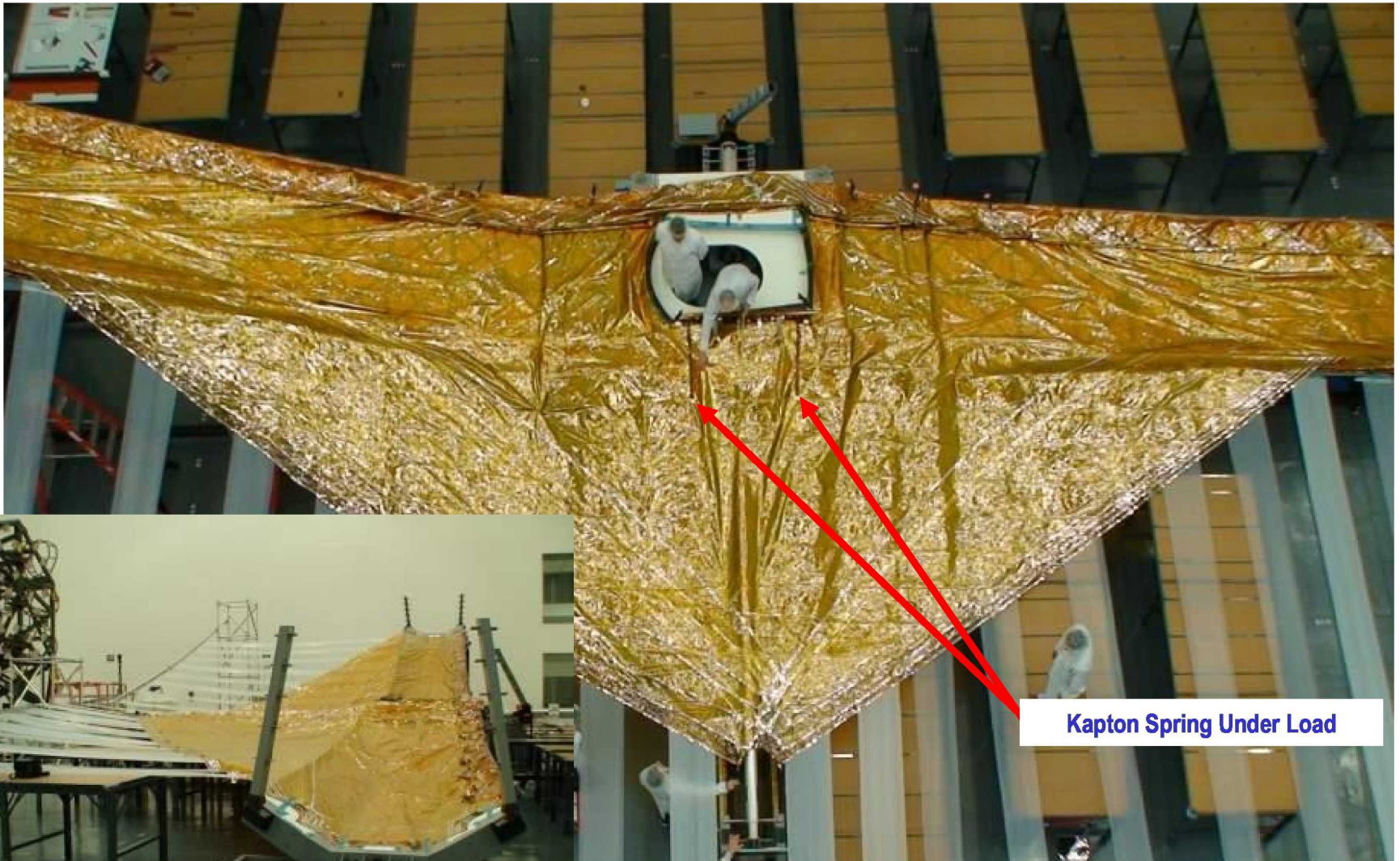


1/3 Scale Sunshield completed testing in December 2009





Sunshield IVA Deployment Testing



Kapton Spring Under Load



Stowed Sunshield IVA with the OTE Simulator





Sunshield Unitized Pallet Structure (UPS) Tool in El Segundo



Rotation to remove the expendable materials between the “splash” and the tool surface



Project Status and Recent Progress (Continued)

■ Ground Segment:

Science instrument teams around the world using their SITS and SIDU systems





Spacecraft Bus Engineering Model Hardware

- Successfully Completed Spacecraft Preliminary Design Review (PDR) in 2009
- Successfully completed & delivered SC Sim 1A



SC Sim 1A upgrade



Software Development Lab CTP EM





Accomplishments since KDP-C (Continued)

■ Optical Telescope Element:

■ Mirrors :

- All 18 flight Primary Mirror (PM) segments have completed initial polishing to ~150 nm and have been shipped to Ball from Tinsley for configuration changes, assembly integration and testing
 - 9 flight PM's are in final polishing at Tinsley
 - Completed third cryo test with 6 flight and the EDU PM's at the MSFC XRCF test chamber in March
 - A total of 11 PM's have completed initial cryo testing at the XRCF
 - The EDU PM has completed it's second and final cryo testing cycle
 - Fourth test with another 6 flight PM's was started in May
- EDU PM completed final polishing at Tinsley and met all PM specifications
 - The results from the post-polishing XRCF cryo test of the EDU PM proved that the baseline cryo polishing plan of one cycle is acceptable
 - EDU PM will be gold coated by QCI in June
- The first flight optic (tertiary mirror) has been gold coated by QCI

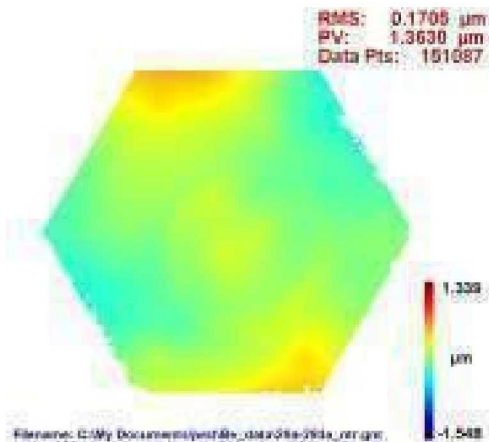


Mirror Polishing



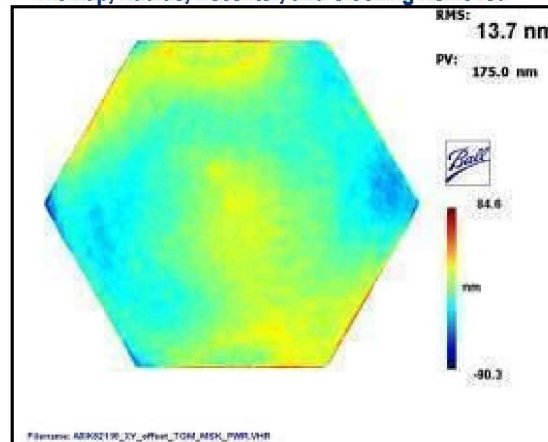
A3 Primary Mirror in Processing at Tinsley

AMSD Circa 2003

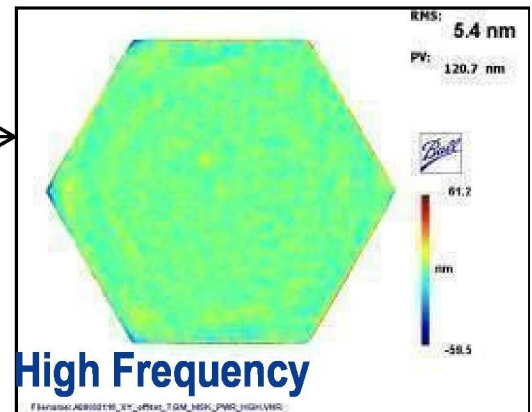
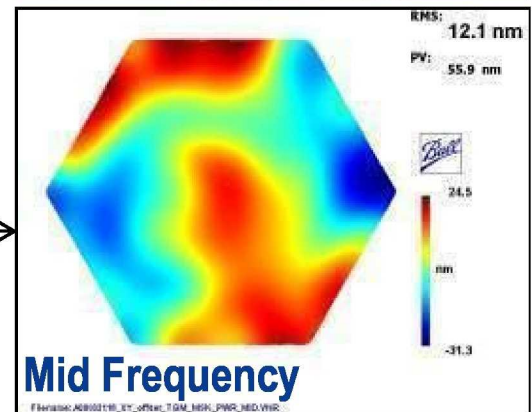


Total Surface Error

Hit Map, Radius, Decenter, and Clocking Removed

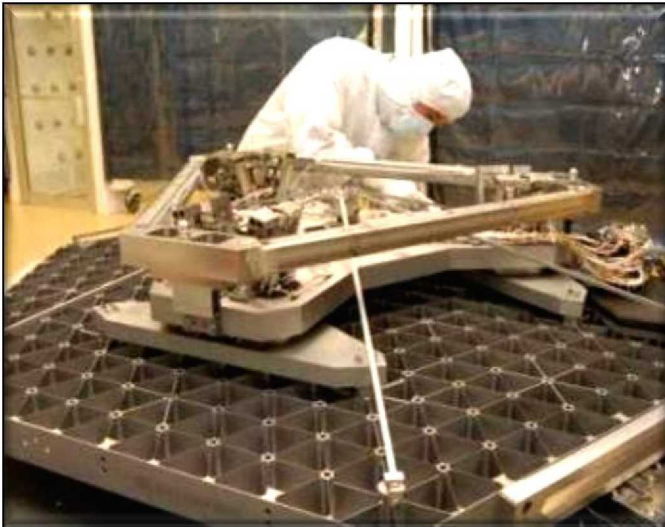


EDU
Primary Mirror
Meets its
Specifications

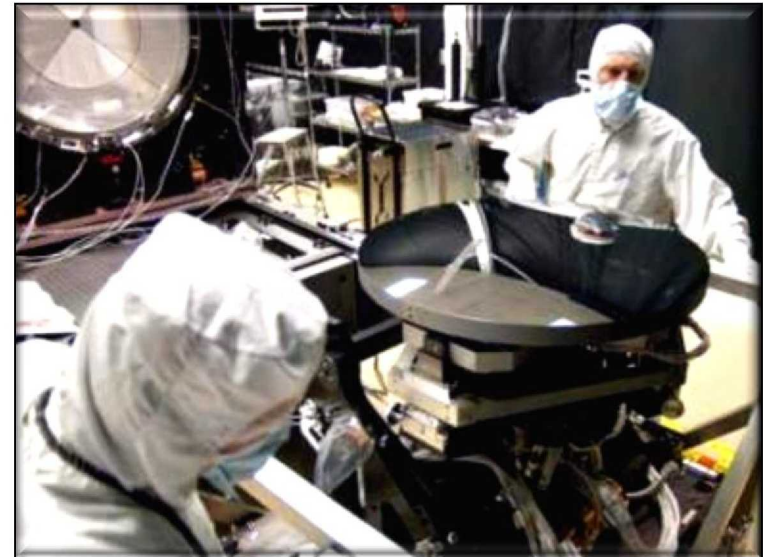




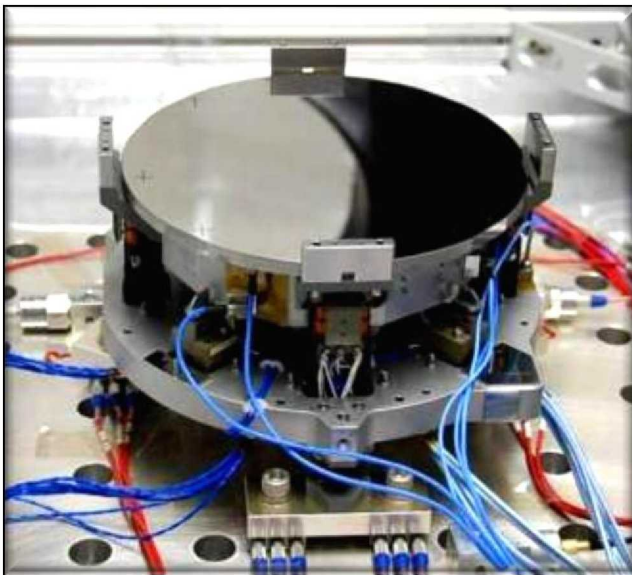
Mirror Processing



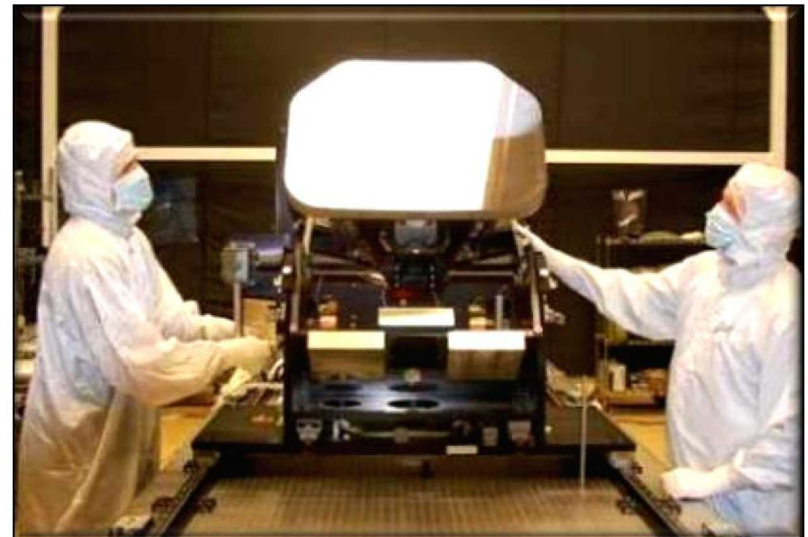
Primary Mirror Processing at Ball



Secondary Mirror Processing at Ball



Fine Steering Mirror Processing at Ball



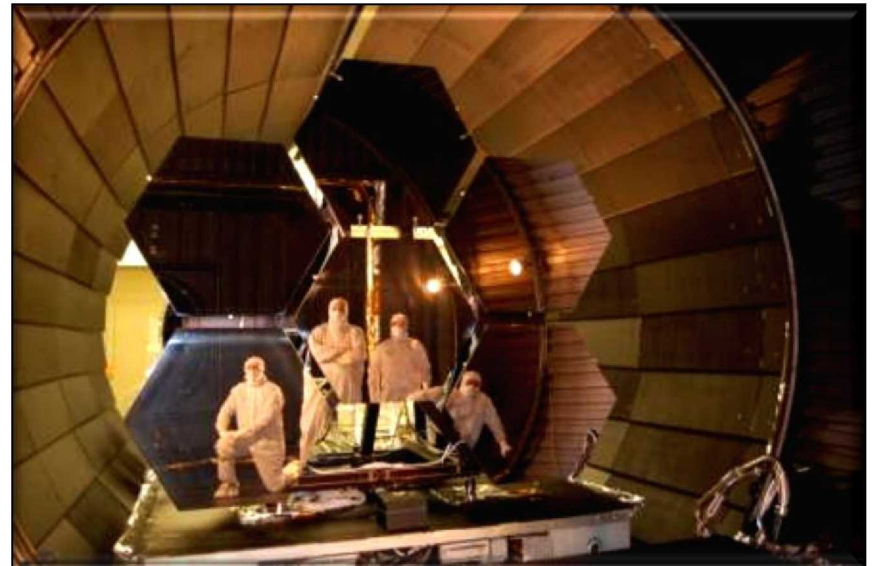
Tertiary Mirror Testing at Ball



Mirror Testing

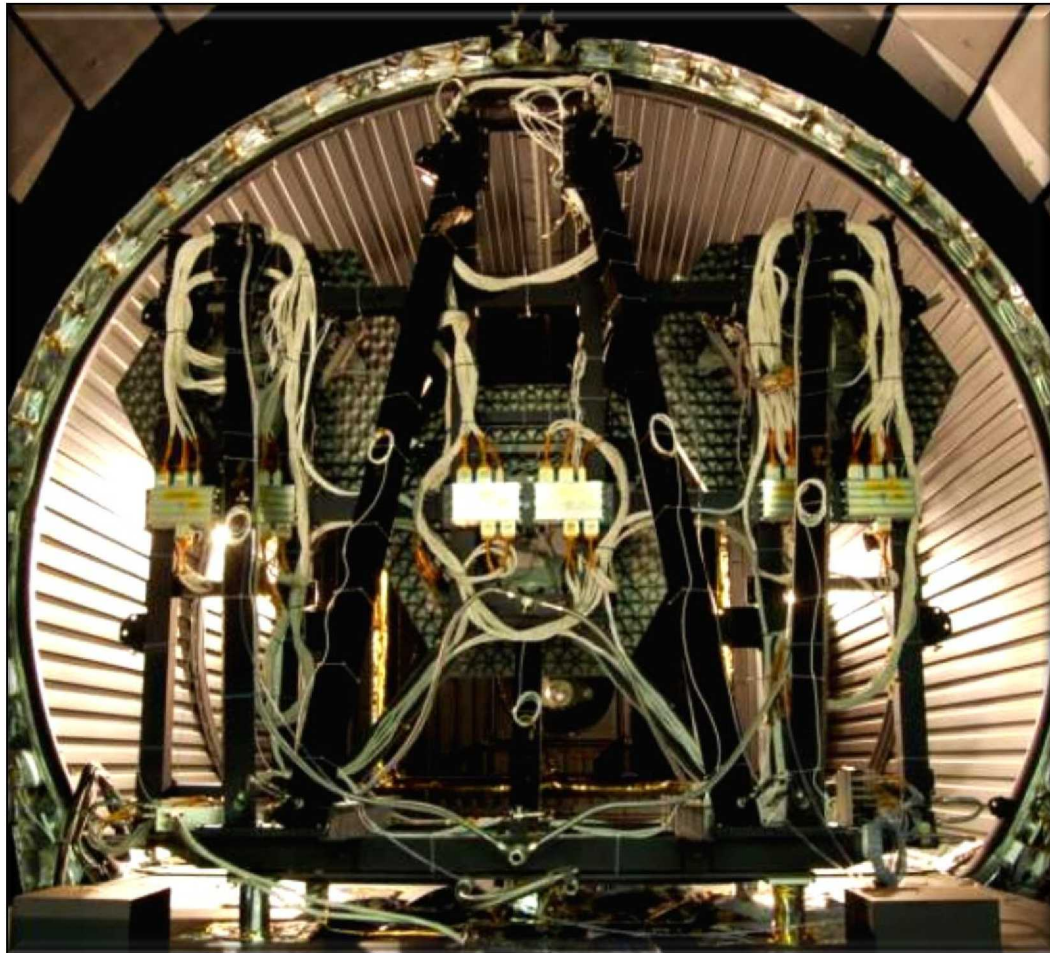


**Views of the EDU Plus
Flight Primary Mirror
Cryo Vacuum Test #3
Preparations at the MSFC
X-Ray and Cryogenic
Facility (XRCF)**

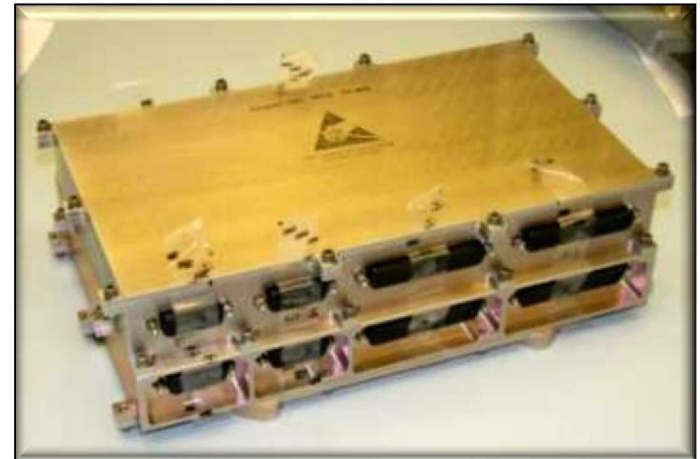
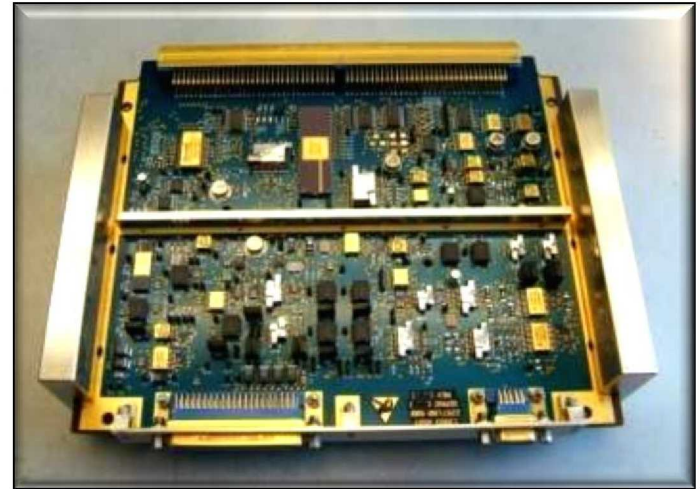




Mirror Electronics Development



**EDU Cryogenic Multiplexer Unit / Cold Junction Box (CMU/CJB)
on XRCF Test Stand**





PMSAs in Transit Storage at BATC





TM Post Coating Inspection at QCI





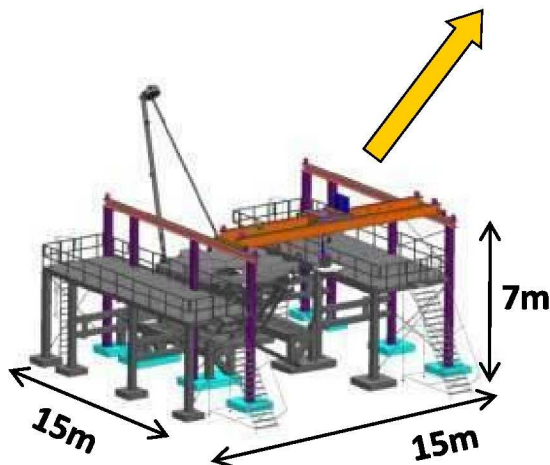
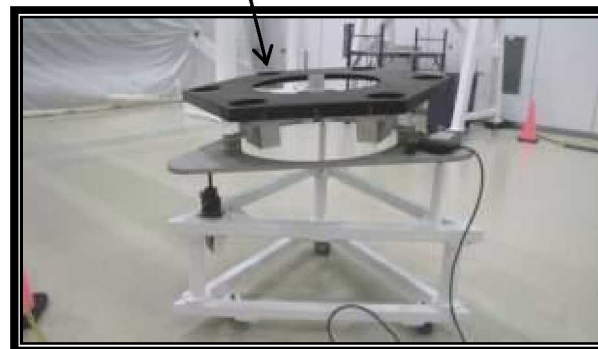
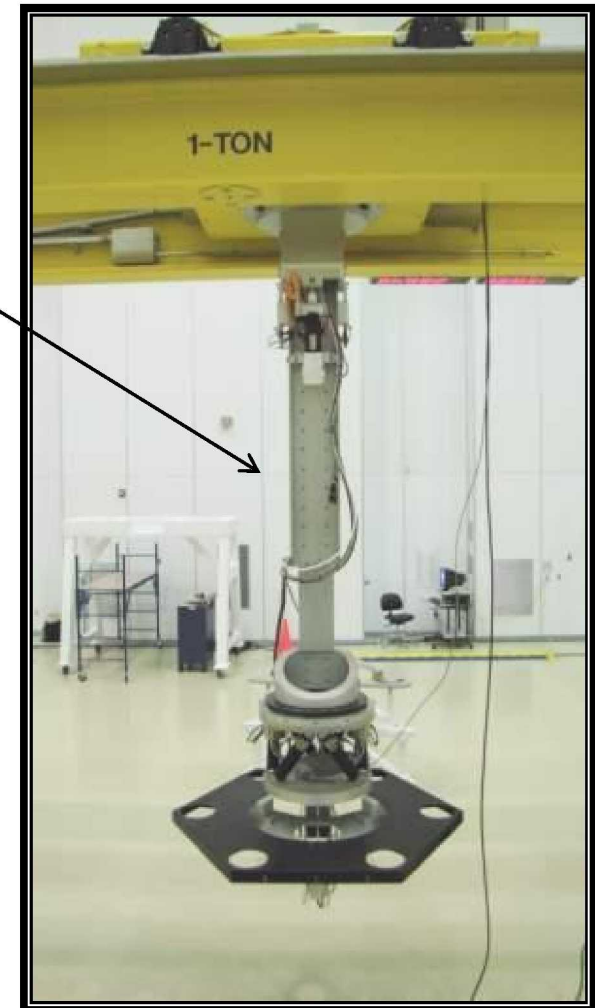
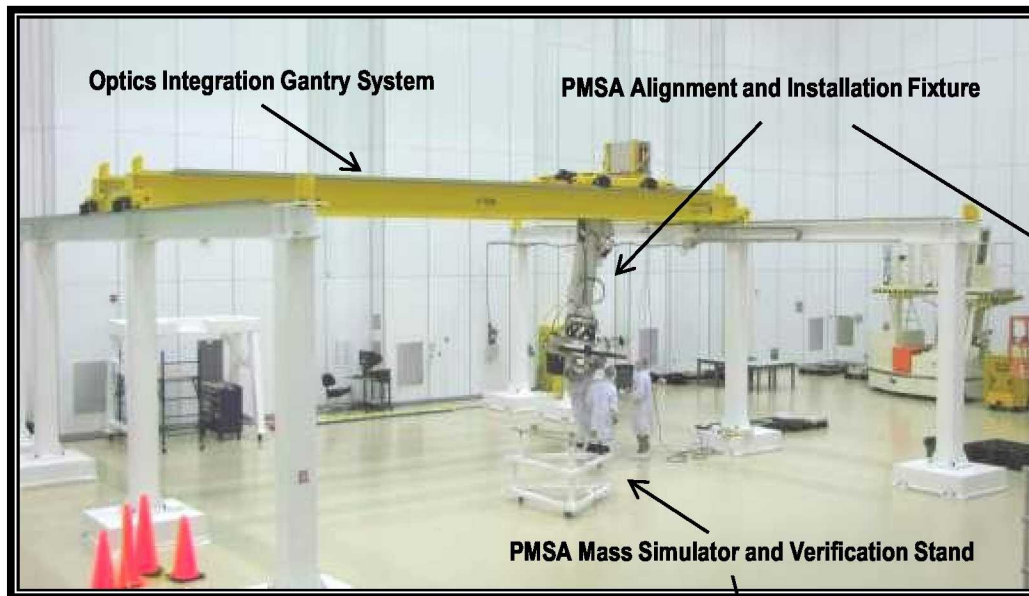
Accomplishments since KDP-C (Continued)

- **Optical Telescope Element (OTE):**
 - **Backplane:**
 - The Center section of the pathfinder OTE Primary Mirror Backplane Support Structures (PMBSS) completed bonding in December 2009
 - Bonding of flight PMBSS continues
 - Secondary Mirror Support Structure (SMSS) struts for the Pathfinder are complete
 - **Telescope:**
 - Aft Optics Bench Assembly Complete
- **OTE I&T:**
 - **Optical Ground Support Equipment for the Telescope Integration and Test has progressed into the fabrication stage**
 - Gantry System and Mirror Alignment System Demonstration Program – Both systems delivered and integrated
 - ACF mirror and cryo testing – First mirror built and cycled through initial cryo skip test
 - JSC Chamber A Isolator design and build & test of first unit – Isolator design completed and is now in fabrication. Verification testing scheduled for May 2010



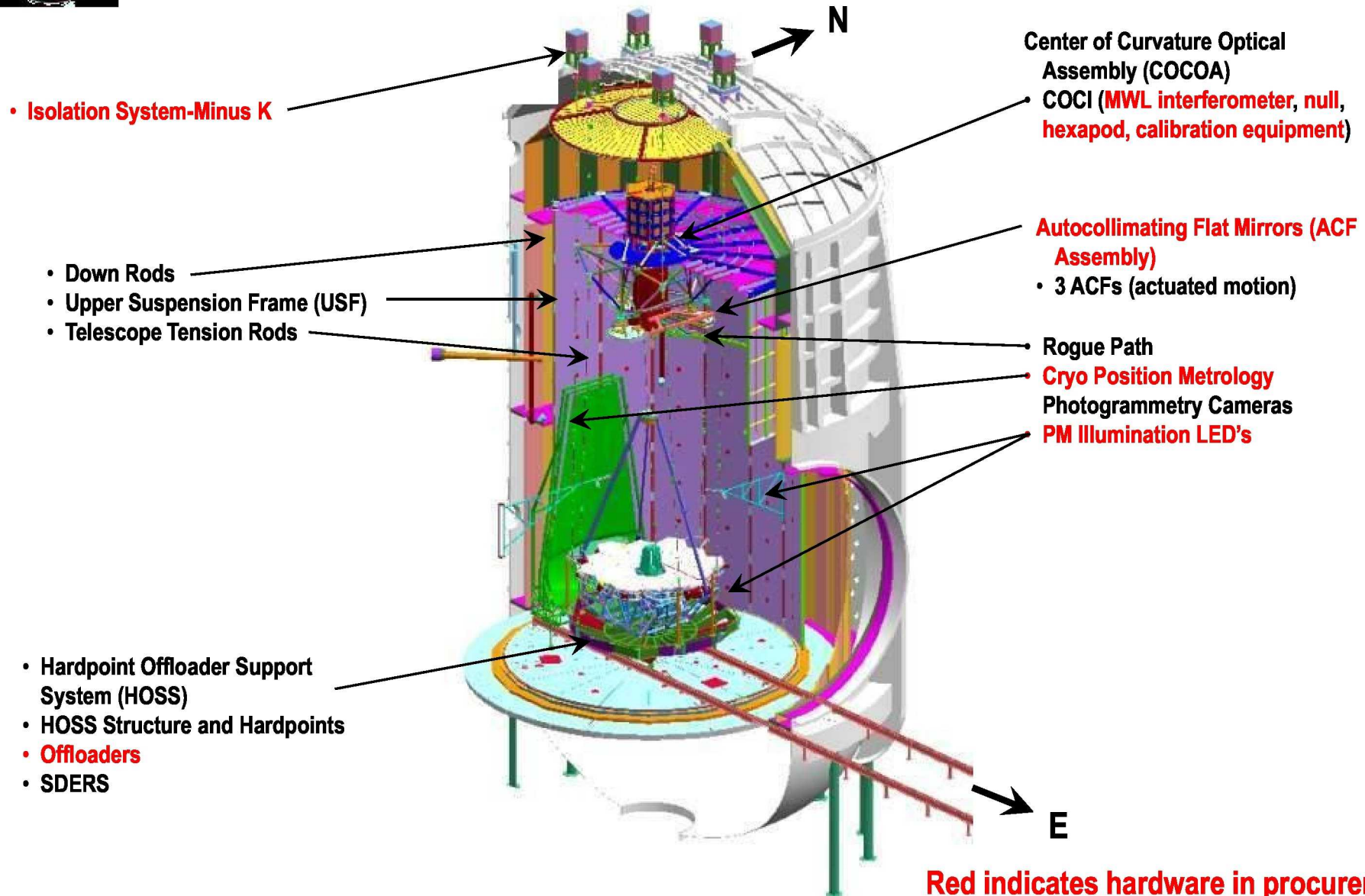
Primary Mirror Installation Demonstration

The Optics Integration Test Bed which include the majority of the PMSA Alignment and Installation hardware has been installed at ITT for training operations and demonstration of critical alignment processes prior to shipment to GSFC's SSDIF





JSC Hardware currently in work or delivered



Red indicates hardware in procurement or initial test evaluation



Accomplishments since KDP-C (Continued)

- **Integrated Science Instrument Module (ISIM):**
 - All flight detectors for all instruments selected
 - MIRI Verification Model (VM) completed testing
 - MIRI Flight Model integration underway
 - MIRI Structural Thermal Model (STM) delivered to GSFC
 - NIRSpec Development Model (DM) delivered to GSFC
 - NIRSpec Flight Microshutter System was delivered to Astrium from GSFC
 - NIRSpec flight Detector System was delivered to Astrium from GSFC
 - NIRSpec Flight Model (FM) integration underway
 - NIRCам Engineering Test Unit (ETU) delivered to GSFC
 - FGS ETU was delivered in place and will be used by CSA as a software test bed until shipped to GSFC in September
 - FGS Flight Model integration is underway
- **ISIM structure completed cryo test testing in the SES test chamber at GSFC**
 - Proved that the structure is very stable after cryo cycling to approximately 25 K
- **All NIRCам flight wavefront sensing and control components have been delivered to LMATC from Ball**



JWST Instrument Engineering, Verification and Development Models



NIRSpec ETU has been delivered to GSFC



NIRCam ETU has been delivered to GSFC



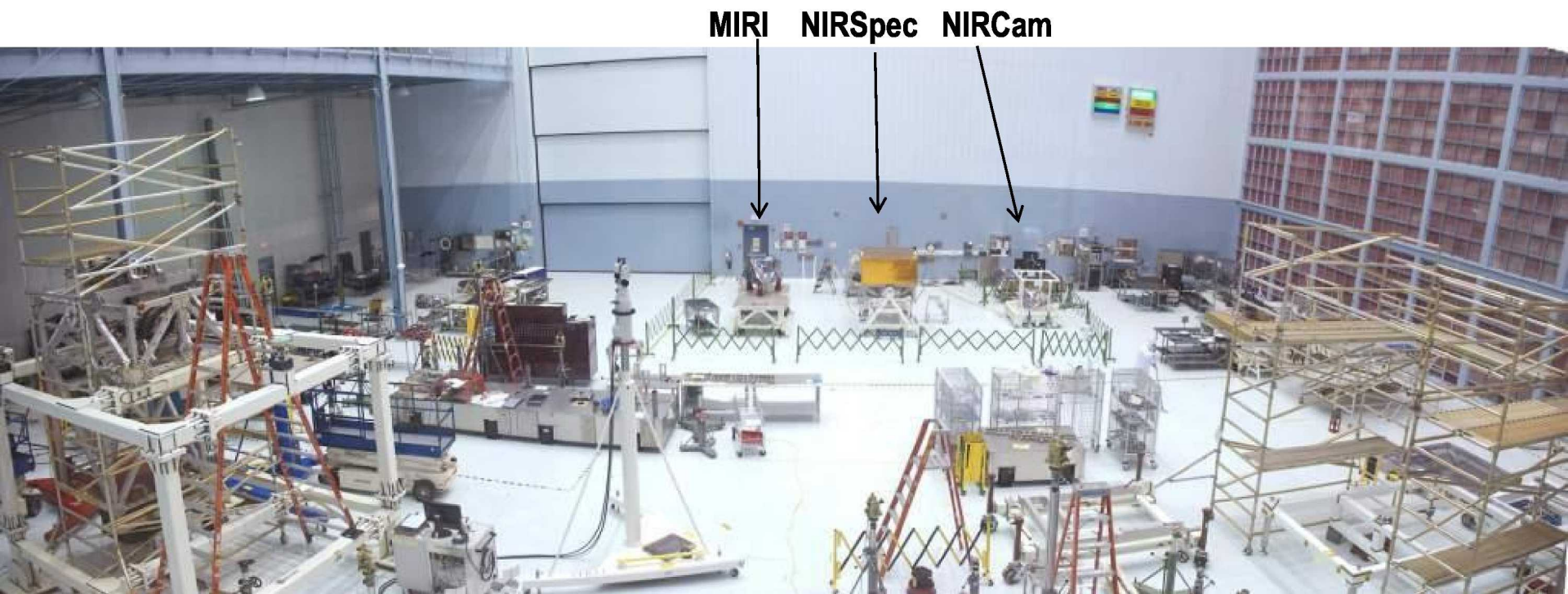
FGS EM has been delivered in place



MIRI STM has been delivered to GSFC

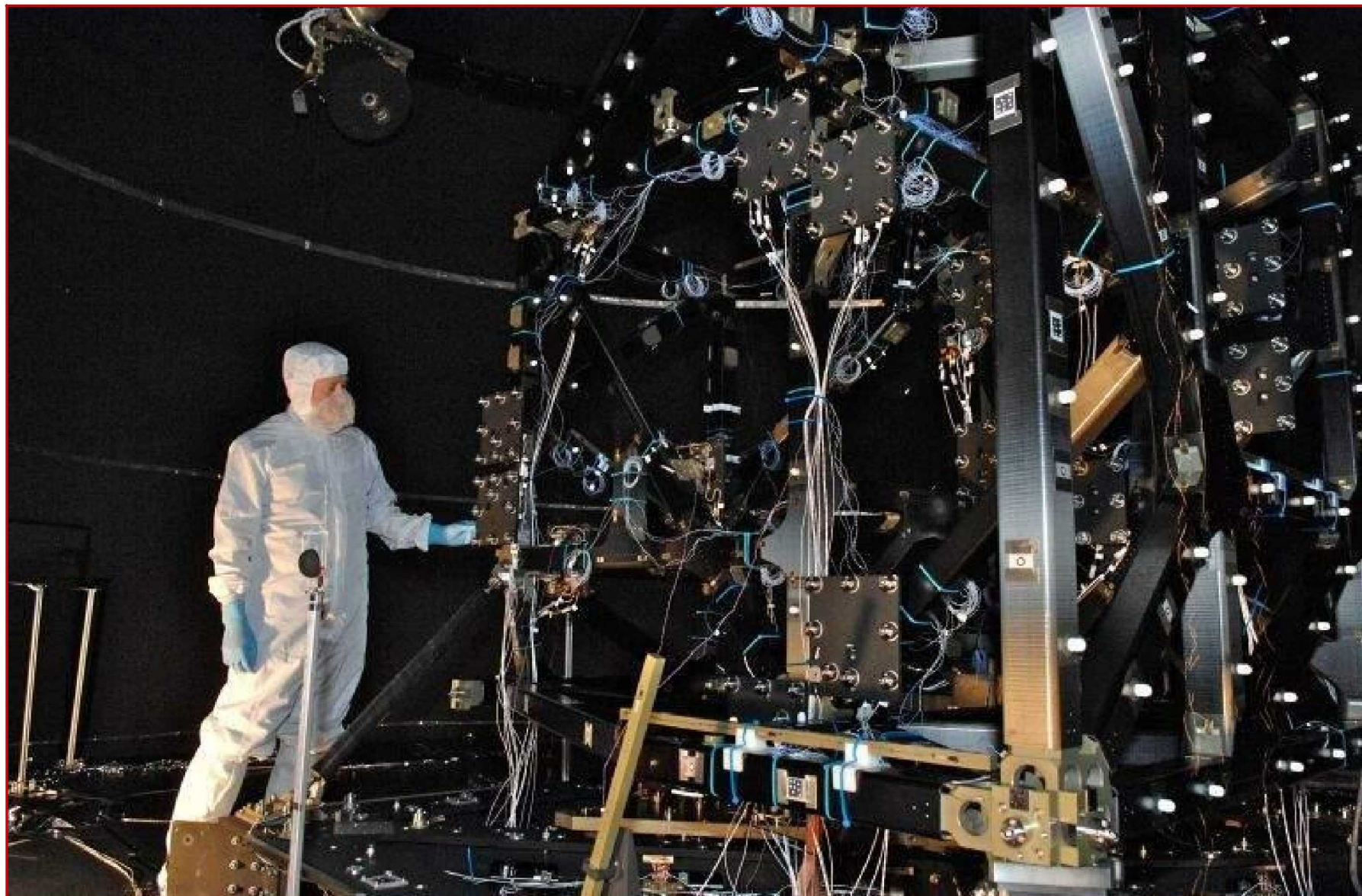


ETU Instruments in the GSFC SSDIF





ISIM Structure Cryoset Test at GSFC





Major Near Term Milestones

- **Major near term reviews, tests and deliveries:**
 - **MIRI flight Focal Plane System (FPS) delivery to RAL in October 2010**
 - **IRSU Flight Model delivery in August 2010**



Major 2011 Milestones

- **Major 2011 reviews, tests and deliveries:**
 - **Deliver Flight NIRSpec to GSFC in January**
 - **Deliver Flight FGS to GSFC in February**
 - **Deliver Flight MIRI to GSFC in March**
 - **ISIM Flight Structure delivery to I&T TBD**
 - **ISIM Electronics Compartment Flight Model TBD**
 - **Spacecraft CDR in May**
 - **Start of Optical Telescope Element (OTE) Pathfinder Integration and Test (I&T) in May**
 - **Deliver Flight NIRCам to GSFC in June**
 - **Start of Flight ISIM Cryo Testing in August**
 - **Start of OTE flight I&T in November**
 - **Start of Sunshield I&T in December**



Project Summary

- **Launch Readiness Date is June 2014**
- **Engineering or Verification Models for the science instruments are complete**
 - **Three have been delivered to the GSFC**
 - **FGS ETU will be delivered in September**
 - **Integration of the flight instruments is underway**
- **Continuing to make good progress on critical path items**
- **Accomplishments since KDP-C have gone a long way towards improving the project's overall technical risk posture**
- **Preparing to start Integration and Test Activities in FY11**