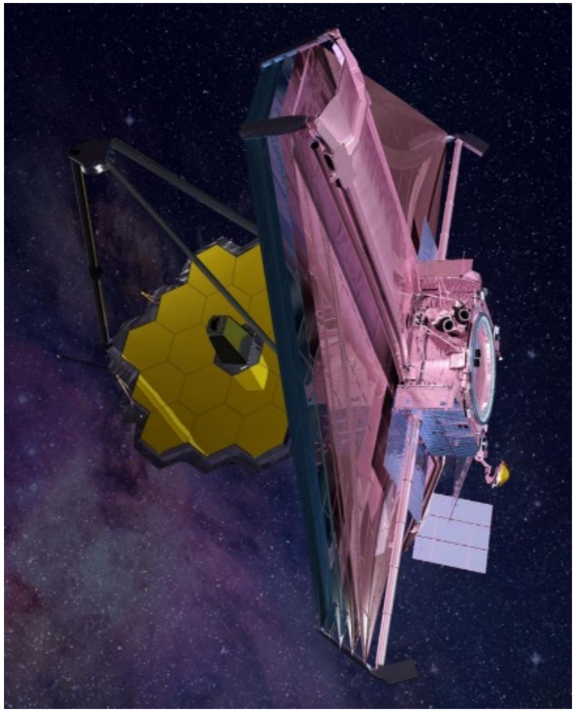
Thermal Management of JWST Cryo-Vacuum Test Support Equipment

Keith A. Havey, Jr. – Harris Corporation
Dwight A. Cooke – Harris Corporation
Jesse A. Huguet – Harris Corporation
Robert L. Day – Harris Corporation

48th International Conference on Environmental Systems
July 2018, Albuquerque, NM

- **JWST has two major differences from HST**
  - 6.5m primary mirror (PM) compared to 2.4m HST
  - Temperature 35 - 50 K compared to 294 K HST
- **JWST will operate in the infrared region of the electromagnetic spectrum to observe far red shifted stars and galaxies**
  - Telescope and all the systems that create the infrared image must operate near 40K.
    - Four science instruments that operate near 40 K
    - Mid-Infra-Red Instrument (MIRI) cooled further to approximately 7 K
- **This operating temperature created many challenges for design, assembly, and test of JWST**
- **Development of these test systems for the OTIS test is the subject of this paper.**



JWST Thermal Test Campaign

JWST program developed a methodical sequence of tests to burn down risk by validating each major test subsystem prior to the Optical Telescope Element (OTE) and Integrated Science Instrument (ISIM), aka OTIS test.

ACF Skip Tests - Rochester 2010-2015
- Mirror Temperature Sensors added
- Mirrors Cryofigured for 32.8K Operation

→ **CoCOA Cryo Test – MSFC June-July 2012**
- Energy balance in LN2 / GHE environment
- Evaluate CoCOA Skid purge system
- Measure shutter & aperture losses
- Test all optical metrology functions

→ **PG Camera Cryo Test – Rochester August 2012**
- Energy balance in GHE environment
- Evaluate PG Skid purge system
- Measure window heat losses

→ **USF Cryo Proof Test – JSC June 2014**
- USF Max Stress Test
- Full PG system checkout

→ **Chamber & GSE Bakeout July 2014**

→ **Chamber Commissioning Test Oct 2014**
- Load Test of MGSE System
- Thermal Operations of GHE zones to manage rates and stresses
- Checkout of Optical GSE

→ **OGSE1 Jun 2015**
- Add BIA for Optical Tests
- ADMA
- Piston Sensors
- Add TTS2

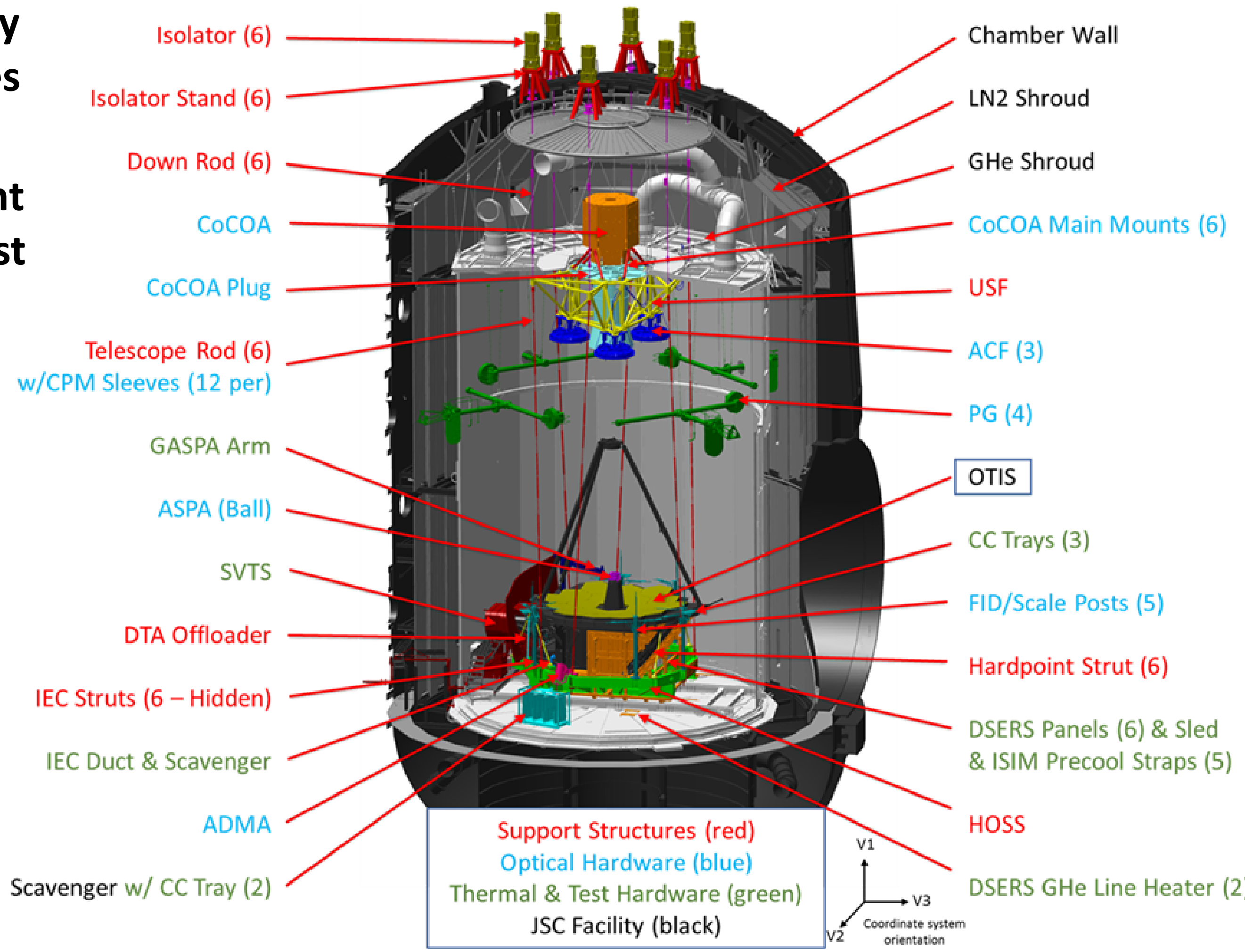
→ **OGSE2 Sept 2015**
- Add AOS and ASPA Optical Tests
- Add DITCE
- Control TM FSM from TTS

→ **Thermal Pathfinder Sept 2016**
- Add AOS Simulator
- Add Mirror Simulators
- Add SVTS Bib, DTA Offloader DSERS
- 3 ACF's with thermal augmentation

→ **OTIS July 2017**
- OTIS!
- Upgraded EGSE harness routing and offloading
- Added DTA and harness heaters
- DTA Offloader implemented
- ISIM Precool Straps and 0-Q

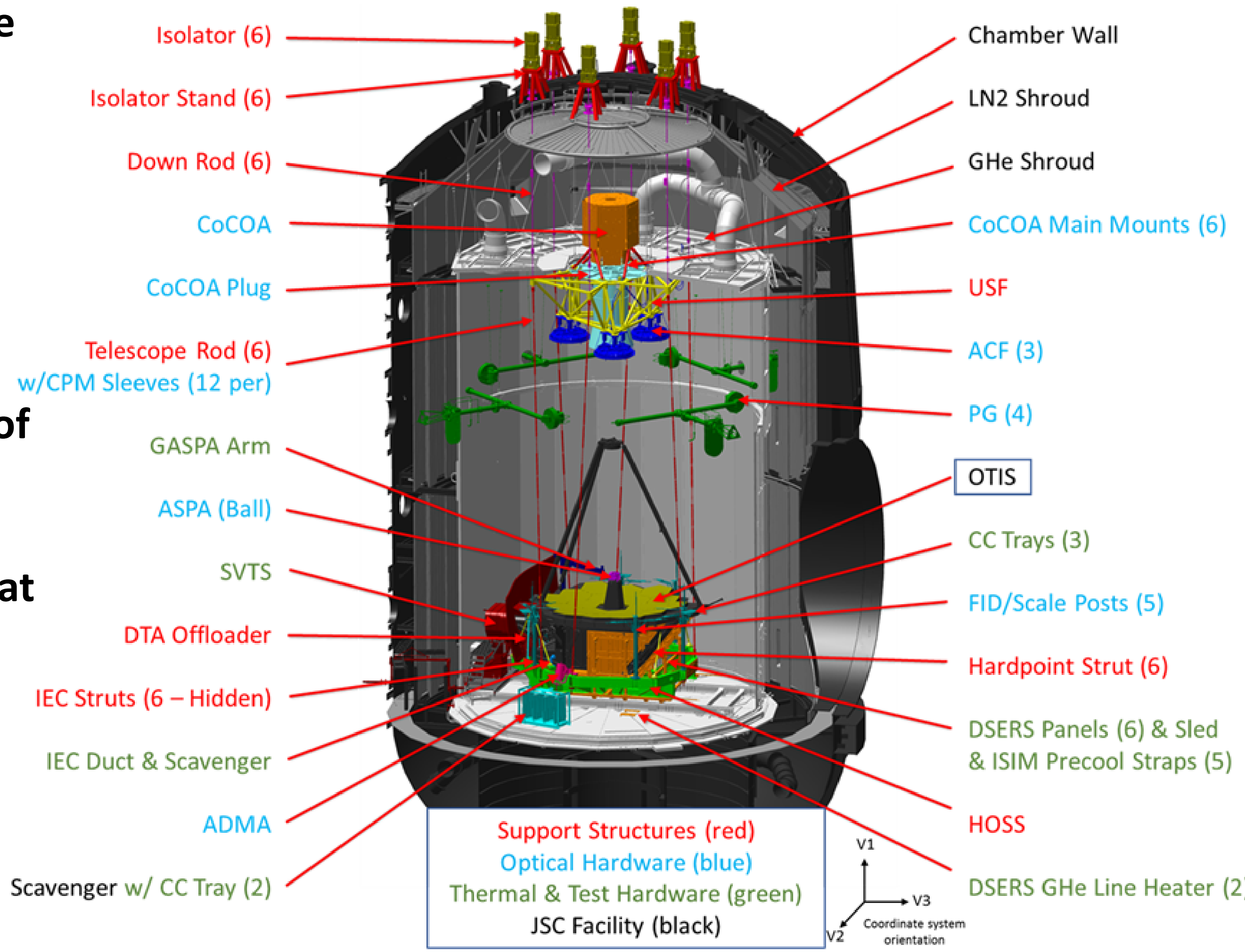
OTIS Configuration with Harris Cryo Test Hardware in JSC Chamber A

- **OTIS test simulated many of the thermal challenges of the flight program**
- **To provide the most flight like environment, the test configurations provided**
  - thermal isolation
  - dynamic isolation
  - precise optical alignment and wavefront measurements
  - stray light control
  - contamination mitigation features
- **The required GSE is illustrated here**



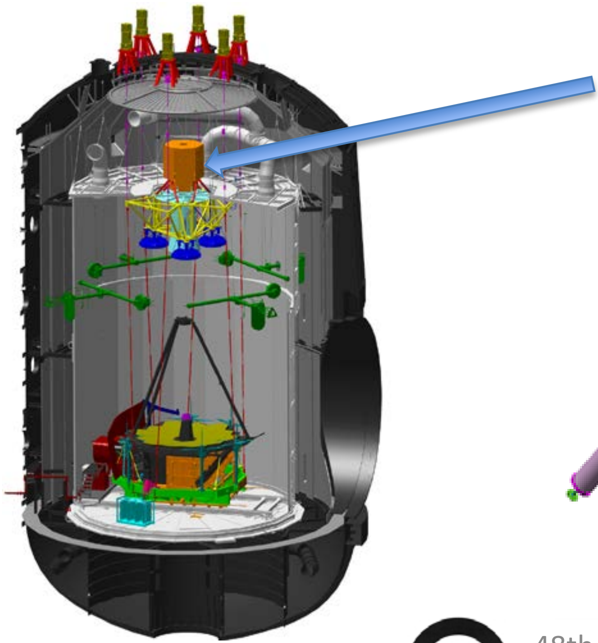
Mechanical Support System

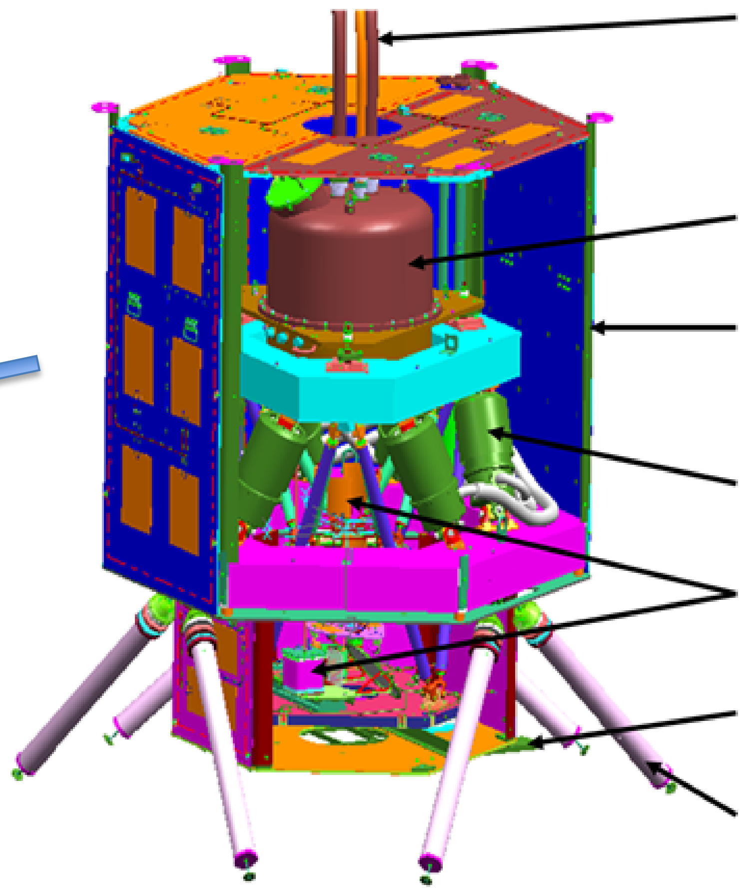
- **Dynamic isolation for the 27,000 kg test support hardware.**
- **Titanium rods 27m long reached from ceiling to HOSS.**
- **Upper Support Frame (USF) supported Center of Curvature Optical Assembly (CoCOA) and three auto-collimating flat (ACF) mirrors.**
- **Hardpoint Offloader Support System (HOSS) hung at the ends of the telescope rods and supported OTIS on composite struts.**



Optical Metrology Systems: Center of Curvature Optical Assembly (CoCOA)

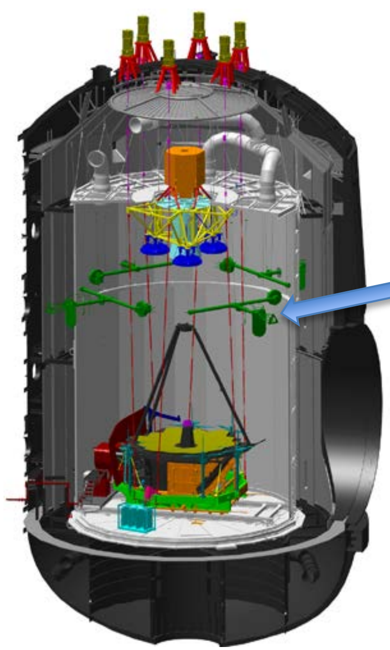
- OTIS test included several major optical systems with design challenges, including CoCOA, PG, ADMA, and ACF mirrors
- CoCOA measured the alignment, phasing, and wavefront of the PM
- Room-temperature optical assembly supported on USF

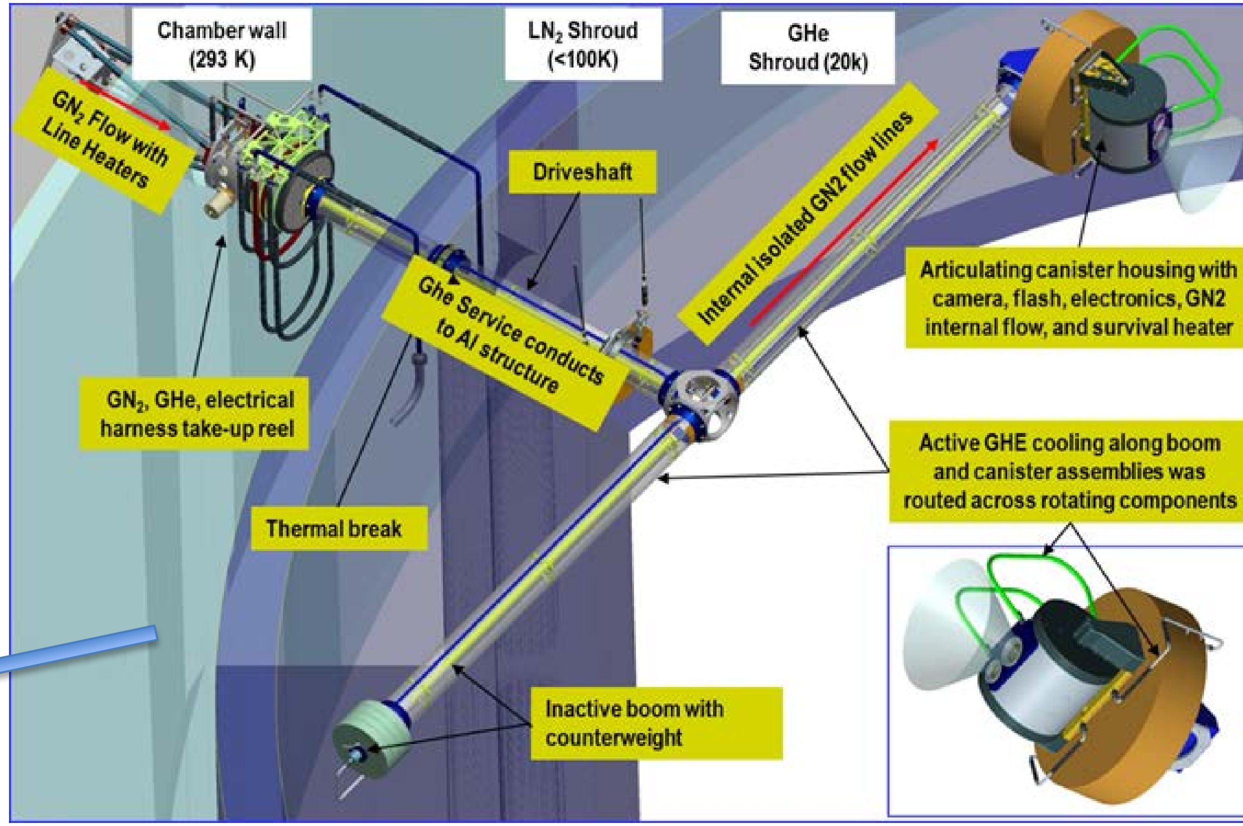




Cryo-Positioning Metrology (CPM) System: Photogrammetry System (PG) and Absolute Distance Meter Assembly (ADMA)

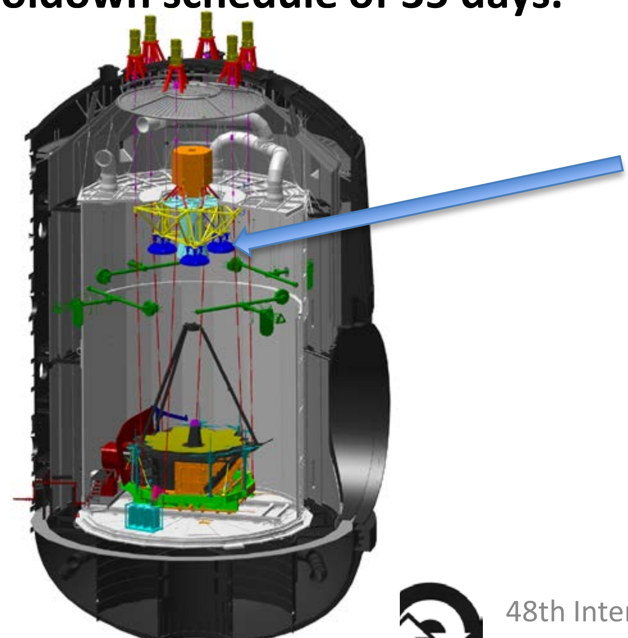
- **CPM tracked relative positions of OTIS and GSE in test**
- **PG and ADMA systems operated with room temperature and pressure interiors but with exterior surfaces <70 K to satisfy stray light and to minimize parasitic thermal loads**

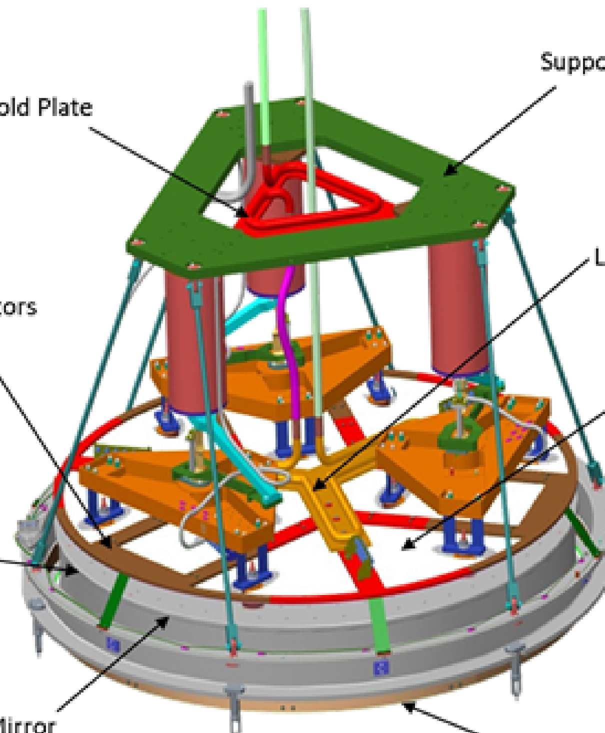




Autocollimating Flat Mirrors (ACFs)

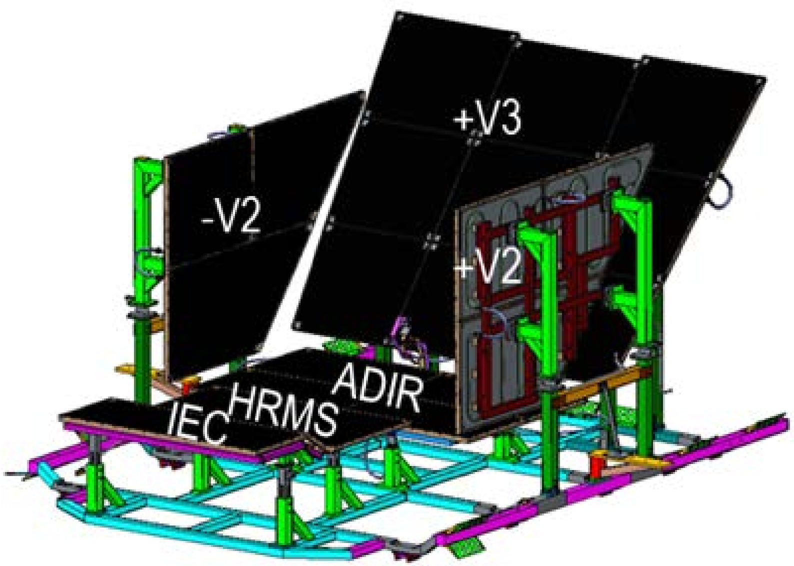
- Three ACF mirror assemblies used in the Pass-and-a-Half (PAAH) test of the JWST flight optics during cryo-stability.
- Radiative heaters were also provided for gradient control and for warmup.
- ACF average temperature of 32.8K and gradient limits were met within the cooldown schedule of 35 days.

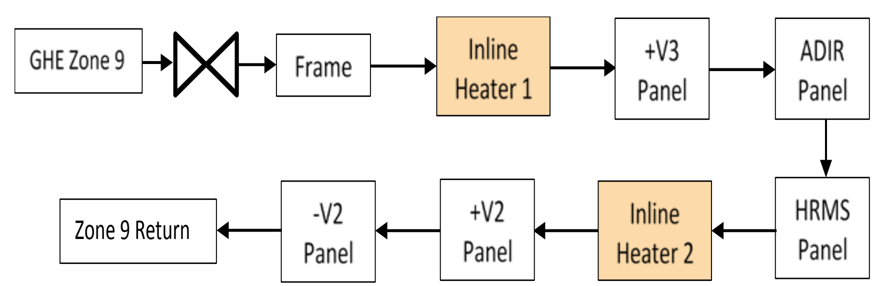




Thermal Simulators: ISIM DSERS

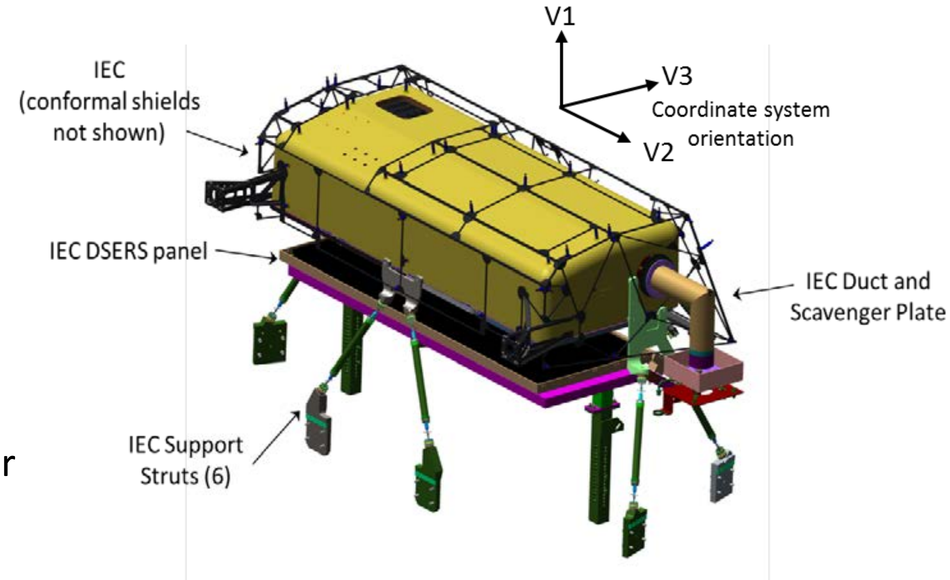
- **Thermal GSE simulators controlled critical OTIS radiative and conductive interfaces**
  - Major systems included DSERS, ISIM precool straps, and SVTS.
- **DSERS GSE provided a radiative sink for the flight radiators.**
  - High emissivity / IR absorption of 0.98 for simulated heat loss to space
  - Panel and in-line heaters were assisted with GHe / panel temperature control
  - Test objective during cryo-stability was met keeping the ISIM DSERS panels stable at 20K with low spatial panel gradients over very large surfaces.





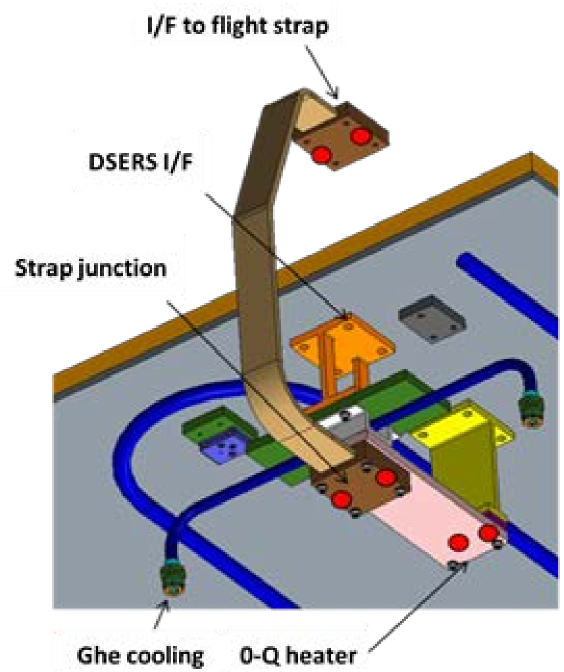
Thermal Simulators: IEC DSERS

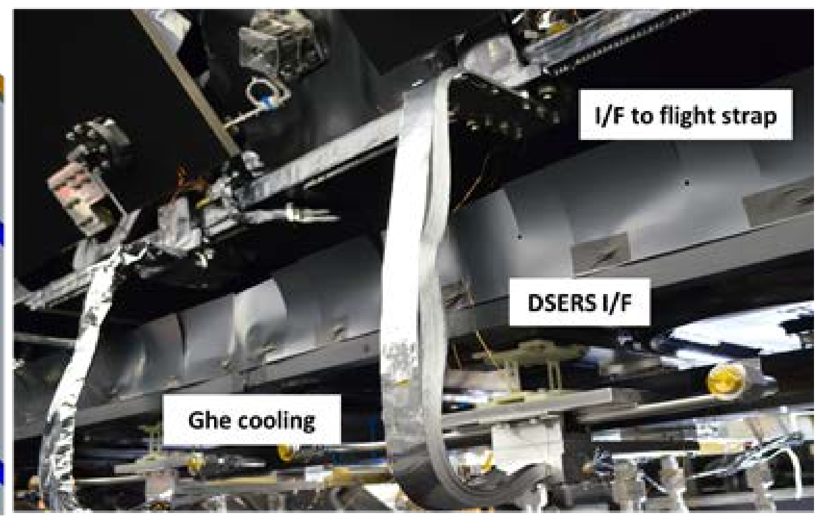
- **Instrument Electronics Compartment (IEC) DSERS GSE had challenging thermal, mechanical, stray light, and venting requirements.**
  - IEC DSERS was cooled and warmed with GHe and had an emergency heater to protect the flight electronics in event of test failure.
  - MLI blanket assembly accommodated the large cryo shift and closed out the volume below the IEC with light-tight seams at the conformal shields.
  - Venting from the warm IEC was managed with a G-10 vent duct attached to the +V2 collar of the IEC to direct outgassing from inside the IEC down to a dedicated scavenger plate on the HOSS.
  - All thermal test temperature control requirements were met.



Thermal Simulators: ISIM Precool Straps and 0-Q Heater

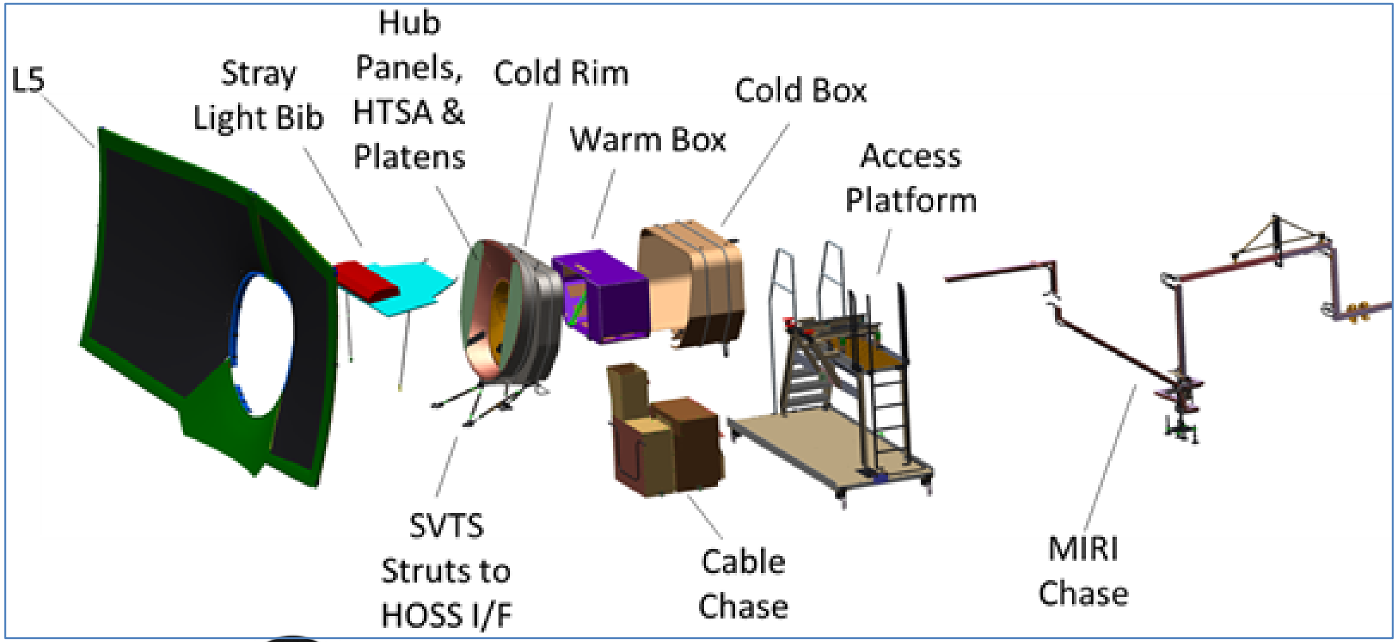
- **ISIM precool flexible aluminum straps bridged the five ISIM radiators to the back side of the DSERS**
  - Provided a heat sink to accelerate ISIM cooldown
  - Managed conductive heat flow from the ISIM to DSERS below 6 mW at thermal balance
- **Several thermal-mechanical challenges were required to accommodate the large cryo shift.**
  - Flexible strap and sensors accommodated the large motion without shorting the straps or SLI.
  - GHe flow piping lines floated without making contact.



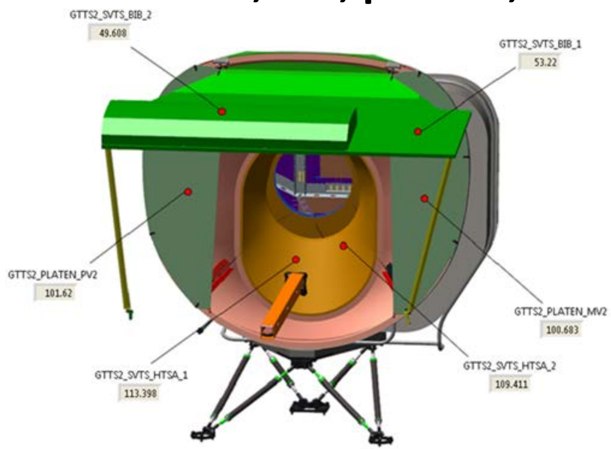


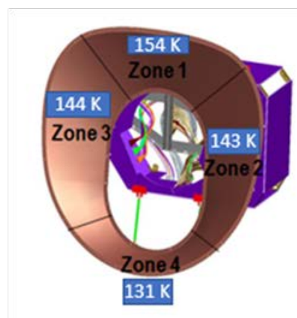
Thermal Simulators: SVTS

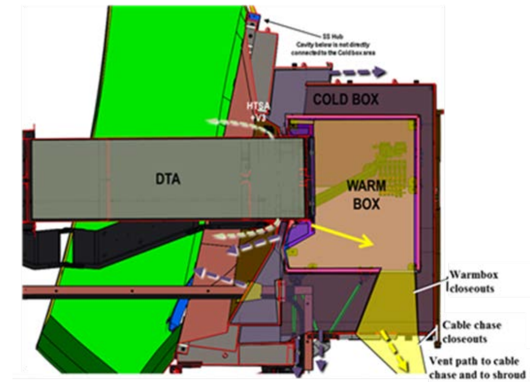
- **SVTS simulated several flight hardware features.**
  - Sunshield Layer 5
  - Hub and rim assembly
  - Harness interconnect panel ICP4
  - Stray light bib
- **SVTS included features unique to OTIS test**
  - A thermal "chase" for the MIRI GSE cryocooler lines
  - Cable chase and vent flow control path with ducting and scavenger plate
  - DTA heater
  - Large cryoshift accommodation

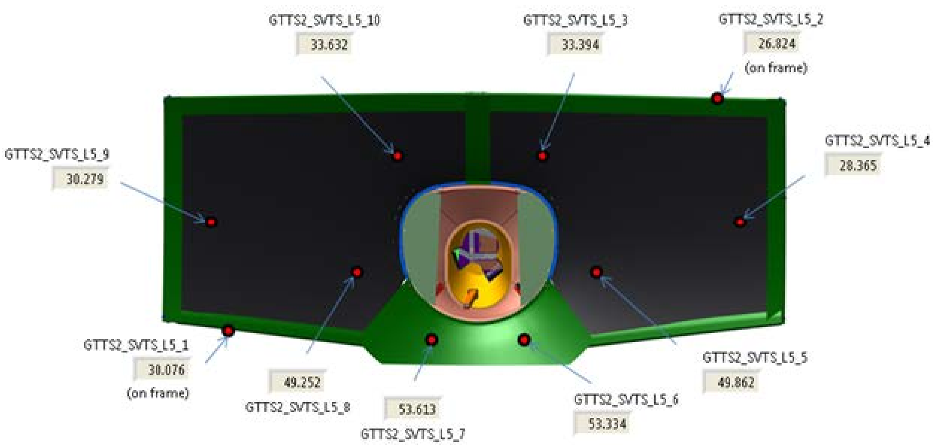


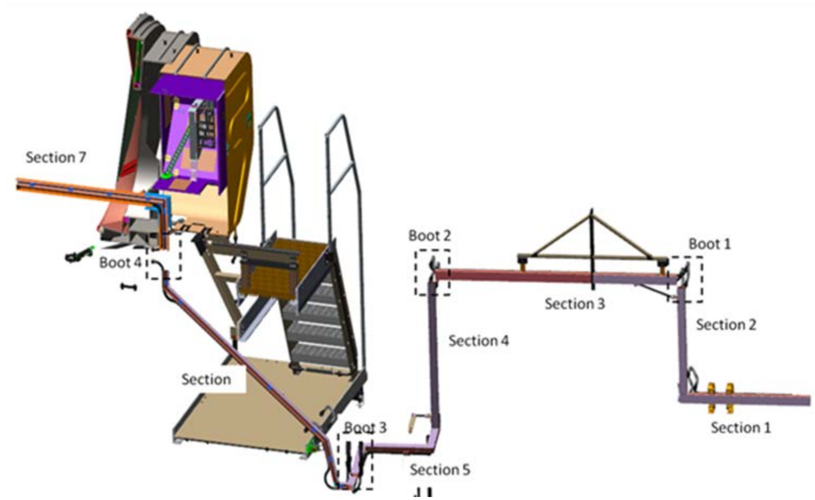
- **SVTS hardware mounted on HOSS: HTSA, bib, platens, heaters, and L5**
- **SVTS hardware mounted on rails: warm and cold box, MIRI chase, and venting**





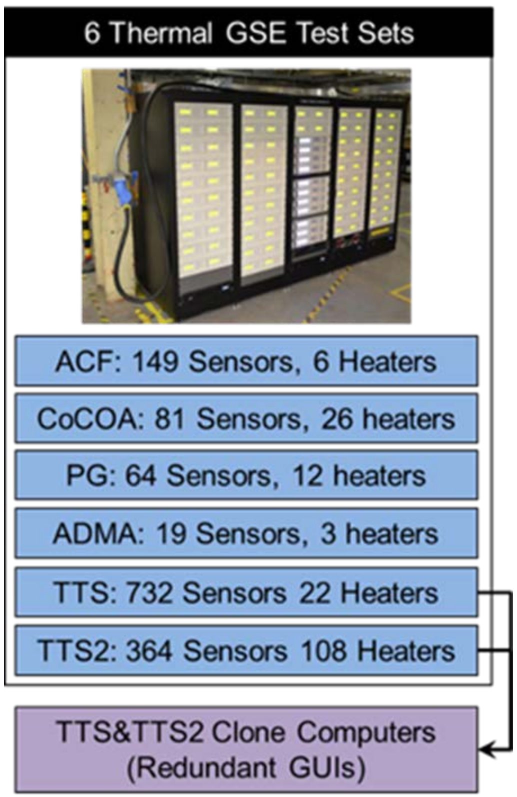


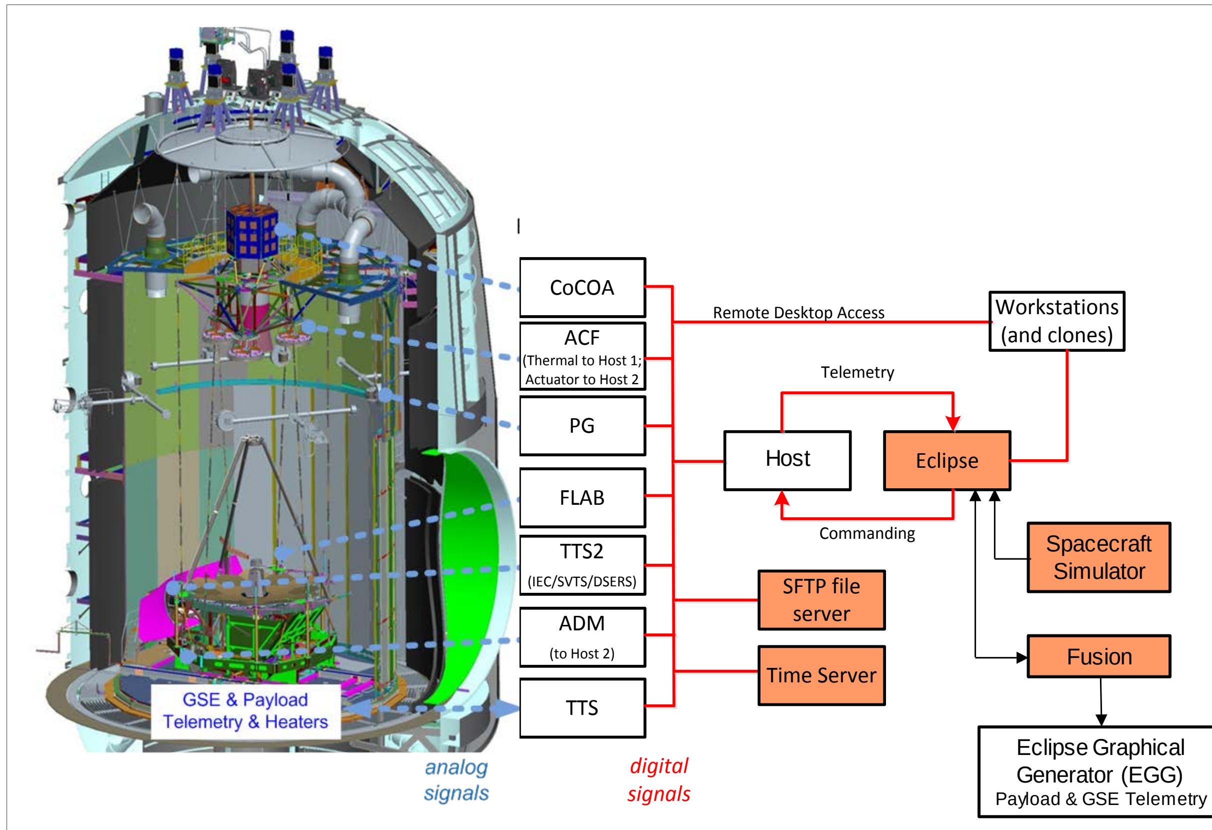




Telemetry and Test Controls: Test Sets

- Harris was responsible for development of six thermal GSE test sets to control and monitor GSE subsystems as well as test-only OTIS sensors
- Thermometry included diodes, PRT’s, Cernox’s and independent measurements with NASA-provided radiometers and calorimeters





Summary

- **The OTIS cryo-vacuum test required the development of an extensive suite of optical, mechanical, and thermal GSE subsystems and devices.**
- **The designs and test campaign required attention to every detail due to the large size of the payload and the challenging cryogenic test environment.**
  - Thermal systems successfully measured milli-Kelvin temperature and milliwatt heat flows
  - Optical systems measured nanometers of displacements while the hardware moved 5 cm
  - Large mechanical structures safely carried 27,000 kg while keeping the flight payload safe and dynamically stable.

OTIS Exiting JSC Chamber A after Three Months of Testing

Acknowledgments

- **JWST is a collaborative effort involving NASA, industry partners, the European Space Agency, the Canadian Space Agency, the astronomy community and numerous principal investigators.**
- **OTIS cryo-vac test GSE hardware design, integration, and execution was carried out under the JWST contracts NNG11FD64C with NASA's Goddard Space Flight Center and NNG15CR64C with ATA Aerospace.**
- **Special thanks to:**
  - The entire Harris thermal team
  - The Harris mechanical and electrical teams and assembly crew who implemented our thermal designs into hardware systems with great attention to detail
  - The entire JWST thermal community and their exceptional technical skills, professionalism, and dedication in all situations over many years