



James Webb Space Telescope Optical Telescope Element/Integrated Science Instrument Module (OTIS) Status

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What is OTIS



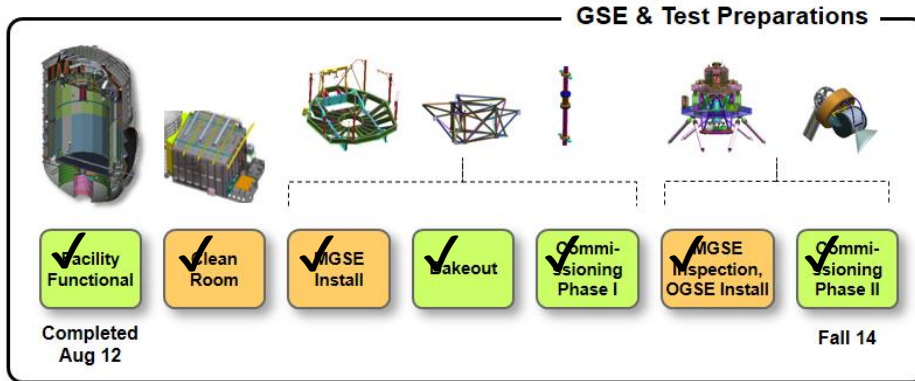
- Optical Telescope Element (OTE) + Integrated Science Instrument Module (ISIM) = OTIS
- Accept delivery of the OTE, ISIM and related components
- Responsible for the integration of ISIM to OTE to create OTIS
- Responsible for the environmental testing of OTIS and necessary Ground Support Equipment (GSE) required to accomplish this
 - Acoustic Testing at GSFC
 - Vibration Testing at GSFC
 - Cryogenic thermal vacuum testing at JSC Chamber A
- Deliver OTIS to observatory for integration and observatory level testing



Where Are We In OTIS Flow



JWST OTIS Integration and Test

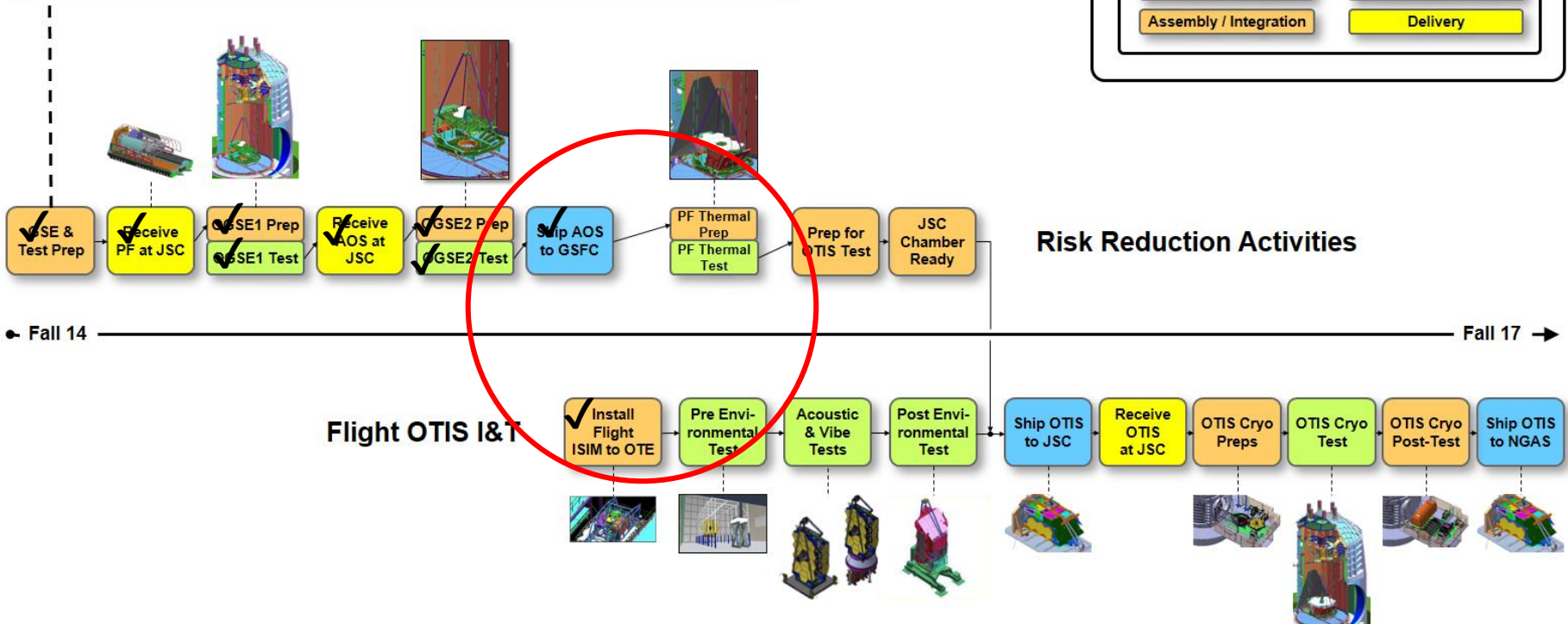


Acronyms

- AOS: Aft-Optics Subsystem
- GSE: Ground Support Equipment
- MGSE: Mechanical Ground Support Equipment
- NGAS: Northrop Grumman Aerospace Systems
- OGSE: Optical Ground Support Equipment
- PF: Pathfinder

Legend

- Prep & Transport (Blue)
- Assembly / Integration (Orange)
- Functional / Test (Green)
- Delivery (Yellow)



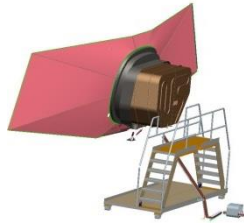
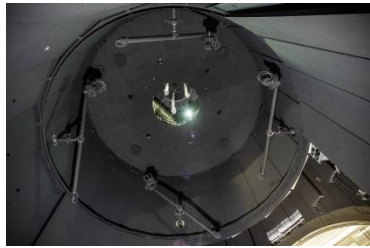
OTIS Test GSE Architecture



Chamber Isolator Units
Dynamically isolates OTIS Optical Test – Integration of 6 units complete



Cryo Position Metrology (CPM) Photogrammetry System
Integration Complete

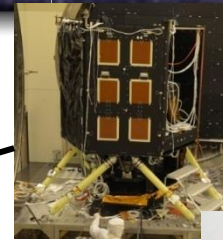


Space Vehicle Thermal Simulator (SVTS) and Sunshield Simulator
Procurements and fabrication

ADM
Testing complete at JHU
Delivered to JSC



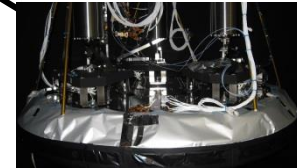
HOSS – Hardpoint Offloader Support Structure
In integration in Clean Room



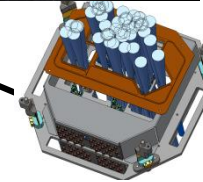
Center of Curvature Optical Assembly (COCOA)
• Multiwavelength interferometer (MWIF), null, calibration equipment, coarse/fine PM phasing tools, Displacement Measuring Interferometer – Installed in Chamber



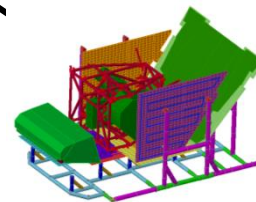
USF Structural Frame – supports Metrology
Installed in Chamber



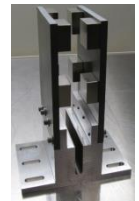
3 Auto collimating Flat Mirrors (ACFs)
1.5 M Plano for Pass and Half Testing
ACF 1 installed in Chamber A, ACF 4 and ACF 5 are complete,



AOS Source Plate Assembly (ASPA)
Testing complete at Ball
Delivered to JSC



Deep Space Edge Radiation Sink (DSERS)
Frame integrated



Mag Damper Cryo Test Article
Delivered

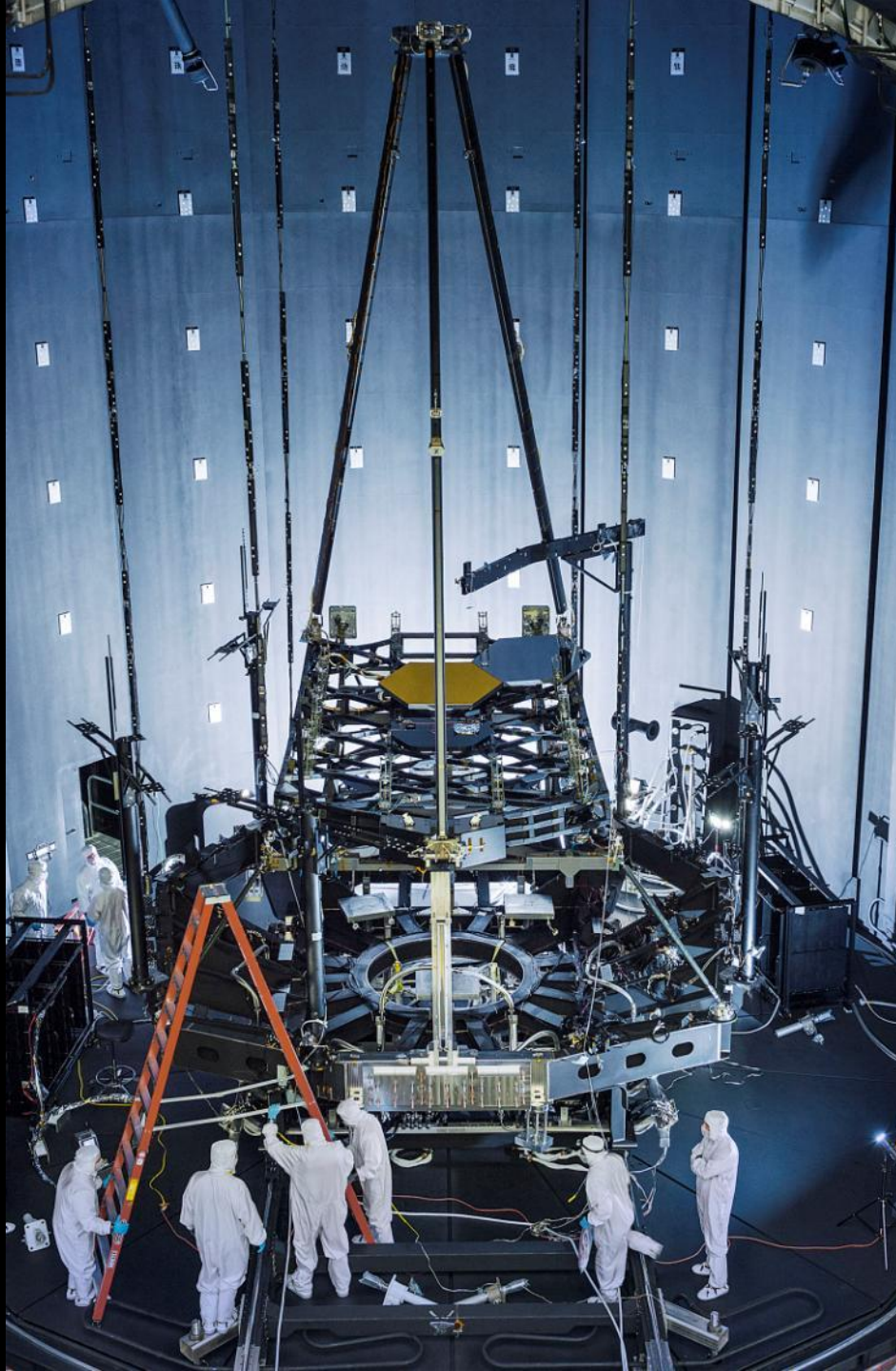


Pathfinder being installed into shipping container at GSFC

Pathfinder mounted to the HOSS as seen from inside the chamber



**Pathfinder in the
chamber for
OGSE1**

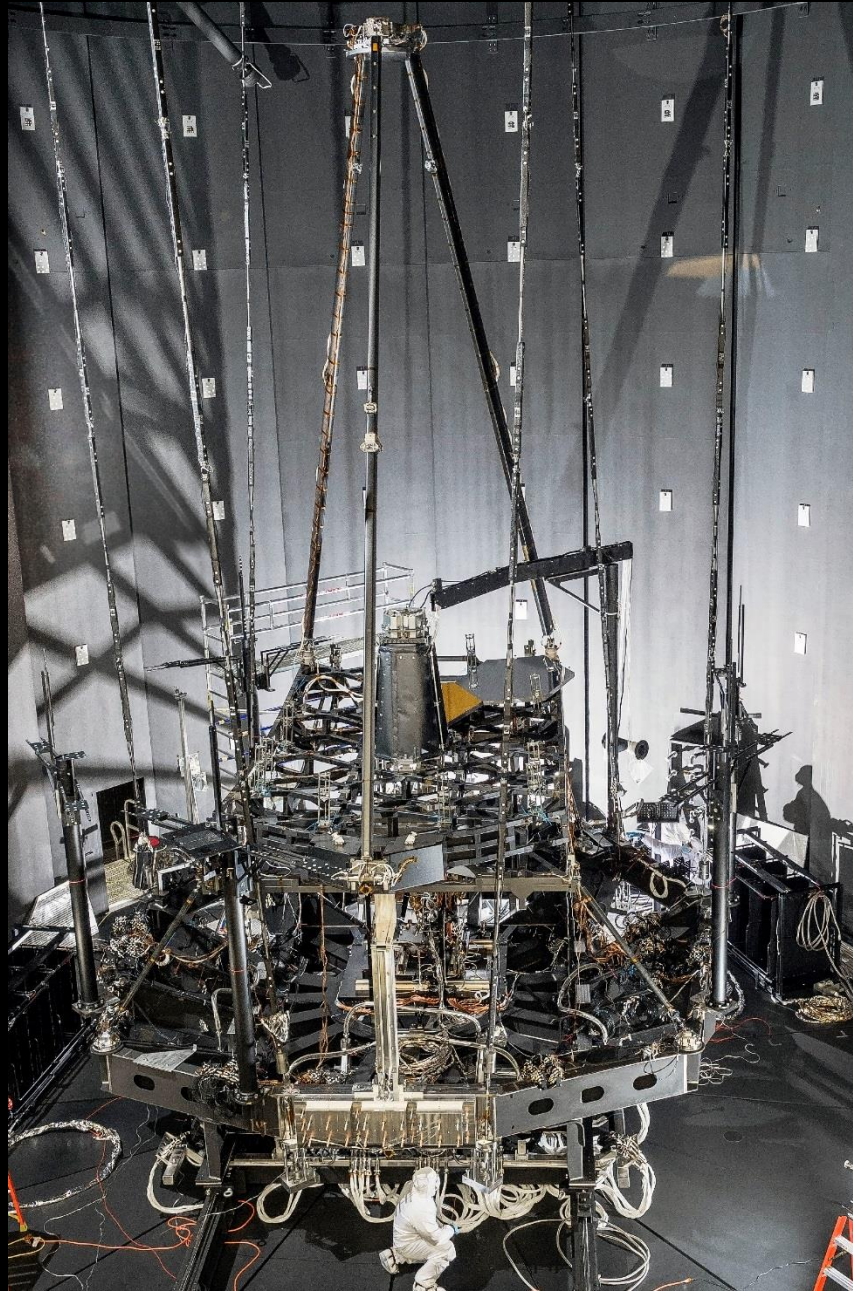


OGSE1 Results



- OGSE1 was extremely successful and met test objectives
 - Achieved the mandatory objective of performing a cryogenic proof load test of the Aft Optics System (AOS) interface to assure OGSE2 can proceed safely
 - Demonstrated Multi-wavelength High Speed Interferometry of the primary mirror including successfully phasing two primary mirror segments
 - Performed detailed dynamics characterization of the isolation system
 - Performed functional testing and characterized the Beam Image Analyzer, showed that it is aligned well enough for OGSE2
 - Trained the team on optical test operations
 - Mirror vertical gravity sag data qualitatively matched models (first time mirrors were tested vertically)
 - Photogrammetry worked extremely well including implementing lessons learned from Cryo Commissioning Test
- OGSE1 did it's job and generated very important lessons learned
 - Identified a mechanical short to ground that happened during cooldown between the DSERS frame and the HOSS magnetic damper bracket that can easily be fixed for future tests
 - Learned a lot about isolator tuning and developed an improved tuning process for OGSE2
 - Got a better understanding of what optically drives the segment optical testing (phase calibration of the interferometer) and the metrics to use to evaluate dynamics performance (velocity) which can be applied to flight OTIS testing

Pathfinder in Chamber for OGSE2

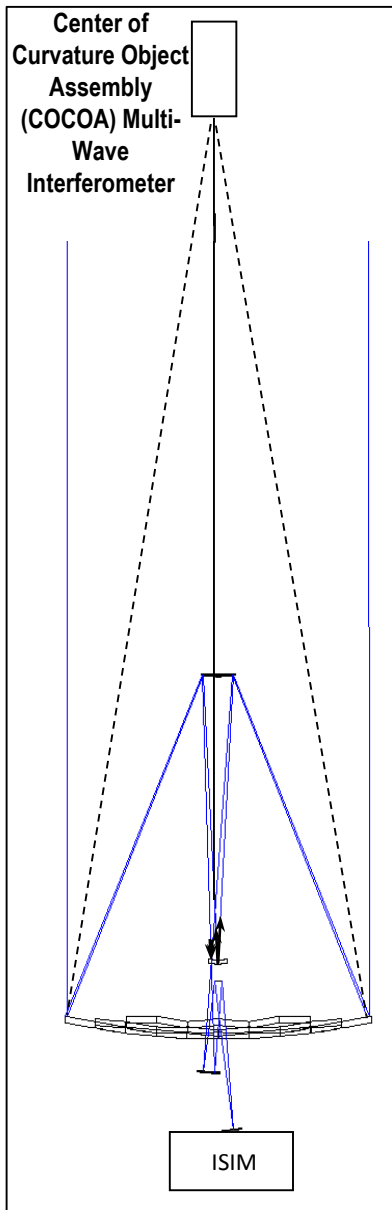


OGSE2 Summary

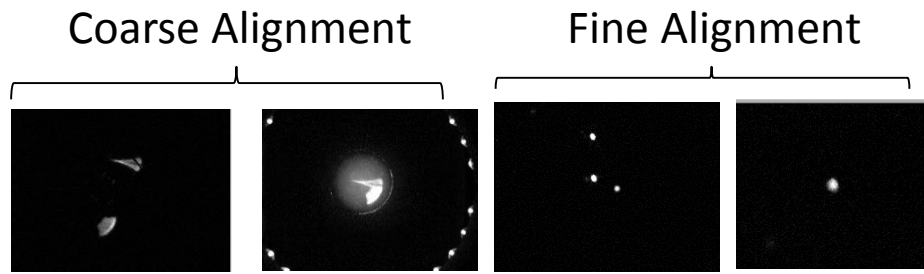


- OGSE2 completed in approximately 35.5 days (allocated 35)
- Overall, OGSE2 was a tremendous success optically
 - All Primary, Secondary, Tertiary Test Objectives were all met
 - Demonstrated every optical test used during OTIS at some level
 - GSE checked out (only exception was only 1 ACF used)
 - Training and practice of test execution and data analysis
 - Only 2 Problem Failure Reports (PFR's):
 - Center of Curvature Object Assembly (COCO) Hexapod worked intermittently but the issue has since been addressed with electrical improvements in the GSE.
 - Dynamics/vibration levels higher than expected
- Despite vibration, optical testing was very robust
 - Photogrammetry, COCO primary mirror testing and half pass testing not impacted by the vibration thanks to the test design
 - Only 2 Pass and a Half tests were impacted, optical workaround developed that is insensitive to vibration but vibration will also be addressed (belt and suspenders)

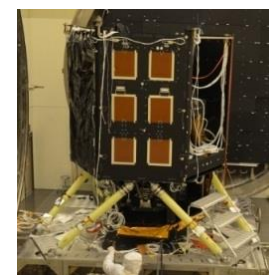
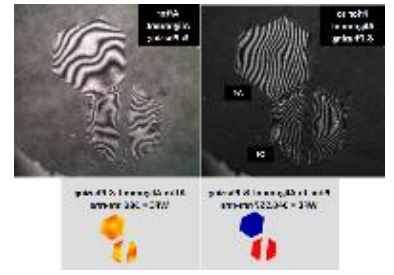
OTIS Center of Curvature Optical Test Demonstrated End to End Phasing



- Interferometric segment phasing demonstrated with 2 flight like segments for OTIS test
- During cryo testing in OGSE 2 the 2 segment primary mirror was phased from mm and mrad tolerances to step heights < 30 nm
 - Several independent teams analyzed data and results are matching well
- All results reviewed with independent Product Integrity Team chaired by Prof Duncan Moore/University of Rochester, positive feedback
- Team will repeat COCOA testing during the Thermal Pathfinder test

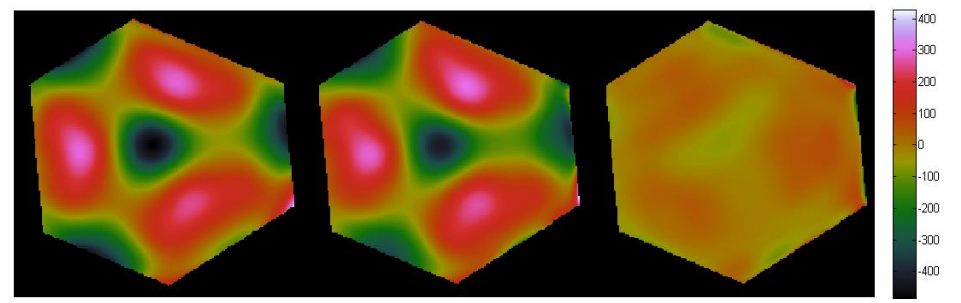


Multi-Wavelength Phasing Using Synthetic Wavelengths



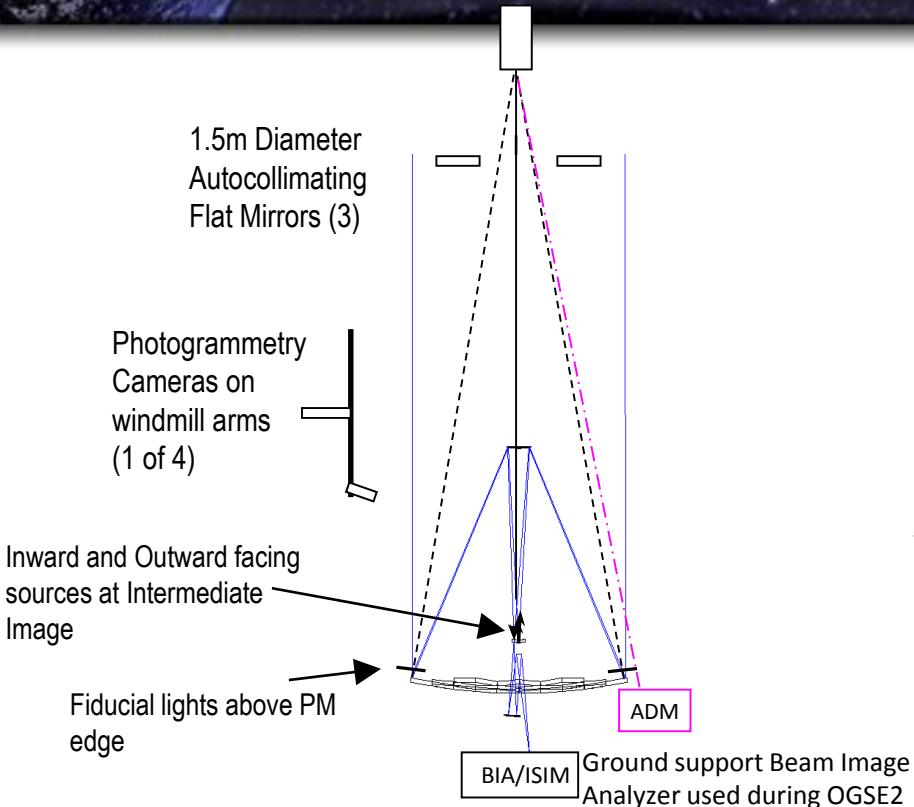
Center of Curvature Object Assembly (COCOA) Multi-Wave Interferometer

Measured (165 nm-rms) Model Predict (161 nm-rms) Difference (31 nm-rms)

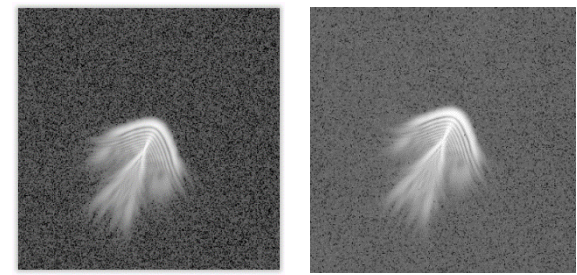


Difference of 31 nm-rms consistent with estimated uncertainty of 30 nm-rms,

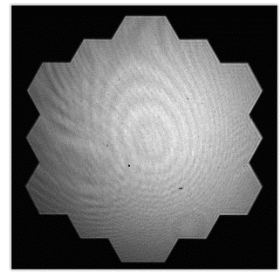
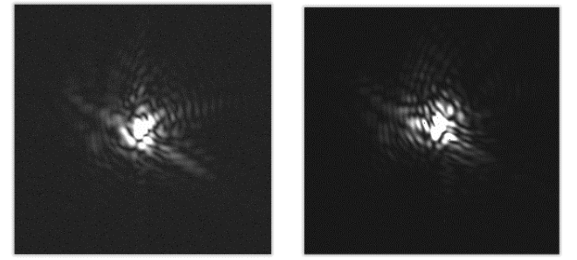
All Optical Tests were Demonstrated



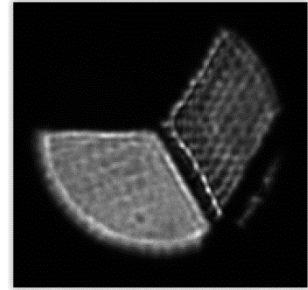
Half pass Prediction vs. Data



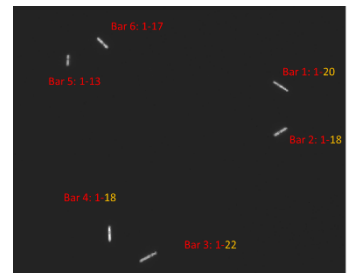
Pass and a Half Prediction Vs Data ("Stacked")



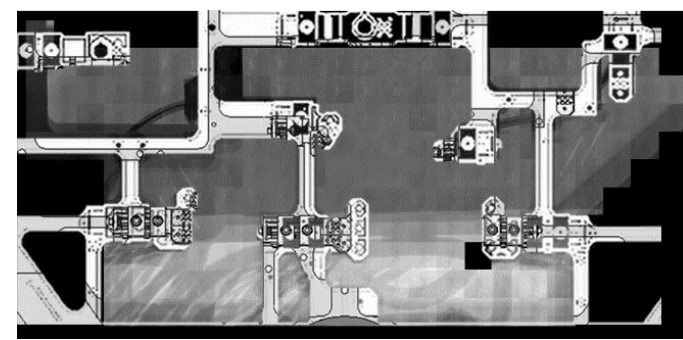
HP OGSE2 Pupil Image



PAAH OGSE2 Pupil Image



LED's used at edge of PM to align pupil to FSM and NIRCAM



Shadowgram tests Indicated No Vignetting Issues

Optical Test Status (Summary)



Priority 1: Verification measurements and critical crosschecks – minimum needed for test success/verification

Priority 2: Important crosschecks – prioritized but can relax requirements for test success

Priority 3: Risk mitigation and secondary crosschecks, high ROI but not required for test success

Parameter	Test	Test Configuration	Status	OGSE 2 Impacted by Dynamics
Image Quality and Optical Alignment	PM to AOS alignment	Photogrammetry	Demonstrated capability during OGSE2	No
	PM to AOS alignment (multifield)	Pass and a Half	Demonstrated capability during OGSE 2	mitigated by Hartmann test
	SM to AOS alignment	Photogrammetry	Demonstrated capability during OGSE2	No
	SM to PM optical axis	Photogrammetry	Demonstrated capability during OGSE1 & 2	No
	SM 5 dof (multifield)	Pass and a Half	Demonstrated capability during OGSE 2	mitigated by Hartmann test
	ISIM to AOS alignment	Half Pass imaging & Pupil Alignment	Combines OTRD 360, 361, 362, & 363 results	No
	AOS to ISIM object surface despace	Half Pass imaging	Demonstrated capability during OGSE2, in evaluation	No
	AOS to ISIM object surface decenter	Half Pass imaging	Demonstrated capability during OGSE2, in evaluation	No
	decenter of NIRCcam ap stop to FSM mask	Half Pass, Pupil Alignment	Demonstrated capability during OGSE2, in evaluation	No
	ISIM tilt via entrance pupil & object surface	Half Pass imaging	Demonstrated capability during OGSE2, in evaluation	No
	ISIM object surface clocking	Half Pass imaging	Demonstrated capability during OGSE2, in evaluation	No
	PMSA Cryo Gap	COC PG	Demonstrated during OGSE1 & 2	No, aborted plan to use edge images
Image Quality and WFE	PM RoC	COC, ADM	Demonstrated pieces (ADM, RoC meas'm't)	No
	low freq PM WFE	COC	Demonstrated capability during OGSE1 & 2	No
	mid frequency PM WFE	COC	Demonstrated capability during OGSE1 & 2	No
	PM conic	COC, ADM	Demonstrated capability during OGSE1 & 2	No
	Ambient PMSA WFE / Astigmatism	COC	NA	NA
Image Quality Stability	Thermal Distortion – PM WFE & RoC Change	COC Figure drift of PM over 2.5K DT	Data from OGSE2 in evaluation, looks promising	No
	Thermal Distortion – OTE Alignment Change	Photogrammetry during warm up from cryo	Demonstrated during OGSE1	No
Radiometric Sensitivity	PM to FSM Mask Alignment / Truant Path	Pupil Alignment Test	Demonstrated capability during OGSE2, in evaluation	No
	PM Collection Area	COC (reflection area)	Demonstrated capability during OGSE1 & 2	No
	Vignetting	Pass and a half	Demonstrated capability during OGSE 2	No
	Vignetting	Pass and a half	Demonstrated capability during OGSE 2	No
	Vignetting	SI images with FLAB illumination of SM	Demonstrated capability during OGSE 2	No
WFSC	Plate Scale	Pass and a Half	Demonstrated capability during OGSE 2	No
	WFS&C Demo	Pass and a Half, COC, photogrammetry	Data from OGSE2 in evaluation, looks promising	fine-range piston
	WFS&C Influence Functions	Pass and a Half, COC, photogrammetry	Data from OGSE2 in evaluation, looks promising	No
Functional	Actuator command repeatability	CMUTS	Demonstrated during OGSE1 & 2	No
	PMSA Envelope Control Limit	COC	Demonstrated during OGSE1	No
	WF Control Signal Path (PMSA, SMA motion control sign check test)	COC	Demonstrated capability during OGSE 1 & 2, in evaluation	No
	Fine Guidance Loop	Half Pass, Pass and a Half	OGSE2 demonstrated feasibility with FGS jitter evaluation	No

Thermal Pathfinder Test

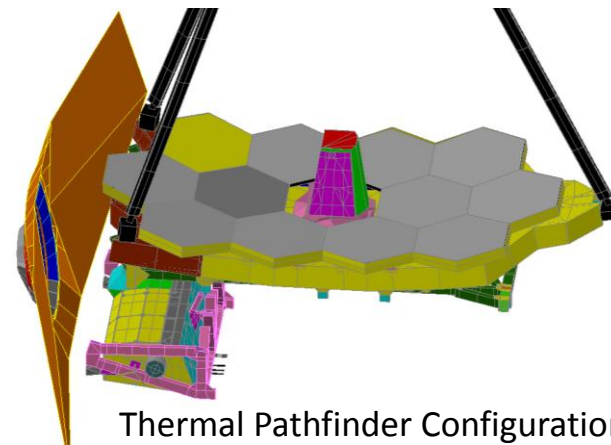


Objectives:

- Verify safety of OTIS transient timeline
 - Execute OTIS cooldown profile showing that OTIS temperature constraints are achievable on the back plane, two Primary Mirrors Segments and secondary mirror assembly.
- Validate operation of key OTIS thermal/GSE cooler components
 - Demonstrate first system functionality of Space Vehicle Thermal Simulator
 - Demonstrate the GSE cryo-cooler operation in the OTIS test configuration and show that parasitic loads are acceptable
- Verify dynamic environment and response of payload
- Thermal Balance of PF with OTIS-like thermal performance – analysis process
- Pre-OTIS thermal personnel training
 - Preparation and In-Test Operation of OTIS-like Thermal Model
 - Thermal Model Correlation with OTIS-like Test Article
 - Exercise/Develop Contingency Procedures

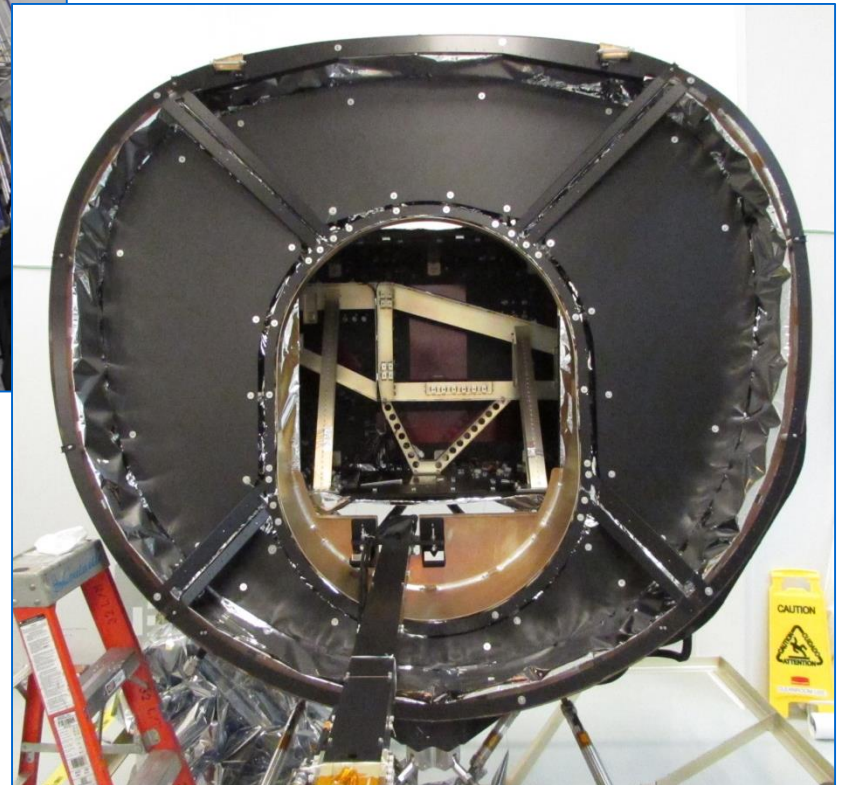
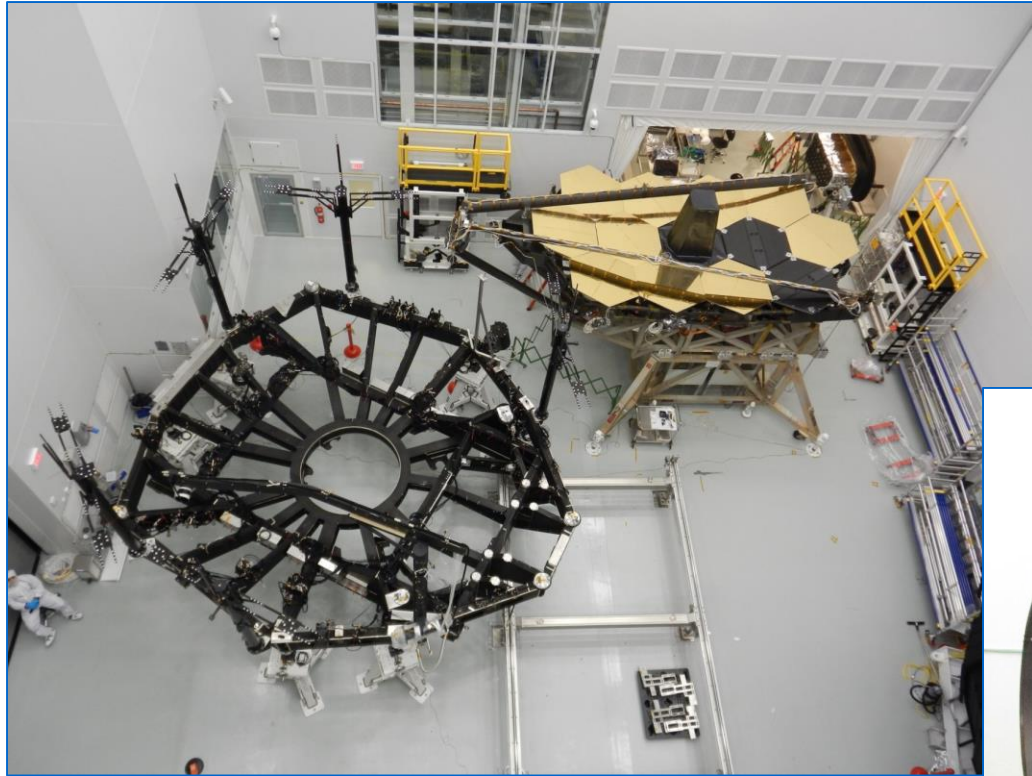
Configuration:

- Pathfinder adds 10 mirror simulators and an AOS simulator, blanketing
- SVTS, IEC simulator, Sun-shield mockup
- Final 2 Auto Collimating Flat's are installed (final test configuration)
- Floating configuration of hanging payload (use of the chamber vibration isolators)
- Pathfinder constraints and limitations maintained throughout test

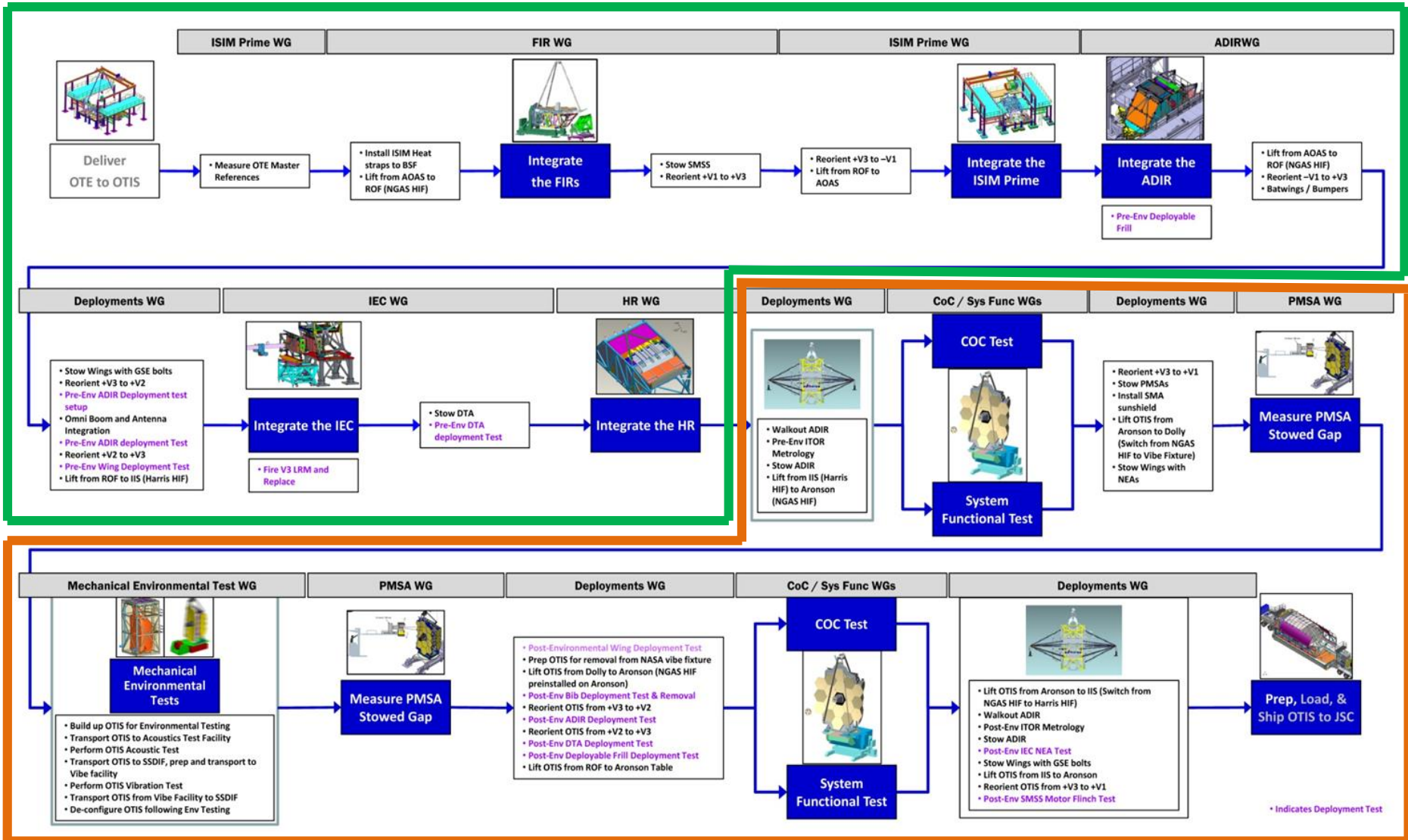


Final Risk Reduction Test provides confidence in Readiness to conduct Flight OTIS Cryo Vac Test

TPF and HOSS in JWST Cleanroom at JSC



OTIS Integration & Test @ GSFC



Pre- and Post- Environmental Tests

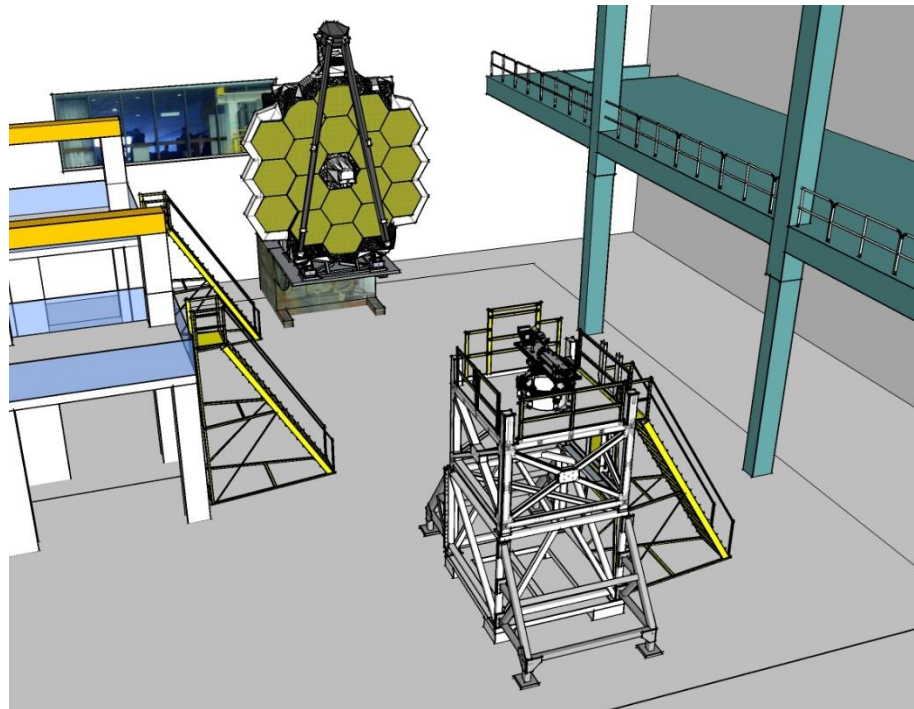


- Tests planned before and after the mechanical environmental tests will verify that no unacceptable changes to the test article have been caused by the environments
- OTIS tests performed before and after mechanical environmental tests
 - System Functional test
 - OTE, ISIM, and OTIS tests performed
 - Deployment Tests
 - Deployable Frill
 - DTA
 - SMSS
 - PMBA Wings
 - ADIR
 - Bib
 - Center of Curvature Test
 - Alignment Checks
 - ISIM
 - SMA
 - AOS
 - PMSA Gap Measurements

OTIS Center of Curvature Test



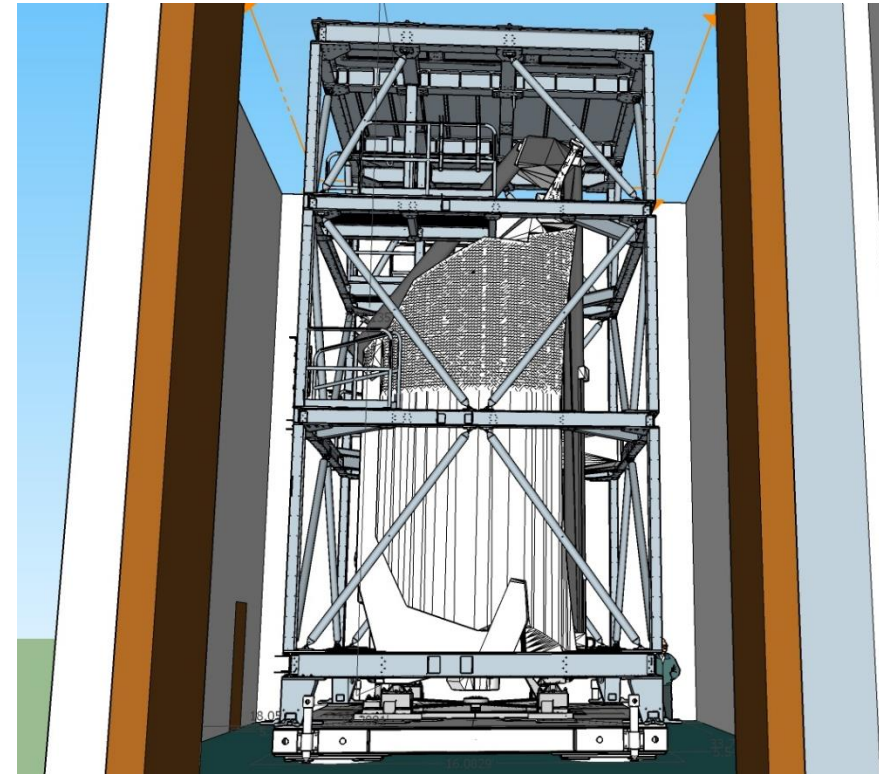
- The OTIS Center-of-Curvature will be performed before and after the acoustic/vibration tests at GSFC.
- The objective of the test is to show that the primary mirror segments (and potentially backplane) are not altered by the OTIS level vibration and acoustic tests occurring at GSFC.
- The interferometer used measures at high speed (6Khz) allowing dynamic measurements for both model crosschecks and additional diagnostics



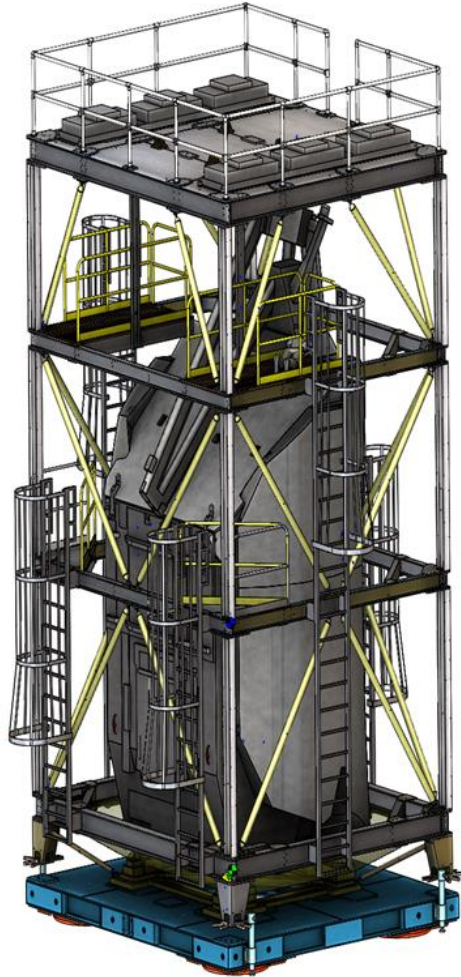
OTIS Acoustic Test Description



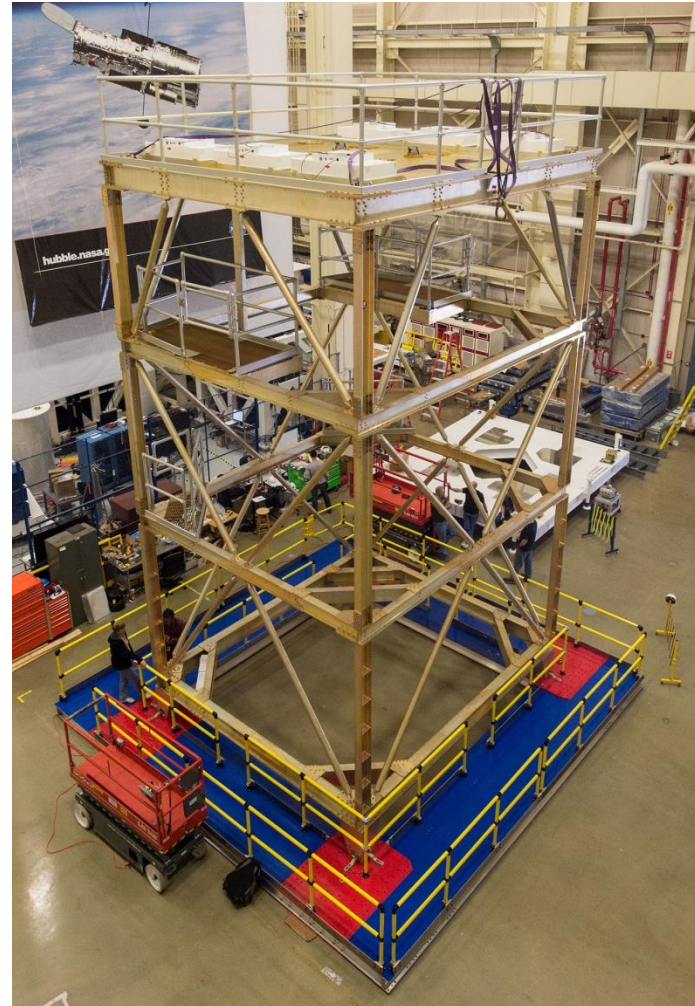
- The OTIS Acoustic Test is a protoflight level test of OTIS in its stowed launch configuration.
- The Building 10 Acoustic Test facility at GSFC is used for this test.
- A tent assembly is used to protect the contamination sensitive test article while it is in the non-clean environment of the acoustic test facility.



Clean Tent and Dolly



Tent on Dolly

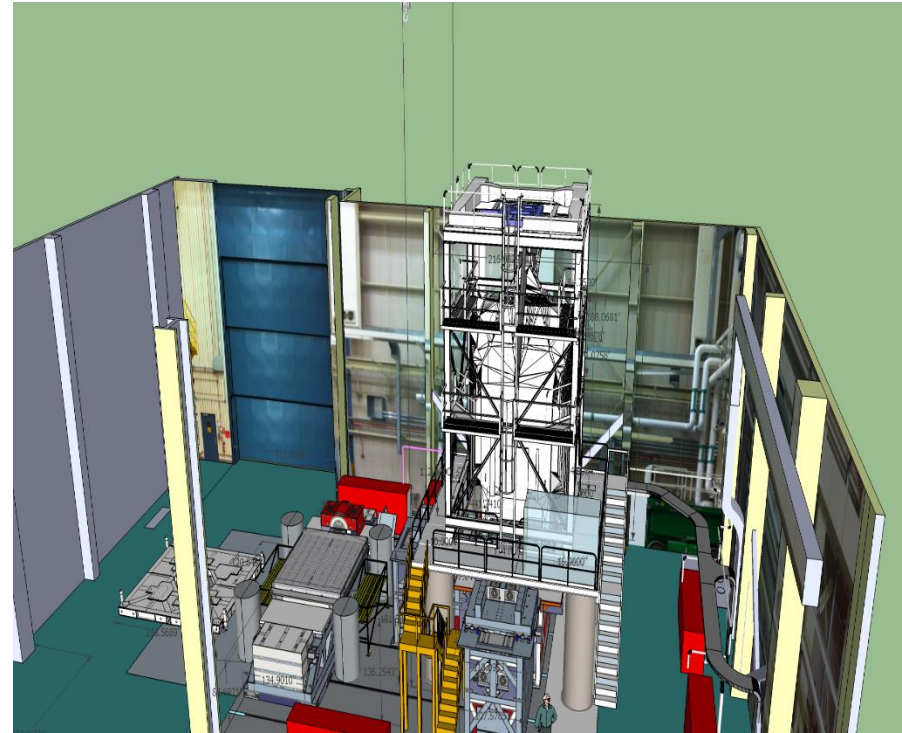


Tent on Work Platform, without ladders

OTIS Vibration Test Description



- The OTIS Vibration Test is a three-axis sinusoidal vibration test is performed with the OTIS in the stowed/launch configuration.
- The sine vibration test level is based on a response spectrum envelope of launch vehicle dynamic events, applied over a band of 5 to 100 Hz
- OTIS remains in the +V3 up configuration while each axis (V1, V2, V3) is tested in this fixed orientation.
- A new vibration test system (VTS) is being installed for this test in the building 29 high bay at GSFC.
- A tent assembly is used to protect the contamination sensitive test article while it is in the non-clean environment of the vibration test facility.



Summary



- OTIS I+T is well underway
- Pathfinder ambient and cryogenic optical testing has been incredibly valuable
- All optical tests have been checked out
- Only outstanding issue are vibration levels. Main impact was to test efficiency so taking a belt and suspender approach to addressing it:
 - Improvements in dynamics to be demonstrated during TPF testing
 - **Switch** to Hartmann type tests for pass and a half tests will make us less sensitive to vibration
- Thermal Pathfinder testing to start in late summer and will check out thermal testing
- Ambient integration will complete in early Fall followed by ambient environmental testing at Goddard
- Cryogenic optical and thermal testing of OTIS on track for 2017 start