James Webb Space Telescope (JWST)
Optical Telescope Element (OTE)
Pathfinder Status and Plans

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MSFC Tech Days

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Contributors:

NGAS, Exelis, ATK, Ball, Sigma, Genesis, GSFC, JSC
The JWST OTE Pathfinder is a partial telescope that is intended to reduce the implementation risk of the assembly, integration, and cryogenic optical test of the JWST optical assembly.

A key goal for the OTE Pathfinder is to allow early checkout of the optical test procedures and test equipment to be used for cryogenic optical testing prior to their use in testing the flight hardware.

The Pathfinder will undergo three basic cryogenic tests:

- Optical Ground Support Equipment 1 (OGSE1)
- Optical Ground Support Equipment 2 (OGSE2)
- Thermal Pathfinder

No flight verification occurs with Pathfinder

The optical and thermal GSE used to test the flight OTIS (Optical Telescope Element + Integrated Science Instrument Module (ISIM)) will be checked out during the Pathfinder testing program.
Pathfinder Overview

- Includes one coated PMSA (A4) and one uncoated PMSA (C4), flight spares
- Secondary Mirror is uncoated, flight spare
- AOS (flight) and ASPA are added only for OGSE2
- All flight optics are complete and in storage
- AOS will be tested with ASPA this fall
Pathfinder with Mirrors Installed
Installed PMSA’s
Pathfinder Deployment
OTIS Flow

GSE & Test Preparations

Facility Functional
Completed Aug 2012

Clean Room
Completed Dec 2013

Install GSE for USF Cryo-Load Test
Perform USF Cryo-Load Test
Inspect GSE, Install HOS for Bakeout
Bakeout Chamber and MGSE
Install GSE w/ 2x OTIS mass sim
OGSE C/O, Comh, HOS, Cryo-Load
Ready for Pathfinder

Pathfinder Risk Reduction Activities

Fall 14

GSE & Test Prep
Receive PF at JSC
OGSE1 Prep
OGSE1 Test
Receive AOS at JSC
OGSE2 Prep
OGSE2 Test
Ship AOS to GSFC
PF Thermal Prep
PF Thermal Test
Ship OTIS Test
JSC Chamber Ready

Flight OTIS I&T

Install Flight ISIM to OTE
Pre Environmental Test
Acoustic & Vibe Tests
Post Environmental Test
Ship OTIS to JSC
Receive OTIS at JSC
OTIS Cryo Prep
OTIS Cryo Test
OTIS Cryo Post-Test
Ship OTIS to NGAS

Legend

Prep & Transport
Functional / Test
Assembly / Integration
Delivery

Acronym

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

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JSC Optical Test Architecture

- Integrated Test Assembly supported from top of chamber with vibration isolation

- Center of Curvature Interferometer for PM WFE
  - Absolute Distance Meter (ADM) for axial distance
  - Alignment cameras for initial capture and setup
  - Displacement Measuring Interferometers (DMI) to monitor axial change during thermal distortion test

- Photogrammetry for position measurements

- Inward and Outward Facing Sources at PM-SM intermediate image for imaging to SI’s
  - Direct to SI’s “Half Pass”
  - End-to-End “Pass and a Half”
    - Autocollimating Flat Mirrors

- Fiducial lights around PM for PM pupil alignment tests
GSE Tested with Pathfinder

Center of Curvature Optical Assembly (COCOA)
- Multiwavelength interferometer (MWIF), null, calibration equipment, coarse/fine PM phasing tools, Displacement Measuring Interferometer – complete, at MSFC

USF Structural Frame – Complete, delivered supports Metrology (COCOA and 3 ACFs).

3 Auto collimating Flat Mirrors (ACFs)
1.5 M Plano for Pass and Half Testing
Last two units in process now.
1 ACF used in OGSE1+2,
Other 2 added after OGSE2

ADM
Updated Model of the ADM to the newest generation, CDA next month

Cryo Position Metrology (CPM)
Photogrammetry System
- First complete system in test

Space Vehicle Thermal Simulator (SVTS)
and Sunshield Simulator
Re-designed to use a GSE cooler and HOSS mounted to improve the interfaces L5 layer reduced

Deep Space Edge Radiation Sink (DSERS)
Frame and interfaces are complete and in fabrication, the actual DSERS panels will be design/built in 2015

Chamber Isolator Units
Dynamically isolates OTIS Optical Test – 6 units delivered to JSC

Mag Damper Cryo Test Article
Mag Dampers are in fabrication at NGAS

HOSS – OTIS support structure
Completed and delivered

AOS Source Plate
Sources for Pass and Half Test
Design in progress to support optical fiber 72 sources
Used only in OGSE2

ADM UPDATED MODEL OF THE ADM TO THE NEWEST GENERATION, CDA NEXT MONTH

USF STRUCTURAL FRAME – COMPLETE, DELIVERED SUPPORTS METROLOGY (COCOA AND 3 ACFS).

3 AUTO COLLIMATING FLAT MIRRORS (ACFS)
1.5 M PLANO FOR PASS AND HALF TESTING
LAST TWO UNITS IN PROCESS NOW.
1 ACF USED IN OGSE1+2,
OTHER 2 ADDED AFTER OGSE2

ADM UPDATED MODEL OF THE ADM TO THE NEWEST GENERATION, CDA NEXT MONTH

CRYO POSITION METROLOGY (CPM)
PHOTOGRAMMETRY SYSTEM
- FIRST COMPLETE SYSTEM IN TEST

SPACE VEHICLE THERMAL SIMULATOR (SVTS)
AND SUNSHIELD SIMULATOR
RE-DESIGNED TO USE A GSE COOLER AND HOSS MOUNTED TO IMPROVE THE INTERFACES L5 LAYER REDUCED

DEEP SPACE EDGE RADIATION SINK (DSERS)
FRAME AND INTERFACES ARE COMPLETE AND IN FABRICATION, THE ACTUAL DSERS PANELS WILL BE DESIGN/BUILT IN 2015

CHAMBER ISOLATOR UNITS
DYNAMICALY ISOLATES OTIS OPTICAL TEST – 6 UNITS DELIVERED TO JSC

NATIONAL SPACE SIMULATION CENTER
NASA.png

CENTER OF CURVATURE OPTICAL ASSEMBLY (COCOA)
- MULTIWAVELENGTH INTERFEROMETER (MWIF), NULL, CALIBRATION EQUIPMENT, COARSE/FINE PM PHASING TOOLS, DISPLACEMENT MEASURING INTERFEROMETER – COMPLETE, AT MSFC
Commissioning Test

- Commissioning of the test is ongoing right now
- Helium system run with mass simulator for cryo proof
- Cryo optical testing includes cryo photogrammetry, cryo fiber optic throughput, cryo ACF and testing of Center of Curvature Object Assembly (COCOA) pressure tight enclosure
Beam Image Analyzer (BIA) is a near copy of the successful system use to test the OSIM simulator (detector faces up)

- Includes IR camera (HgCdTe), stages, pupil imaging for ASPA checkout with one ACF
- Room temperature detector inserted for ambient testing
- Will perform cryo calibration of detector location with PG during OGSE1
- Used to test ASPA sources during OGSE2 (simulates ISIM)
OGSE1

- Checks out key Optical GSE: Center of Curvature Object Assembly (COCOA), Photogrammetry (PG), Hanging Configuration
- Includes mass simulator of AOS to cryo proof the Pathfinder AOS interface (AOS and ASPA are not on for OGSE1)
- Includes Beam Image Analyzer for Calibration with PG
- Piston Sensors used for Thermal Distortion testing w/COCOA
- Allows for dynamics checkout (ambient and cryo) using a combination of optical and accelerometer data
AOS Source Plate Assembly (ASPA)

- AOS is installed on Pathfinder at JSC after OGSE1 is complete, ASPA is installed on AOS

- AOS Source Plate Assembly provides downward and upward infrared sources
  - Fiber fed except for MIR sources (uses MEMS MIR sources)
  - Sources can illuminate downward into AOS
  - Sources can illuminate upward to ACF’s
  - Except for MIR, sources are supplied by externally accessible light sources
ASPA End View
ASPA on AOS
OGSE2

- Includes AOS, ASPA, Beam image Analyzer
- First vertical orientation of AOS
- Ambient metrology crosschecks the AOS gravity and crosschecks between photogrammetry and ambient laser trackers
- Will practice OTIS level testing of OTE+ISIM as much as possible
- OGSE2 allows us to check out any issues that came up during OGSE1 that required mitigations
Thermal Pathfinder Test

Objectives:

- **Verify safety of OTIS transient timeline**
  - Execute OTIS cooldown and warmup profiles with PMSA sensors

- **Dry run of key OTIS thermal/GSE cooler components**
  - First system checkout of SVTS
  - JSC checkout of GSE Cryocooler for MIRI instrument

- **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

Configuration:

- Pathfinder adds mirror and AOS simulators, MLI closeouts

- SVTS, IEC simulator

- Follows OTIS cooldown and warmup timeline and approaches

- Final 2 ACF’s are installed (final test configuration)
# Pathfinder Testing

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test</th>
<th>Optical Test Equipment</th>
<th>Pathfinder Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiometric Sensitivity</td>
<td>PM Collection Area</td>
<td>COCOA (reflection area)</td>
<td>With 2 PMSAs</td>
</tr>
<tr>
<td></td>
<td>Vignetting</td>
<td>Pass and a Half</td>
<td>With BIA</td>
</tr>
<tr>
<td></td>
<td>Pupil Alignment / Truant Path</td>
<td>Fiducial lights</td>
<td>With 2 PMSAs &amp; BIA</td>
</tr>
<tr>
<td>WFSC</td>
<td>Plate Scale</td>
<td>Pass and a Half</td>
<td>With BIA</td>
</tr>
<tr>
<td></td>
<td>(tilt of single ACF &amp; NIRCam)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WFS&amp;C Demo</td>
<td>Pass and a Half, COCOA, photogrammetry</td>
<td>With 2 PMSAs, SMA &amp; BIA</td>
</tr>
<tr>
<td></td>
<td>WFS&amp;C Influence Functions</td>
<td>Pass and a Half, COCOA, photogrammetry</td>
<td>With 2 PMSAs, SMA &amp; BIA</td>
</tr>
<tr>
<td>Functional</td>
<td>PMSA Envelope Control Limit</td>
<td>COCOA</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>WF Control Signal Path</td>
<td>COCOA</td>
<td>With 2 PMSAs &amp; SMA</td>
</tr>
<tr>
<td></td>
<td>(PMSA, SMA motion control sign check test)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fine Guidance Loop</td>
<td>Half Pass, Pass and a Half</td>
<td>Partial (no FGS)</td>
</tr>
<tr>
<td>Image Quality</td>
<td>PM to AOS alignment</td>
<td>Photogrammetry</td>
<td>With 1 PMSA</td>
</tr>
<tr>
<td></td>
<td>SMA to AOS alignment</td>
<td>Photogrammetry</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>ISIM to AOS alignment</td>
<td>Half Pass, Fiducial Lights</td>
<td>With BIA</td>
</tr>
<tr>
<td></td>
<td>PM RoC</td>
<td>COCOA, ADM</td>
<td>Partial</td>
</tr>
<tr>
<td></td>
<td>low freq PM WFE</td>
<td>COCOA</td>
<td>With 2 PMSAs</td>
</tr>
<tr>
<td></td>
<td>mid frequency PM WFE</td>
<td>COCOA</td>
<td>With 2 PMSAs</td>
</tr>
<tr>
<td></td>
<td>PM conic</td>
<td>COCOA, ADM</td>
<td>With 2 PMSAs</td>
</tr>
<tr>
<td></td>
<td>Ambient PMSA WFE</td>
<td>COCOA</td>
<td>With 2 PMSAs</td>
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<tr>
<td></td>
<td>Multi-field PSF (single ACF aperture, each SI)</td>
<td>Pass and a Half</td>
<td>With BIA</td>
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<td>SI FOV Survey</td>
<td>Pass and a Half</td>
<td>With BIA</td>
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<tr>
<td>Image Quality Stability</td>
<td>Thermal Distortion: PM WFE &amp; RoC Change (Figure drift of PM over temp change)</td>
<td>COCOA</td>
<td>With 2 PMSAs</td>
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<tr>
<td></td>
<td>Thermal Distortion: Alignment Change (SMA alignment drift over temp change during warm up from cryo test temp)</td>
<td>Photogrammetry</td>
<td>Yes</td>
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</table>
Summary

- The Pathfinder is built and aligned, final sensors are being installed
  - Will ship to JSC in February
- Commissioning testing at JSC has begun, the first Pathfinder test begins in Spring 2015
  - Huge amount of learning both in terms of operations and GSE performance
- Two optical oriented Pathfinder tests and a thermal Pathfinder test is planned prior to the flight OTIS test
- Once Pathfinder testing is complete, we will have done everything feasible to check out the system to be confident the flight OTIS test will go smoothly