JWST telescope integration and test progress

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OTIS AI&T Status

- **Telescope Test Activities**
  - Optical Telescope Element (OTE) and OTE/ISIM (OTIS) integration will occur at GSFC in the large SSDIF clean room
  - Most of OTE Optical Ground Support Equipment (OGSE) has been completed and was used for Pathfinder integration operations

- **Pathfinder OGSE Test Program**
  - A series of three cryo tests planned prior to the flight that increase in complexity and designed to cover all aspects of the flight test program
    - CCT – Chamber Commissioning with the OGSE installed - Complete
    - OGSE#1 – Center of Curvature and Dynamic Testing - Complete
    - OGSE#2 – Half Pass and Pass and a Half Testing
    - Thermal Pathfinder (TPF) – OTIS Thermal Simulation

- **Optical Telescope Element (OTE) Integration**
  - Optical integration of the flight OTE scheduled for Fall 2015
This document is not subject to the controls of the International Traffic in Arms Regulations (ITAR) or the Export Administration Regulations (EAR).
Work continues at JSC to prepare for the OTIS cryo test

First series of tests were optical based tests
   – Check out of the optical ground support equipment
   – Increasing complexity for the optical equipment

Excellent optical results with many lessons learned
Three, 1.5m Auto-Collimating Flats (ACF)

Isolators (6 units)

PG Systems (4 units)

Telescope Rods (6 units)

OTIS

Center of Curvature Optical Assembly (COCOA)

Downrods (6 units)

LN2 Outer Shroud

Space Vehicle Thermal Simulator (SVTS) – Ready for Thermal PF

GHe Shroud

Deep Space Edge Radiation Sinks (DSERS)

Upper Support Frame (USF)

Telescope Rods (6 units)

OTIS

Hardpoint/Offloader Support Structure (HOSS)
OGSE Test Program

- Checkout Optical GSE that has not seen cryo before: CoC test, Hanging Config, Photogrammetry
- No flight hardware except flight spare PMSA/SMA
- Dynamics and Thermal Distortion portion of PF Augmentation occur here

OGSE-1
Complete

OGSE-2
Complete

Pathfinder Thermal
PF Updated to be more Flight Like

- Checkout Pass and a half test with flight AOS and GSE source plate system
- Uses BIA camera as SI simulator

- Thermal GSE Checkout (includes SVTS)
- Dry run cooldown and warmup
- Will allow risk reduction of some OTE Thermal Balance (design validation off the critical path)
Chamber Configuration for CCT

- Isolators
- Downrods
- COCOA
- USF
- ACF
- PG Systems
- Telescope Rods
- OTIS 2X Mass Sim
- HOSS
## Range of Motion

- Range of COCOA and ACF actuation systems

<table>
<thead>
<tr>
<th>COCOA</th>
<th>V1 (mm)</th>
<th>V2 (mm)</th>
<th>V3 (mm)</th>
<th>RV1 (urad)</th>
<th>RV2 (urad)</th>
<th>RV3 (urad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>+/- 24.6</td>
<td>+/- 32</td>
<td>+/- 32</td>
<td>N/A</td>
<td>+/-5.6</td>
<td>+/-5.6</td>
</tr>
<tr>
<td>Cryo Position (margin)</td>
<td>-7.4 (70%)</td>
<td>7.2 (76%)</td>
<td>0.4 (98%)</td>
<td>-0.6</td>
<td>0.5 (92%)</td>
<td>-0.5 (90%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ACF</th>
<th>Decenter (mm)</th>
<th>Tilt (mrad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>N/A</td>
<td>10.8</td>
</tr>
<tr>
<td>Cryo Position (margin)</td>
<td>N/A</td>
<td>0.15 (99%)</td>
</tr>
</tbody>
</table>
## Photogrammetry Accuracy

<table>
<thead>
<tr>
<th>Hardware Component</th>
<th>Measurement Direction</th>
<th>Requirement</th>
<th>Measured Value</th>
<th>Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM to AOS</td>
<td>Piston</td>
<td>0.1mm</td>
<td>0.04mm</td>
<td>62%</td>
</tr>
<tr>
<td></td>
<td>Decenter</td>
<td>0.1mm</td>
<td>0.08mm</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>Tilt</td>
<td>0.15mrad</td>
<td>0.09mrad</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td>Clocking</td>
<td>1.0mrad</td>
<td>0.31mrad</td>
<td>69%</td>
</tr>
<tr>
<td>SM to AOS</td>
<td>Piston</td>
<td>0.15mm</td>
<td>0.08mm</td>
<td>43%</td>
</tr>
<tr>
<td></td>
<td>Decenter</td>
<td>1.25mm</td>
<td>0.65mm</td>
<td>48%</td>
</tr>
<tr>
<td></td>
<td>Tilt</td>
<td>0.335mrad</td>
<td>0.27mrad</td>
<td>24%</td>
</tr>
</tbody>
</table>
## Typical PG Accuracies

<table>
<thead>
<tr>
<th></th>
<th>$2\sigma$ M1 (mm)</th>
<th>$2\sigma$ M2 (mm)</th>
<th>$2\sigma$ M3 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACF</td>
<td>0.040</td>
<td>0.067</td>
<td>0.124</td>
</tr>
<tr>
<td>SM</td>
<td>0.034</td>
<td>0.020</td>
<td>0.058</td>
</tr>
<tr>
<td>ASPA Support Arm</td>
<td>0.047</td>
<td>0.021</td>
<td>0.022</td>
</tr>
<tr>
<td>ASPA</td>
<td>0.021</td>
<td>0.007</td>
<td>0.008</td>
</tr>
<tr>
<td>AOS Base</td>
<td>0.020</td>
<td>0.015</td>
<td>0.013</td>
</tr>
<tr>
<td>PM</td>
<td>0.023</td>
<td>0.010</td>
<td>0.014</td>
</tr>
<tr>
<td>Strut Base</td>
<td>0.116</td>
<td>0.024</td>
<td>0.053</td>
</tr>
</tbody>
</table>
PMSA Figure Error

Measured (165 nm-rms)  Model Predict (161 nm-rms)  Difference (31 nm-rms)
Inward Source Light Path

ASPA Inward Source

FSM

TMA

Image of ASPA Inward Source
## ASPA Image Location

### Difference between Best Image Location and Predicted Location

<table>
<thead>
<tr>
<th>Instrument FOV</th>
<th>ASPA Source Designation</th>
<th>dM1 (mm)</th>
<th>dM2 (mm)</th>
<th>dM3 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIRCamB</td>
<td>I-1</td>
<td>0.987</td>
<td>0.137</td>
<td>-0.120</td>
</tr>
<tr>
<td>NIRCamB</td>
<td>I-3</td>
<td>0.578</td>
<td>0.055</td>
<td>-0.395</td>
</tr>
<tr>
<td>NIRCamB</td>
<td>I-4</td>
<td>0.792</td>
<td>0.168</td>
<td>0.127</td>
</tr>
<tr>
<td>NIRCamA</td>
<td>I-5</td>
<td>0.784</td>
<td>0.327</td>
<td>-0.151</td>
</tr>
<tr>
<td>NIRCamA</td>
<td>I-6</td>
<td>0.749</td>
<td>-0.176</td>
<td>-0.192</td>
</tr>
<tr>
<td>FGS1</td>
<td>I-7</td>
<td>0.579</td>
<td>0.030</td>
<td>-0.204</td>
</tr>
<tr>
<td>FGS1</td>
<td>I-8</td>
<td>0.531</td>
<td>0.013</td>
<td>-0.176</td>
</tr>
<tr>
<td>FGS1</td>
<td>I-9</td>
<td>0.167</td>
<td>0.099</td>
<td>-0.215</td>
</tr>
<tr>
<td>FGS2</td>
<td>I-11</td>
<td>0.946</td>
<td>0.060</td>
<td>-0.092</td>
</tr>
<tr>
<td>FGS2</td>
<td>I-13</td>
<td>0.870</td>
<td>0.069</td>
<td>-0.094</td>
</tr>
<tr>
<td>NIRISS</td>
<td>I-15</td>
<td>-0.129</td>
<td>0.051</td>
<td>-0.267</td>
</tr>
<tr>
<td>NIRISS</td>
<td>I-16</td>
<td>0.084</td>
<td>0.074</td>
<td>-0.188</td>
</tr>
<tr>
<td>MIRI</td>
<td>I-23</td>
<td>0.013</td>
<td>0.195</td>
<td>0.135</td>
</tr>
<tr>
<td>MIRI</td>
<td>I-24</td>
<td>-0.217</td>
<td>0.108</td>
<td>-0.385</td>
</tr>
<tr>
<td>NIRSPEC</td>
<td>I-25</td>
<td>0.265</td>
<td>0.102</td>
<td>-0.191</td>
</tr>
<tr>
<td>NIRSPEC</td>
<td>I-26</td>
<td>-0.035</td>
<td>0.094</td>
<td>-0.247</td>
</tr>
</tbody>
</table>

**Average**

<table>
<thead>
<tr>
<th>dM1 (mm)</th>
<th>dM2 (mm)</th>
<th>dM3 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.435</td>
<td>0.088</td>
<td>-0.166</td>
</tr>
</tbody>
</table>

**Standard Deviation**

<table>
<thead>
<tr>
<th>dM1 (mm)</th>
<th>dM2 (mm)</th>
<th>dM3 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.410</td>
<td>0.103</td>
<td>0.144</td>
</tr>
</tbody>
</table>

**Range**

<table>
<thead>
<tr>
<th>dM1 (mm)</th>
<th>dM2 (mm)</th>
<th>dM3 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.204</td>
<td>0.503</td>
<td>0.530</td>
</tr>
</tbody>
</table>
### Fid Light Bar Performance

**FSM Mask Projection**

**Linear LED Arrays**

<table>
<thead>
<tr>
<th>Bar</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Last visible LED</td>
<td>20</td>
<td>18</td>
<td>21</td>
<td>17</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>Actual last visible LED</td>
<td>19</td>
<td>18</td>
<td>22</td>
<td>18</td>
<td>13</td>
<td>17</td>
</tr>
</tbody>
</table>
Thermal Pathfinder (TPF) Test

- Final test prior to OTIS is thermally focused
  - How does the system cool down with an OTIS simulator

- Incorporation of all the thermal hardware
  - DSERS
  - SVTS
  - Zero-Q heaters
  - Actively cooled ACF’s due to “no He gas” for the OTIS test
HOSS Thermal Configuration
TPF Pathfinder Configuration

- SMMS
- PMSA
- AOS Geo Sim
- PMBs
- HOSS
- SVTS
- DTA Stub
- PMBSS
- IEC-Frame (DSS)
- IEC
- IEC Vent Duct
- OTIS DSERs
Summary

- The first of three Optical Ground Support Equipment and Thermal Tests is complete

- Test results have been excellent
  - COCOA works as designed
    - The two PMSA’s were phased
  - PG system is fully operational
  - Isolation system worked as designed
    - Short during cryo temperatures identified and will be corrected prior to OGSE#2

- Pathfinder has been very important and enables the flight program
  - Provides critical experience in preparation for the critical path flight program
  - Well worth the investment by the program