Performance of the Primary Mirror Center-of-Curvature Optical Metrology System during Cryogenic Testing of the JWST Pathfinder Telescope

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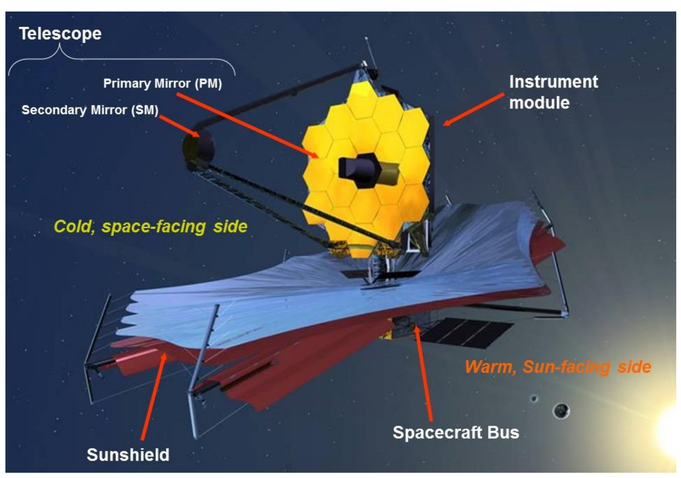
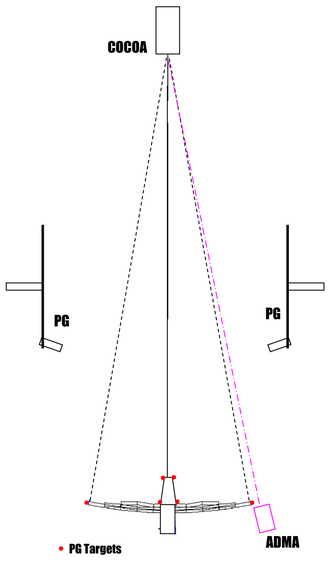
Introduction

The JWST primary mirror consists of 18 1.5 m hexagonal segments, each with 6-DoF & RoC adjustment. The telescope will be tested at its cryogenic operating temperature at Johnson Space Center. The testing will include center-of-curvature measurements of the PM, using the Center-of-Curvature Optical Assembly (COCOA) and the Absolute Distance Meter Assembly (ADMA). The performance of these metrology systems, including hardware, software, & procedures, was assessed during two cryogenic tests at JSC, using the JWST Pathfinder telescope. This paper describes the test setup, the testing performed, and the resulting metrology system performance.

JWST

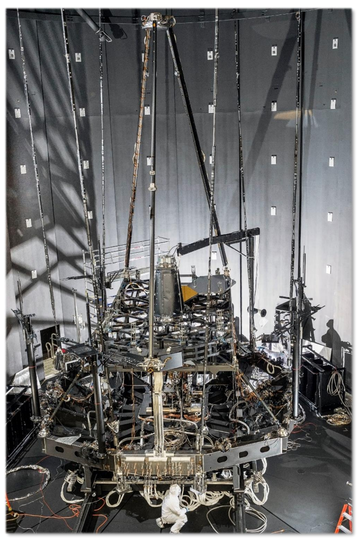


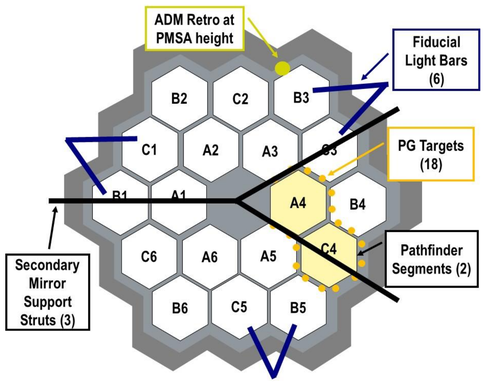
Telescope Cryogenic Test



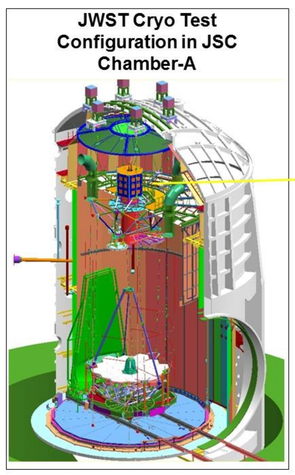
- **Photogrammetry (PG) system for global PM position.**
- **Center-of-curvature optical assembly (COCOA) for segment alignment & PM WFE measurement.**
  - Alignment cameras for initial capture.
  - Multi-wavelength interferometer (MWIF) for phasing of segments from mm to nm.
  - Reflective null to generate PM wavefront.
  - Computer-generated-hologram (CGH) for interferometer/null WFE calibration.
- **Absolute distance meter assembly (ADMA) for axial PM-to-COCOA distance.**

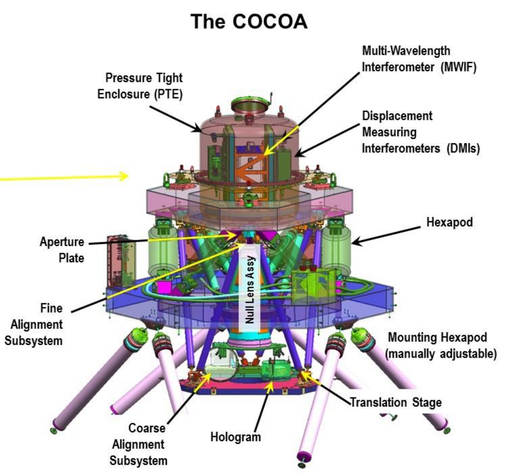
Pathfinder Telescope





The COCOA

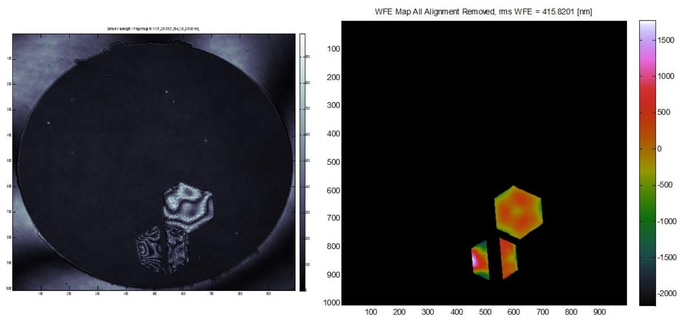




Goals of Pathfinder Testing

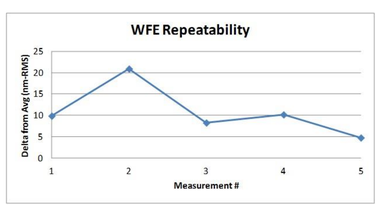
- Operate optical metrology systems in flight telescope test environment.
- Complete commissioning, characterization, & stress testing of COCOA, ADMA, & PG.
- **Demonstrate COCOA & ADMA ability to align & phase PMSA's and measure PM WFE.**
- **Demonstrate PG ability to globally align PM.** ***See reference 5.***
- **Quantify performance of optical metrology systems.**
- Confirm/update procedures, software, & analyses.
- Increase test team experience.

Alignment & Phasing of PMSA's

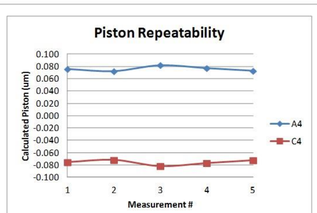


Successfully aligned & phased PMSA's from 160,000 nm-PV down to 32 nm-PV in piston.

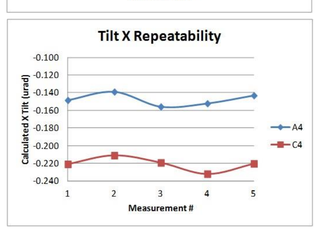
PM WFE Measurement Repeatability



- **RMS precision for measured PM WFE of 11 nm-rms.**



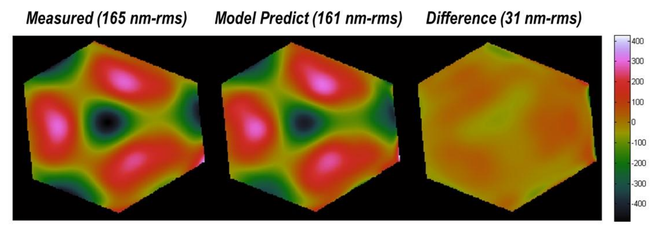
- **Variation of measured segment piston of 7 nm-rms.**



- **Variation of measured segment tilt of 7 nrad-rms.**
- **All results within error budget allotments.**

Measured vs Predicted WFE

Measured WFE of segment A4 compared to prediction from opto-mechanical model, generated using previous cryogenic measurement of A4 and vertical gravity deformation from structural model. Alignment aberrations removed, optimized for lateral alignment & scale, and 136-term Zernike fit applied to reduce high-frequency noise.



Difference of 31 nm-rms consistent with estimated combined measurement/predict uncertainty of 30 nm-rms.

ADMA Performance

- Cross-check of ADMA performance carried out using laser tracker measurements at atmosphere.
  - **ADMA & laser tracker measurements agreed to 96 um, against requirement of 120 um.**
- System repeatability at vacuum well within expected values.
  - **PMSA Target 2σ repeatability of 2 um**
  - **COCOA Target 2σ repeatability of 23 um**
- Successfully demonstrated functionality at vacuum & cryo.

Summary & Conclusions

- Demonstrated that PM center-of-curvature optical metrology system meets all of the test requirements required for the flight telescope test.
- Greatly improved procedures, software, & analyses.
- Test team gained invaluable experience.
- One further Pathfinder test, the Thermal Pathfinder Test, will provide an opportunity for a final check of the hardware, procedures, and data analysis tools.
- **The knowledge gained and the lessons learned during the Pathfinder testing will be of great benefit to the accurate & efficient cryogenic testing of the JWST flight telescope.**

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