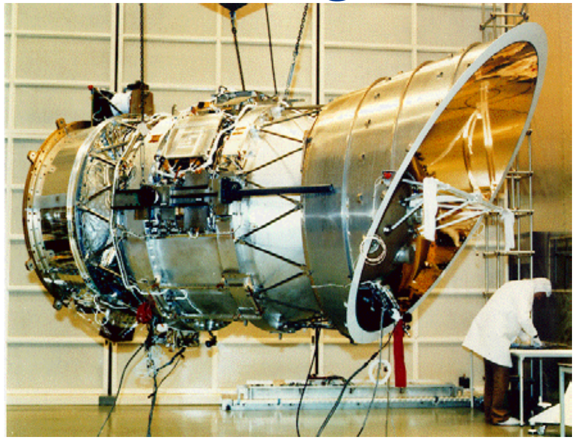
James Webb Space Telescope

Beryllium AMSD Technology

MSFC Tech Days Briefing
September 16, 2003
Ball Aerospace & Technologies Corp.

Beryllium Primary Mirrors Have a Long Heritage Associated with NASA Programs

NORTHROP GRUMMAN Space Technology



IRAS

NASA's First Large Aperture Cryogenic Infrared Space Telescope Beryllium Primary Mirror

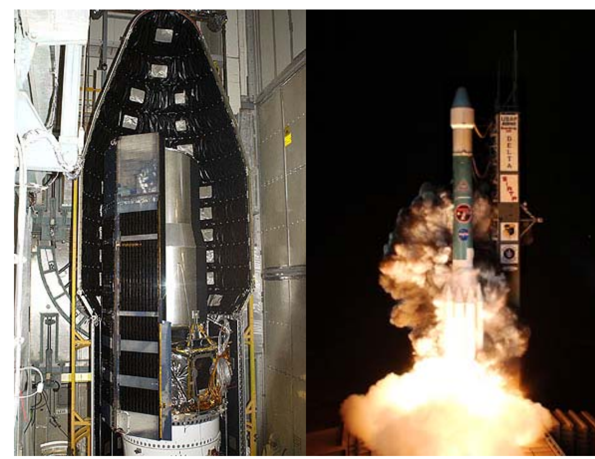
JWST

NASA's Third Large Aperture Infrared Space Telescope Beryllium Primary Mirror

IRAS Launch, January 26, 1983

SIRTF

NASA's Second Large Aperture Cryogenic Infrared Space Telescope Beryllium Primary Mirror



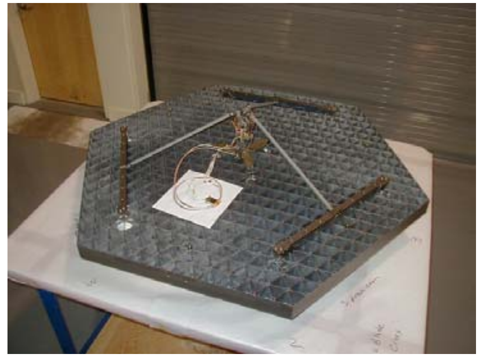
SIRTF Launch, August 24, 2003

Overview of Ball's Beryllium AMSD Design

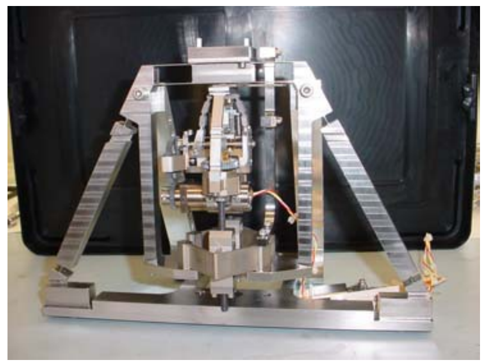
- 1.39 m point-to-point light-weighted beryllium semi-rigid mirror
- 10.3 kg/m2 beryllium substrate areal density
- 15.6 kg/m2 areal density for mirror system including mirror, reaction structure, flexures, actuators
- Optical and physical characteristics traceable to JWST
- Benefits from "lessons-learned" on Sub-scale Beryllium Mirror Demonstrator (SBMD), which achieved 19 nm, rms, surface at 38K
- Figure (RoC) Control and Rigid Body Motion Control

BATC's AMSD-II Beryllium Mirror System Includes RoC and Rigid Body Control

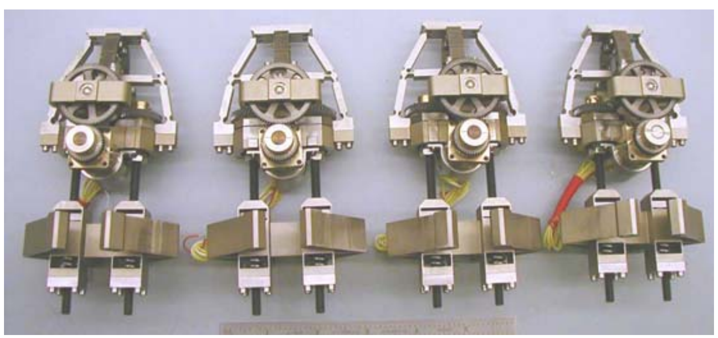
Machined beryllium mirror blank with 10.8 kg/m^2 areal density



Load Spreaders, Tripod and RoC Strongback

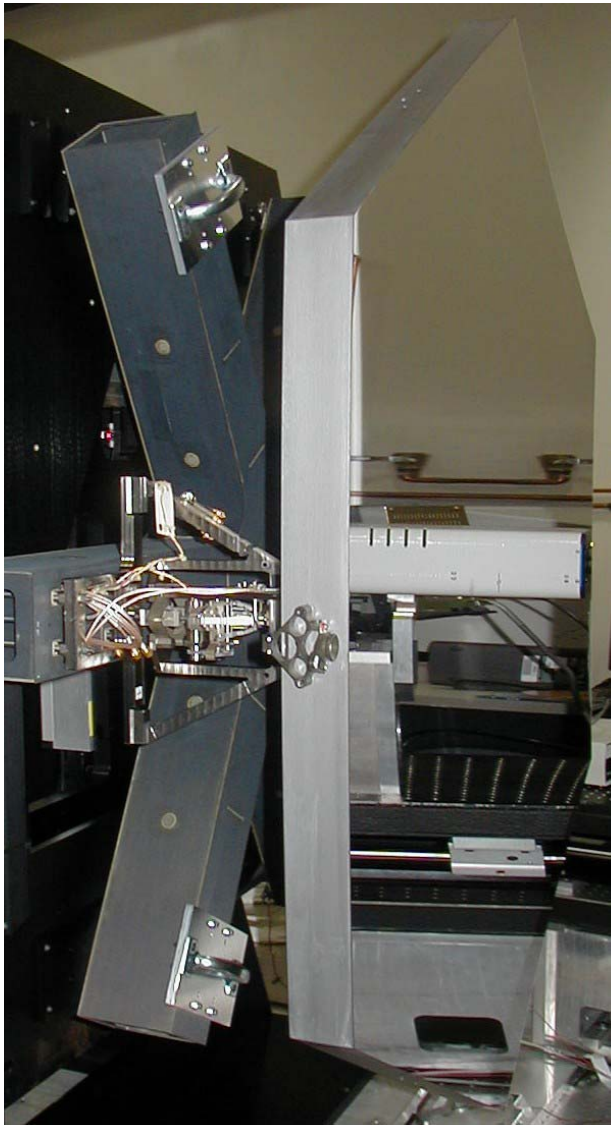


Actuator with Caging Device



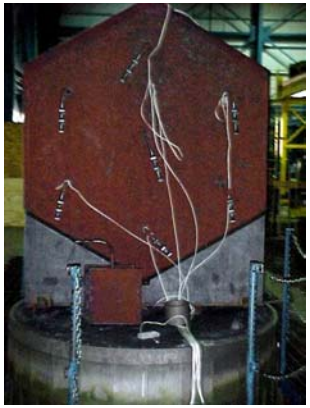
RoC and rigid body control actuators with 10 nm step size

Graphite Composite Reaction Structure



Fully Integrated AMSD Beryllium Mirror System

Beryllium HIP Processing at Brush Wellman Inc.



Loaded HIP Can

Protective Cover

Clearance between HIP can And protective cover

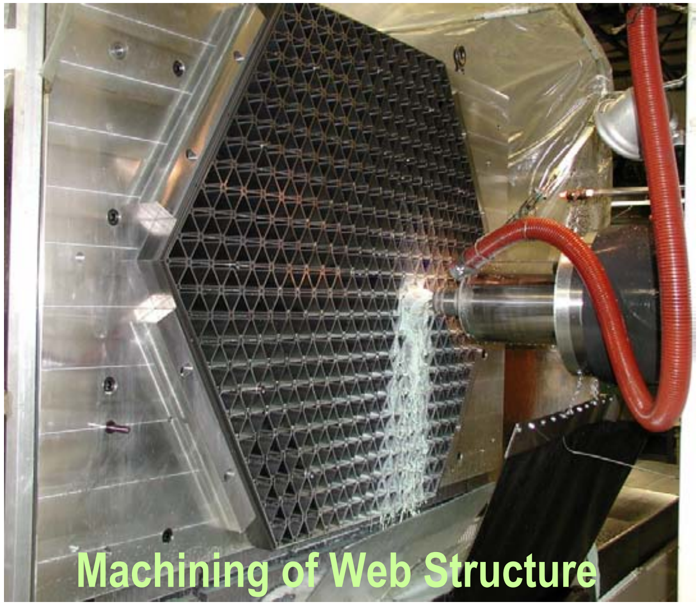
HIP Vessel being loading into chamber

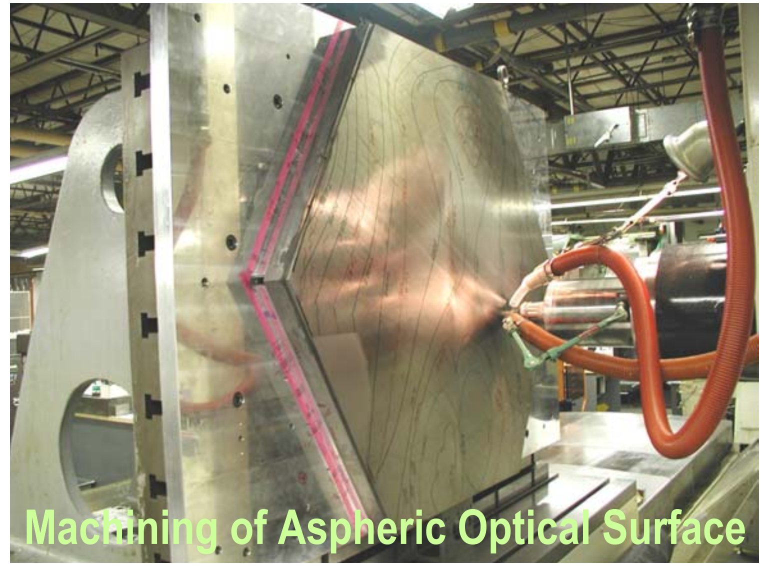
Thermal vacuum chamber

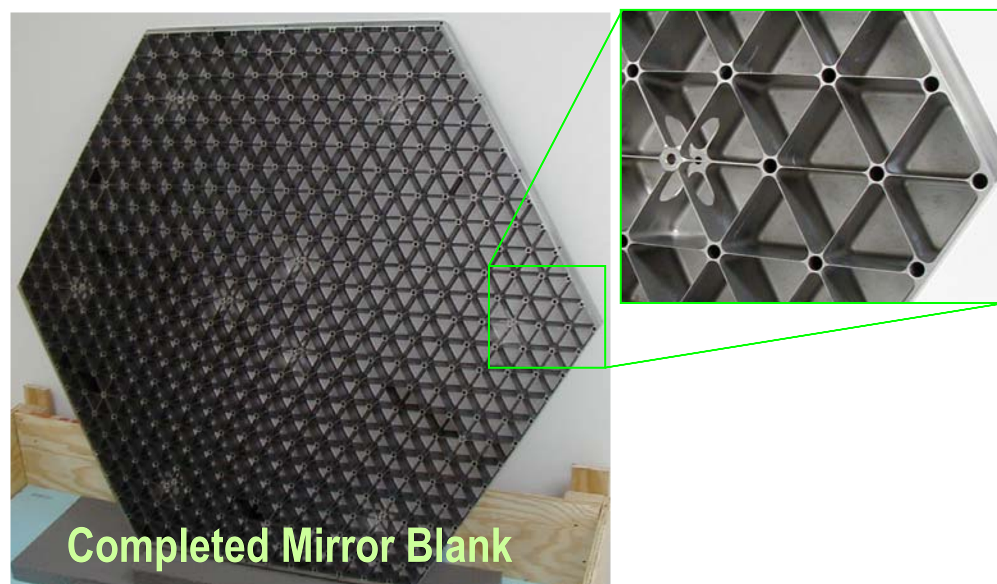
HIPed Blank inside protective cover

What Comes out, before machining

Beryllium Mirror Machining Process at Axsys Technologies

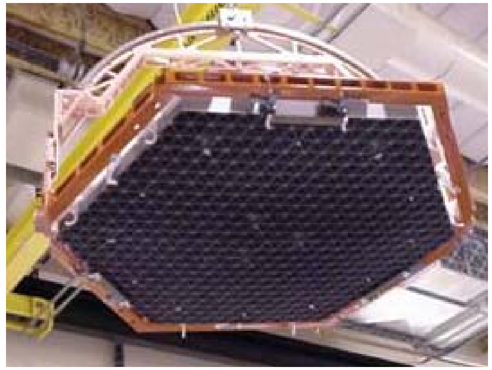






AMSD Mirror In-Process Optical Processing At SSG-Tinsley

Incoming Inspection

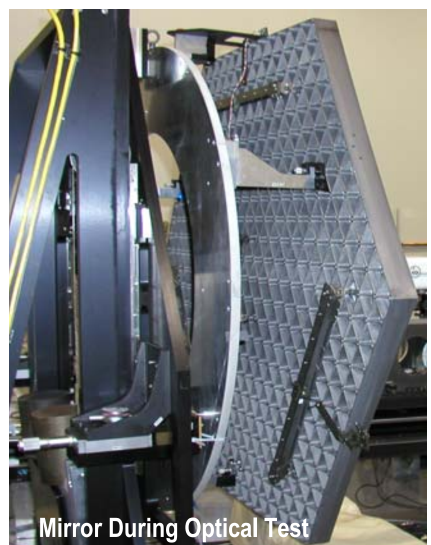


Lifting Fixture

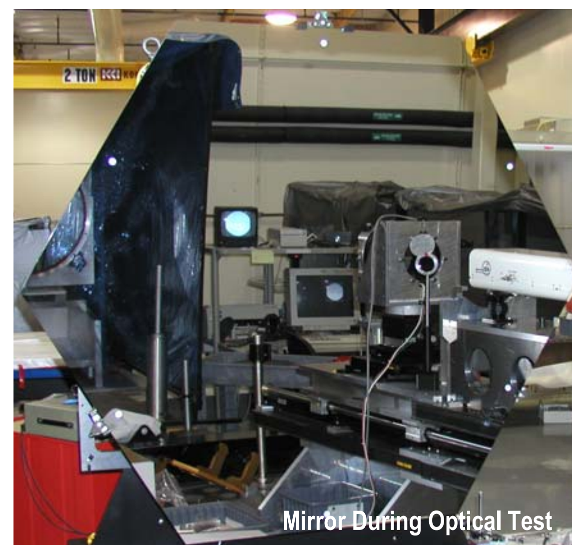
CCOS Polishing Machine

Mirror Ready for Profilometer Test

Mirror mount integration and fit-check

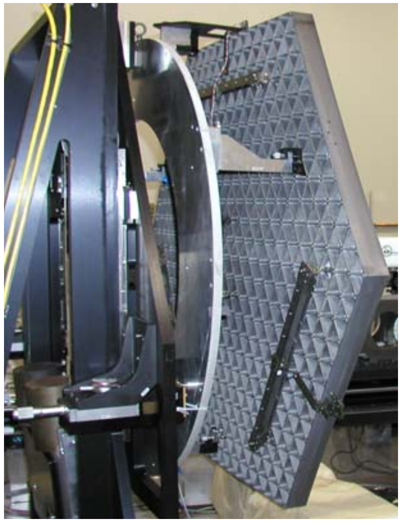


Mirror During Optical Test



Mirror During Optical Test

System Integration & Cryogenic Test at NASA Marshal Space Flight Center



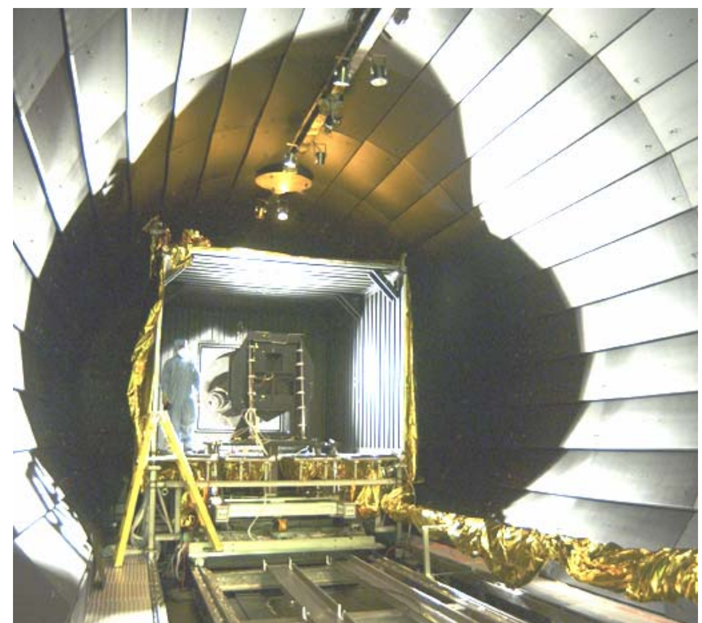
Segment Level Optical Testing

RoC Strongback Integration

Optical testing with RoC Strongback and Actuator Attached

System Integration

Ambient Optical Test

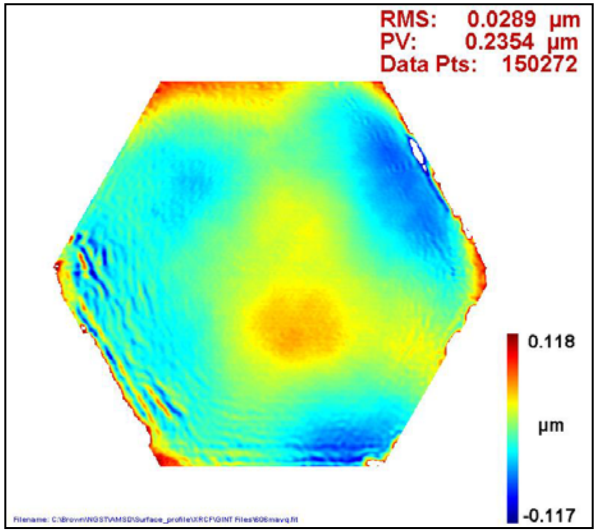


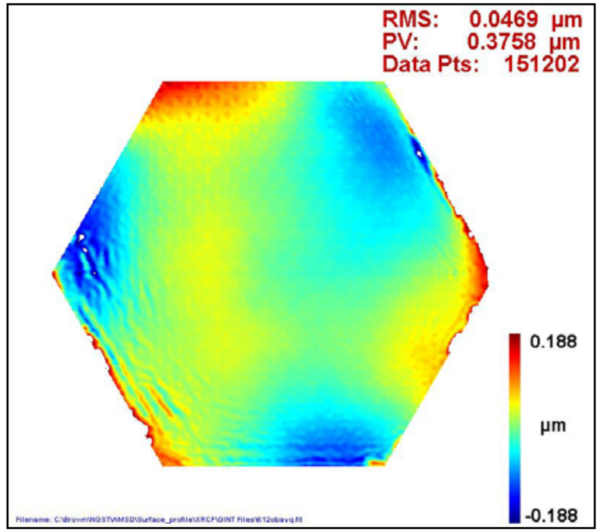
Cryogenic Optical Test

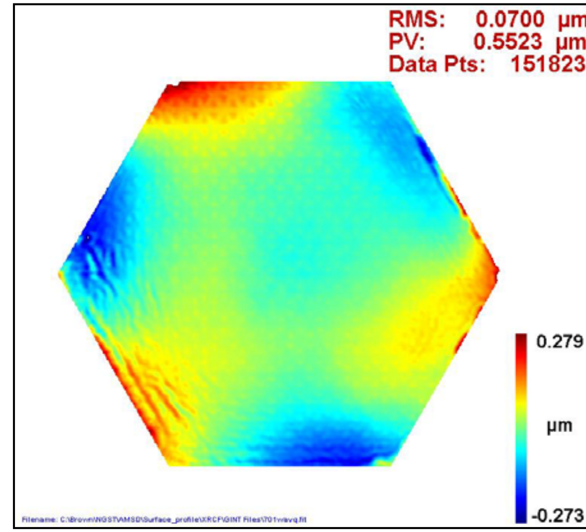
AMSD Performance Summary

Ambient Optical Performance Summary

Integrated Mirror Assembly Figure is 70 nm-rms



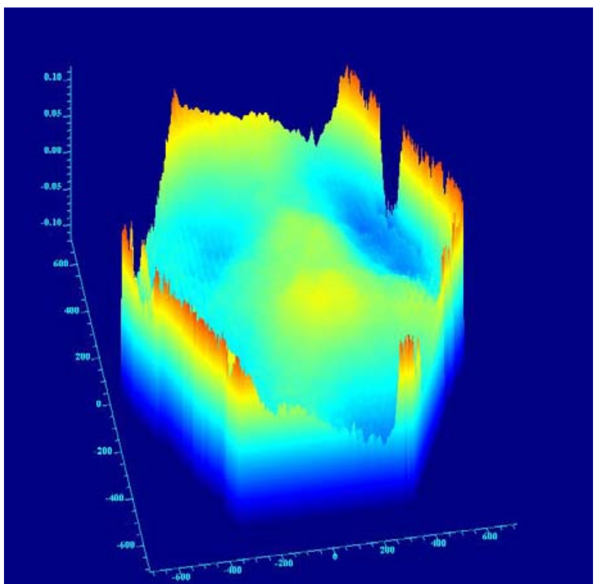


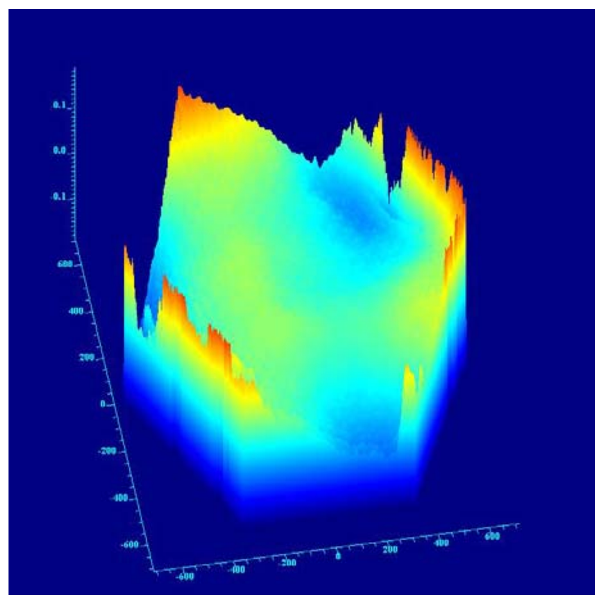


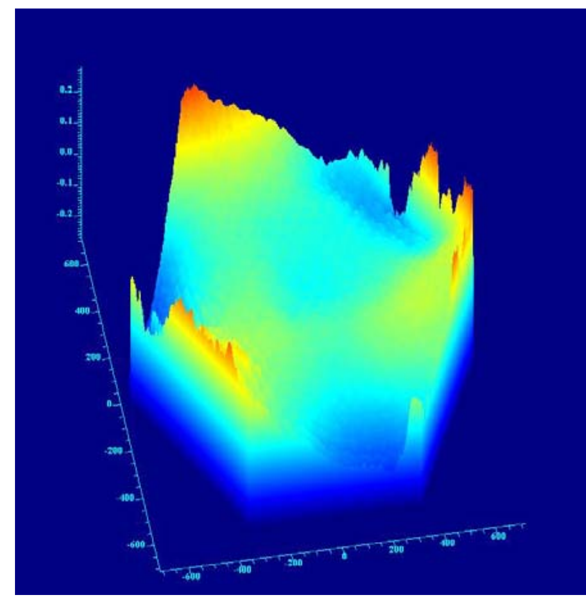
Best Segment Figure Achieved

Figure Prior To System Integration

Figure After System Integration







Outstanding Reproducibility of AMSD System Integration of 11 nm-rms

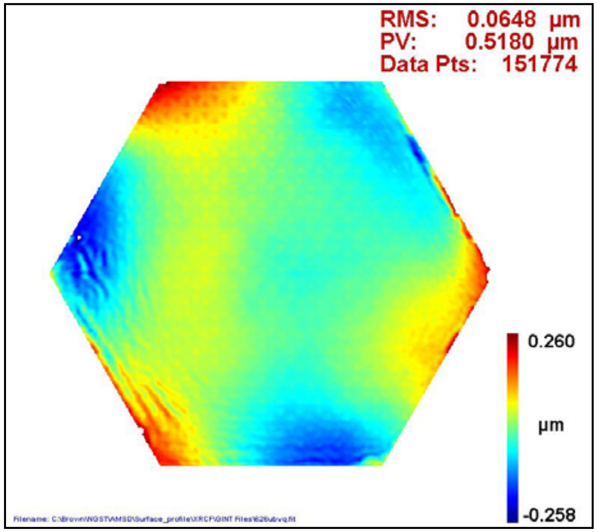


Figure Prior to Complete Disassembly

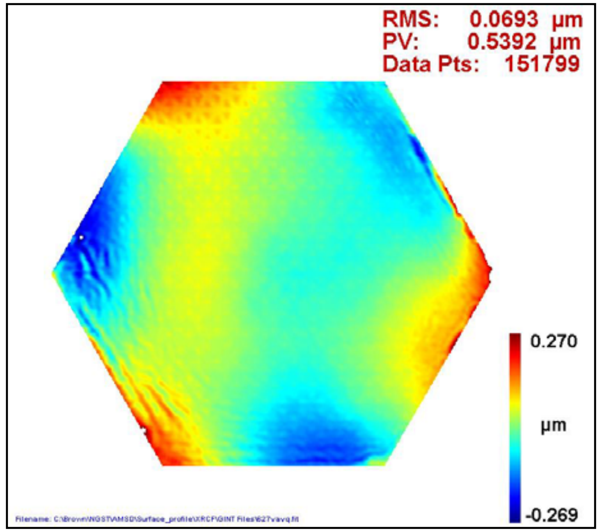
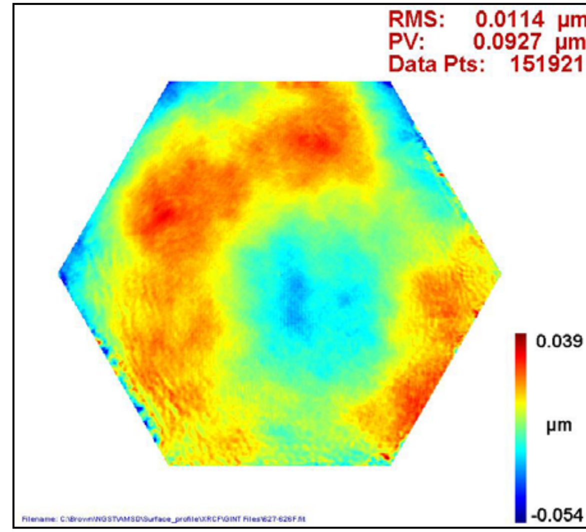
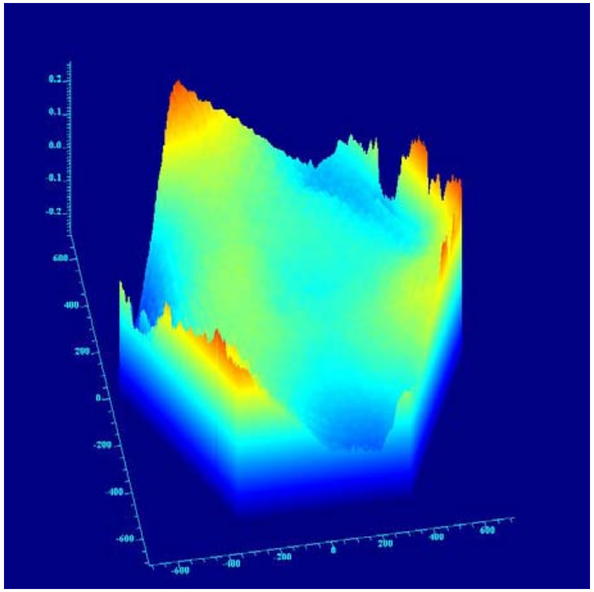
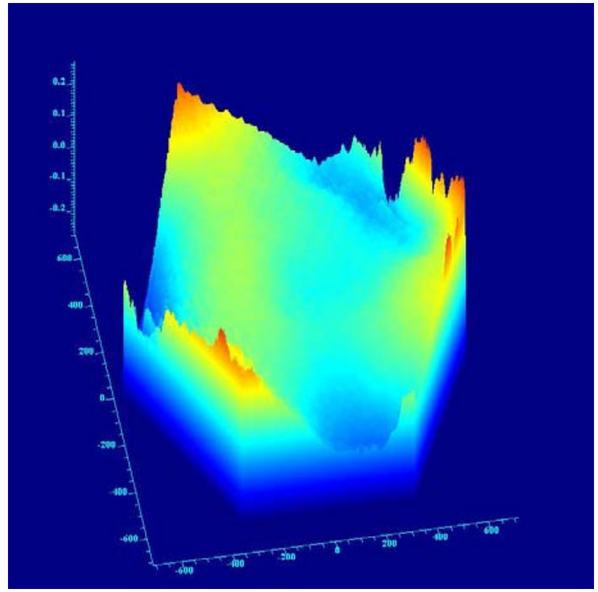


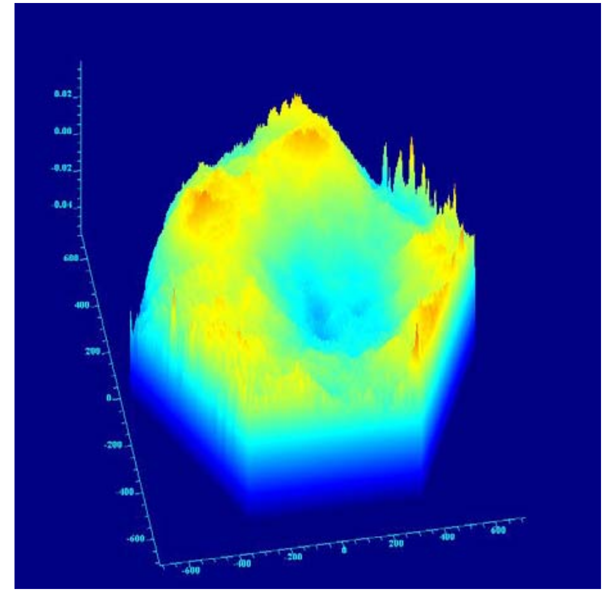
Figure After Reassembly



Reproducibility of System Integration

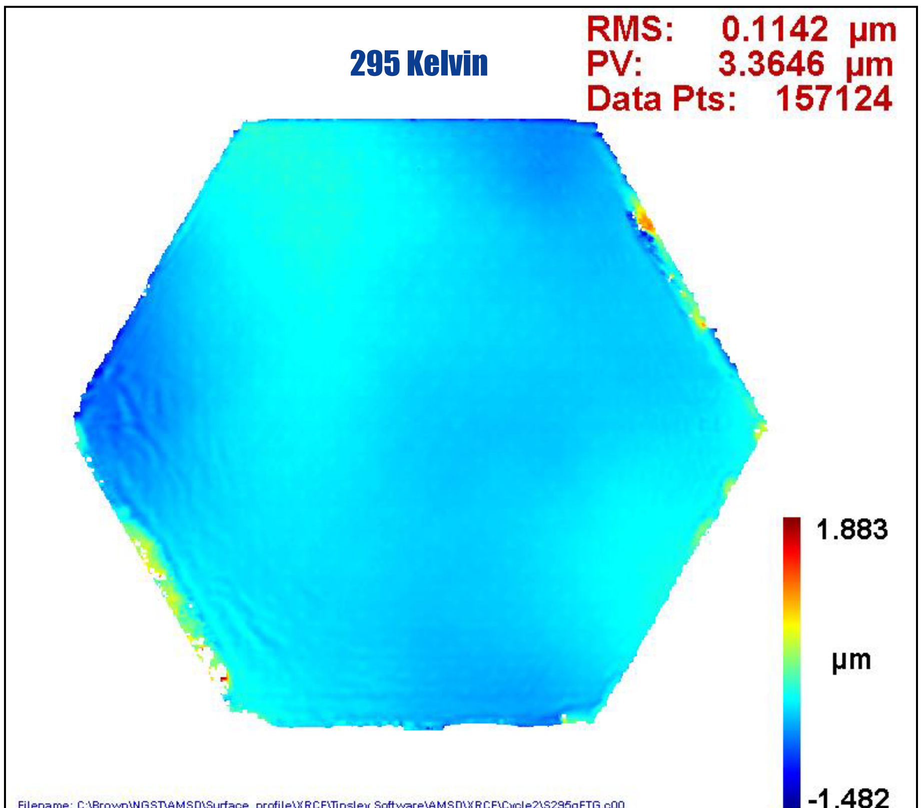


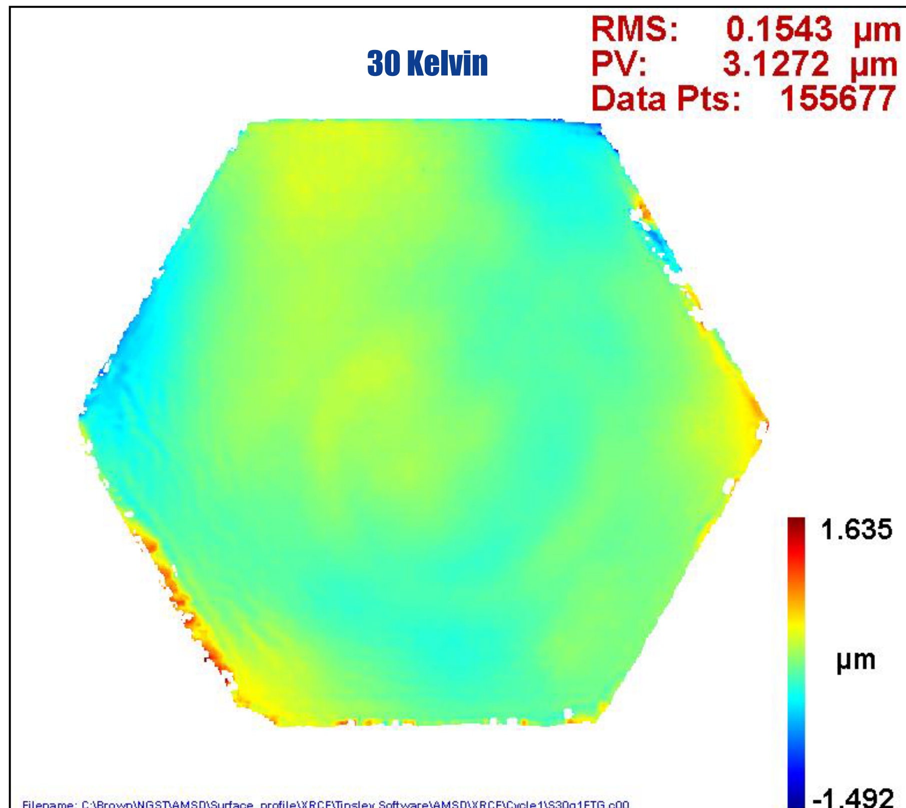




Area of Mirror Seen At XRCF Exceeds AMSD 15 mm Edge Boundary Requirement

Edge Band	Flat to Flat	Area of Mirror	Percentage Filled by AMSD
0 mm Edge	120 cm F-F	159775 data points	98.3% at 295 K & 97.4% at 30 K
5 mm Edge	119 cm F-F	157514 data points	99.8 % at 295 K & 98.8% at 30 K
15 mm Edge	117 cm F-F	152064 data points	103% at 295 K & 102% at 30 K

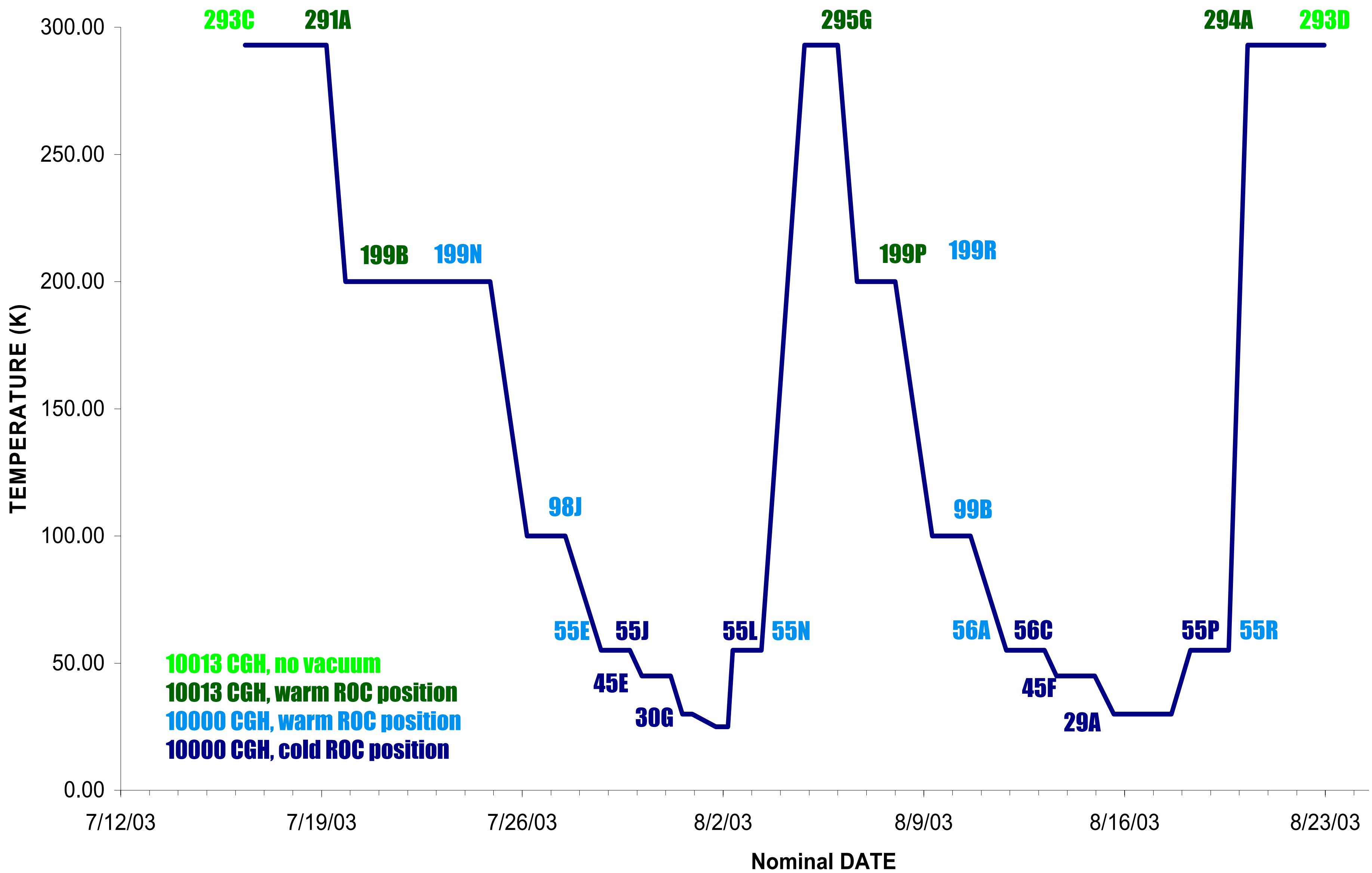




AMSD Performance Data

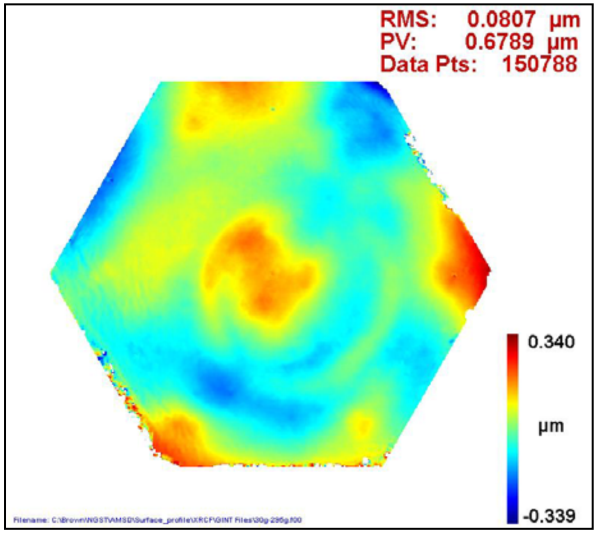
Measured Cryogenic Performance

Beryllium Cryogenic Test History (All testing completed as planned)

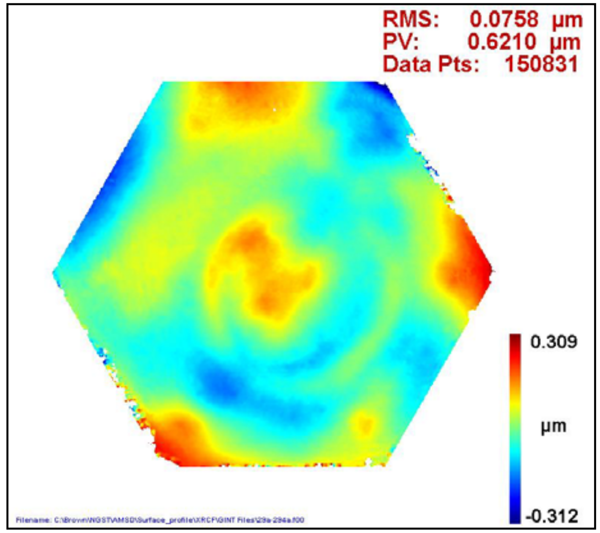


Measured Cryogenic Deformation

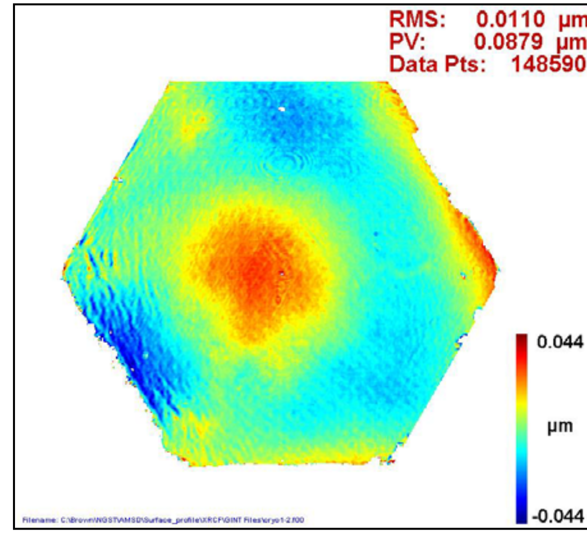
Alignment Removed, Trimmed 15 mm, 4X data Clipped



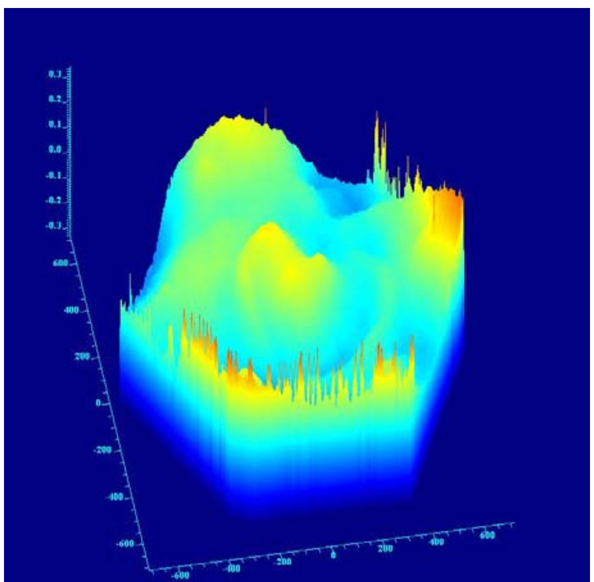
Cycle #1 (30G – 295G)

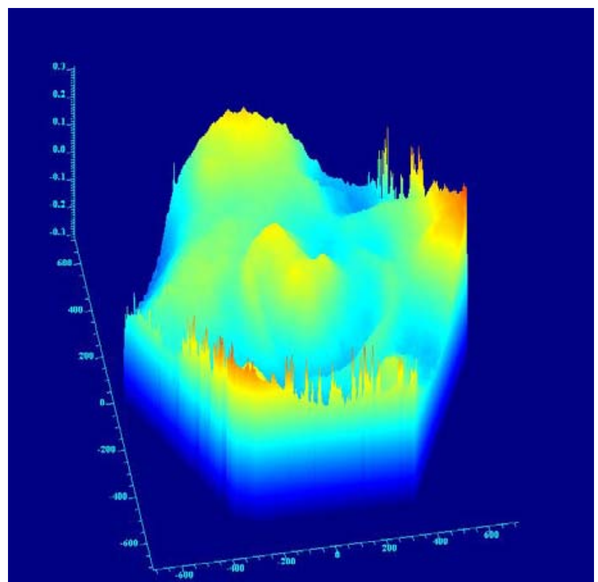


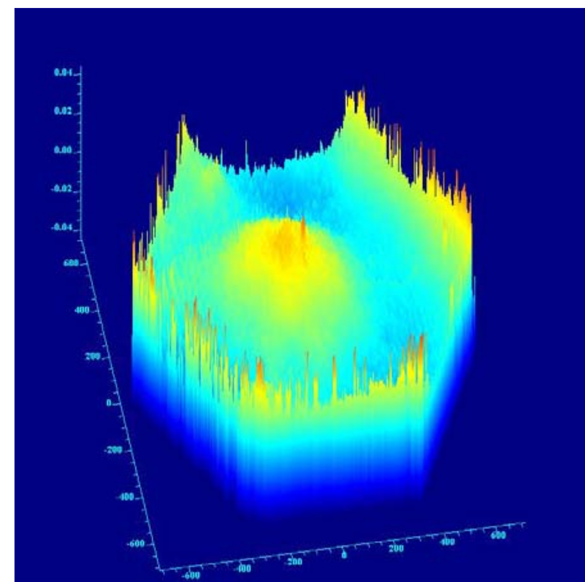
Cycle #2 (29a- 294A)



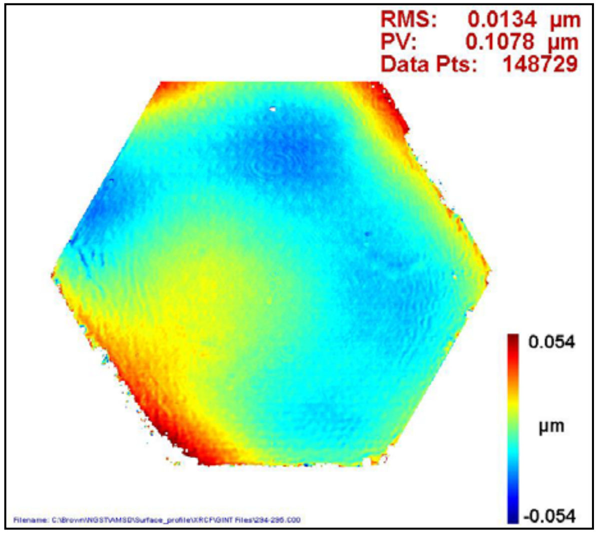
Reproducibility of Cryogenic Deformation



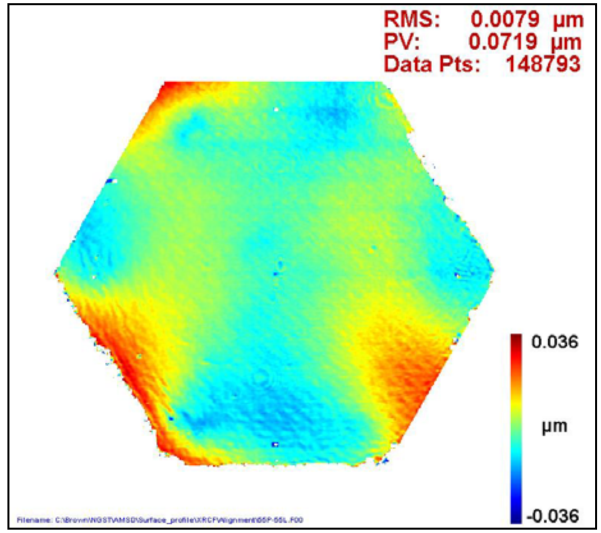




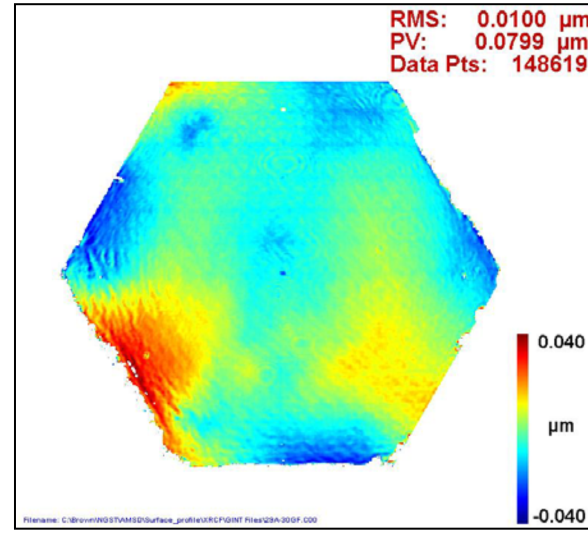
Measured Figure Reproducibility are Less than Stated XRCF Measurement Accuracy



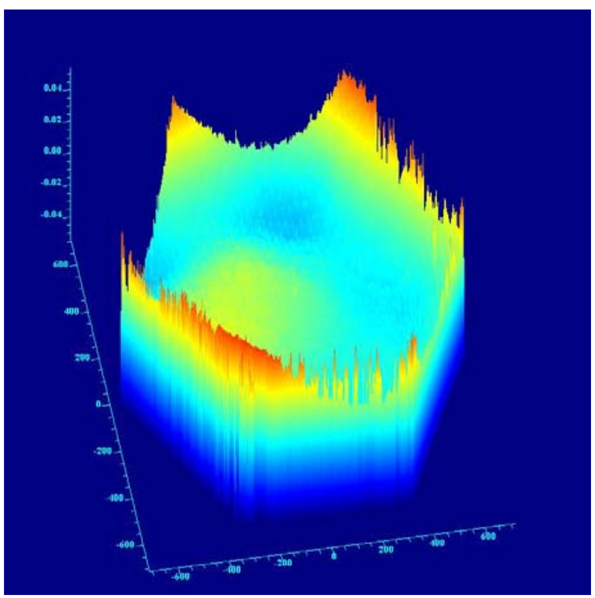
Room Temperature Repeatability (294A – 295G)

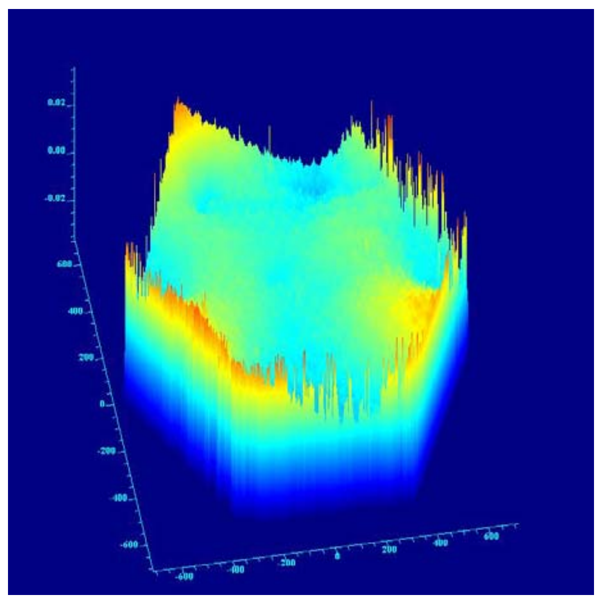


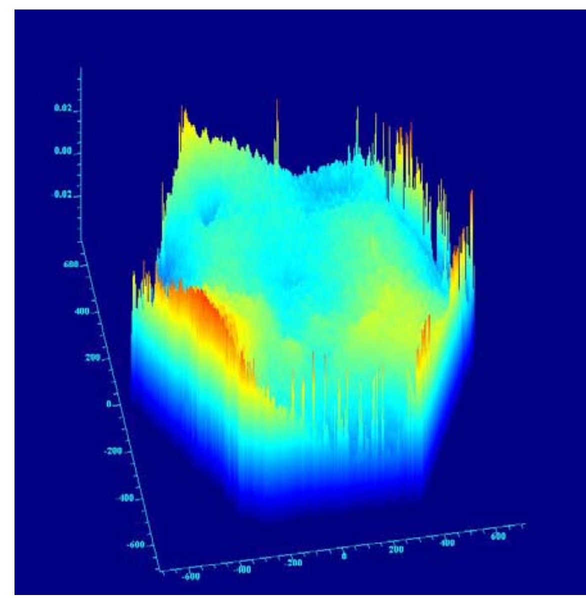
55 Kelvin Repeatability (55P – 55L)



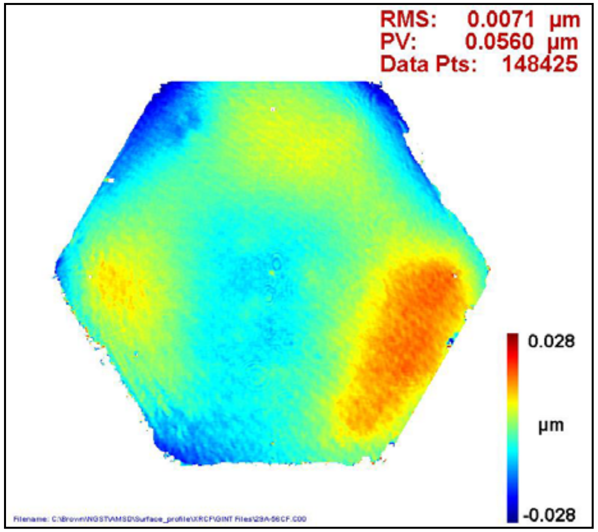
30 Kelvin Repeatability (29A – 30G)



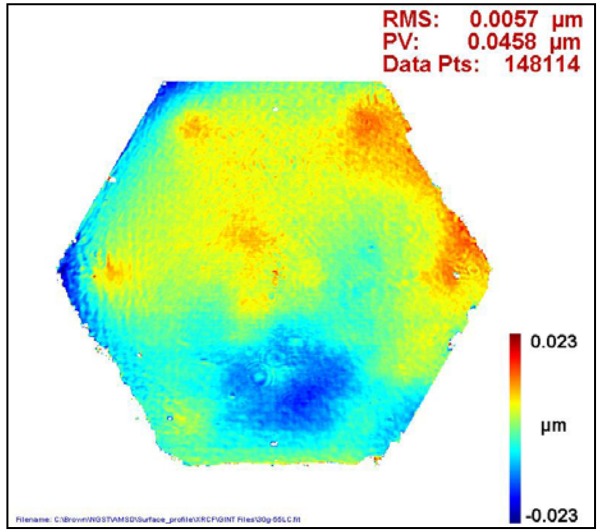




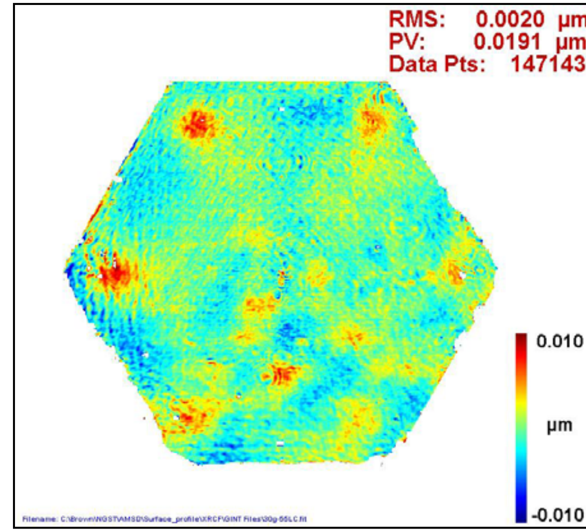
Measured Performance from 30 to 55 K is Stable Over Operational Temperature Range



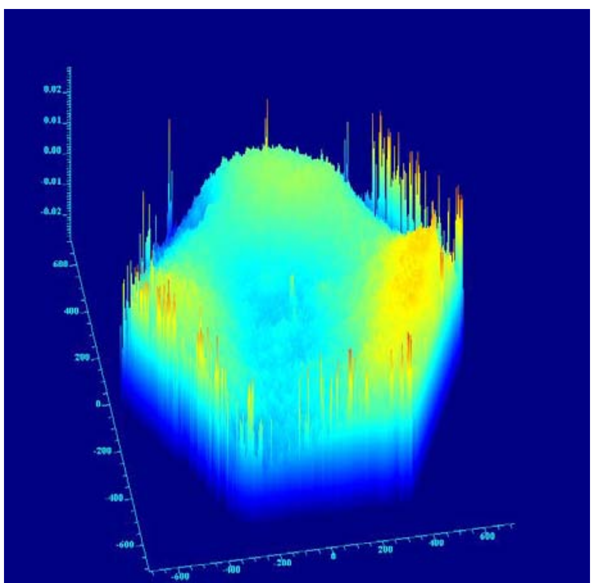
Cycle #2 (29A– 56C)

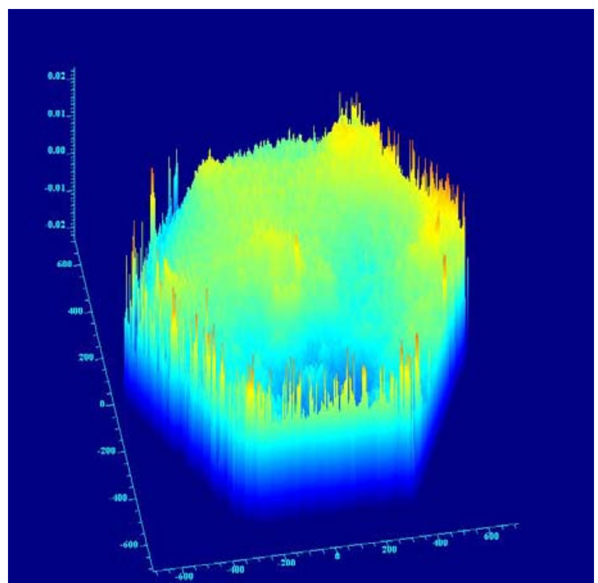


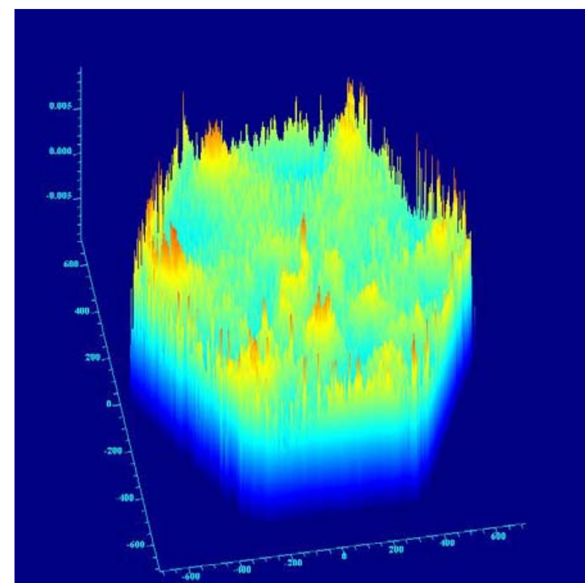
Cycle #1 (30g– 55L)



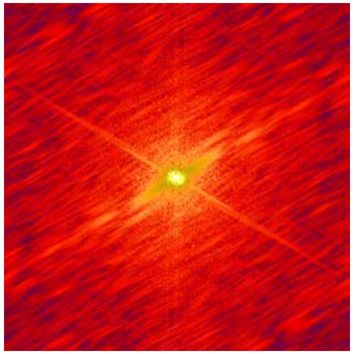
Cycle #1 36-Term Zernike Fit Removed



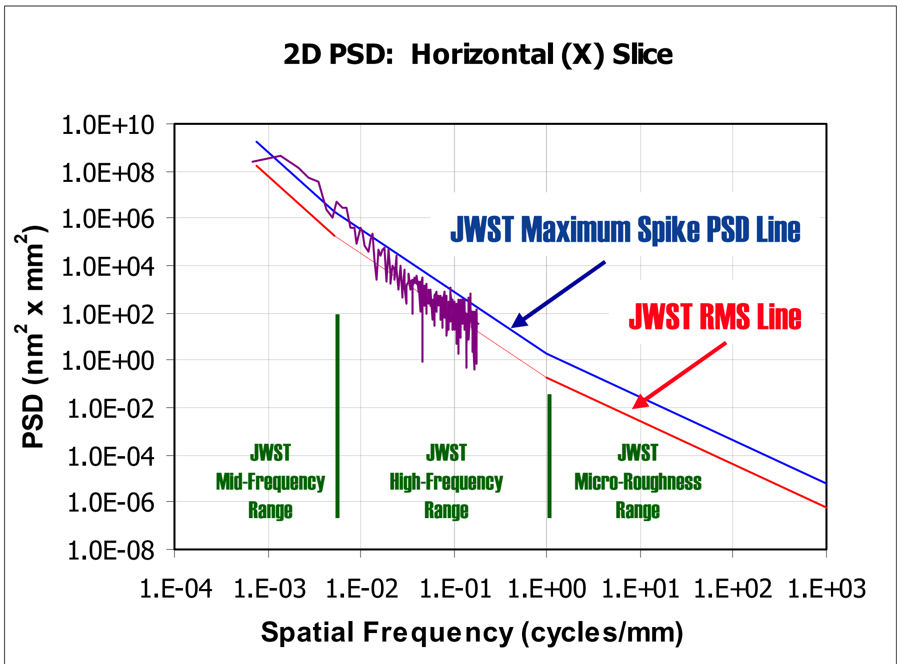


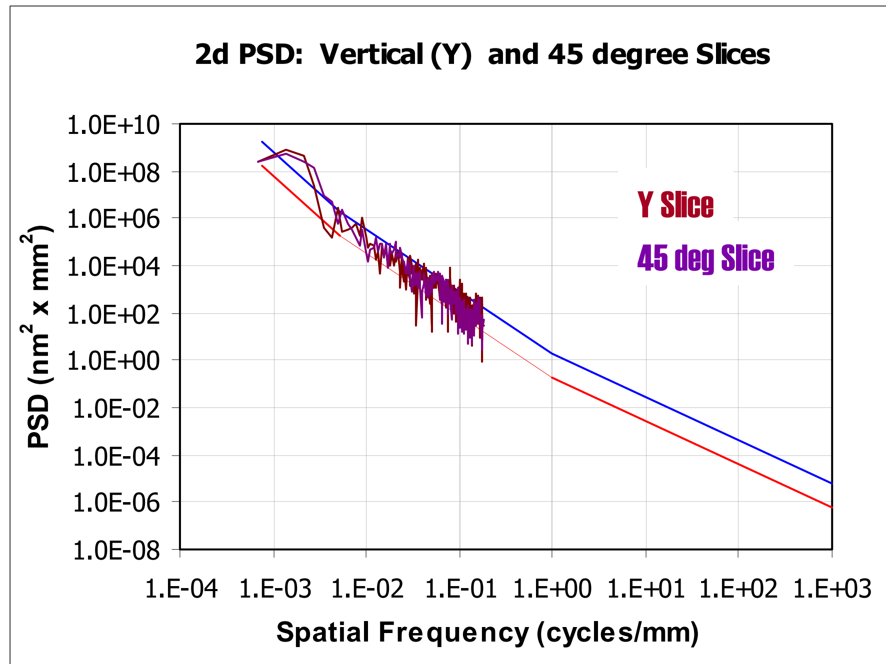


AMSD 30K Cryo-Deformation PSD is Well Within Tinsley Cryo-Figuring Capability

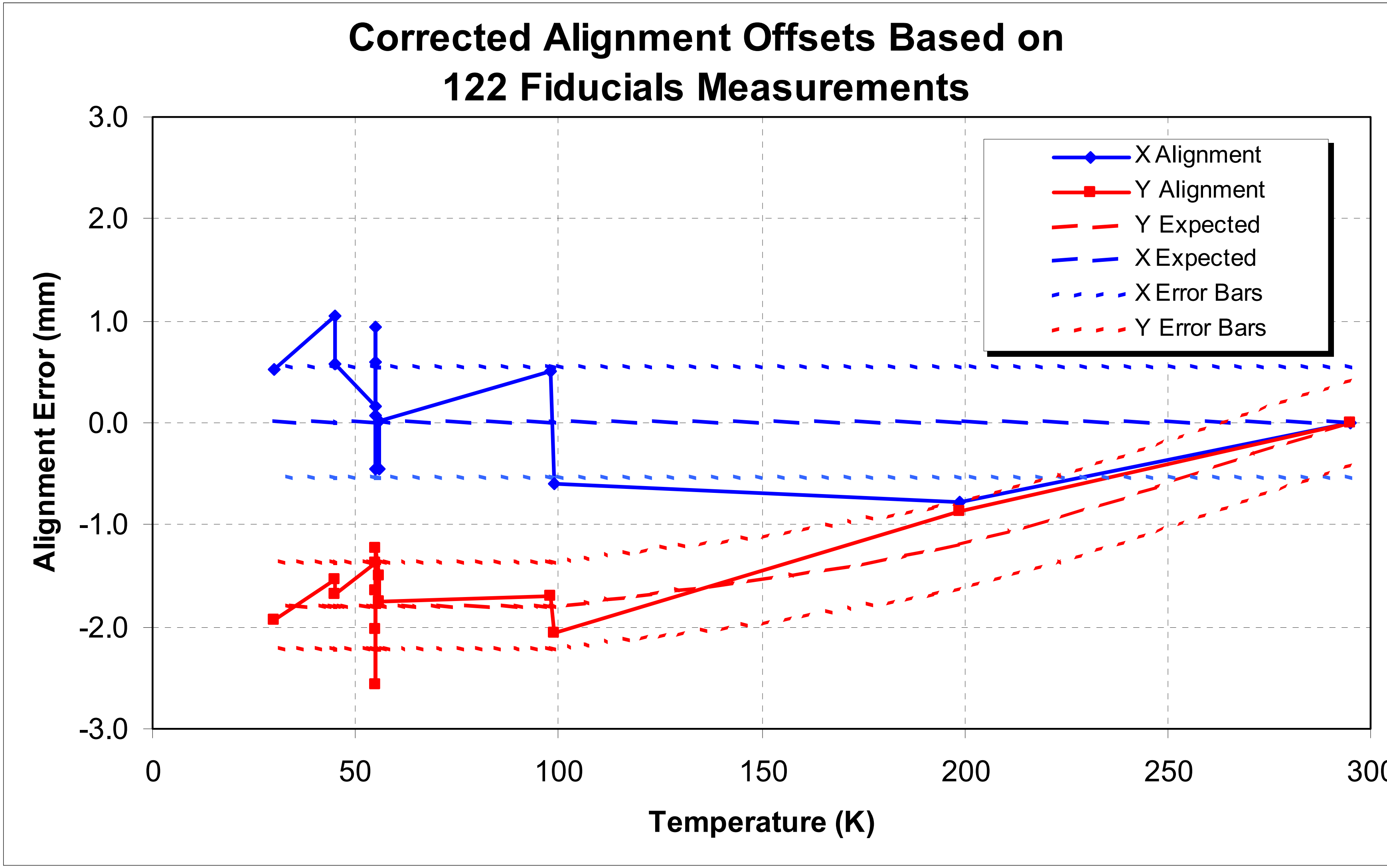


- Hanning Window applied but data is not padded with zeros
- AMSD cryo-deformation shows very little print-through from rib structure.
- RMS of cryo-deformation is 76nm with mostly mid frequency errors.



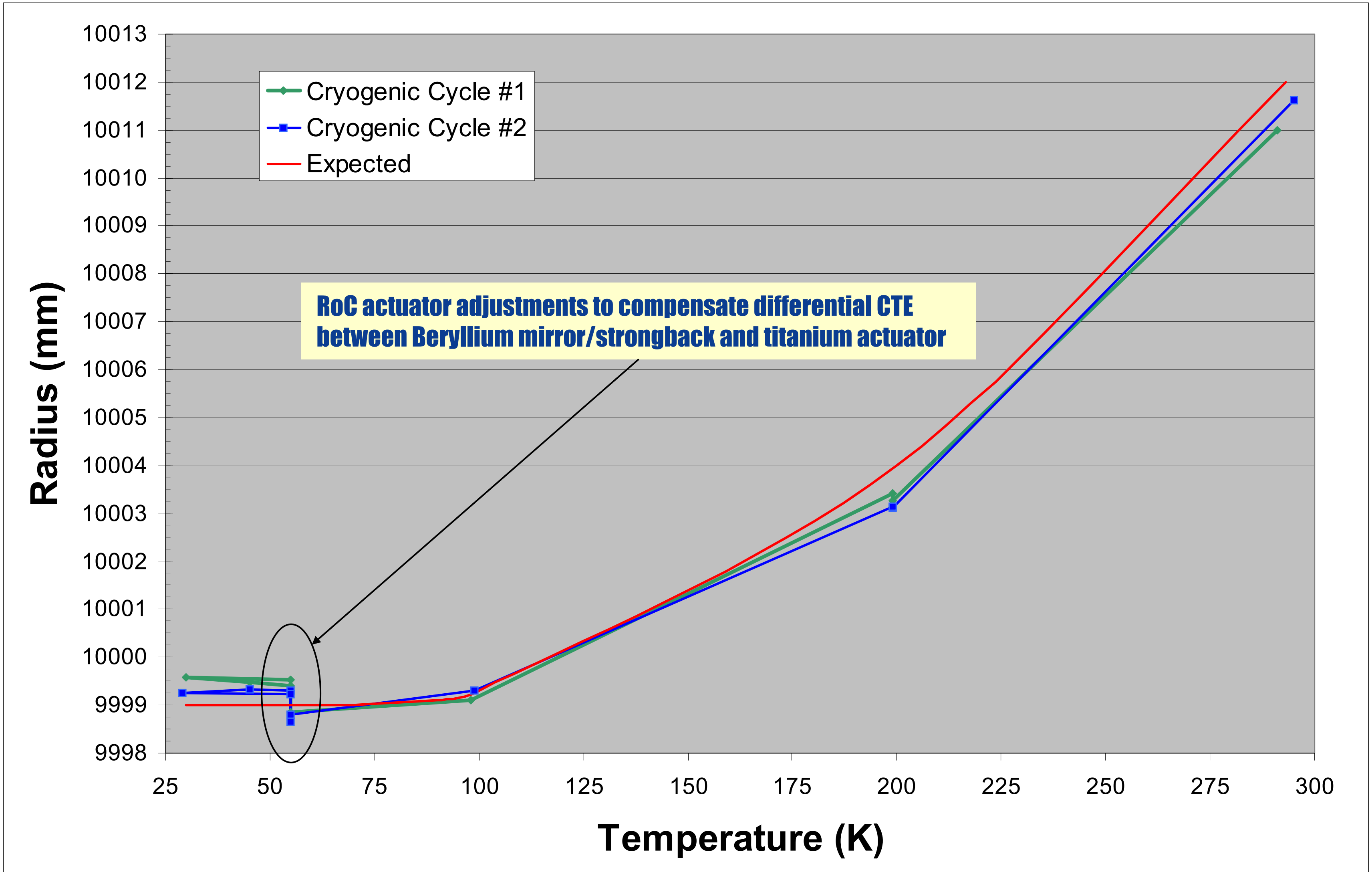


Application of Offset Data to Beryllium Mirror Alignment Data Confirms Expected Performance

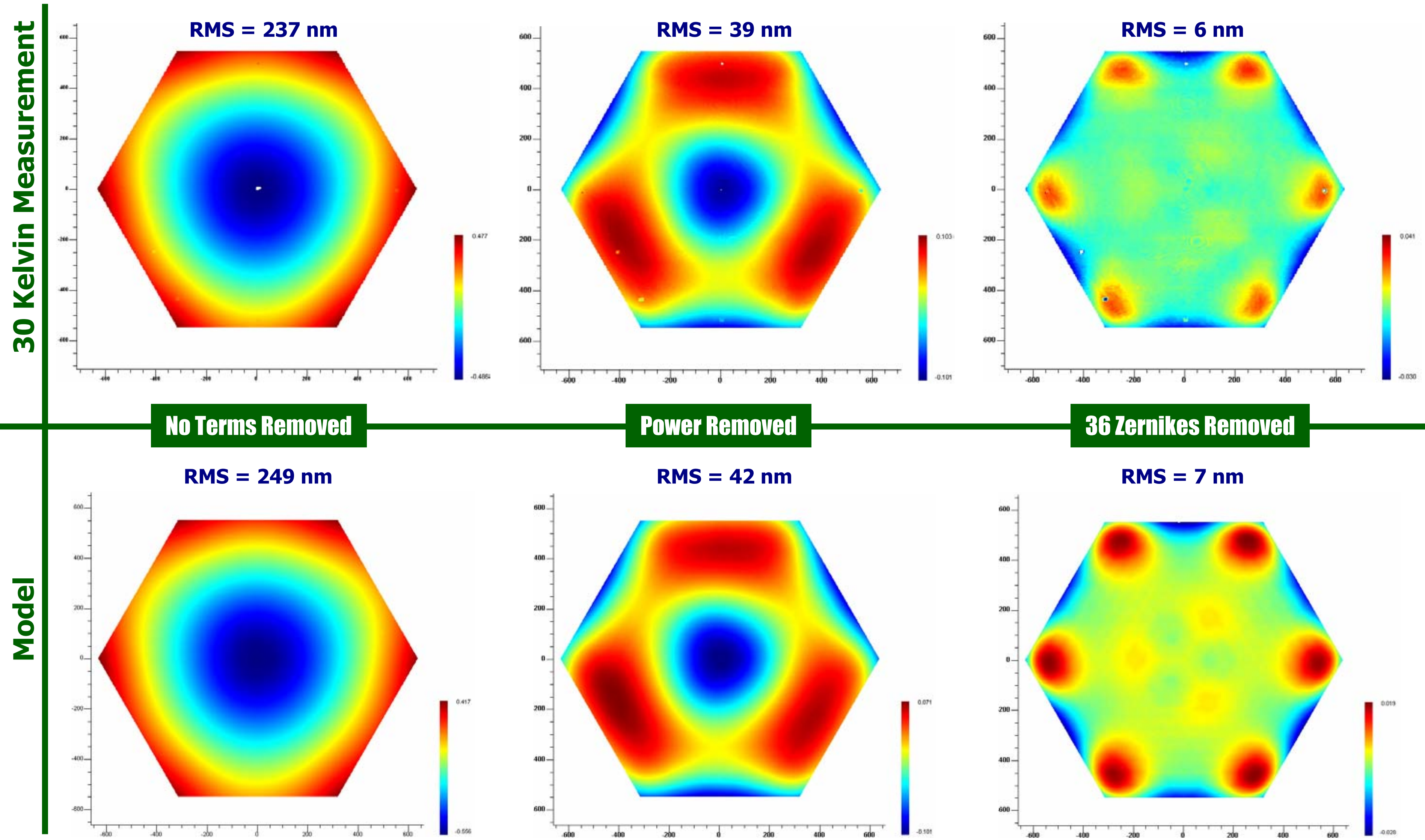


We expect -1.8 mm of Y-Alignment shift going cold due the application of 0.00131 ΔL/L to the 1400 mm off-axis distance in Y

Preliminary Cryogenic Radius Data Closely Tracks Prediction Based on Beryllium CTE



RoC Actuation Residual Accurately Matches the Model Prediction



Demonstrated AMSD Beryllium Technology Advancements are Key to Meeting JWST Requirements

Size:	1.2 meters flat-to-flat
Areal Density:	10.8 Kg/m^2 Demonstrated on AMSD
5-mm edge:	99.8% of area defined by 5-mm edge band
Ambient segment optical surface figure:	29.6 nm-rms in-process, 46.9 nm-rms prior to integration
Ambient integrated system surface figure:	70.0 nm-rms after system integration
Reproducibility of system integration:	11.4 nm-rms reproducibility demonstrated
Ambient rigid body control	± ½ mm rigid body control (tip/tilt/piston) demonstrated
Ambient radius of curvature control	± 1 µm of sag change demonstrated
Ambient RoC Residual:	39.2 nm-rms residual for 1 µm of sag change demonstrated
Ambient gravity induced deformation:	Gravity deformation empirically removed at ~750 nm-rms
Cryogenic deformation:	
30-294 Kelvin:	75.8 nm-rms cryogenic deformation demonstrated
30-55 Kelvin:	5.7 nm-rms cryogenic deformation demonstrated
Cryogenic deformation reproducibility:	
30 Kelvin:	10.0 nm-rms figure reproducibility at 30 K demonstrated
55 Kelvin:	7.9 nm-rms figure reproducibility at 55 K demonstrated
294 Kelvin:	13.4 nm-rms figure reproducibility at 294 K demonstrated
Cryogenic rigid body control:	± ½ mm rigid body control (tip/tilt/piston) demonstrated
Cryogenic radius of curvature control:	± 1 µm of sag change demonstrated
Cryogenic RoC Residual:	38.9 nm-rms residual for 1 µm of sag change demonstrated
Cryogenic radius change:	Expected 13 mm radius change demonstrated
Cryogenic alignment:	Expected 1.8 mm Y-alignment shift demonstrated
Ambient to Cryogenic RoC Residual:	2.4 nm-rms ambient to cryo reproducibility demonstrated
JWST back plane interface:	Beryllium to composite differential CTE accommodation