Space Interferometry Mission

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SIM PlanetQuest: The TOM-3 (Thermo-Optical-Mechanical) Siderostat Mirror Test

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Agenda

- SIM Spacecraft Overview
  - Collector Subsystem Description
  - Siderostat Mirror Description
- Collector Bay Environment
- TOM-3 Test Configuration
- Integrated Model Description
- Conclusion

SIM PlanetQuest – Mission Description

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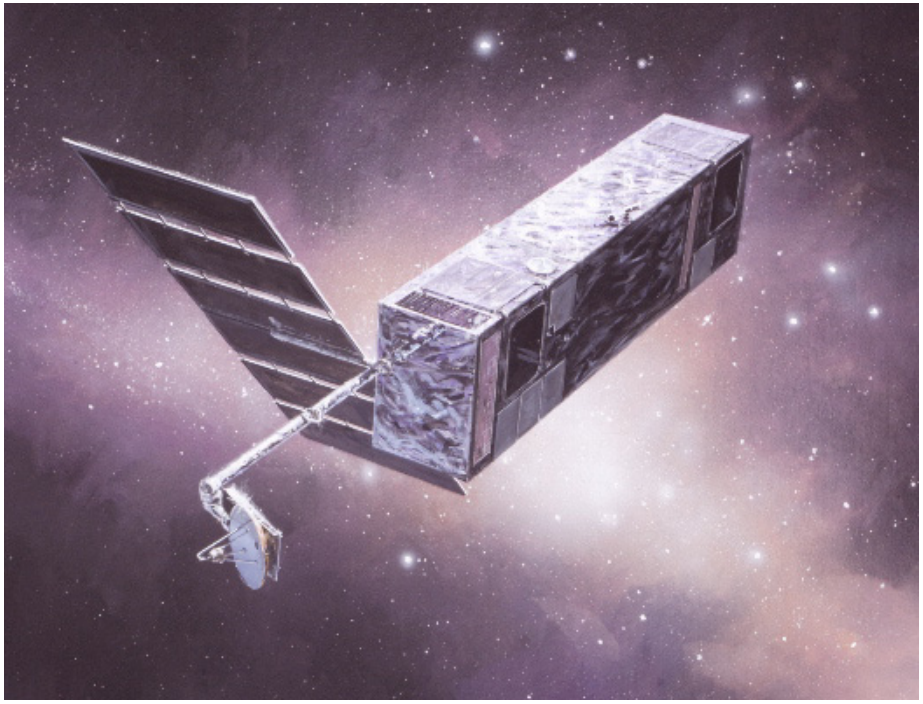
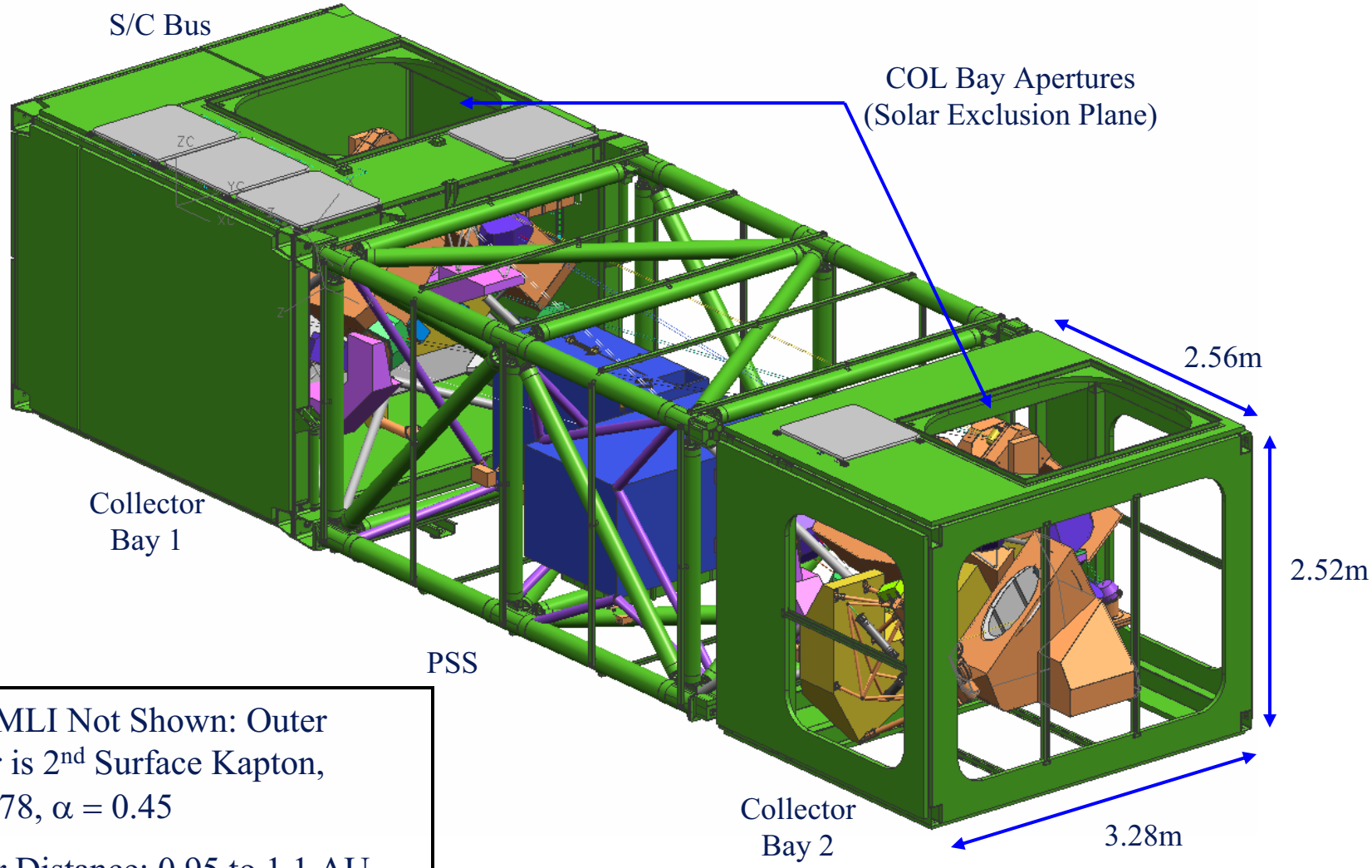
- Designed to Detect Earth-Like Planets (as Small as 4 Earth Radii) Around 250 Nearest Stars
- Will Also Catalog Positions of 1300 Nearest Stars with Micro-Arc-Second Resolution.
- 3 Michelson Interferometers Operating in Visible Wavelength
- 10-meter Science Baseline
- 5 Year Primary Mission with 10 Year Goal
- Earth Trailing Orbit (0.95 to 1.1 AU)
- Complex Opto-Mechanical Systems
- mK-Level Thermal Stability on Select Components



SIM Instrument



- S/C MLI Not Shown: Outer Layer is 2nd Surface Kapton, $\varepsilon = 0.78$, $\alpha = 0.45$
- Solar Distance: 0.95 to 1.1 AU (1515 W/m^2 to 1130 W/m^2)

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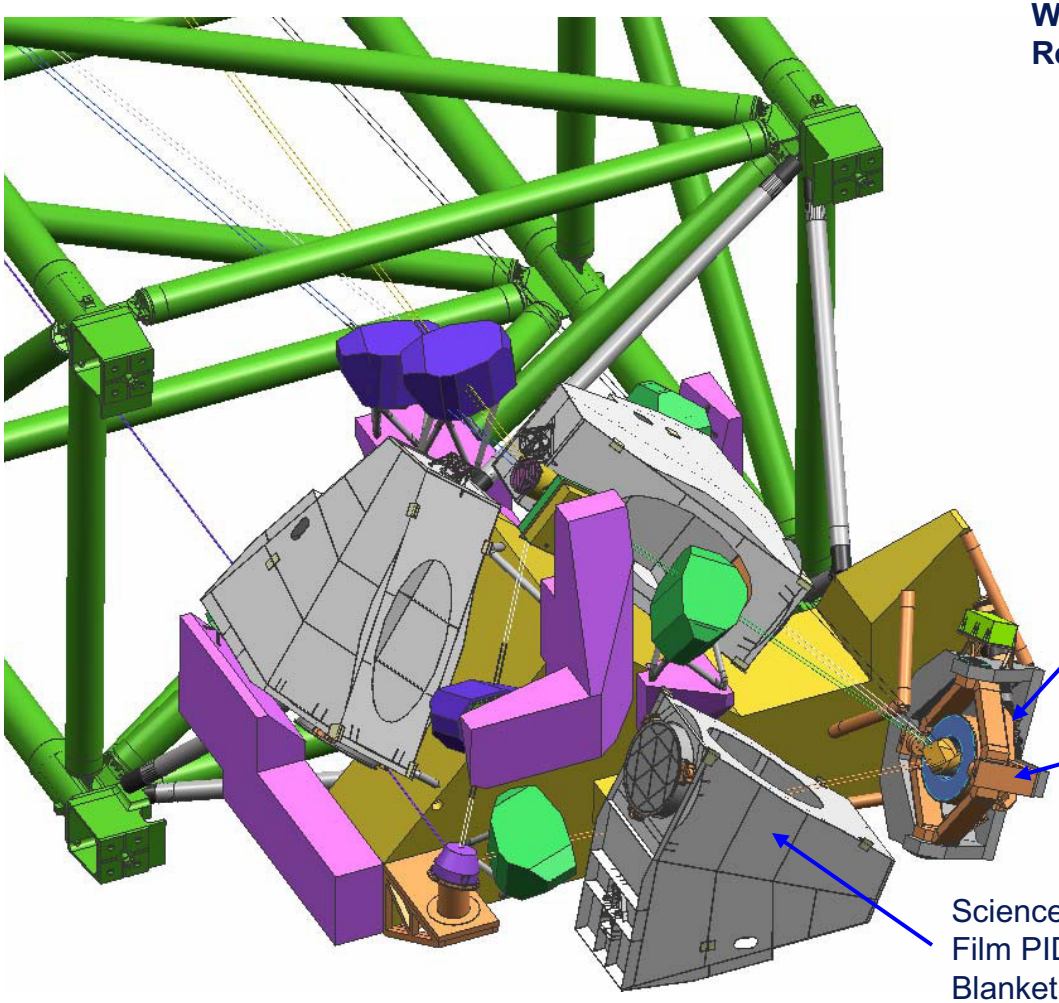
SIM Collector Bays

Wide Angle Stability Requirements in Bold



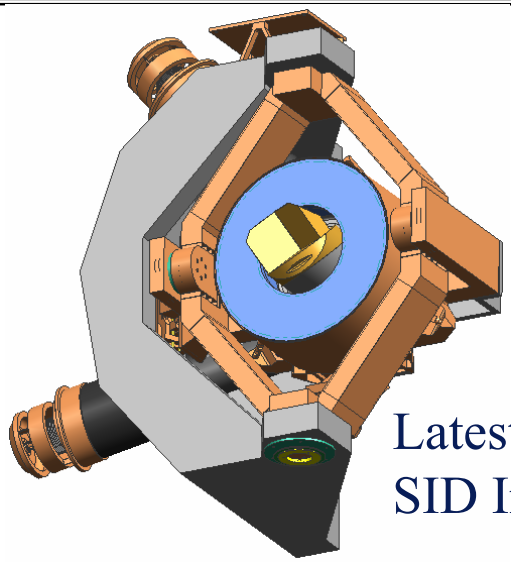
SID Mirror, Aluminum Thermal Can, PID Kapton Film Heaters, MLI, **25 mK/hr**

SID Outer Gimbal, PID Kapton Film Heaters, MLI, **25 mK/hr**

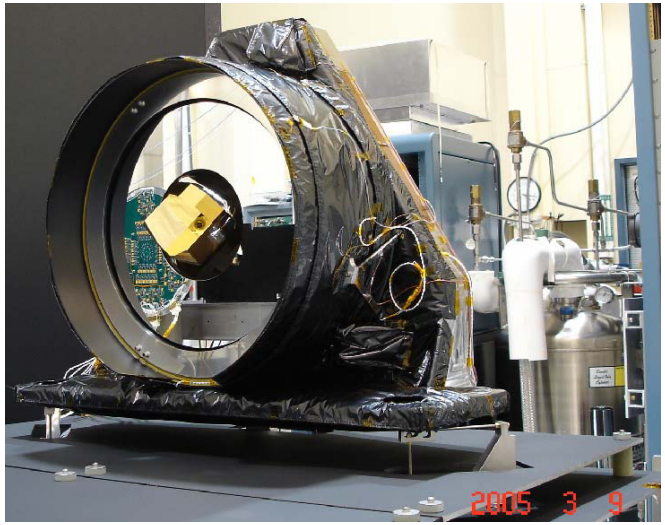
Science Compressor Bench, Kapton Film PID Surface Heaters, MLI Blanketing, **100 mK/hr**

SIM Collector Siderostat Mirrors

- One Mirror Located in Each Collector Bay
- Articulating Mirror (Coarse Stage Can Rotate Mirror +/- 3.5^{o}
- Used to Acquire Target Starlight and Direct it Toward Science Light Compressor
- 35-cm Flat Mirror
- 25 mK/hr Thermal Stability
- 22C +/- 5C Absolute Temperature Requirement
- Identified Early on in Technology Program as a High Risk Item
- Subject of TOM-3 Thermo-Optical-Mechanical Test



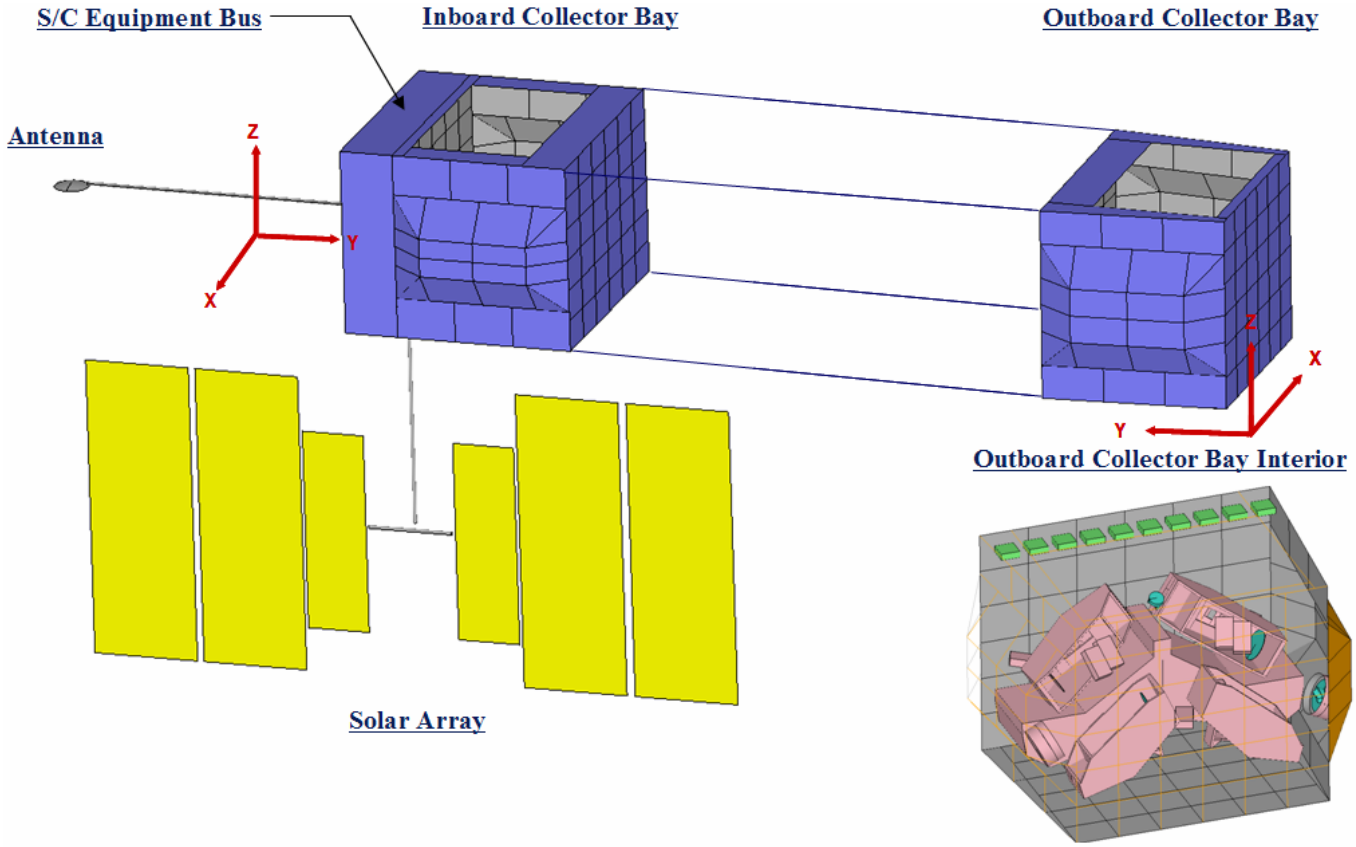
Latest Flight SID Incarnation



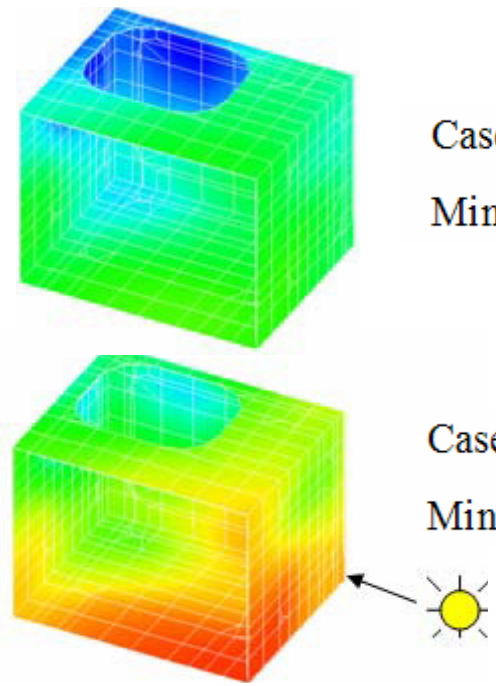
Brassboard SID

COL Bay Thermal Environment (1 of 2)

- Primary Boundary Temperature for COL Bay Components is NGST COL Bay Enclosure Inner MLI Temperature and Aperture to Space
- The COL Bay is Isolated from the Rest of the Instrument with MLI Blanketing
- Range for COL Bay Inner MLI Absolute Temperature is Driven By Solar Loading Vector, Solar Flux, and Materials Degradation



COL Bay Thermal Environment (2 of 2)



Case 1: Bore-Sight Sun

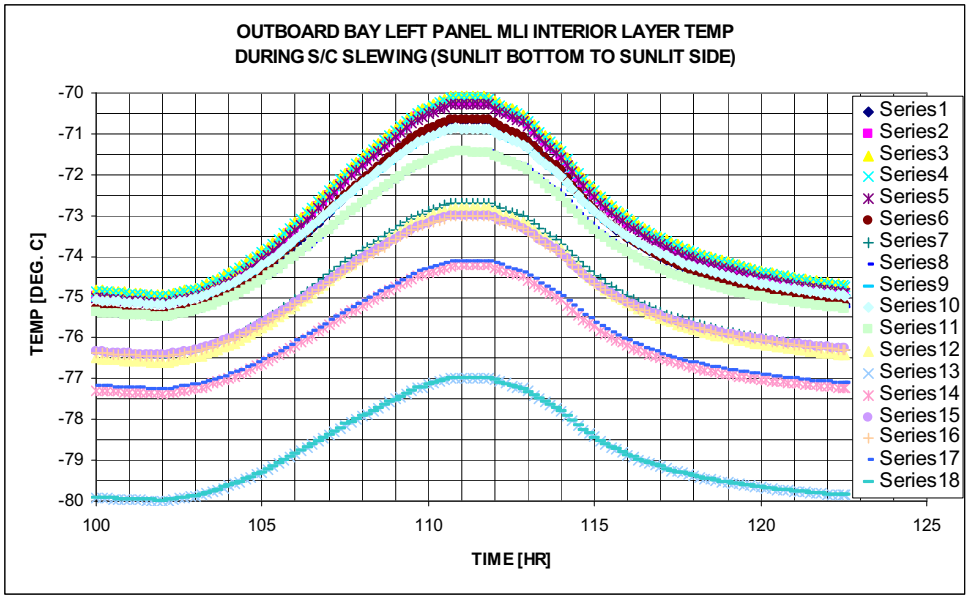
Min = 196K, Max = 235K

Case 5: -Z,-Y Solar Loading

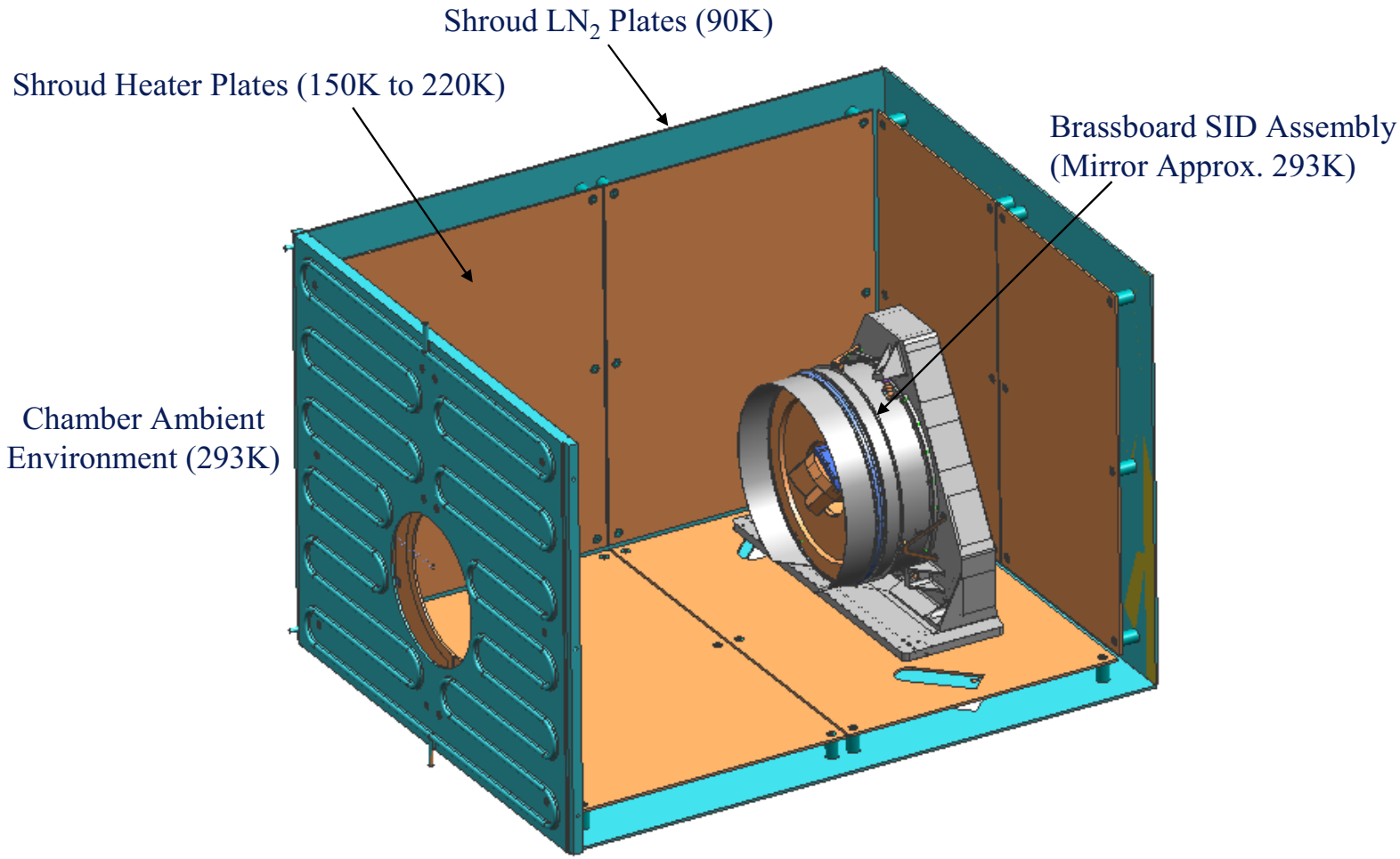
Min = 212K, Max = 259K

Goal of Thermal Design is to Minimize Temps Inside COL Bay in Order to Minimize Radiative Heat Transfer

Sample Transient Boundary Prediction



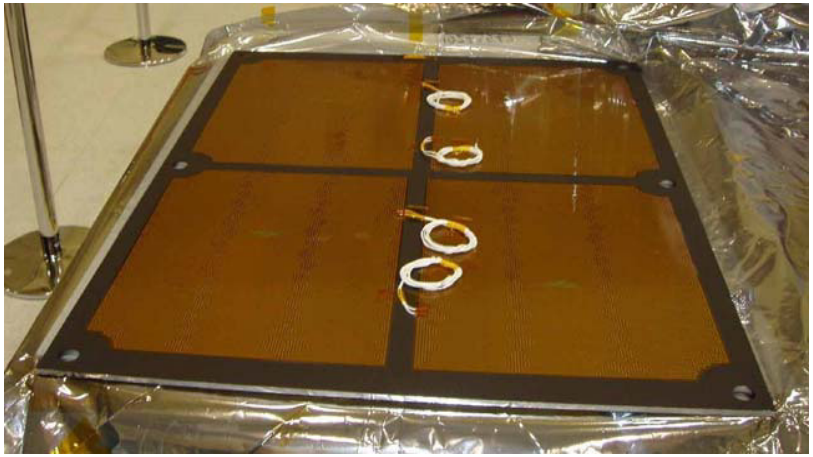
TOM-3: Replicating COL Bay Environment



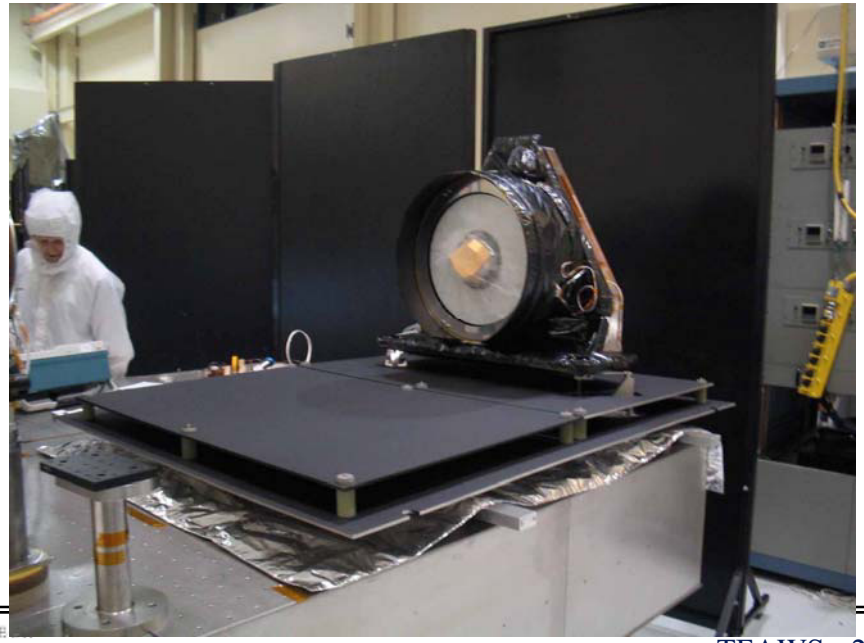
Note: Right and Top Shroud/Heater Plate Panels Not Shown

BB-SID Test Setup Photos

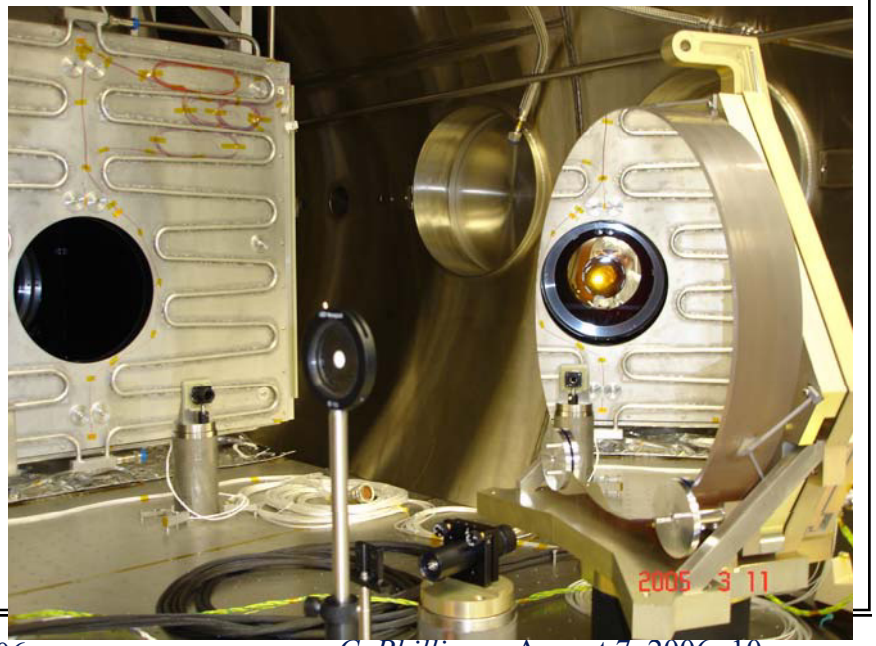
Typical panel with large heaters



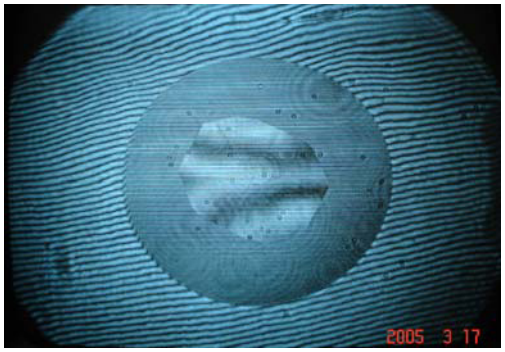
SID on bottom heater plate

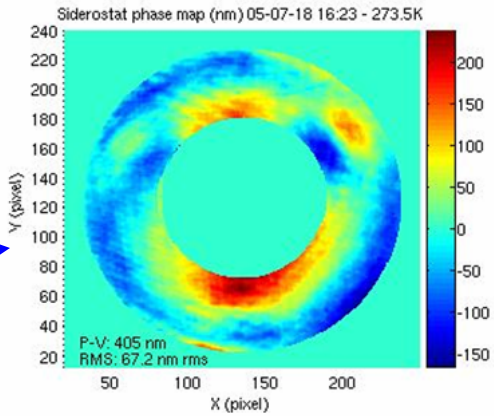


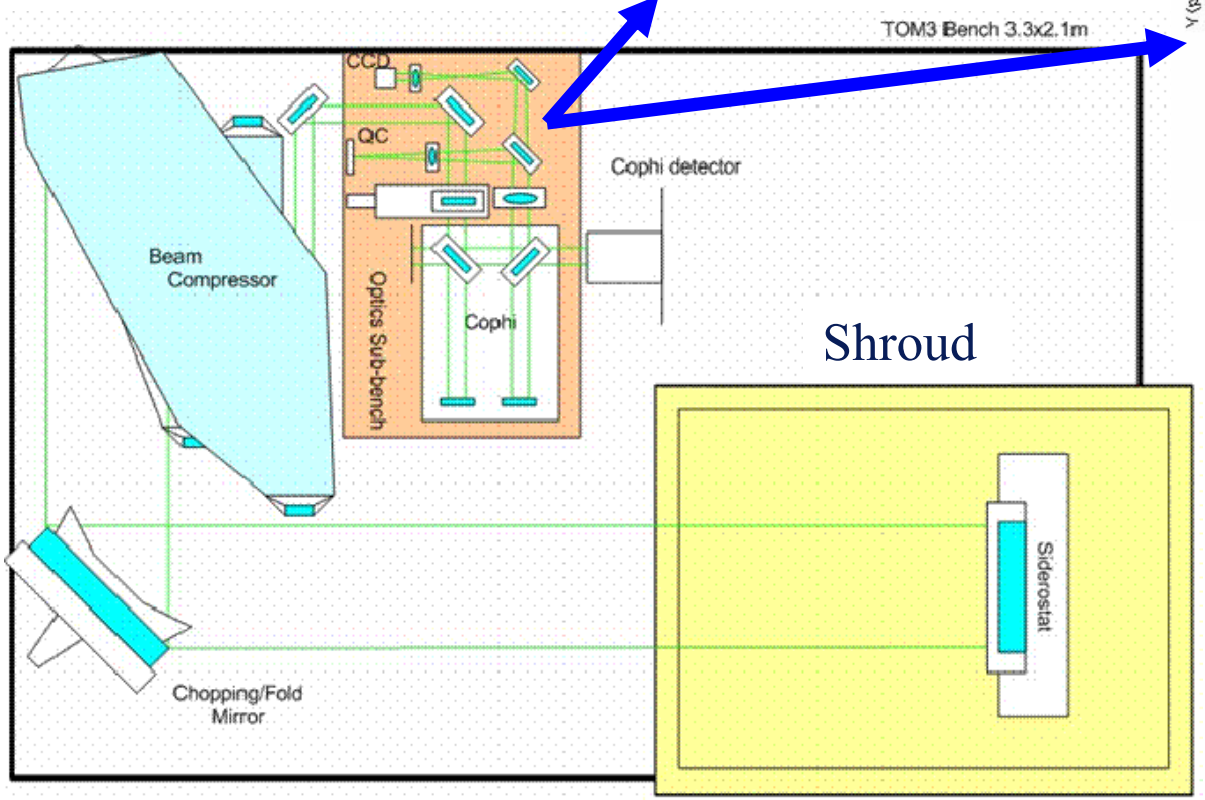
LN_2 shroud and chopping mirror in chamber



BB-SID Vacuum Chamber Configuration







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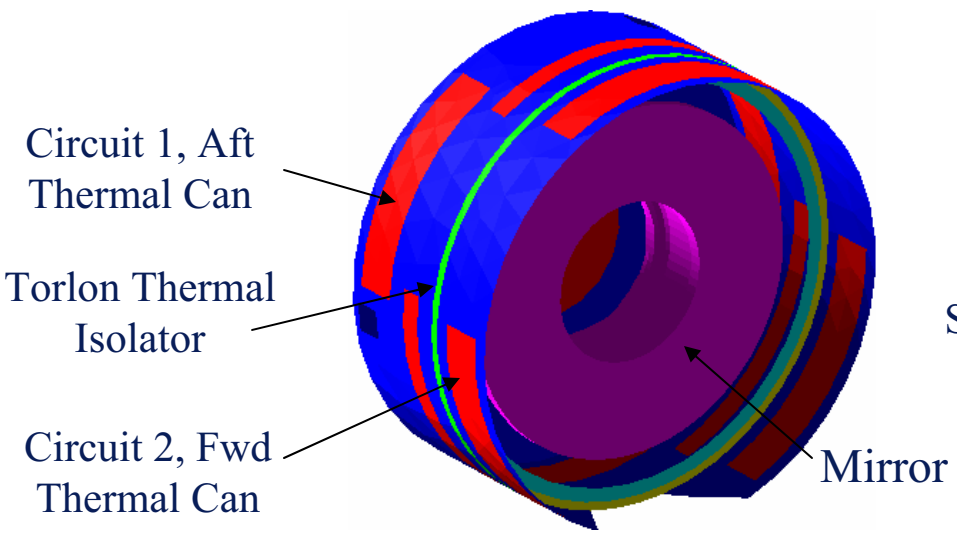
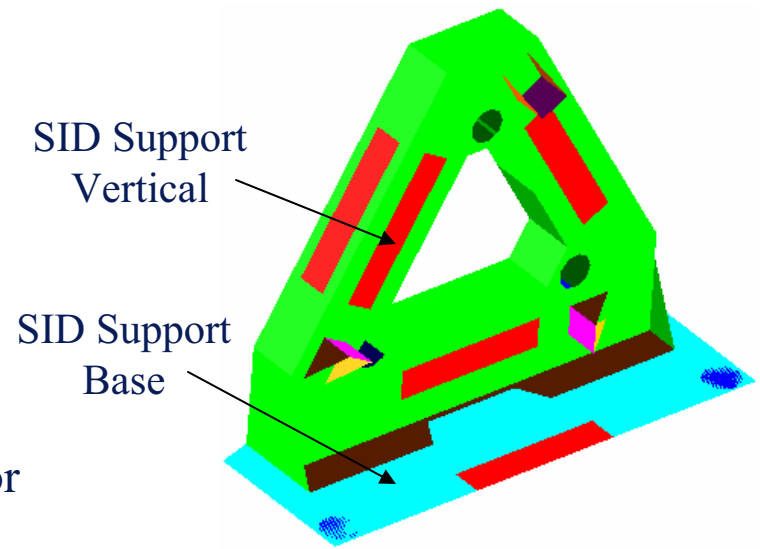
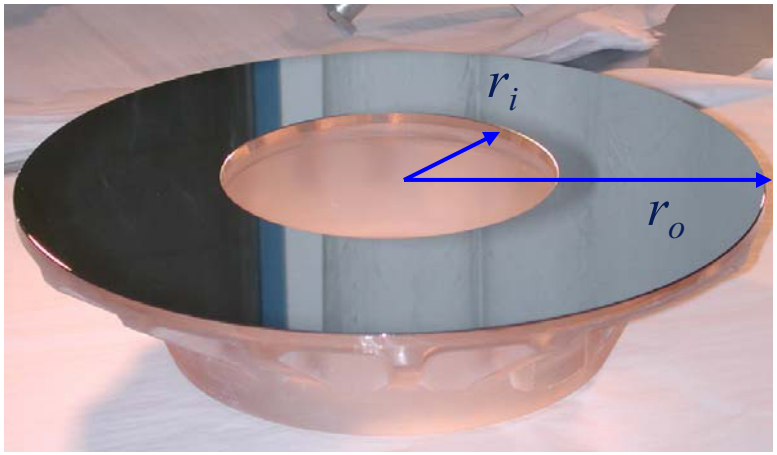
Thermal Hardware - SID Heater Control

- The SID mirror assembly is temperature controlled by the following four heater circuits.
  - **Aft Thermal Can.** The Aft Can is isolated from the shroud environment by a 20-layer MLI blanket and has a low-e inner coating to attenuate temperature fluctuations. 7 individual patch heaters are installed in series on the Aft Can and are controlled by a PID heater control algorithm.
  - **Forward Thermal Can.** The purpose of the forward heater can is to reduce lateral gradients across the mirror face. The forward can circuit has three individual patch heaters wired in series, and is PID controlled.
  - **SID Support (Vertical).** The vertical portion of the SID support has five individual heater patches and is PID controlled.
  - **SID support (Base).** The horizontal portion of the SID Support has one heater patch and is also PID controlled.





How Does Thermal Drive Changes in OPD?



$$OPD = \frac{\alpha \Delta T}{4h}\left(r_o^{\,2} + r_i^{\,2}\right)$$

α= CTE (+/- 5 Parts/Billion for ULE)

ΔT = Axial Temperature Gradient

h = Mirror Thickness

R_o = Mirror Outer Radius

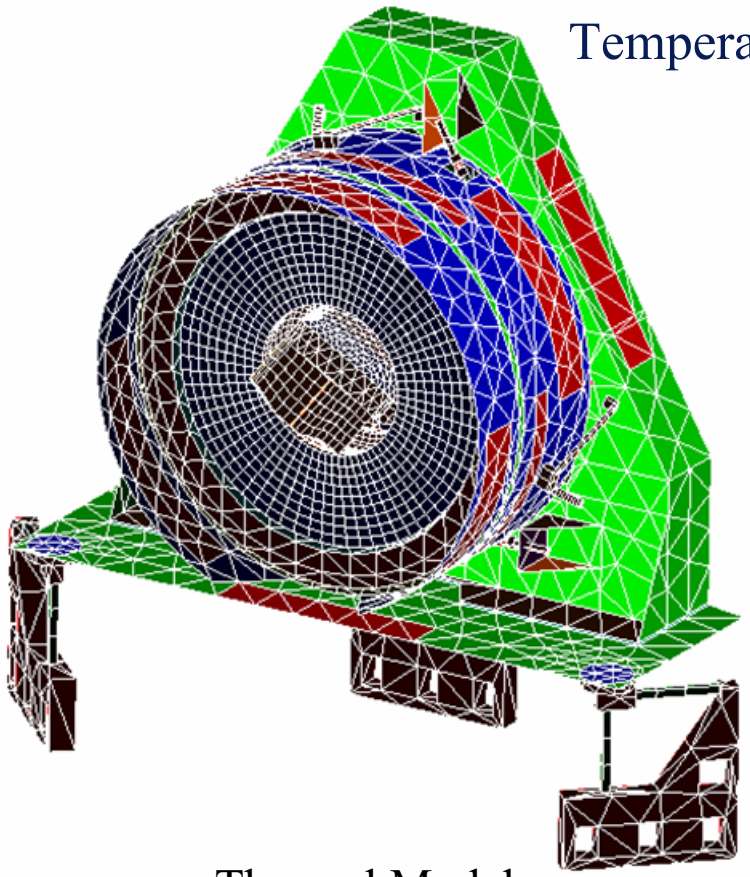
R_i = Mirror Inner Radius

Changes in OPD Over Time Degrade Optical Performance

Goal of TOM-3 is to Measure and Predict ΔOPD/dt

Ideas TMG Thermal and Structural Models

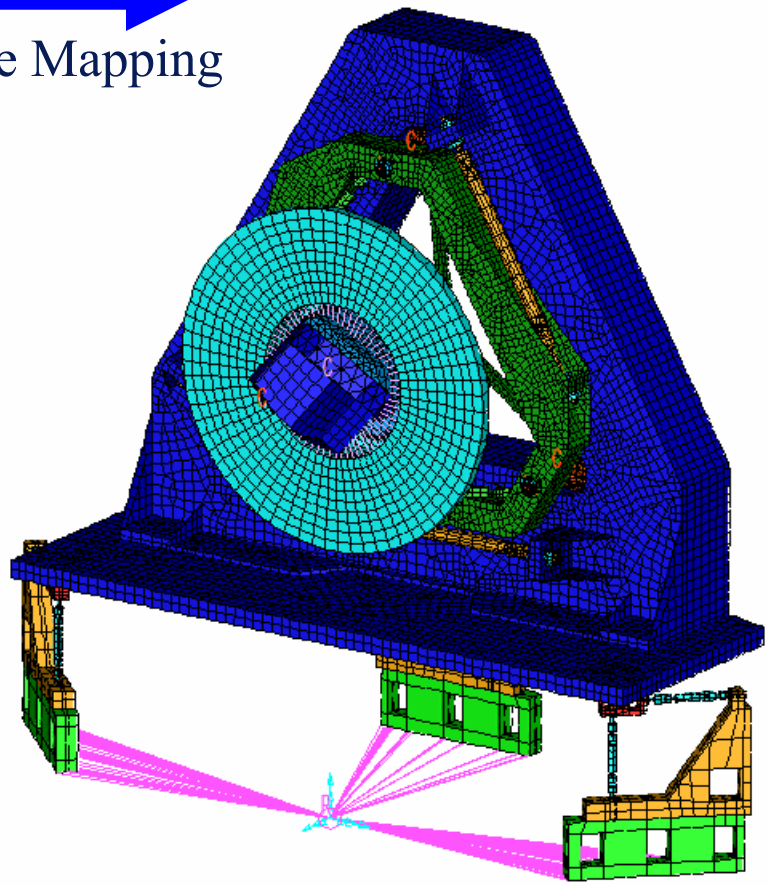
Temperature Mapping



Thermal Model

21600 Elements

13600 Nodes



Structural Model

47000 Elements

168000 Nodes

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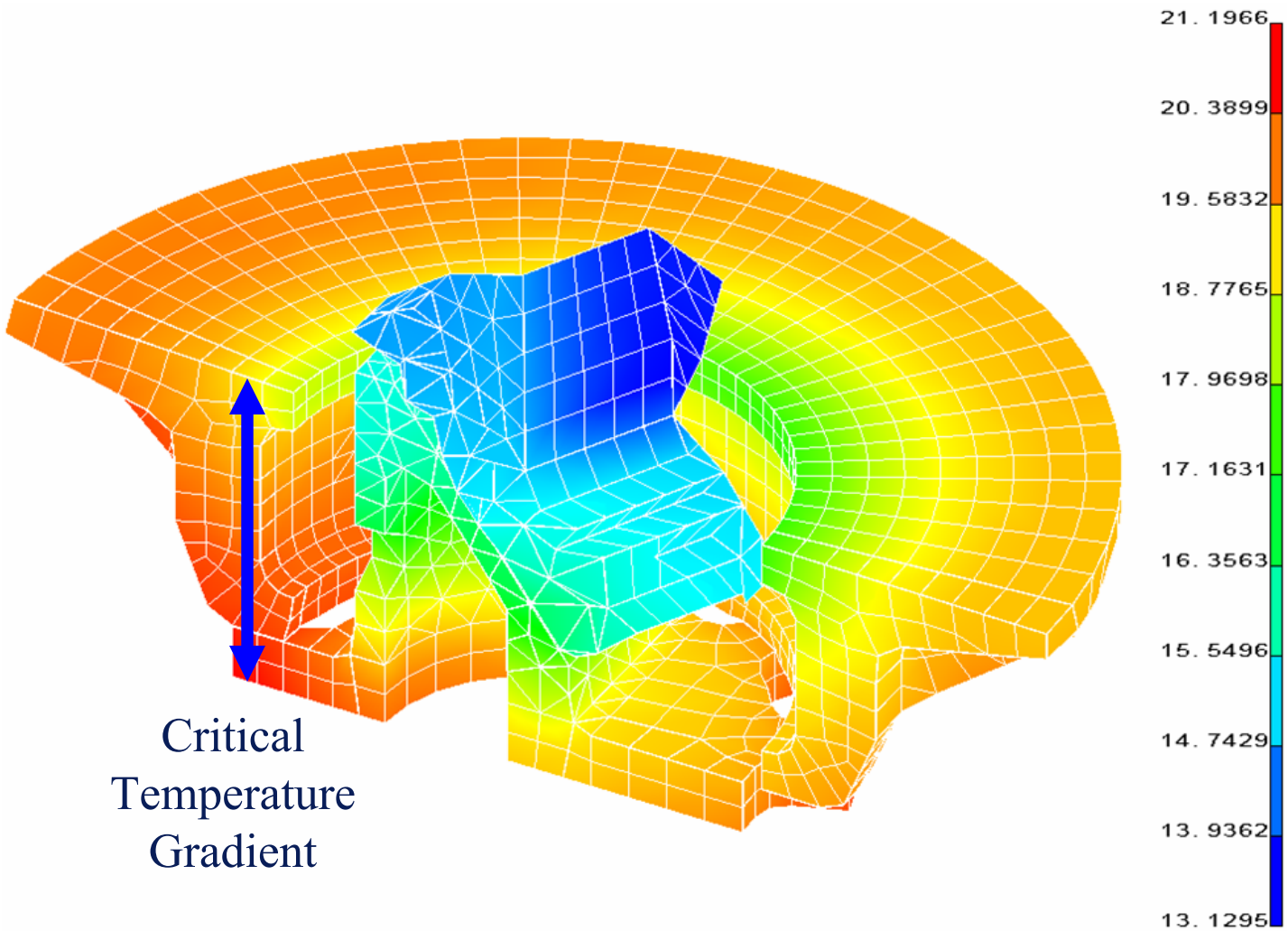
SID Sample Steady State Temperature Map



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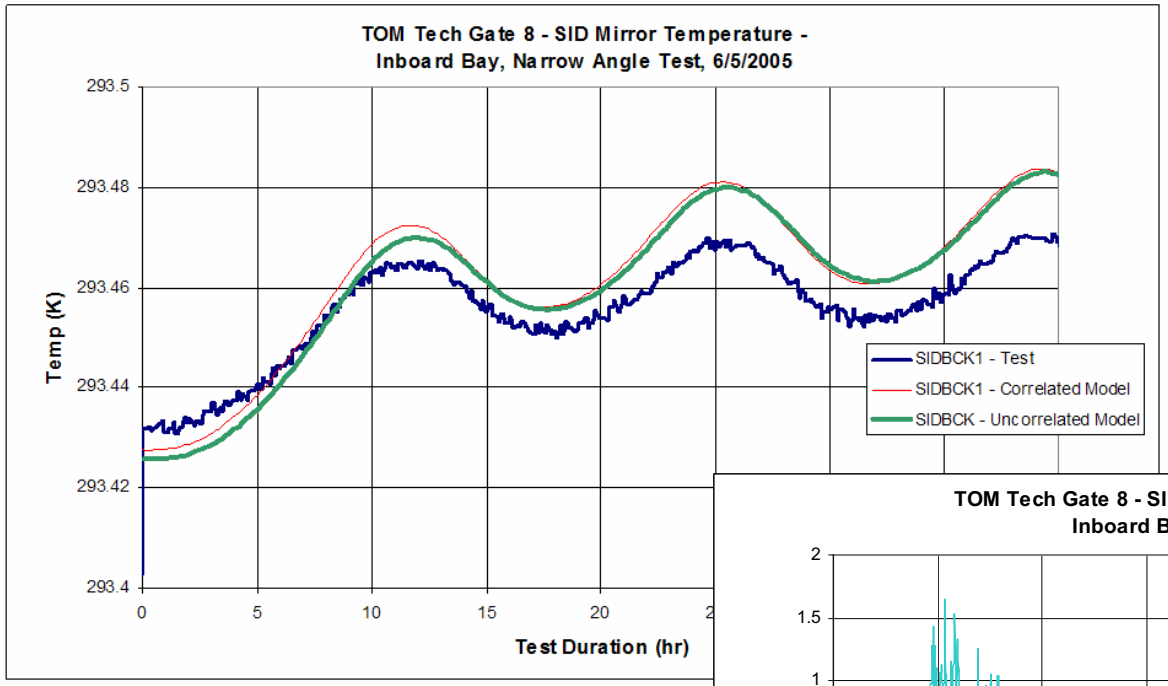
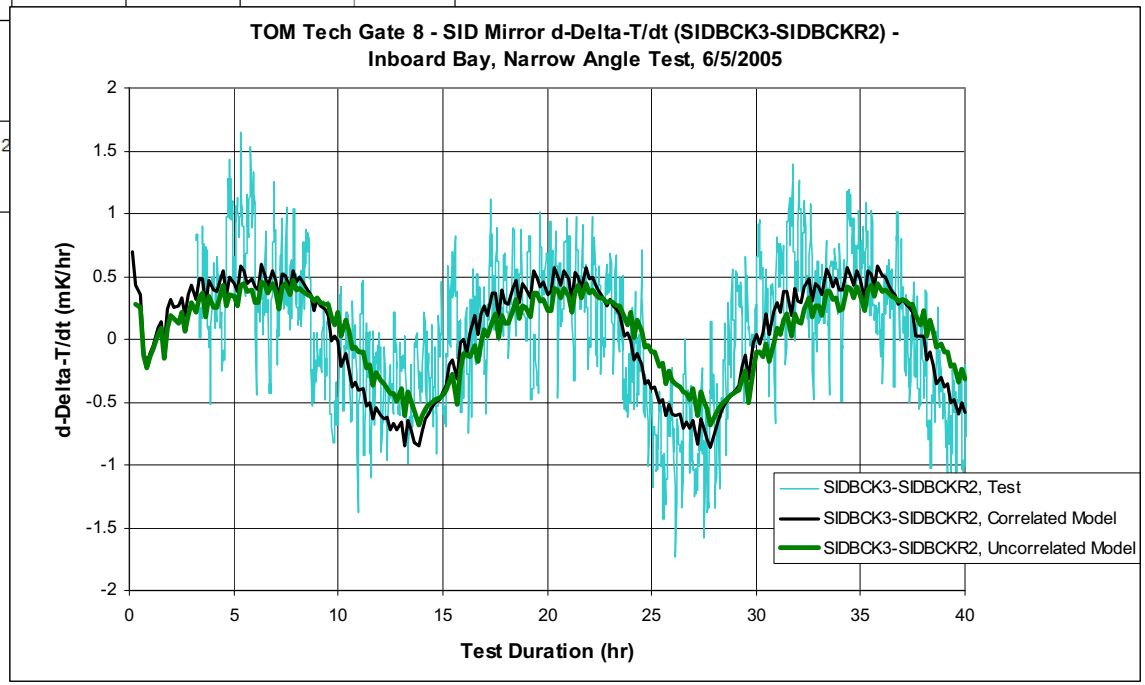
SID Sample Transient Results/Test Data





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Conclusions and Lessons Learned

- Flight Thermal Environment was Successfully Replicated
- Measured Siderostat Optical Performance Met Optical Requirements by a Wide Margin.
- Despite a Good Thermal Model Correlation, Uncertainties in Material Properties Complicated Structural Correlation (assumed ULE CTE of +/-5 ppm, Recently Measured at +30ppm)
- ULE Bool Had Non-Homogeneous CTE (Homogeneous ULE Assumed in Model)
- MLI Blanket Seams Complicated Thermal Model Correlation (Used Average e* of 0.05 where e* was More Like 0.1 Near Seams)
- Thermal Model Probably did not Need to be so Detailed. Mesh Size was Selected Using a Grid Refinement Study and TMG Benchmarking Studies.