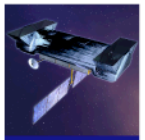
SIM PlanetQuest

Development and Validation of High Precision Models for SIM Planetquest

Chris A. Lindensmith, H. Clark Briggs, Yuri Beregovski, V. Alfonso Feria, Renaud Goullioud, Yekta Gursel, Inseob Hahn, Gary Kinsella, Matthew Orzewalla, Charles Phillips

California Institute of Technology, Jet Propulsion Laboratory
Pasadena, CA 91109

Overview



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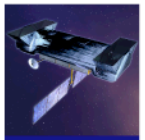
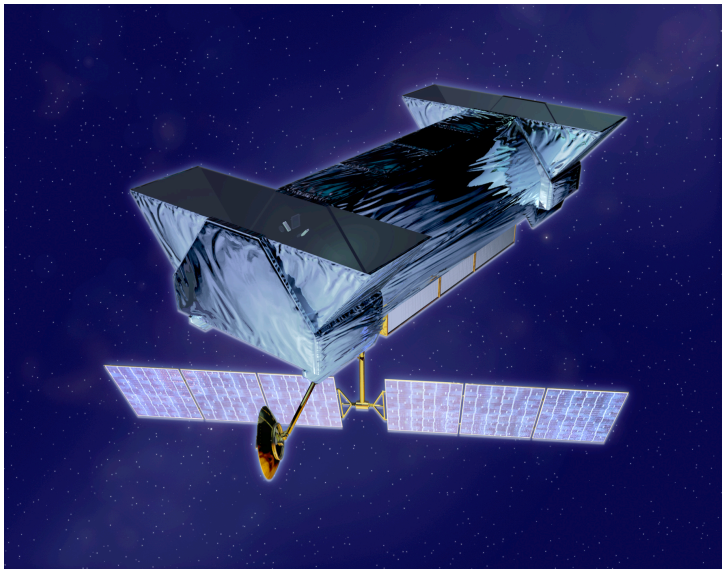
- High Precision Modeling
  - Why SIM needs it
  - Technical issues
  - Process flow
- Development of the SIM Thermo-Opto-Mechanical Models
  - Compressor Modeling
    - Compressor Bench
    - M1 Model
  - Siderostat Modeling
    - Thermal models
    - Structural model results
- Summary

Why SIM needs precision models



- SIM is a very large optical system (10 m) that needs to be stable to tens or hundreds of picometers over time scales from 90 s to 1 hr.
- Availability of high fidelity precision models can reduce the need for intermediate hardware development and tests.
- Can run test cases that would be difficult or time consuming to build, such as sensitivity to changes in materials properties or environmental conditions.



Issues in High Precision Modeling

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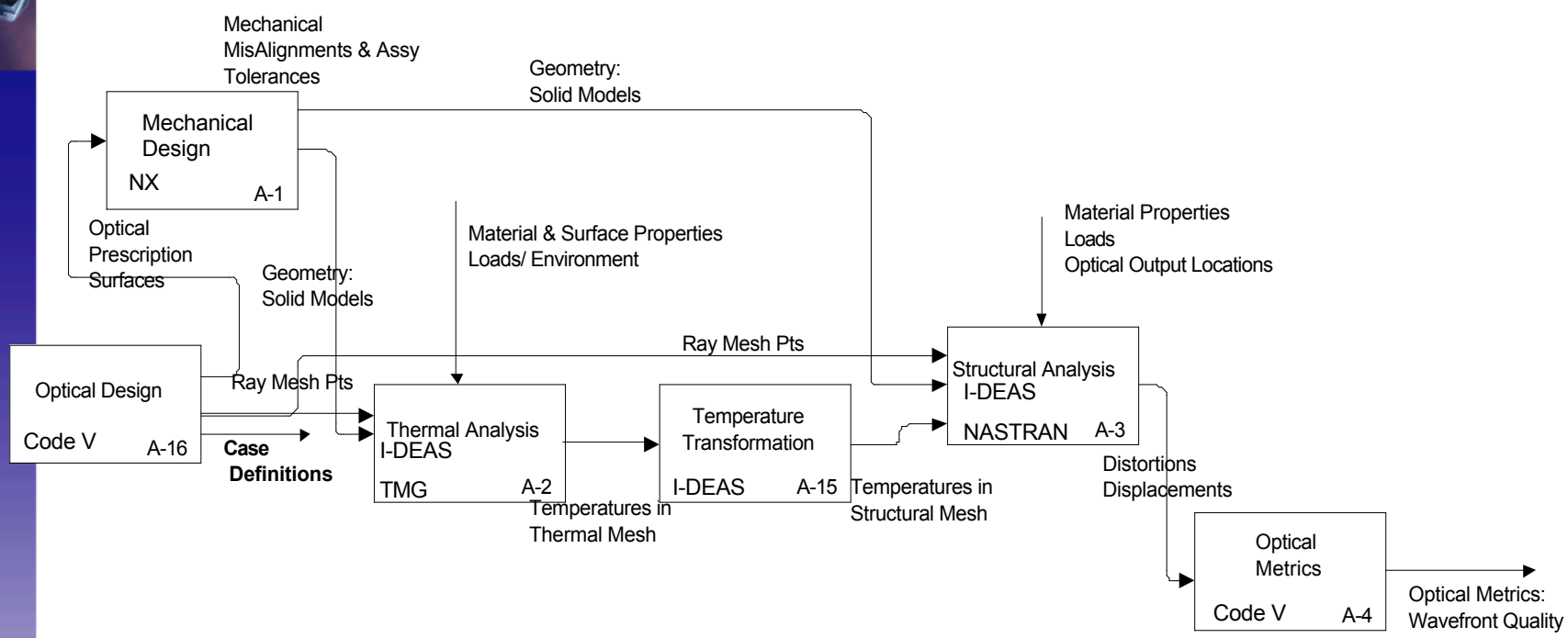
- Procedural Effects- generally well understood or controlled.
  - -Physical phenomena
  - -Solution techniques
  - -Geometry capture
  - -Data Interfaces
  - -Numerical precision
- Most sensitive variables affecting steady state correlation:
  - MLI blanket effective emittance (e*)
  - MLI blanket variations in e* (seams, folds)
  - Aft Thermal Can internal emissivity variability (abraded aluminum, e=0.05)
  - Mirror front face emissivity (e=0.023)
  - Power input into Thermal Can
- Most sensitive variables affecting transient correlation:
  - Heater control method (TMG does not have a PID routine)
  - Material Thermal Capacitance
- Material Properties
  - -Properties used without temperature or time
  - -Common materials- fairly well understood
  - -Athermal materials - have significant uncertainties
  - -Thermal and mechanical properties with significant uncertainty are CTE, C_p, and Emissivity.

The Integrated Modeling Process



- "Bucket Brigade" Modeling Approach
  - Based Upon LMATC Prior Work
  - Scaled up for Larger SIM Team
  - Use JPL Strategic Tools (UG, I-DEAS, TMG) w/ Config Control
  - Carefully Selected and Verified Modeling Process Details

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Beam Compressor

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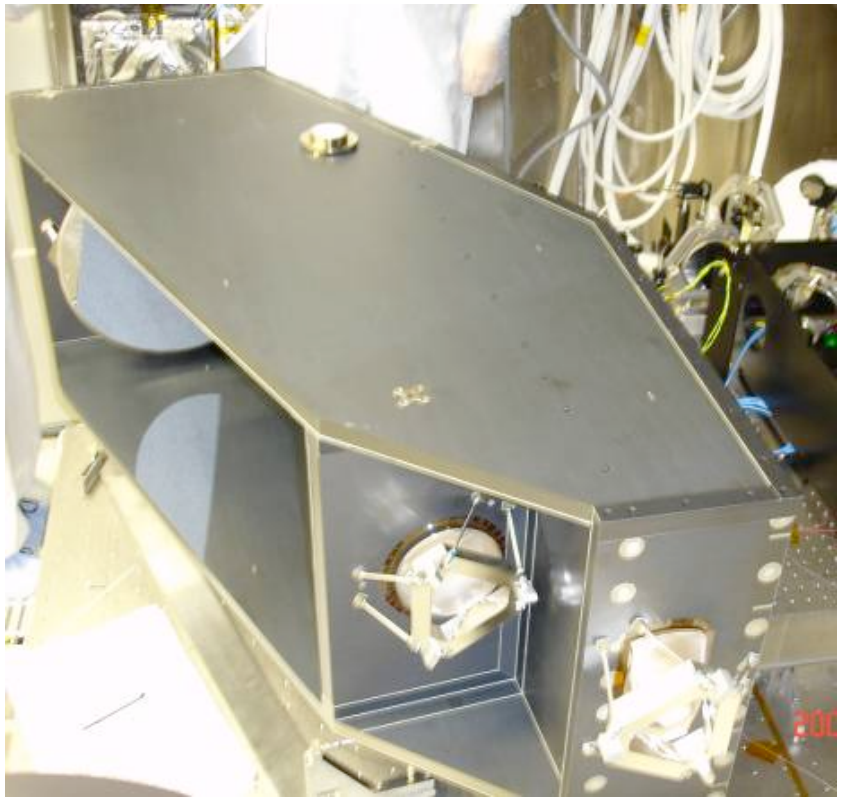
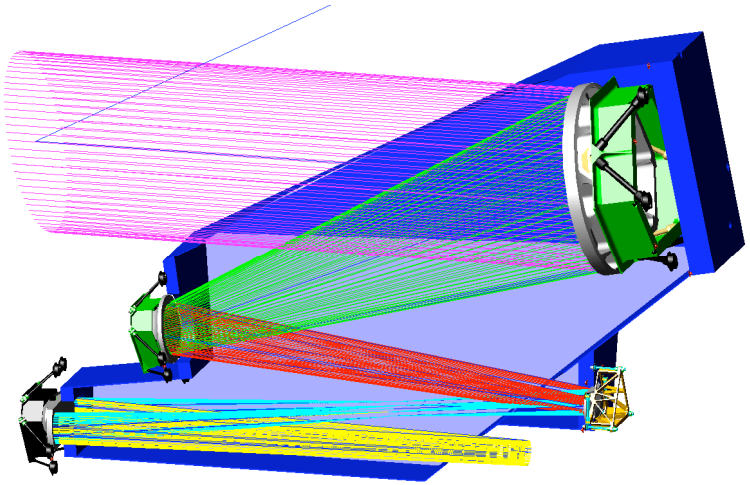
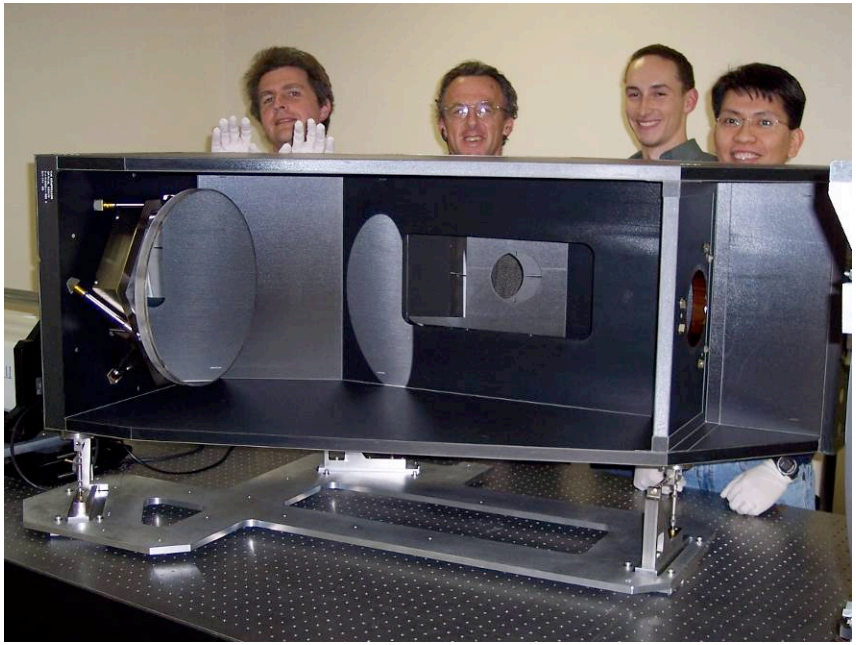
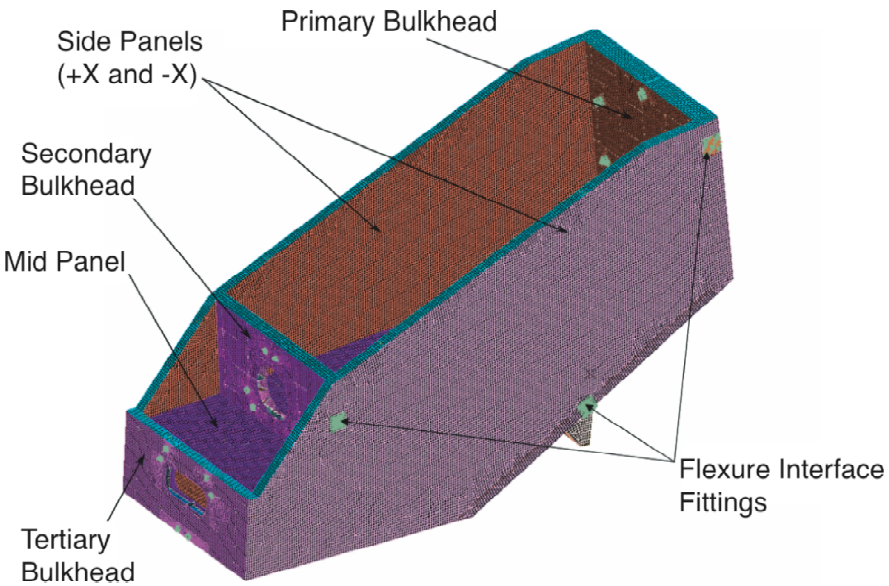
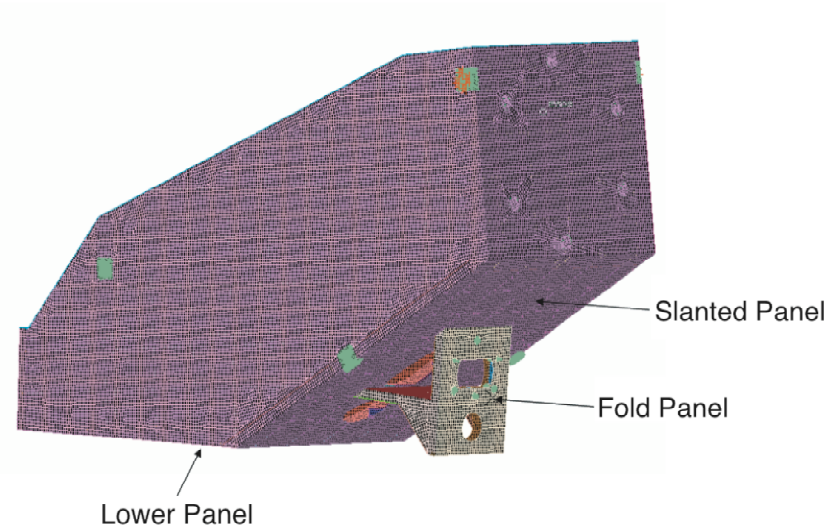






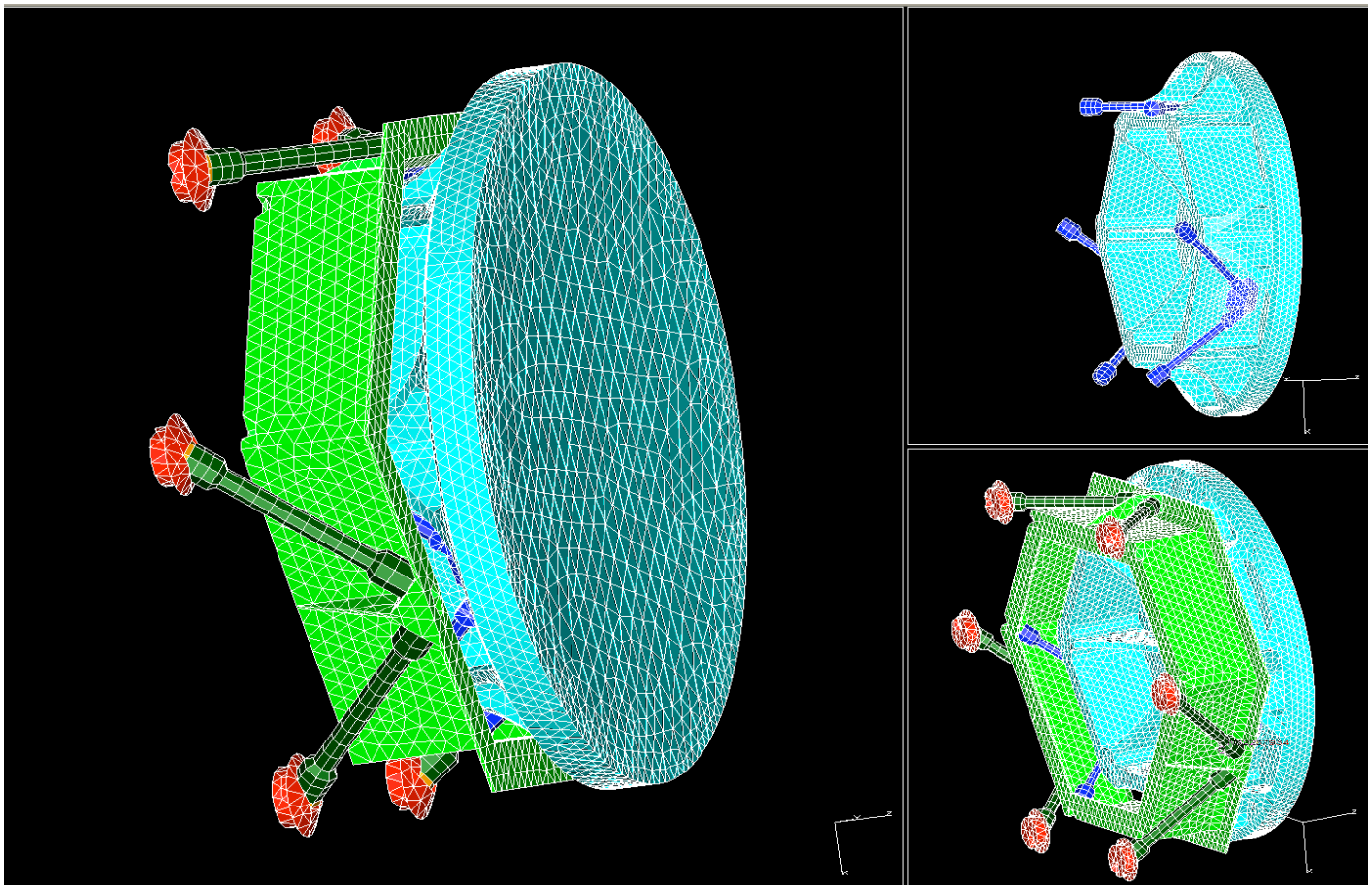
Compressor Finite Element Model





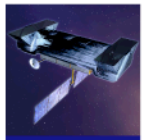
- ~526,000 nodes.
- ~382,000 elements.
- M1 and M2 mirror models generated by JPL.
- Bench model generated by ATK.
- Fold and M3 mirrors absent from model.

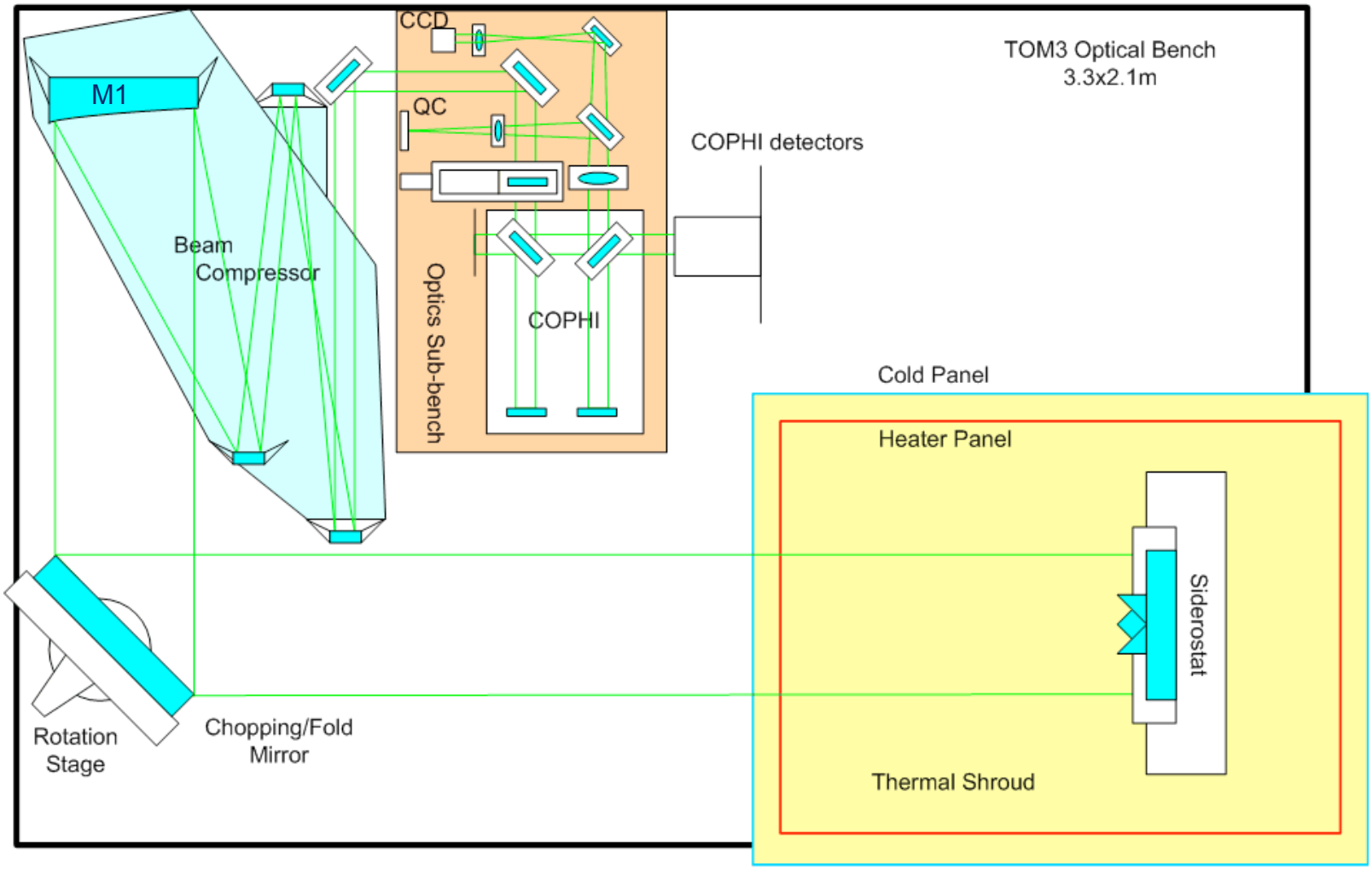
Compressor M1 Mirror Model



M1 mirror has approximately 98,000 nodes and 49,000 elements.

TOM3 layout





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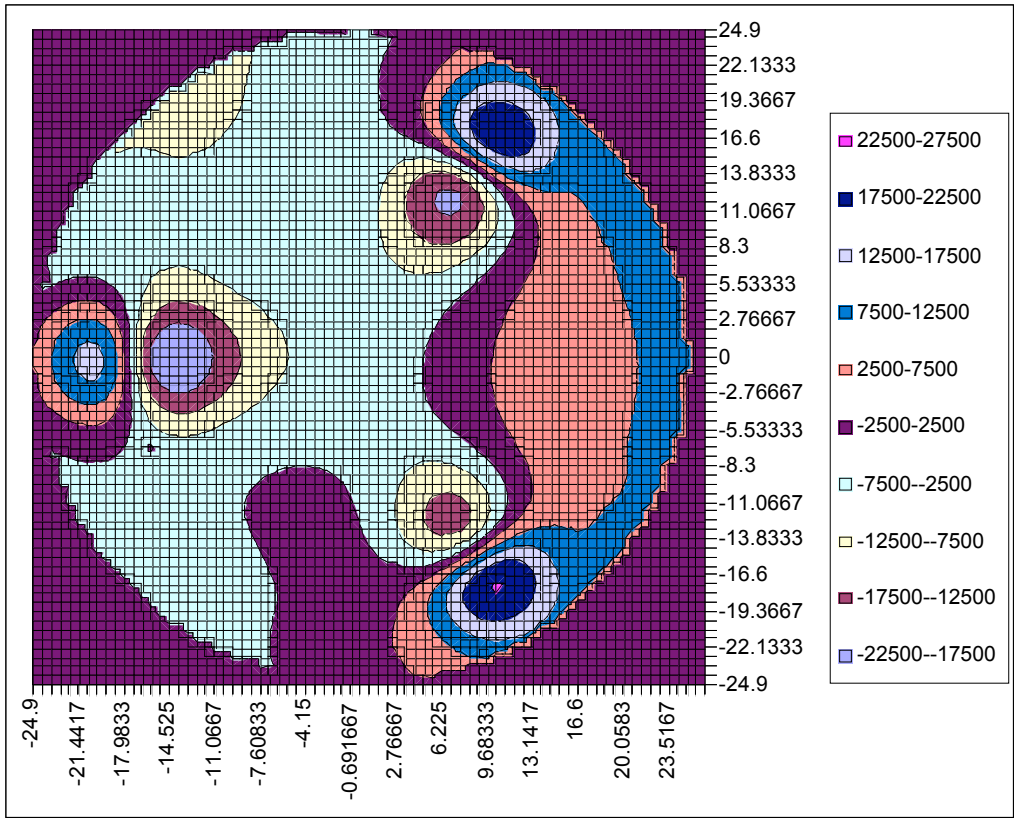
Modeling results

Results are for 9 COPHI detectors

Uniform 1K soak data produce 9.97 nm OPD change

- Match the experimental data to within 20%
- Error in CTE knowledge is likely much greater than interpolation errors in optical modeling
- OPD surface map built for verification



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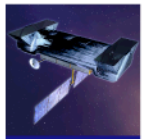
SIM Collector – Structural Modeling



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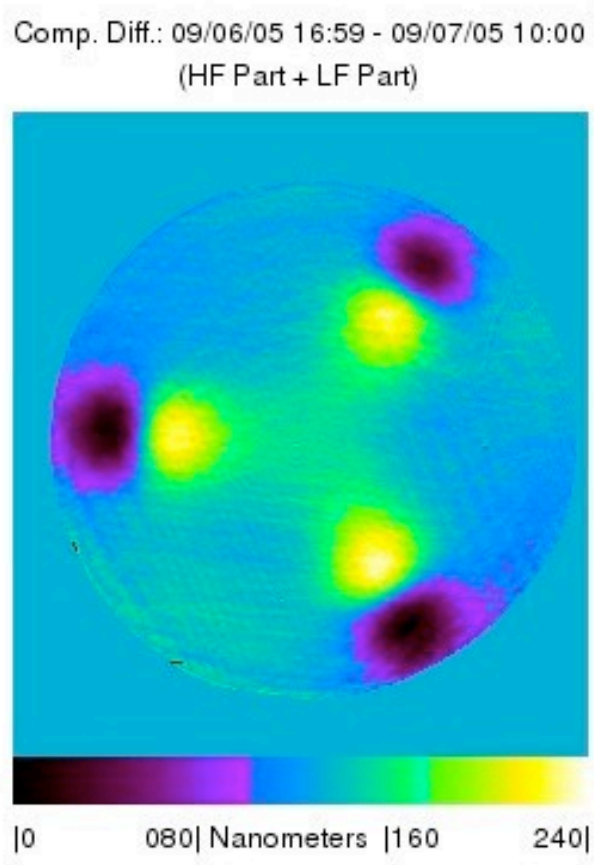
M1 Surface Map under a Uniform Temperature Drop

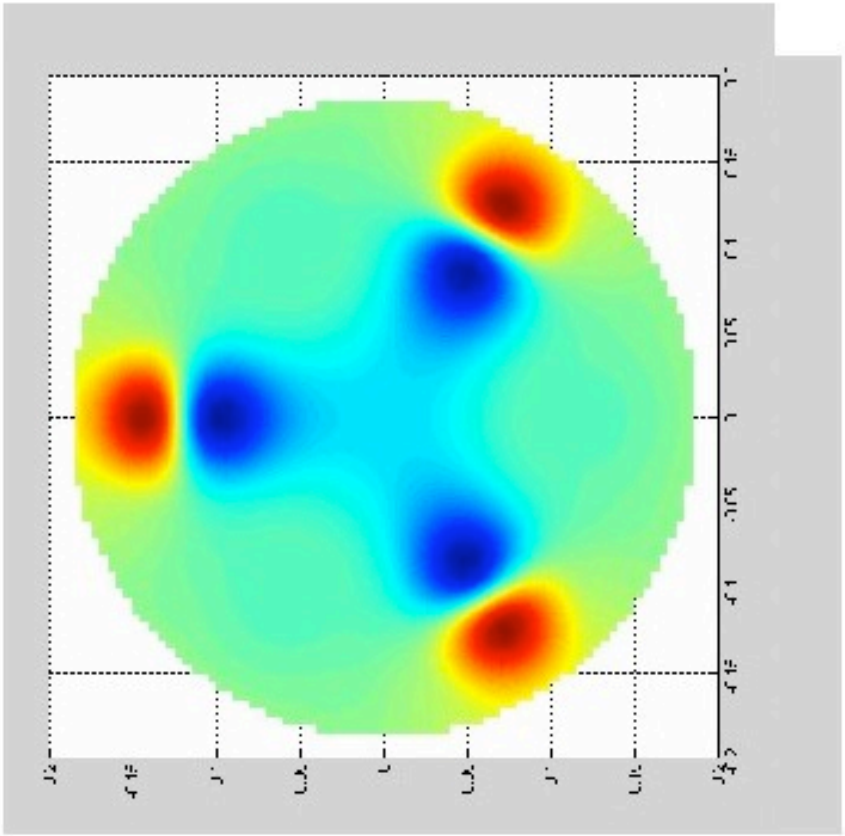
Measured Results

RMS = 6.1 nm/°K OPD error
P-V = 14.25 nm/°K

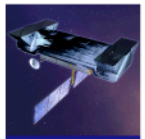


Analytical Results

RMS = 7.2 nm/°K OPD error
P-V = 14 nm/°K



SIM Collector – Structural Modeling



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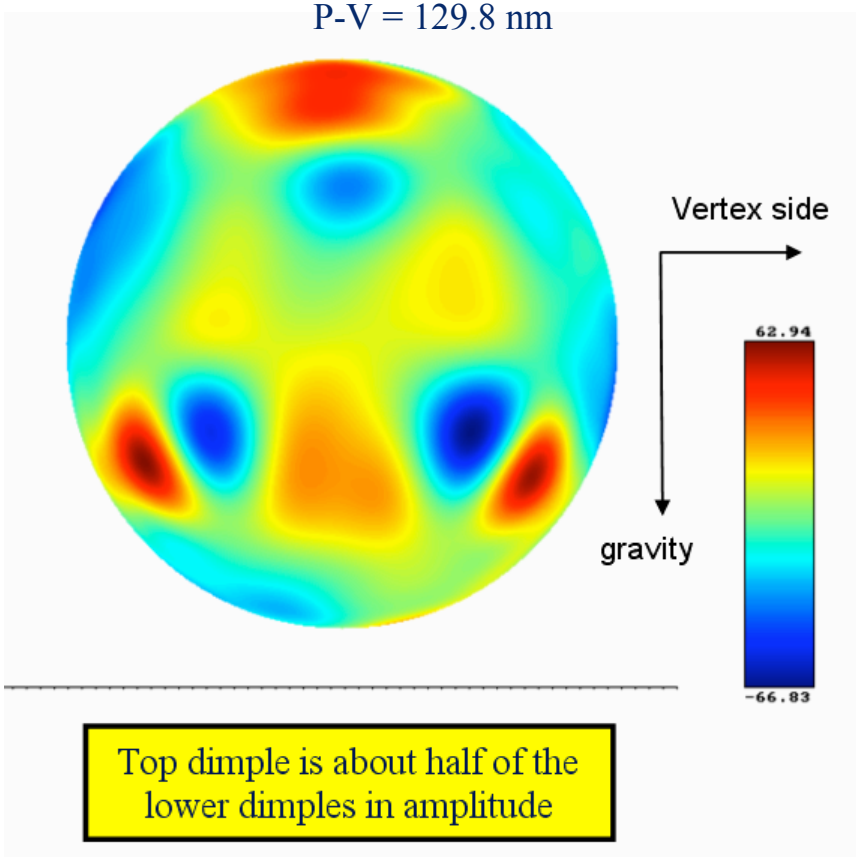
M1 Mirror Print-Through Analysis

Mfr Surface Figure Difference:

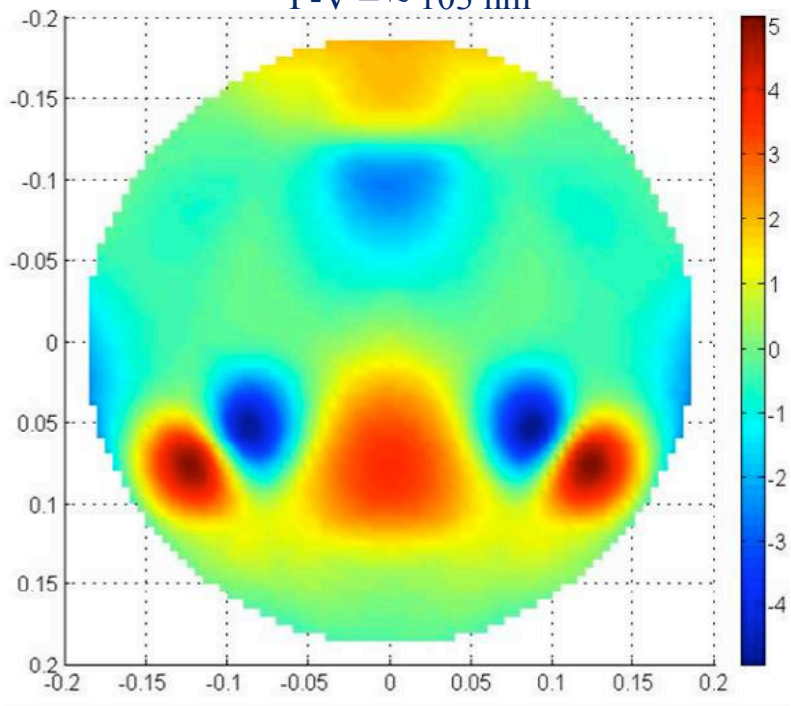
Pre- to Post-Mounting
RMS = 20 nm equivalent surface error
P-V = 129.8 nm



Top dimple is about half of the lower dimples in amplitude

FEA Combined Case:

Inverted Tinsley's Dimples
+ 1G Gravity on Bipods
+ Post-Mounting Hanging Case
RMS = 14 nm
P-V = ~ 103 nm



Siderostat

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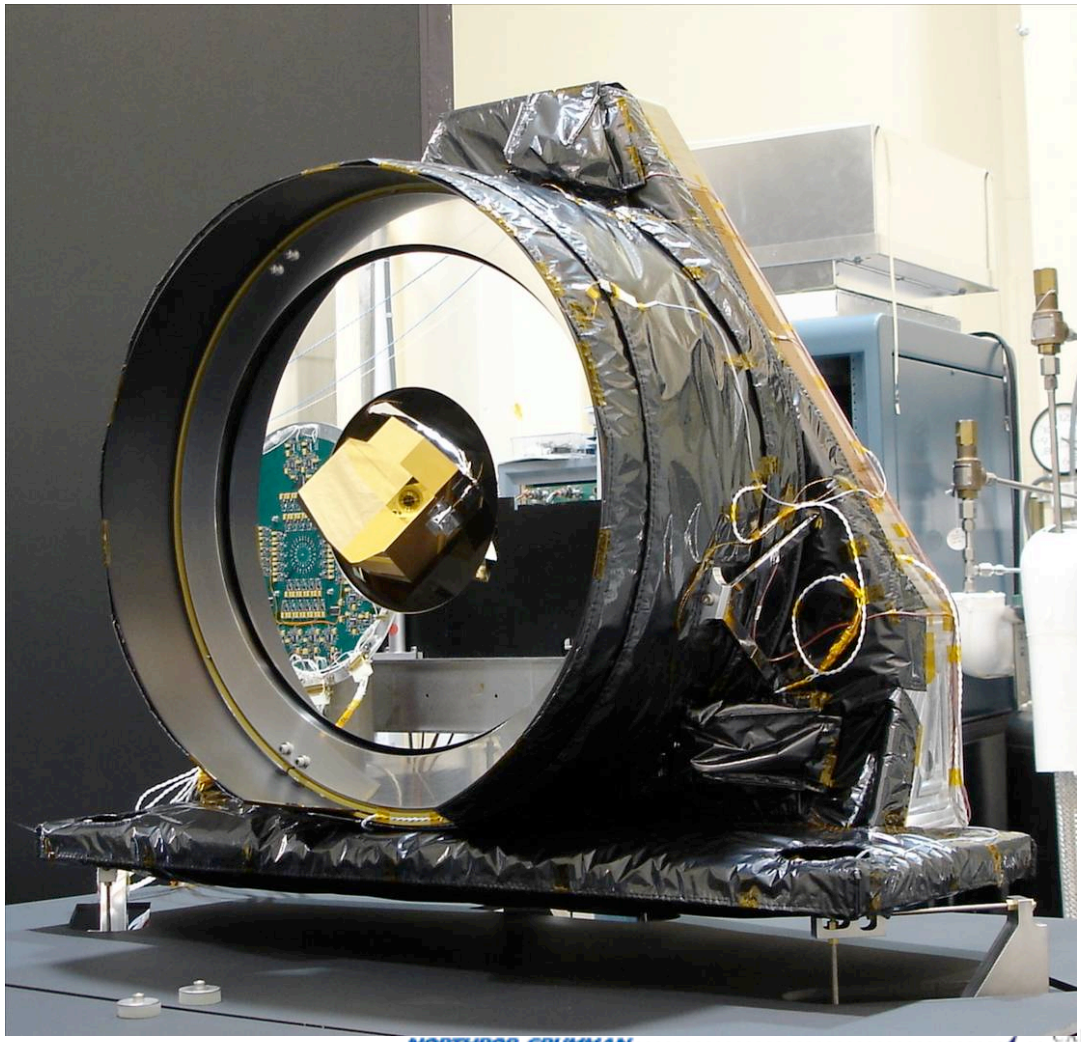
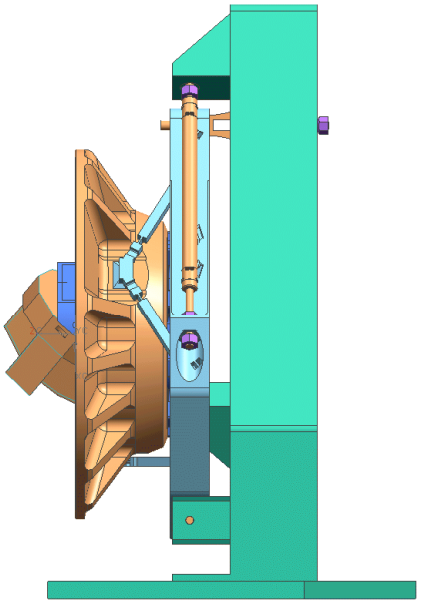
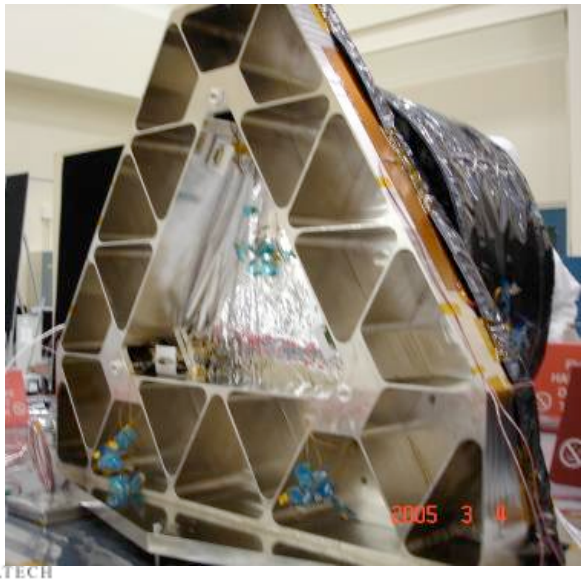
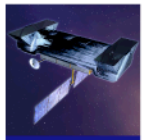
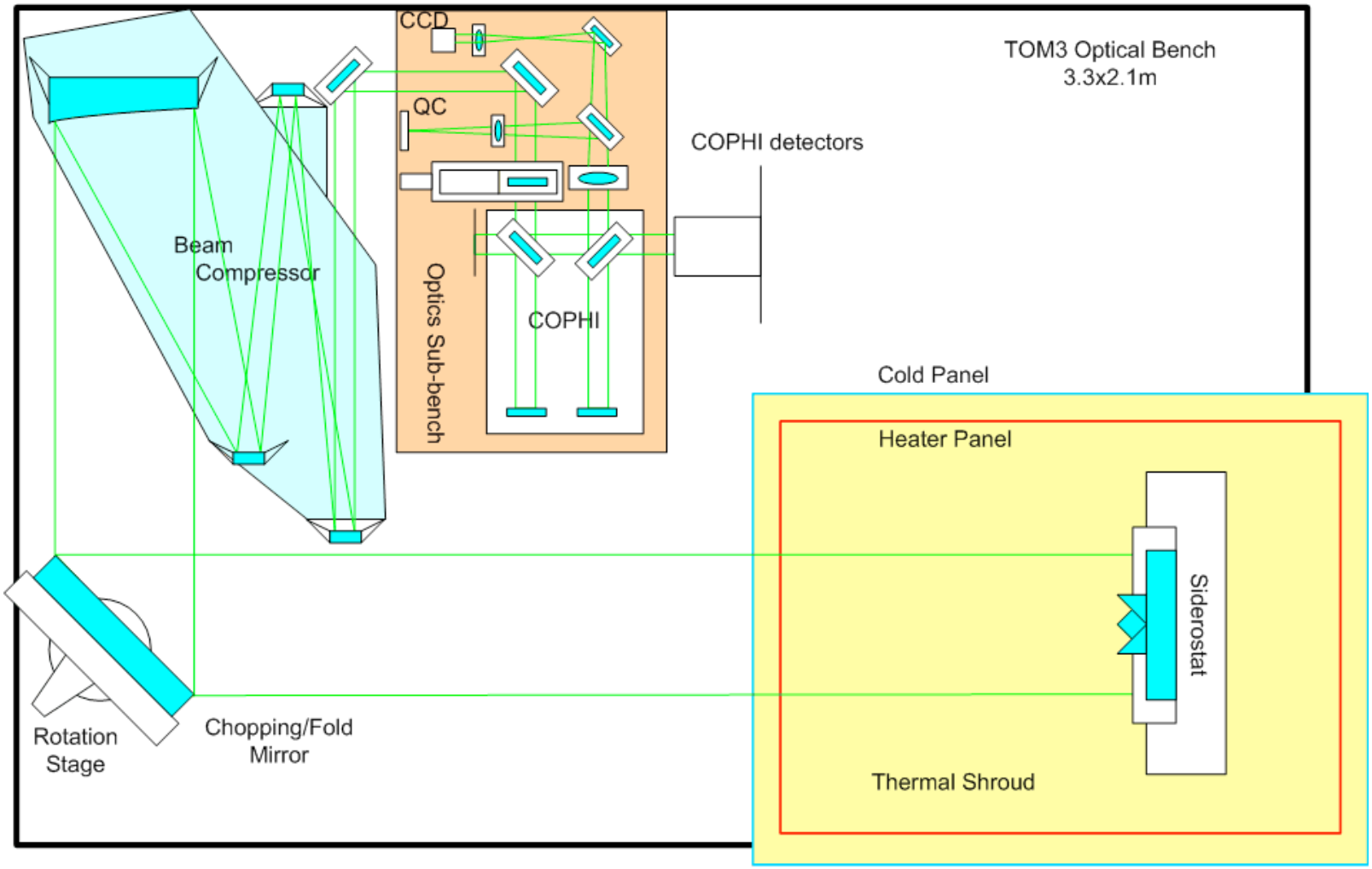






TOM3 layout





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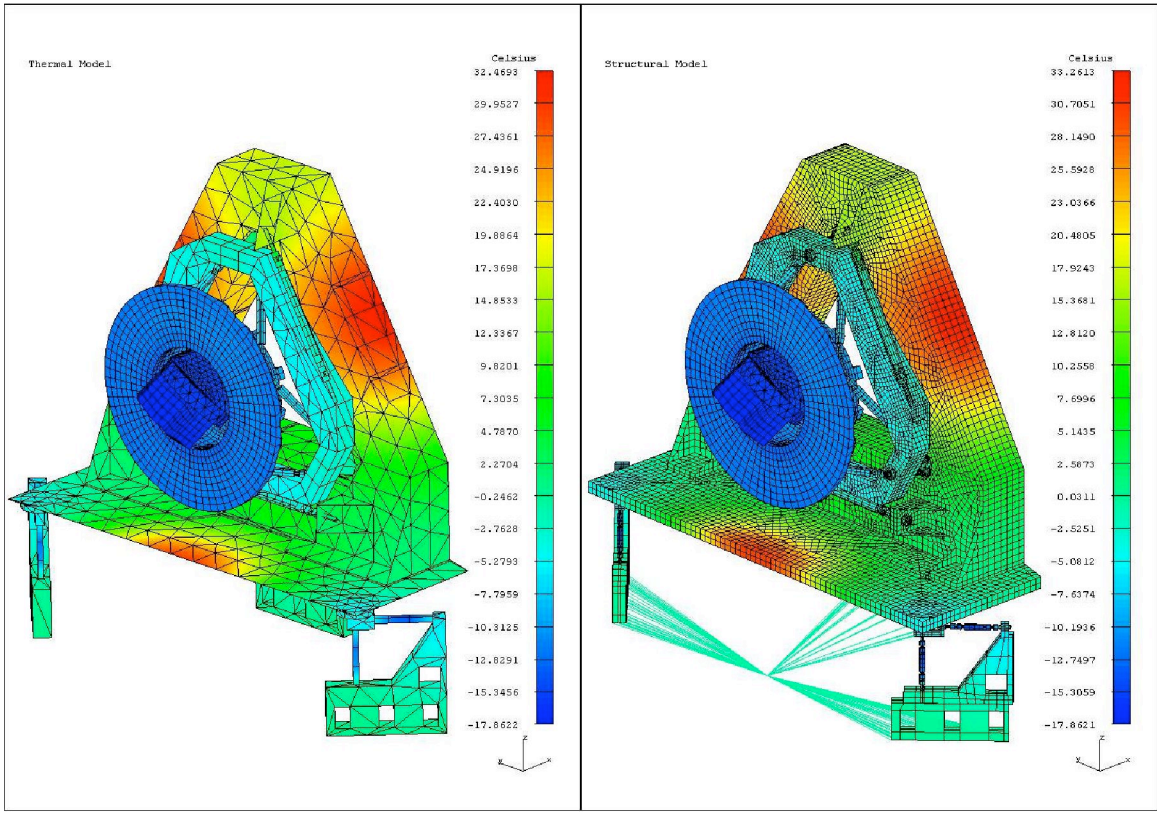
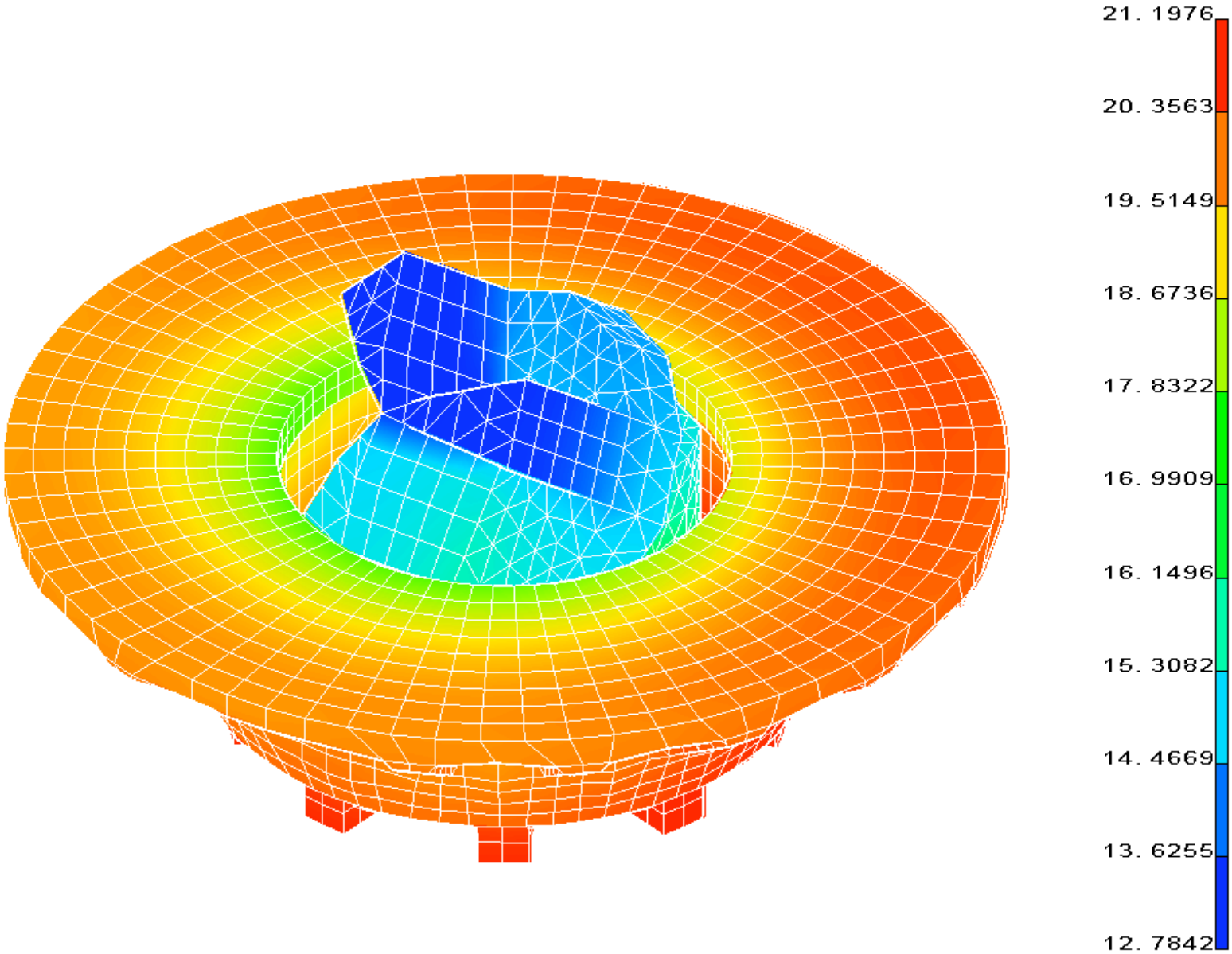
Example of FEM mapping



Correlated SID Temperature Contour for 200K Steady State Thermal Shroud



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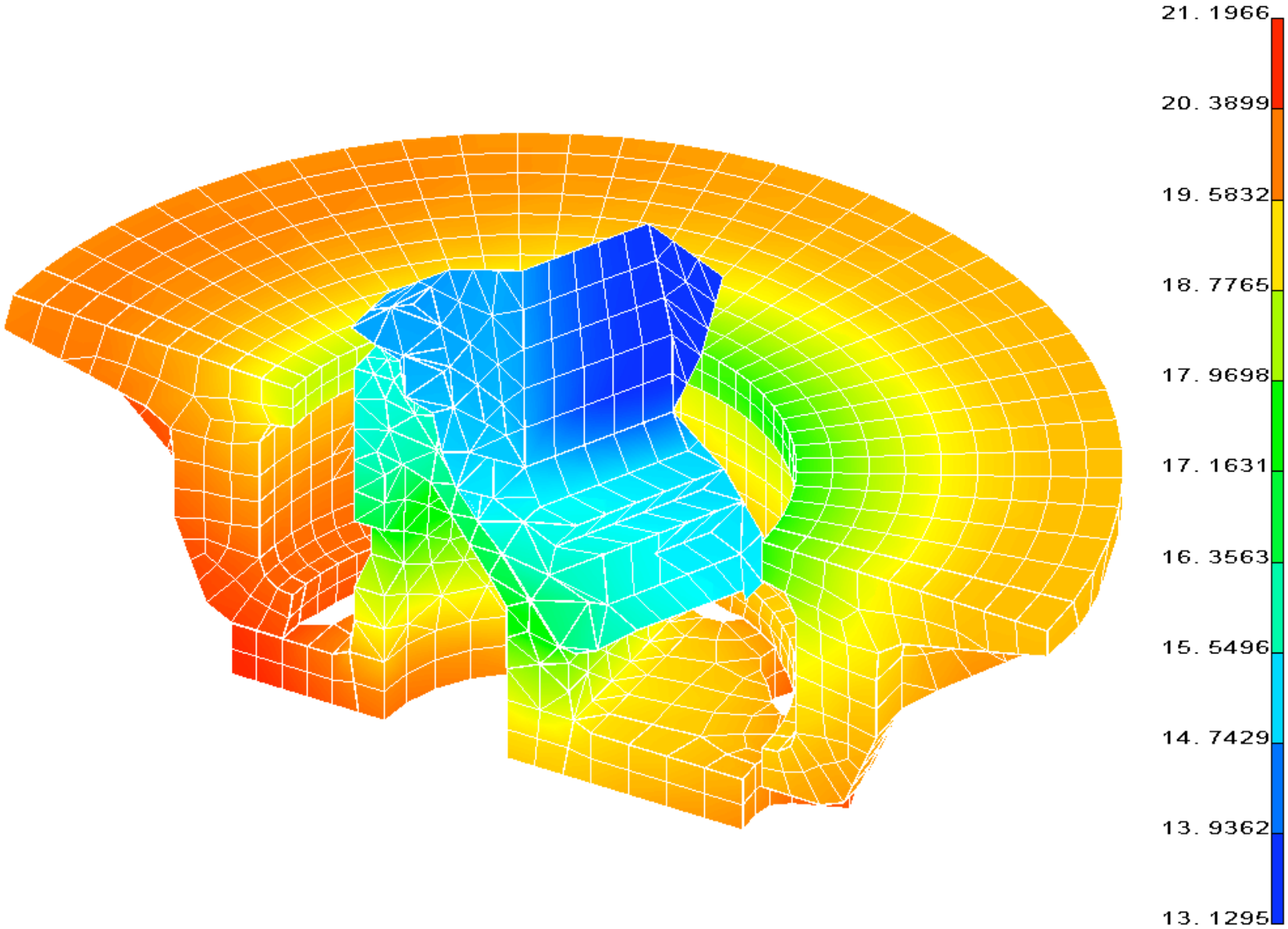

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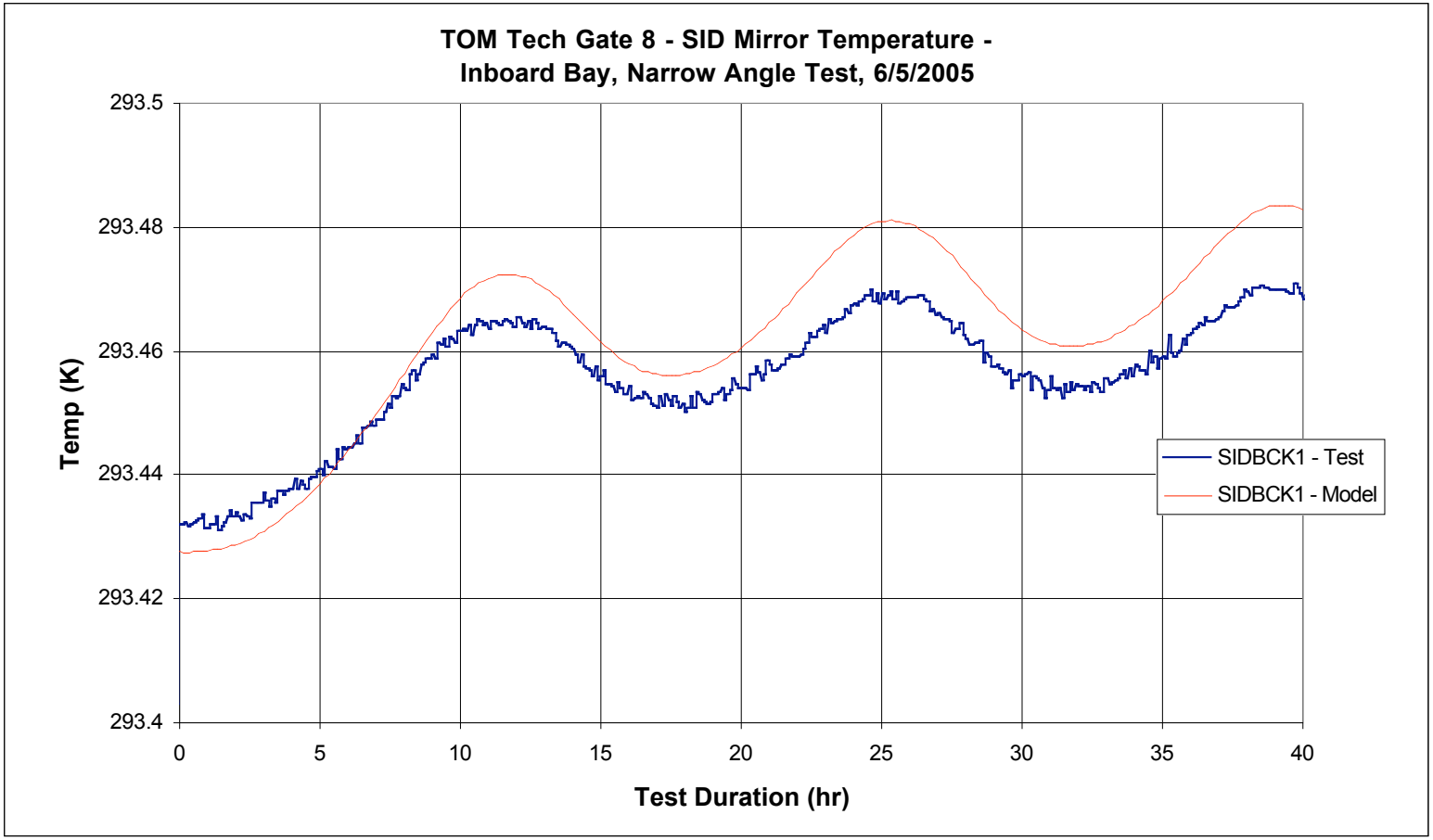
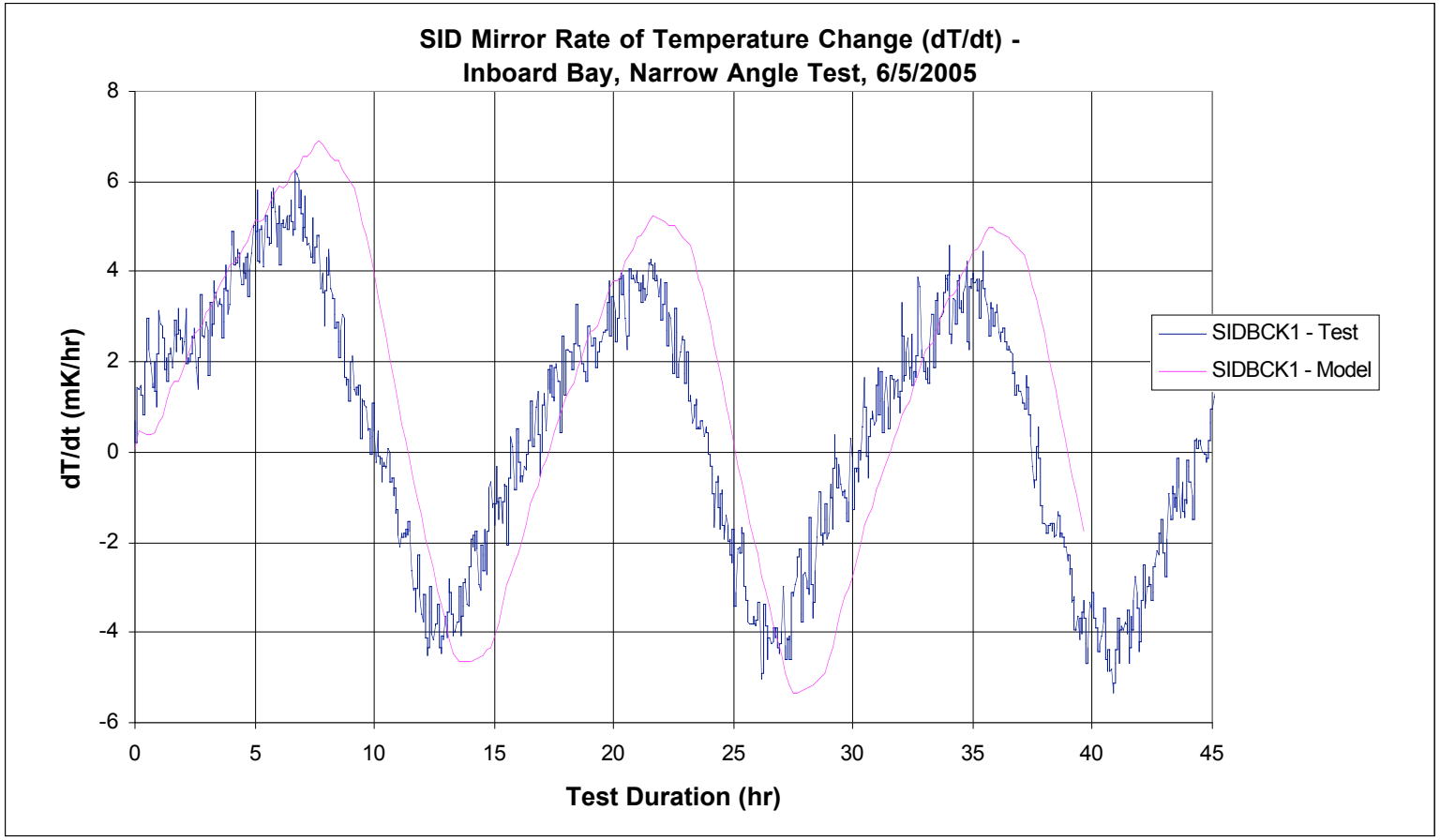
SID Mirror Temperature Response – NA, Inboard Test



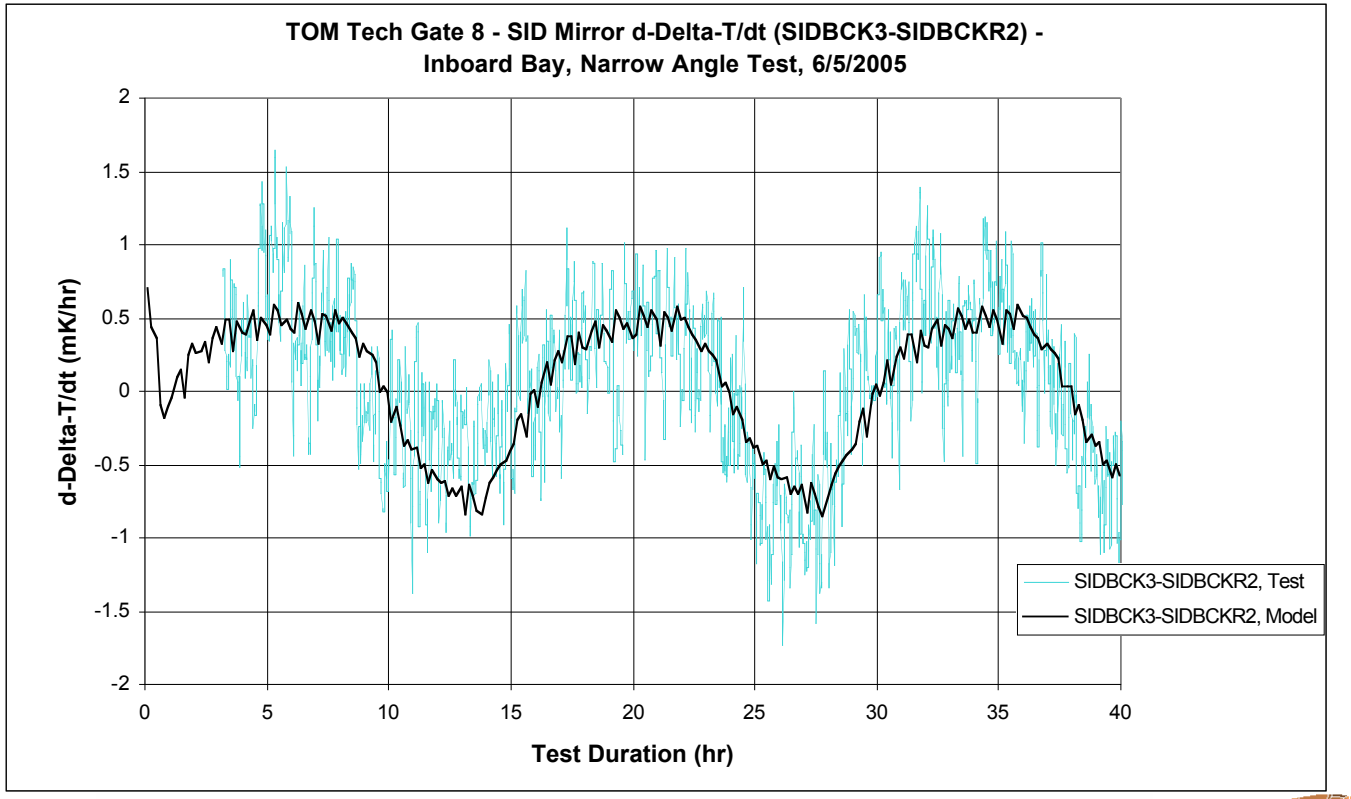
Note: SIDBCK1 Temperature Offset by 1.3C

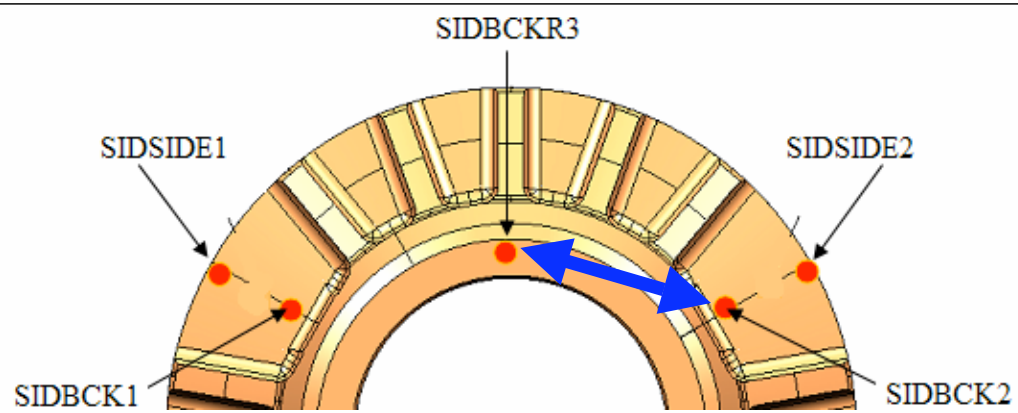
SID Mirror Rate of Temperature Change – NA, Inboard Test

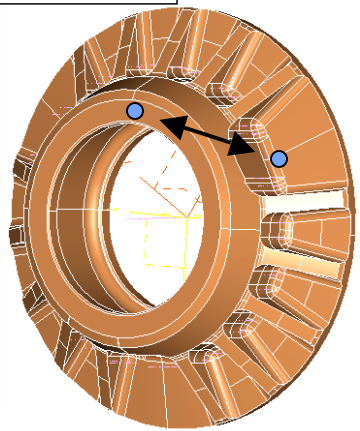


Note: Current SID Temporal Thermal Requirement is 5mK/hr

SID Mirror Gradient
Rate of Temperature Change (dΔT/dt) – NA, Inboard Test







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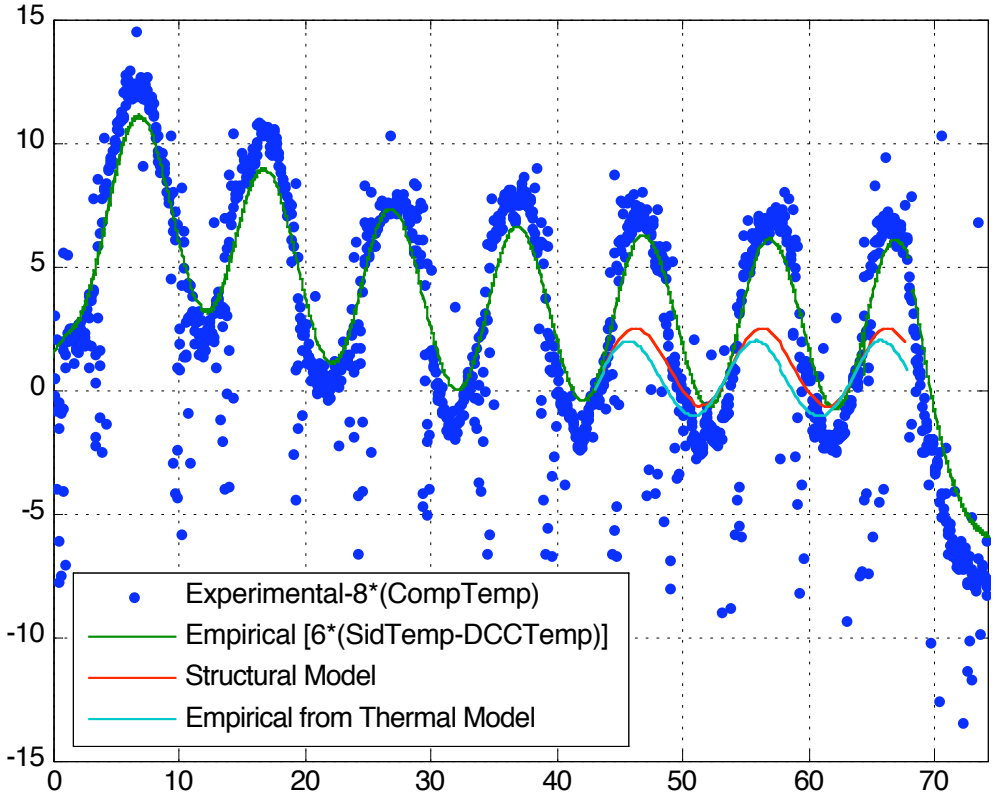
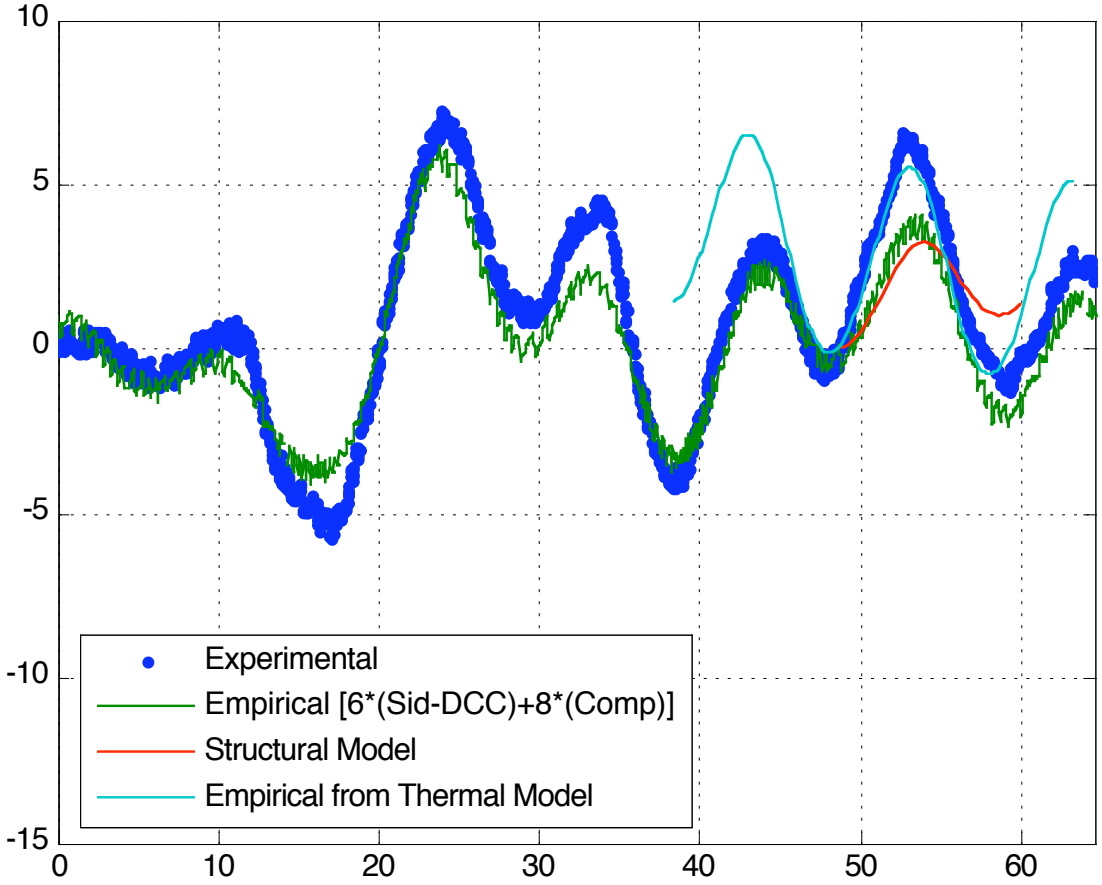
SID at 20 C, Shroud at 225+50sin(t)



Structural model correlates well in time, amplitude is low by ~3x

20x Flight Environment



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Model Fidelity and System Design

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- The integrated modeling process is working and allows thermo/opto/mechanical modeling at mK/pm levels needed for sim.
- Commercial FEA tools are being used without need for tool development-- only process development for practical work and model flow.
- The models have been validated against experimental data at OPD response levels that meet the SIM system requirements (despite requiring overdrive of the thermal environment)
- Knowledge of the materials parameters is key to having good predicting models-- sensitivity analyses will be delivered with the TOM3 final report.
    - Accurate measurements of material properties needs to be done on the actual materials used and the data supplied to modelers
    - Tests will still need to be done at various lower levels (coupon,component, subassembly, assembly) to verify or support model predictions.