SIM

Space Interferometry Mission

TFAWS 2006

SIM PlanetQuest: Milli-Kelvin Analysis of the Collector Subsystem Thermal Model

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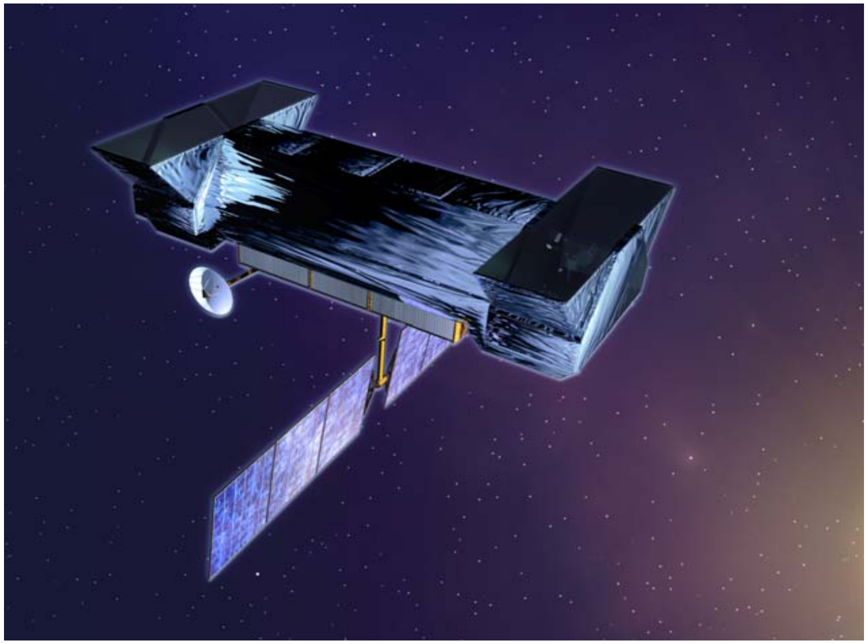
8/7/2006



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Presentation Agenda

- The SIM PlanetQuest Mission
- Spacecraft Subsystems
  - Collector Bay Hardware
- Temperature Requirements
- Thermal Control Approach
- Milli-Kelvin Modeling Approach Flow Chart
  - Spacecraft FEM
  - OOPCC Optical Assembly FEM
  - Spacecraft Slew Scenario during Normal Operation
  - Results for OOPCC Optical Assembly
  - Thermal-Structural Temperature mapping
- Conclusion

SIM PlanetQuest

Space Interferometry Mission

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- Part of the NASA Astronomical Search for Origins program (ASO)
- Orbiting Michelson Interferometer
  - 10m baseline
  - Locate small planets (4 times Earth radius) around the nearest 250 stars
  - Earth trailing orbit
- Launching between 2011 and 2015
  - 5 year primary mission life
  - 10 year goal

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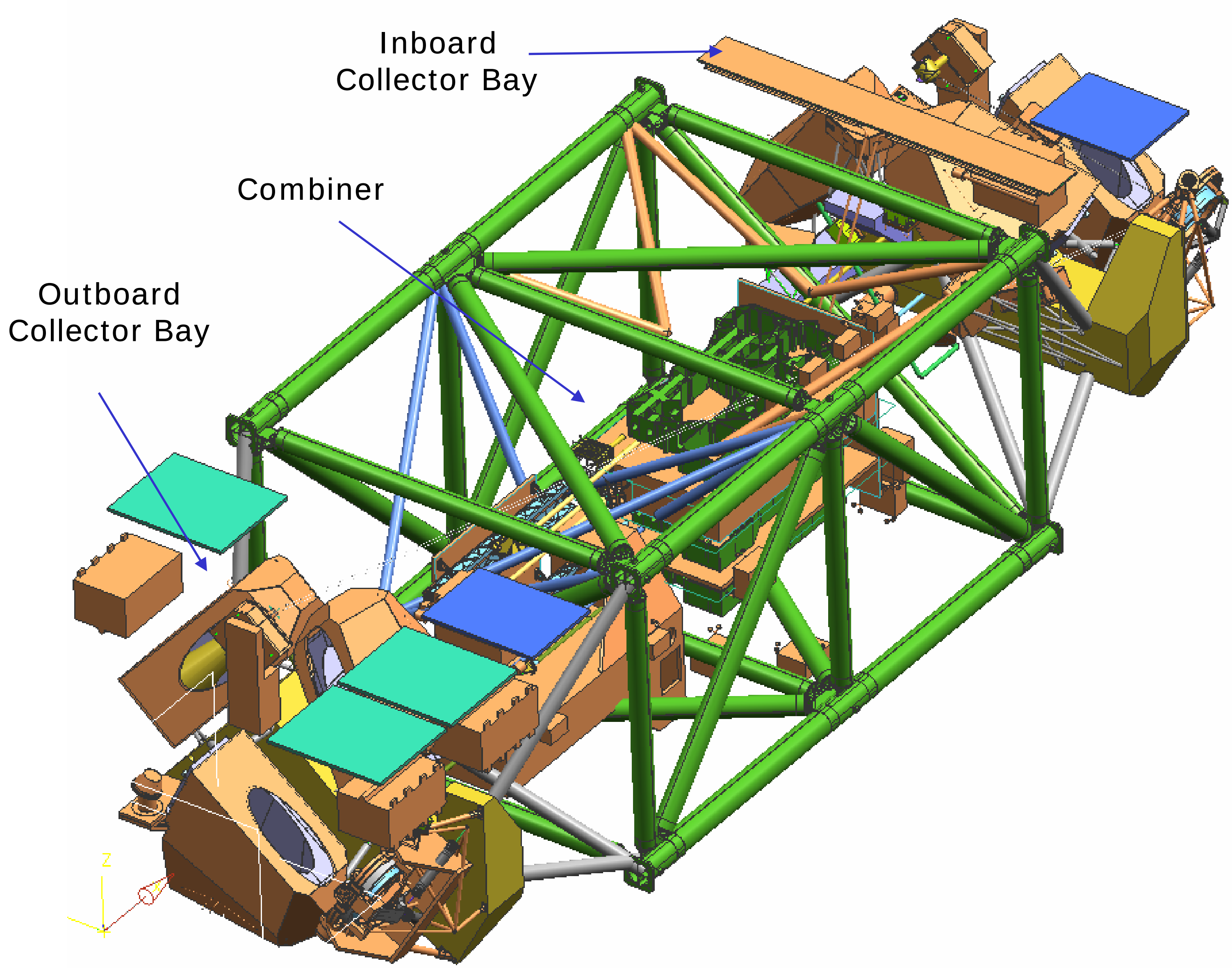
SIM Instrument Subsystem Concept



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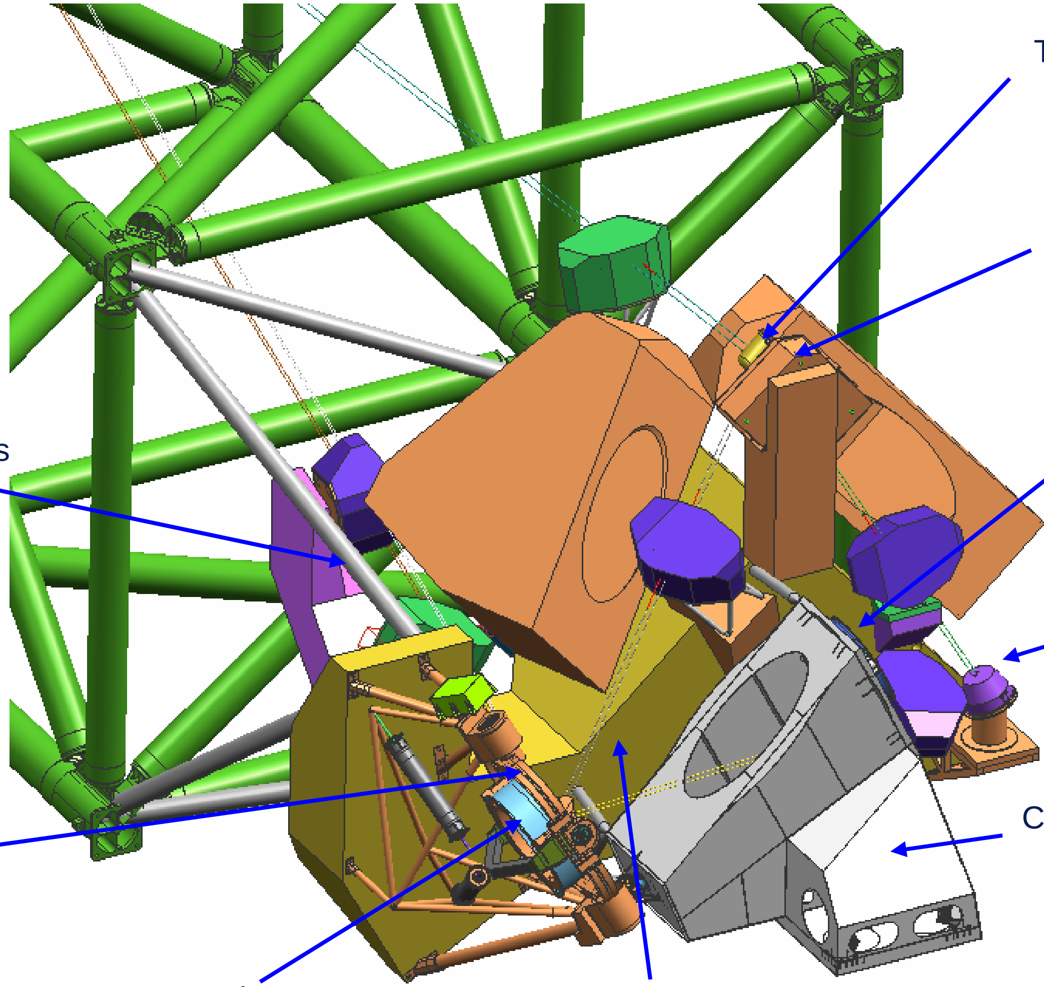
Collector Bay Assembly Concept



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Temperature Requirements

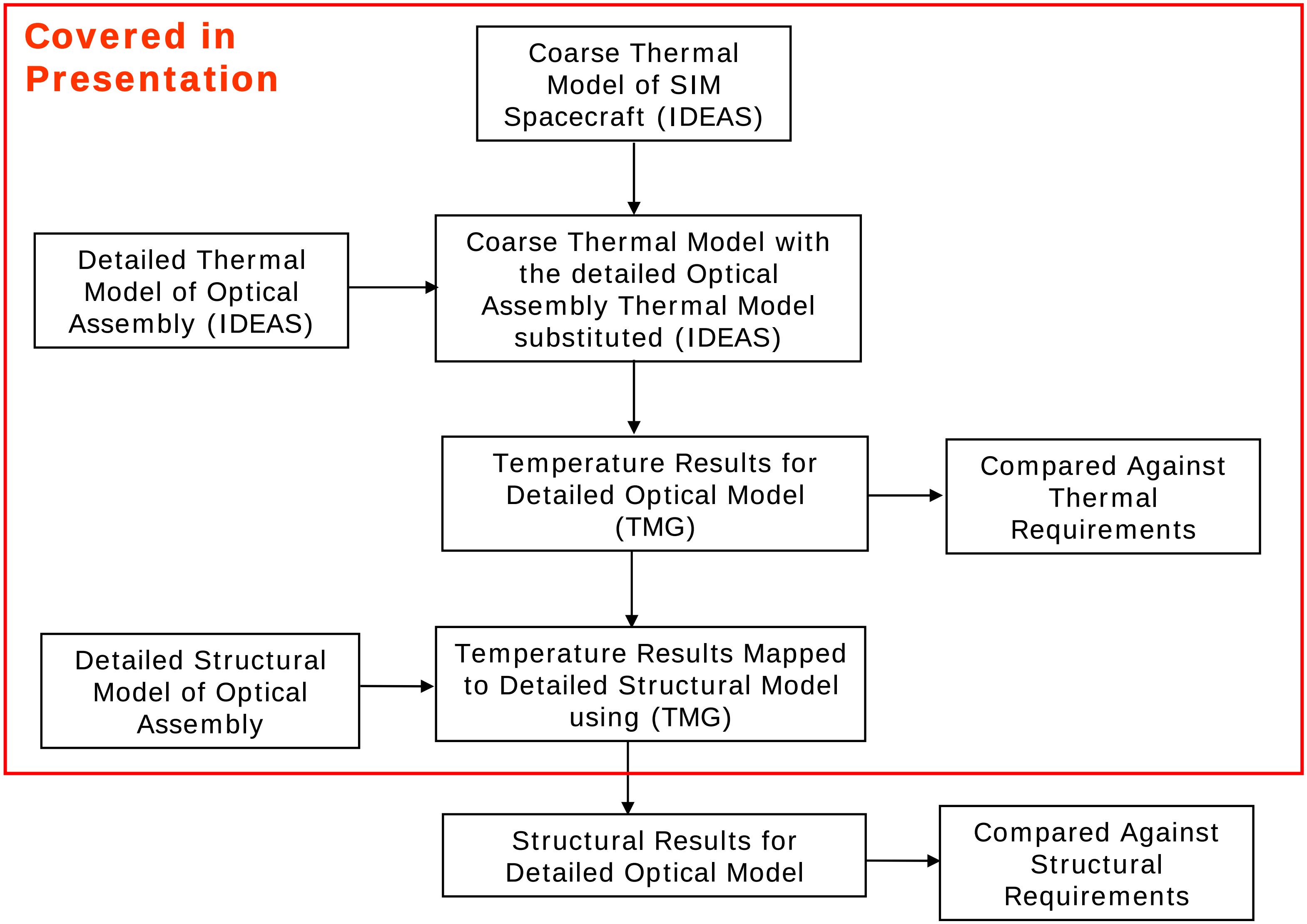
- Instrument optics and optical support structure have small allowable flight temperature (AFT) ranges and tight stability requirements
  - AFT ranges are between 10 and 30°C
  - Stability requirements between 10 and 150 mK/hr

Hardware	AFT Range (°C)		Stabilty Requirement (mK/hr)
	MIN	MAX	
Siderostat Optic	10	30	25
Siderostat Strut	10	30	150
COB Composite Bench	10	25	100
COB M1 Optic	15	25	40
COB M2 Optic	15	25	40
COB M3 Optic	15	25	40
Collector Bay Stucture	5	35	500
Collector Bay Truss	10	30	500
DCC Optic	10	30	10
TCC Optic	10	25	10
OOPCC Glass	10	25	10

Thermal Control Concept and Implementation

- Collector bay is cold biased
  - Ensures heater control authority
  - Minimizes stability impact on critical optics
  - Collector aperture always faces space with no view of the Sun
- Optics must be held at on-ground alignment temperatures (approx. 20°C)
  - Optics are heated with thermal enclosures
    - Optic and optical support structure heaters controlled with PID
    - PID set-points can be changed during mission to correct for ground to orbit temperature differences
    - PID heaters provide tight temperature control
- Less critical hardware heated with steady state thermal switch and/or insulated with MLI

Milli-Kelvin Modeling Process Flow Chart



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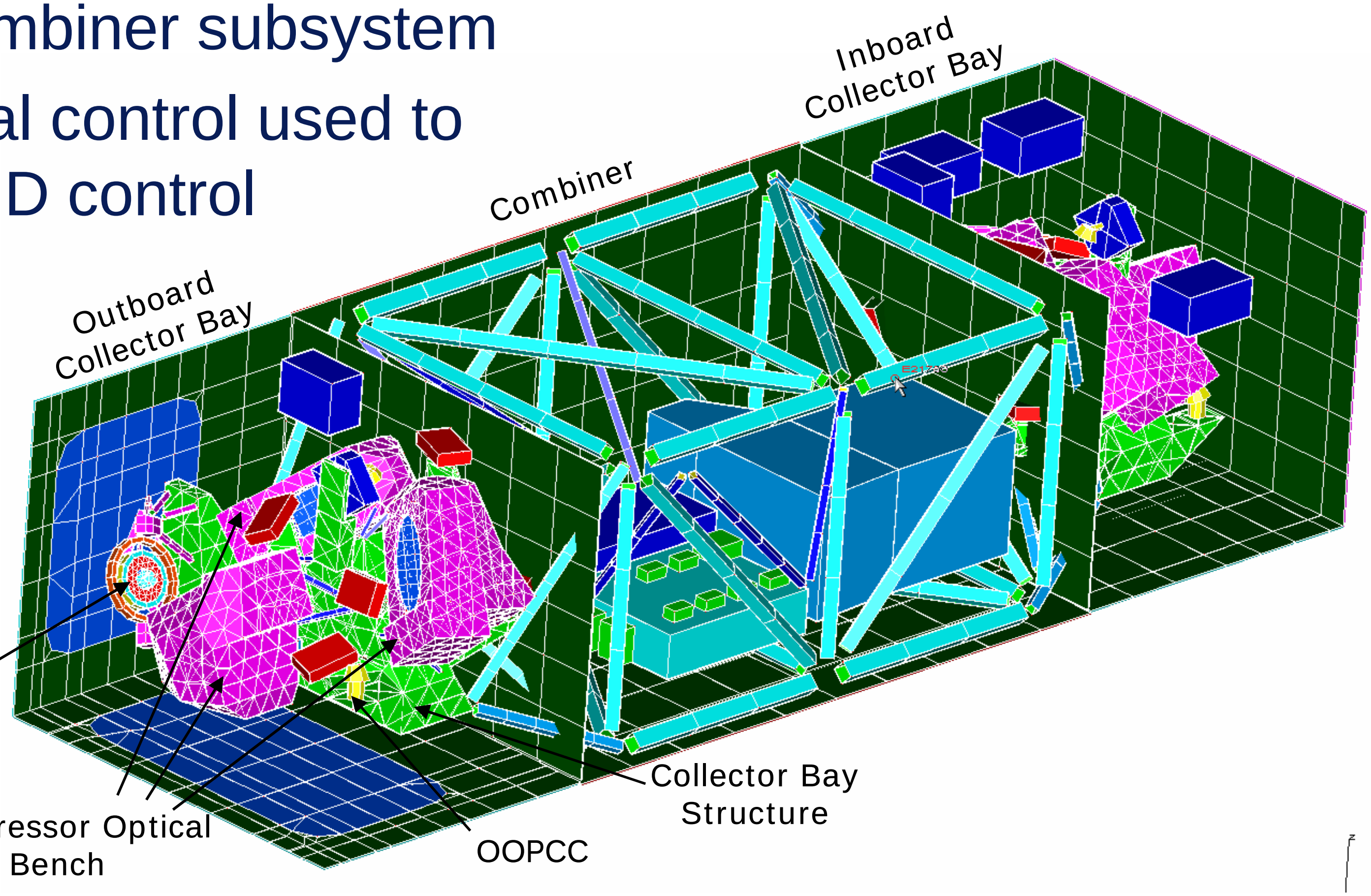
Instrument Thermal Model

- 34,700 elements
- Incorporates both collector bays and the combiner subsystem
- Proportional control used to simulate PID control



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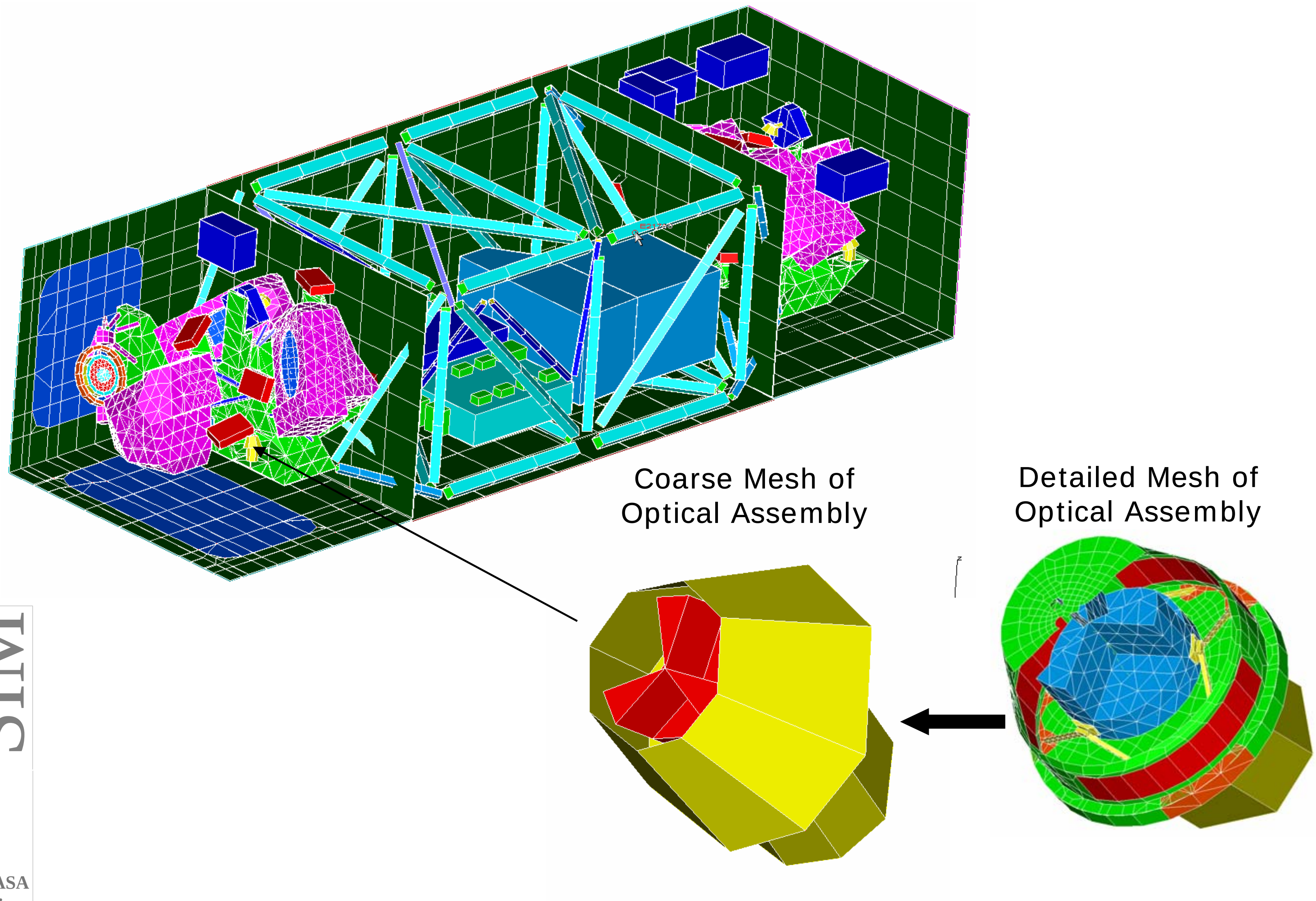
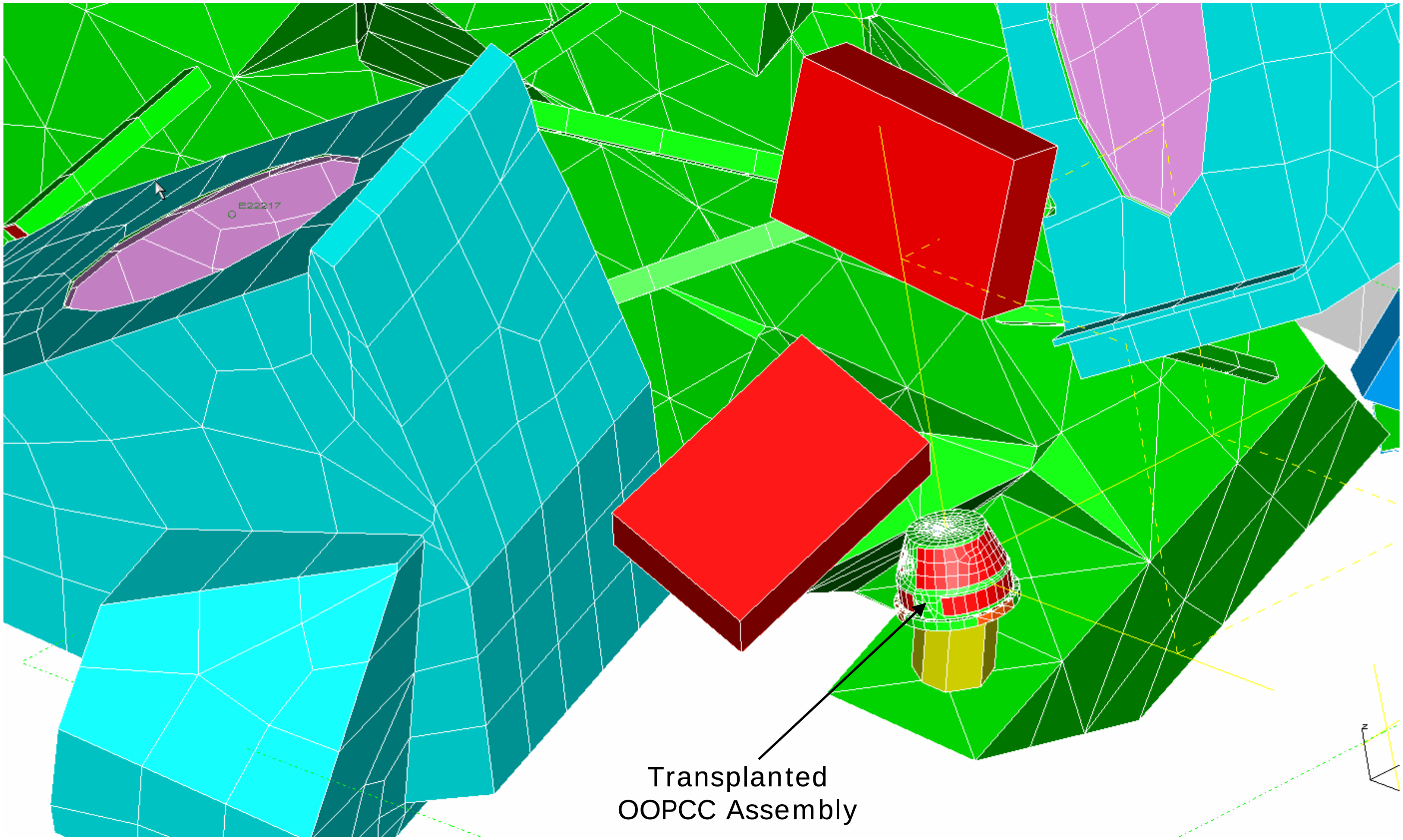
Substitution of the Coarse OOPCC Mesh with the Detailed Mesh



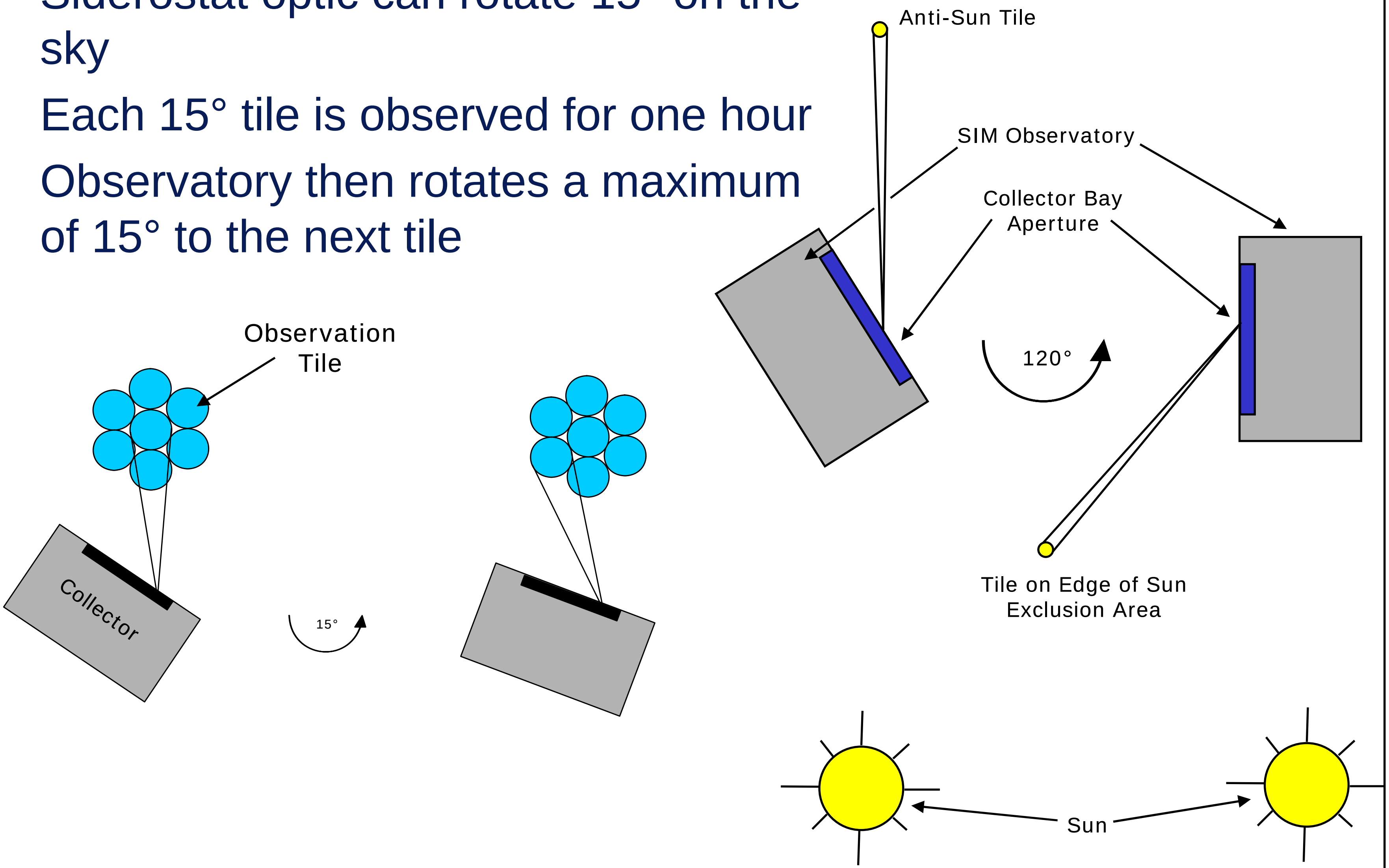
OOPCC FEM in Course Mesh

Spacecraft Model



Analysis – Mission Slew Scenario

- Siderostat optic can rotate 15° on the sky
- Each 15° tile is observed for one hour
- Observatory then rotates a maximum of 15° to the next tile



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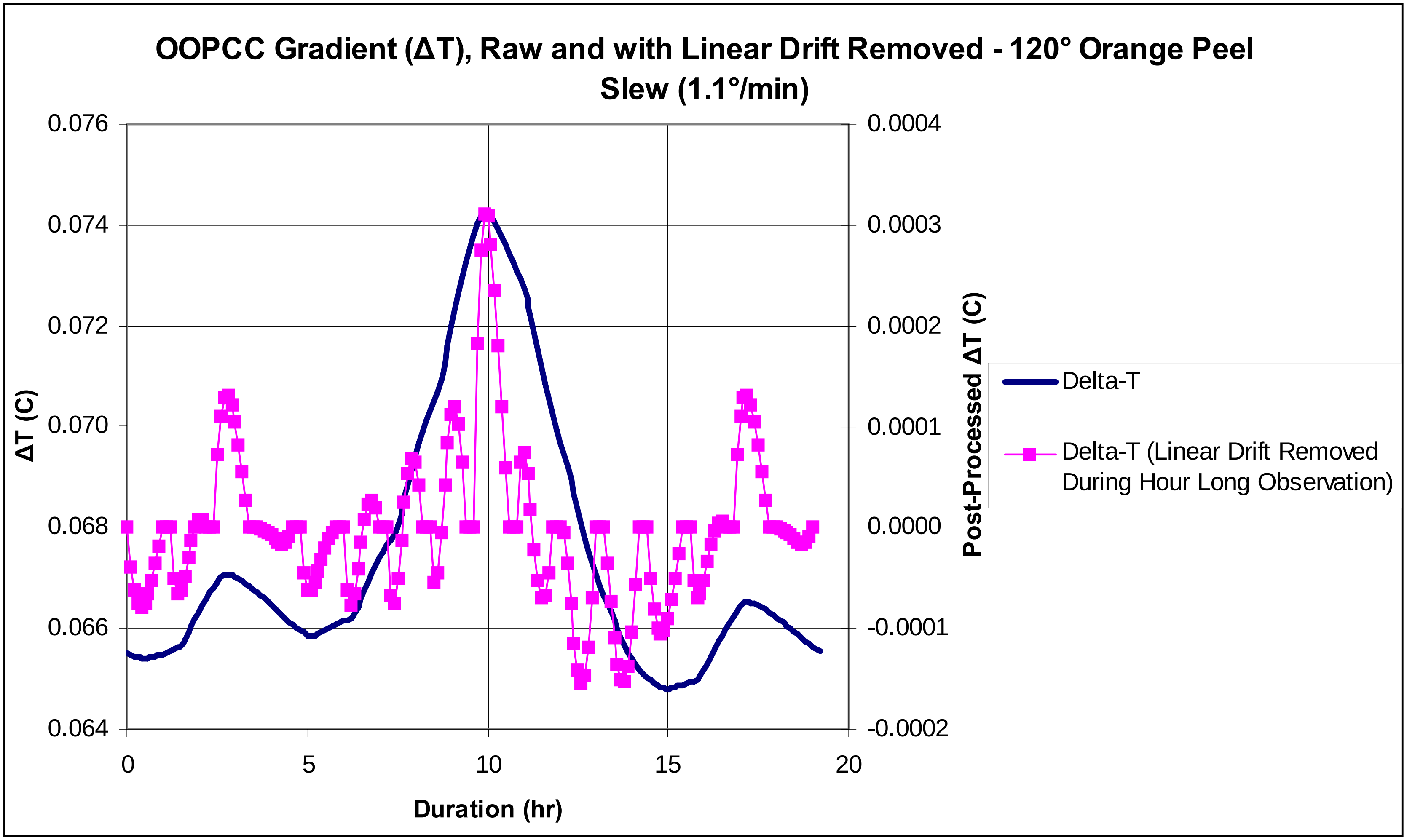
OOPCC Predicted Temperature Results



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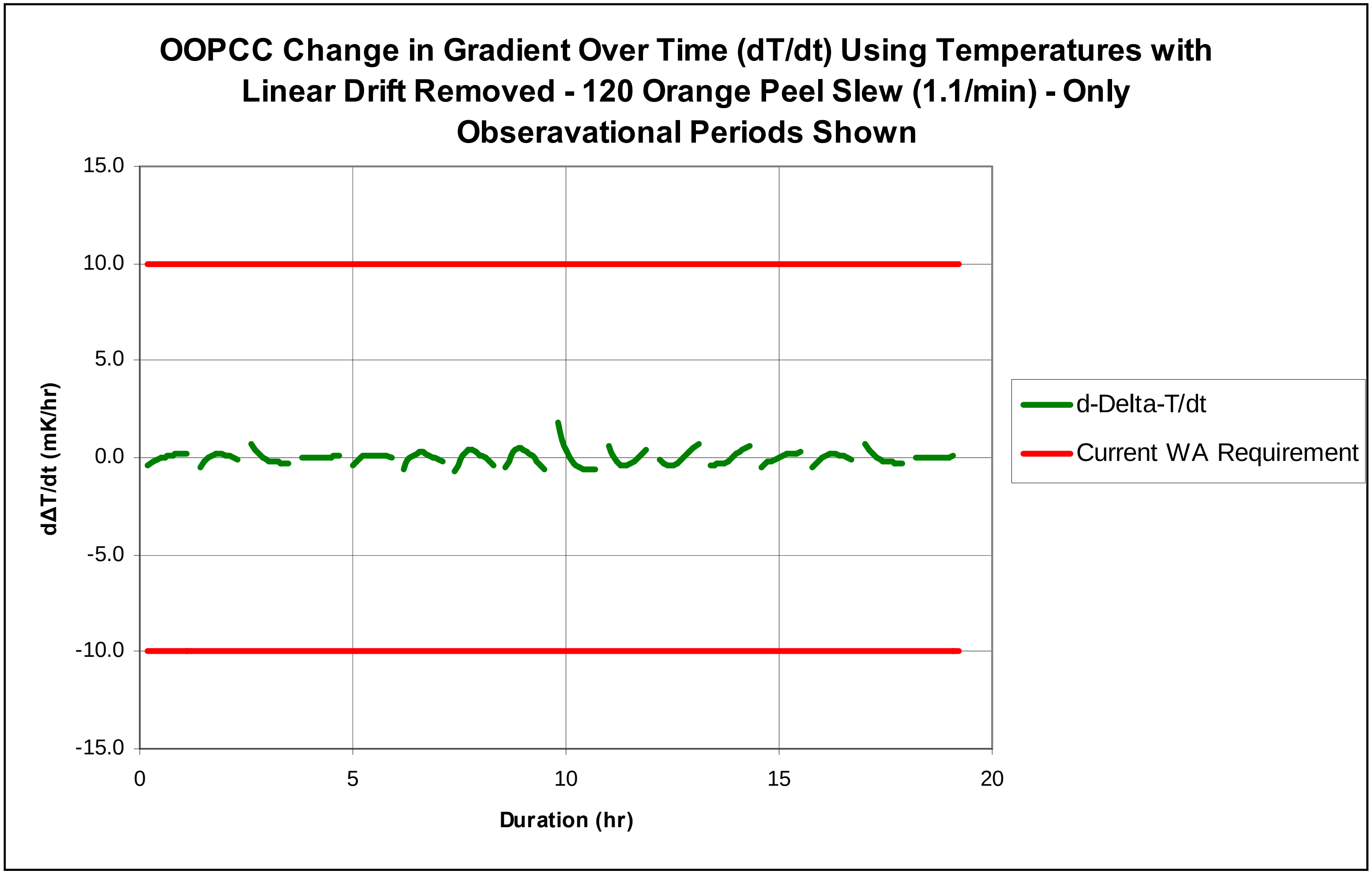
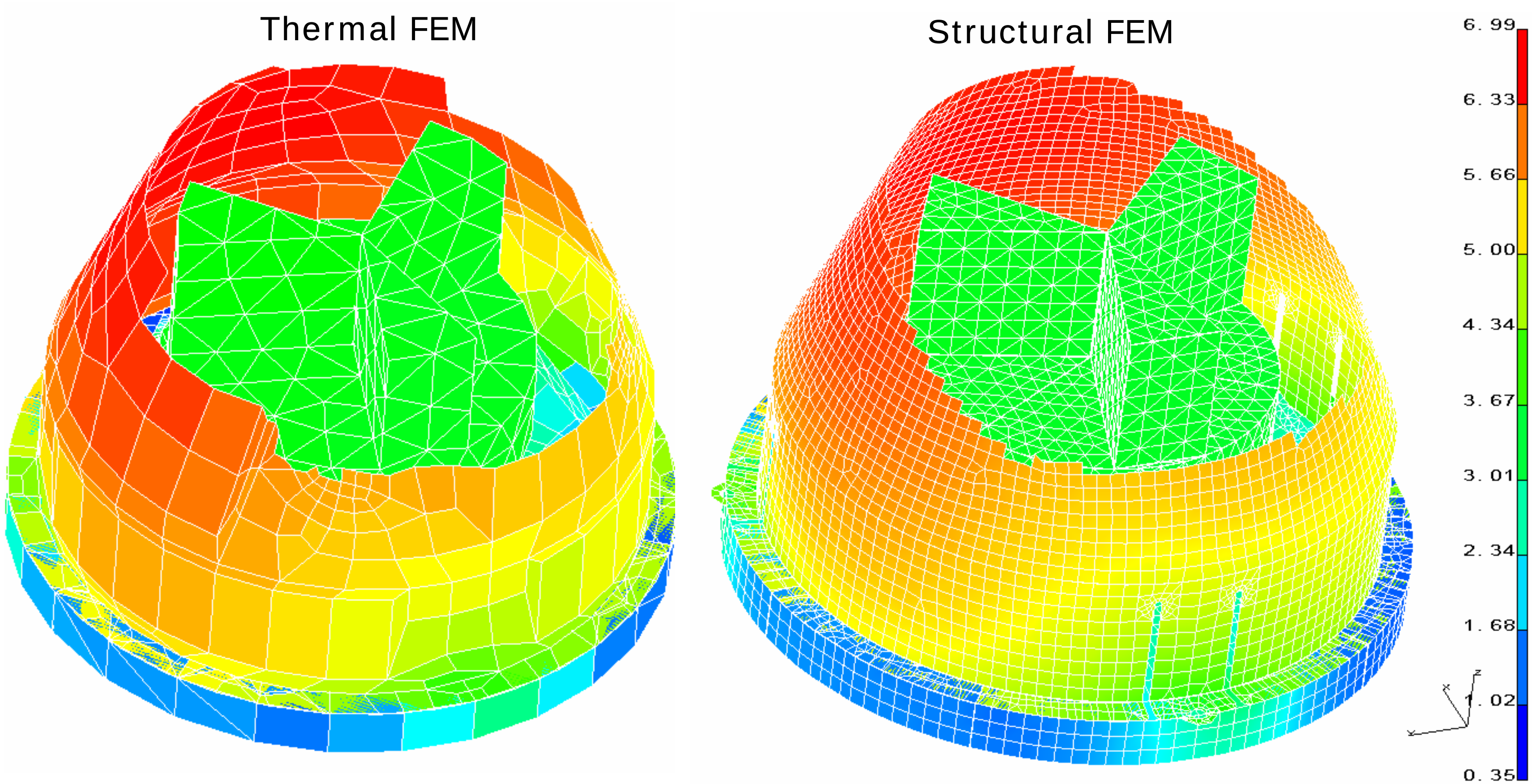
OOPCC Predicted Stability Results



Predicted Temperature Mapping

- After thermal anlysis is complete the temperature results are mapped to a more detailed mesh for structural analysis.
- Temperature mapping for time t_0 shown below*.



* Temperatures Relative to 20°C

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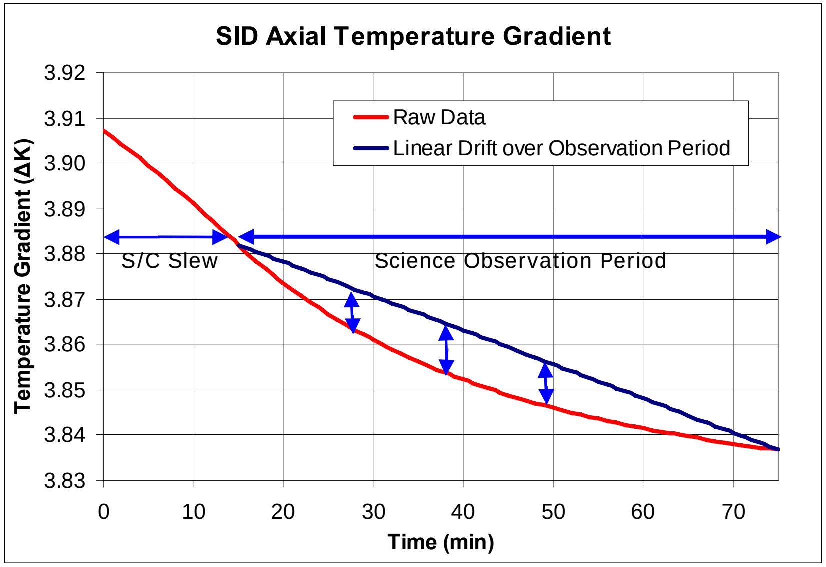
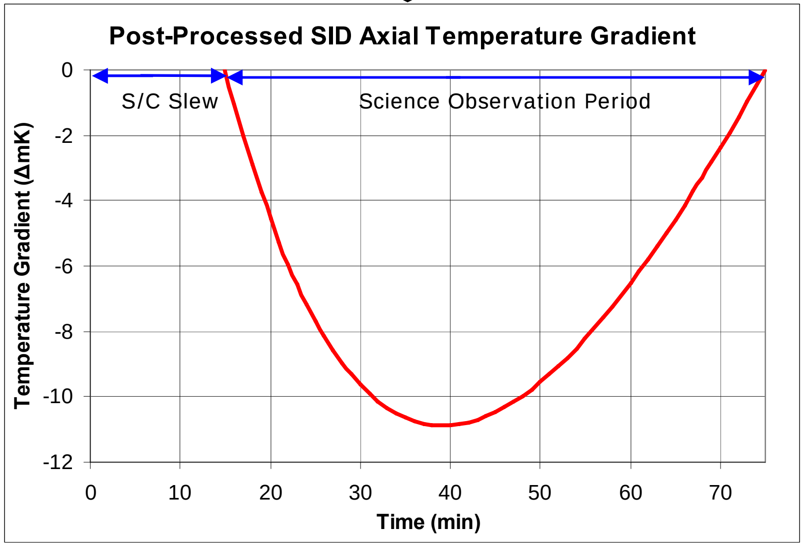
Conclusion

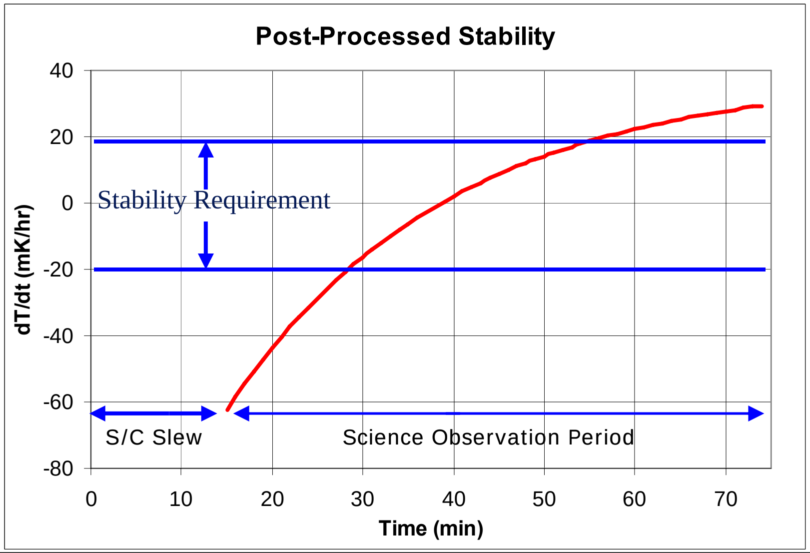
- Milli-Kelvin Analysis can be preformed when using the proper modeling process
  - Creation of both a coarse system level model and detailed optical assembly model needed
  - Coarse system level model used as a boundary condition for the detailed optical model
- Current SIM thermal design meets temperature stability requirements on the OOPCC optic
- SIM absolute temperature requirements are met through the robustness of the thermal design (i.e. PID control)

Back-Up Slides Predicted Temperature Post-Processing

- OPD is the optical path length difference between the starlight beam and the metrology beam.
  - The linear drift in the raw OPD data caused by changing temperature is taken out through post-processing.
  - The design requirements are written against the post-processed OPD value.
- Temperature Post-Processing Example
  - Step 1: Linear drift of temperature results computed during the hour long observation period (WA)
  - Step 2: Linear drift of temperature results removed
  - Step 3: The stability is computed by taking the derivative of the post-processed temperature results. Stability is compared against requirements.







Collector Predicted Stability Results

- All collector optics meet thermal stability requirements
- Narrow angle requirements (stability over 90s) easily met due to long time constants and PID control

Component	Stability Requirements (Temporal Gradients)		Model Predictions (Temporal Gradients)		Margin (Temporal Gradients)	
	Narrow-Angle (mK/90 sec)	Wide-Angle (mK/hr)	Narrow-Angle (mK/90 sec)	Average* Wide-Angle (mK/hr)	Narrow-Angle (mK/90 sec)	Wide-Angle (mK/hr)
Siderostat Mirror	2	25	0.20	15	1.8	10
M1 Mirror (1)	2	40	0.05	5	1.9	35
M1 Mirror (2)			0.02	5	2.0	35
M1 Mirror (3)			0.03	5	2.0	35
M2 Mirror (1)	2	40	0.01	3	2.0	37
M2 Mirror (2)			0.01	3	2.0	37
M2 Mirror (3)			0.01	3	2.0	37
M3 Mirror (1)	2	40	0.00	2	2.0	38
M3 Mirror (2)			0.01	2	2.0	38
M3 Mirror (3)			0.01	2	2.0	38
TCC	2	10	0.04	5	2.0	5
OOPCC	2	10	0.08	5	1.9	5
CMP (1)	3	100	0.03	64	3.0	36
CMP (2)			0.03	86	3.0	14
CMP (3)			0.03	96	3.0	4
COL Bay Structure	50	500	0.08	231	49.9	269

* Times involving extreme changes in spacecraft attitude where temperature stability is poor are neglected

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