Optical Thermal Mechanical Model

Jay Ambrose
FAME TIM
LMMS Advanced Technology Center
Palo Alto, CA
October 25-26, 2000
Topics

• Optical Thermal Mechanical Model Status
• Overall Instrument Thermal Design Status
• Sunshield Blanket - Is it Needed?
OTM Model
Objectives

• Support flowdown of instrument optical performance requirements to thermal gradient/stability requirements on individual components and bench structure
  - Requires facsimile of detailed thermal control scheme
  - Evolve robust thermal design approach in parallel
Approach

- Simplified TMG and TSS models developed to support thermal design analysis cases
- Evaluate transient orbital heating effects
- Assess preliminary heater power requirements for new instrument layout
- Develop detailed thermal model from IDEAS OTM FEM by Larry Sokolsky
OTM Thermal Model

External Thermal Model
Sunshield based on $45^\circ$ sun-angle

- FPA Radiator
  $\alpha/\varepsilon = 0.3/0.8$

- Instrument MLI Outer Surface
  $\alpha/\varepsilon = 0.12/0.04$

- Sunshield Back and Bus Surface
  $\alpha/\varepsilon = 0.3/0.8$
OTM Thermal Model
OTM Thermal Model
OTM Model Status

• Preliminary thermal results obtained and fed into structural analysis
• ‘Place-holder’ displacements calculated for closing loop (not checked out yet)
• Meetings held to discuss handoff of results to ray-tracing analysis by Optics group
• Expect several iterations to allow refinement of thermal/structural design for better instrument performance
Preliminary Displacement Calculation - Optical Bench

RESULTS: 3- B.C. 4, DISPLACEMENT_3, RESTRAINT SET 1
DISPLACEMENT - MAG MIN: 1.48E-07 MAX: 3.40E-06
DEFORMATION: 3- B.C. 4, DISPLACEMENT_3, RESTRAINT SET 1
DISPLACEMENT - MAG MIN: 1.48E-07 MAX: 3.40E-06
FRAME OF REF: PART

VALUE OPTION: ACTUAL

3.40E-06
3.08E-06
2.75E-06
2.43E-06
2.10E-06
1.78E-06
1.45E-06
1.12E-06
7.99E-07
4.74E-07
1.48E-07
Preliminary Displacement Calculation - Optics
Orbit Heating - Simplified Models

Simplified models used to facilitate rapid evaluation of thermal design features

Single Orbit Point-

Account for 40 minute period spin

Full Orbit-

Account for solar/earth shadowing and eclipse

Predicted orbital heating transients will be compared with ‘full’ orbit model
Orbit Heating - Full Model
First-Cut Panel
Heater Requirements

- 12 W
- 10 W
- 16 W
- 8.5 W
- 13 W
- 3 W
- 6 W
- 0 W (baffles not heated)
Orbit Heating - Average Absorbed IR, Eclipse Orbit

- Time = 18 hrs, Max. IR = 2.3 W/m²
- Time = 12 hrs, Max. IR = 3.1 W/m²
- Time = 6 hrs, Max. IR = 1.7 W/m²
- Time = 0 hrs, Max. IR = 3.41 W/m²
Orbit Heating - Average Absorbed Albedo, Eclipse Orbit

Time = 18 hrs, Max. Albedo = 0.8 W/m²

Time = 12 hrs, Max. Albedo = 2.3 W/m²

Time = 6 hrs, Max. Albedo = 0.5 W/m²

Time = 0 hrs, Max. Albedo = 0 W/m²
Orbit Heating - Absorbed IR, Single Point in Orbit

- Time = 30 min, Max. IR = 1.7 W/m²
- Time = 20 min, Max. IR = 2.1 W/m²
- Time = 10 min, Max. IR = 1.8 W/m²
- Time = 0 min, Max. IR = 2.15 W/m²
Orbit Heating - Absorbed Albedo, Single Point in Orbit

Time = 30 min, Max. Albedo = 0.5 W/m²

Time = 20 min, Max. Albedo = 2.7 W/m²

Time = 10 min, Max. Albedo = 0.5 W/m²

Time = 0 min, Max. Albedo = 0 W/m²
Quasi-Steady Temperatures Time = 6 hrs

RESULTS: 13-NODE TEMP, T= 2.160E+04
TIME STEP: 0  TIME: 21600.0
TEMPERATURE - MAX MIN: -192.89 MAX: 73.95

VALUE OPTION: ACTUAL
Thermal Design
Findings

- Thermal environment investigated using updated instrument configuration
- Calculated heater power requirements are quite similar to those from preliminary thermal model results
- Dissipation of heat from the electronic boxes may be difficult to fully utilize in current configuration - will require additional design study to develop a good solution
- Effect of earthshine and albedo variations are quite small, over a single rotation and a full orbit (without eclipse)
- Mirror temperature gradients found to be extremely stable
- Mirror temperature gradients for highly lightweighted optics are significantly larger than others
Sunshield Blanketing

- Blanketing of sunshield thought to be a more robust thermal design from viewpoint of instrument environment - since sunshield dominates instrument IR loading
- Simplified full-orbit transient model run to investigate effect of sunshield blanket
- Worst-case conditions assumed to be during eclipse orbit
- Thermal gradient change on compound mirror found to approximately double when blanket removed from sunshield
- On the other hand, required instrument heater power approximately 25 W less without sunshield blanket
Average Sunshield Temperatures

- Sunshield Front with MLI
- Sunshield w/o MLI
- Sunshield MLI

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<th>Time, hours</th>
<th>Temperature°C</th>
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<tr>
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<td>-150</td>
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Legend:
- FRONT
- BACK
- No MLI
Compound Mirror Gradients

![Graph showing temperature differences over time for Sunshield without MLI and Sunshield MLI.](image)