AMTD: Mirror Substrate Design Trade Study

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Trade Study

Using Arnold Lightweight Mirror Modeler tool, evaluate candidate primary mirror substrate and assembly designs.

Assembly is Substrate, Support Structure & Interface Geometry

Evaluation Criteria

<table>
<thead>
<tr>
<th>Criterion</th>
<th>This Study</th>
<th>Future Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>This Study</td>
<td></td>
</tr>
<tr>
<td>Thickness (volume)</td>
<td>This Study</td>
<td></td>
</tr>
<tr>
<td>First Mode Frequency (stiffness)</td>
<td>This Study</td>
<td></td>
</tr>
<tr>
<td>1.5 G Internal Stress</td>
<td>Future Study</td>
<td></td>
</tr>
<tr>
<td>Dynamic Launch Loads</td>
<td>Future Study</td>
<td></td>
</tr>
<tr>
<td>Thermal Deformation</td>
<td>Future Study</td>
<td></td>
</tr>
<tr>
<td>Thermal Time Constant</td>
<td>Future Study</td>
<td></td>
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</tbody>
</table>

This presentation is reporting on Substrate Trade Study only
Current Mirror Substrate Trade Study

Evaluated four mirror architectures:
- 4 meter solid
- 4 meter lightweight closed back
- 8 meter solid
- 8 meter lightweight closed back

Maximize First Mode Frequency as a function of:
- Depth
- Face sheet Thickness
- Rib Thickness
- Radius of Curvature

Constraints:

<table>
<thead>
<tr>
<th></th>
<th>4 m monolithic</th>
<th>8 m monolithic</th>
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<tbody>
<tr>
<td>Mass</td>
<td>&lt; 720 kg</td>
<td>&lt; 10,000 kg</td>
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<tr>
<td>Thickness</td>
<td>&lt; 500 mm</td>
<td>&lt; 500 mm</td>
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</table>
Future Mirror Substrate Trade Study

We plan to expand the study to include:
Open Back Substrates

And study Performance Criteria as a function of:
Depth
Face sheet Thickness
Rib Thickness
Radius of Curvature
Material Choice
Material Property Variation
Mount Interface (3, 6, 9 point)
Backing Structure Design
Design Process

Defining dimensions on left & check boxes for design elements
Design Process

Specify “reals” or real constants used by Ansys
Design Process

Core Specification has its own tab.
Core depth is total core thickness divided by number layers.
Front & back depths include facesheet thickness & pocket depth.
Grid View

Grid view shows internal core segments, lips, cells, and isogrid

4 meter Design  

8 meter Design
ANSYS performs Modal Analysis
Trade Study Concept #1: 4 m Solid

Design:

- Diameter: 4 meters
- Thickness: 22 mm
- Mass: 595 kg
- First Mode: 8.2 Hz
Trade Study Concept #2: 4 meter Lightweight

Design:
Diameter  4 meters
Thickness  410 mm
Facesheet  3 mm
Mass       621 kg
First Mode 124.5 Hz

SET   TIME/FREQ
  1   124.48
  2   124.77
  3   199.39
  4   257.85
  5   275.88
  6   321.22
  7   321.60
  8   350.07
  9   350.08
 10   350.33
Trade Study Concept #3: 8 meter Solid 22 MT

Design:

Diameter 8 meter
Thickness 200 mm
Mass 21,800 kg
First Mode 18 Hz

Same as ATLAST Study

<table>
<thead>
<tr>
<th>SET</th>
<th>TIME/FREQ</th>
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<tbody>
<tr>
<td>1</td>
<td>18.026</td>
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<tr>
<td>2</td>
<td>18.035</td>
</tr>
<tr>
<td>3</td>
<td>42.449</td>
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<tr>
<td>4</td>
<td>42.452</td>
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<tr>
<td>5</td>
<td>47.827</td>
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<tr>
<td>6</td>
<td>74.041</td>
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<td>7</td>
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<td>8</td>
<td>75.174</td>
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<tr>
<td>9</td>
<td>75.176</td>
</tr>
<tr>
<td>10</td>
<td>112.96</td>
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</tbody>
</table>
Trade Study Concept #4: 8 meter Lightweight

Design:
- Diameter: 8 meter
- Thickness: 510 mm
- Facesheet: 7 mm
- Mass: 3,640 kg
- First Mode: 48.4 Hz
Parameter Trade Studies

4 meter
Symmetric vs. Offset

For a 4 meter, 310 mm thick mirror substrate, there is no observable difference between symmetric and off-set.
As expected, Core Depth has the greatest impact on stiffness; the deeper the Core the Stiffer and more Massive the Substrate.

**Stiffness vs. Core Height**

![Graph showing the relationship between frequency, mass, and core height for 4 meter stiffness and mass vs core height.](image-url)
4 m Stiffness & Mass vs Facesheet Thickness

Increasing Facesheet thickness increases stiffness only to a point, then the stiffness decreases with additional thickness.
4 m Stiffness & Mass vs Internal Core Thickness

Increasing thickness of internal Core Elements results in minor stiffness increase.

![Stiffness vs Lip thickness](image-url)
4 m Stiffness & Mass vs Radius of Curvature

At 4 meter, Radius of Curvature has insignificant effect on Stiffness and Mass
Parametric Trade Studies

8 meter
Symmetric vs. Offset

For a 8 meter, 500 mm thick mirror substrate, there is only minor differences between symmetric and off-set

Symmetric (48.3 Hz)  Offset (47.9 Hz)
8 m Stiffness & Mass vs Facesheet Thickness

Increasing Facesheet thickness increases stiffness only to a point.
At 8 meter, Radius of Curvature has an insignificant effect on Stiffness and Mass – plot is misleading mass change is 6 kg.
Conclusion

We have used the Arnold Lightweight Mirror Modeler tool to generate 4 point designs and several parameter trade studies.

These trade studies allow one to manipulate design architectural elements to maximize mirror stiffness for mass constraint.

Tool allows one to generate a complete model and analysis in less than 60 minutes.
# Results Summary

## 4m Trade Study

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Solid</th>
<th>Closed Back</th>
<th>Closed Back</th>
<th>Closed Back</th>
<th>Closed Back</th>
<th>Closed Back</th>
<th>Closed Back</th>
<th>Optimized</th>
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</thead>
<tbody>
<tr>
<td>Mass</td>
<td>595 Kg</td>
<td>512 Kg</td>
<td>590 Kg</td>
<td>604 Kg</td>
<td>632 Kg</td>
<td>660 Kg</td>
<td>700 Kg</td>
<td>621 Kg</td>
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<tr>
<td>First Mode Frequency</td>
<td>8.2 Hz</td>
<td>101.4 Hz</td>
<td>115.0 Hz</td>
<td>117.5 Hz</td>
<td>120.9 Hz</td>
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<tr>
<td>Core Depth</td>
<td>N/A</td>
<td>30mm</td>
<td>40mm</td>
<td>40mm</td>
<td>40mm</td>
<td>40mm</td>
<td>50mm</td>
<td>40mm</td>
</tr>
<tr>
<td>Facesheet Thickness</td>
<td>22 mm</td>
<td>2.5 mm</td>
<td>2.5 mm</td>
<td>3 mm</td>
<td>4 mm</td>
<td>5 mm</td>
<td>2.5 mm</td>
<td>3 mm</td>
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</table>

## 8m Trade Study

<table>
<thead>
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<th>Solid</th>
<th>Closed Back</th>
<th>Closed Back</th>
<th>Closed Back</th>
<th>Closed Back</th>
<th>Optimized</th>
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<tbody>
<tr>
<td>Mass</td>
<td>21801 Kg</td>
<td>3091 Kg</td>
<td>3305 Kg</td>
<td>3574 Kg</td>
<td>3637 Kg</td>
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<tr>
<td>First Mode Frequency</td>
<td>18.0 Hz</td>
<td>39.3 Hz</td>
<td>42.3 Hz</td>
<td>44.3 Hz</td>
<td>48.4 Hz</td>
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<tr>
<td>Core Depth</td>
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<td>50 mm</td>
<td>50 mm</td>
<td>50 mm</td>
<td>50 mm</td>
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<tr>
<td>Facesheet Thickness</td>
<td>200 mm</td>
<td>3 mm</td>
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<td>7.5 mm</td>
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