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

Mass
Thickness (volume)
First Mode Frequency (stiffness)
1.5 G Internal Stress
Dynamic Launch Loads
Thermal Deformation
Thermal Time Constant

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>
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<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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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

- **Nodal Solution Date:** July 13, 2012, 11:26
- **Frequency:** 114.956 Hz
- **Maximum Nodal Values:**
  - **UX:** 0.06512
  - **UY:** 0.06512
  - **UZ:** 0.06512

- **Nodal Solution Date:** July 13, 2012, 14:11:26
- **Frequency:** 114.956 Hz
- **Maximum Nodal Values:**
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  - **UY:** 0.06512
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- **Table:**
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<td>124.77</td>
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<td>199.39</td>
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<td>275.88</td>
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<td>9</td>
<td>350.08</td>
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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

![Design Illustration]
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

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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 offset.

Symmetric (103 Hz)  Offset (103 Hz)
4 meter Stiffness & Mass vs Core Height

As expected, Core Depth has the greatest impact on stiffness; the deeper the Core the Stiffer and more Massive the Substrate.
4 m Stiffness & Mass vs Facesheet Thickness

Increasing Facesheet thickness increases stiffness only to a point, then the stiffness decreases with additional thickness.
Increasing thickness of internal Core Elements results in minor stiffness increase.
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 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

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<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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<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>
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<td>Core Depth</td>
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<td>40mm</td>
<td>40mm</td>
<td>40mm</td>
<td>40mm</td>
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<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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### 8m Trade Study

<table>
<thead>
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<th>Architecture</th>
<th>Solid</th>
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<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>
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<td>48.4 Hz</td>
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<td>Core Depth</td>
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<tr>
<td>Facesheet Thickness</td>
<td>200 mm</td>
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<td>7.5 mm</td>
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