Evolving design criteria for very large aperture space-based telescopes and their influence on the need for integrated tools in the optimization process

William R. Arnold, Sr.
NASA Marshall Space Flight Center
AI Solutions Inc., Huntsville, Al. USA 35806
INTRODUCTION

• System design as an optimization problem
  • Often, the desires are out reaching the realities

• What are the key merit functions
  • Optical Performance
  • Mechanical Performance
  • Thermal Performance
  • Complexity & Reliability

• What are the constraints
  • Mass – available & planned launch vehicles
  • Volume – shroud interior volume
  • Cost & Schedule
  • Risk – technical, schedule, cost and mission success

• How Advanced Mirror Technology Development program fits in to all this
  • Building better tools
  • Increasing TRL levels
APERTURE OF ALL TELESCOPES

As the technical capabilities grow, so grows the desire for larger and larger telescopes, both terrestrial and space-based.
Hubble represented the state-of-the art when first designed, but much of its cost was actually long term storage. Each component was designed almost independent of other parts of the satellite and the primary mirror was only a small portion of the total mass.
Kepler was cost sensitive and no backup mirror was available for the primary mirror, so it and its support system were designed to have two rotation positions for attachment (in the event of damage during testing).

All the manufacturing and handling equipment were design simultaneously with the mirror and special reinforcements added just for tooling.
This was the first segmented space telescope, and much of the design was done by different organizations for different assemblies. One of the driving constraints was the shroud volume of the intended launch vehicle.
The goals of AMTD are to establish the technology basis for these anticipated projects.

Tools to evaluate the optical, mechanical and thermal performance efficiently.

Material databases and proven manufacturing techniques to feed the analysis tools.

Databases to establish risks and cost estimates on a neutral basis.
WHAT MAKES UP THE MASS

• Primary Mirror and Suspension
• Metering Structure
  • Secondary Mirror and suspension
  • PMA backplane/truss
  • Stray-light and Thermal Baffles
• Science Instruments
• Satellite
  • Power
  • Communications
  • Station keeping and pointing

EVERYONE FIGHTING FOR A LARGER SHARE
OPTICAL PERFORMANCE

• Here the science dominates the requirements
• Monolithic versus segmented (diffraction)
• Thermal and mechanical stability over time
• On axis versus off axis

• Bigger is almost always better, but not always!
MECHANICAL PERFORMANCE

• Has to survive launch environments.
• Has to deploy and function on orbit.
• Has to survive qualification and ground testing.
• Has to survive manufacture.
• Has to survive in stowed configuration

LOADING INCLUDES ACCELERATION, SINUSODAL, RANDOM AND THERMAL
THERMAL PERFORMANCE

- Response to gradients
- Response to transients
- Temporal stability
RISKS AND RELIABILITY

• Science expectations
• Mission life expectations
• Deployment risk (more complex, more risks)
• Manufacturing risks
• Test and alignment risks
• Cost and schedule risks

SCIENCE BUDGETS ARE LIMITED, THE PROJECT(S) WITH THE LOWEST COST AND RISKS WITH GOOD SCIENCE WILL HAVE THE BEST CHANCE OF FUNDING.
**ILLUSTRATION**

- Example of imposing a criteria, such as lowest bending mode of the mirror, which is not difficult for small mirrors to achieve, but impossible for larger mirrors.
- Assumptions, ULE as material, waterjet light-weighted core, frit bonded, limited to current or reasonable future enhancement capabilities of these techniques.

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>2 meter</th>
<th>4 meter</th>
<th>6 meter</th>
<th>8 meter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg</td>
<td>hz</td>
<td>kg</td>
<td>hz</td>
</tr>
<tr>
<td>100 hertz</td>
<td>88</td>
<td>100</td>
<td>911</td>
<td>106</td>
</tr>
<tr>
<td>200 hertz</td>
<td>130</td>
<td>231</td>
<td>5727</td>
<td>204</td>
</tr>
</tbody>
</table>

(1) Doubling facesheet thickness (24010 kg) still only increased f=109 hz.
(2) Upper limits of feasible design (32,312 kg) only produced f=66 hz at 8 meter OD
ACKNOWLEDGEMENTS