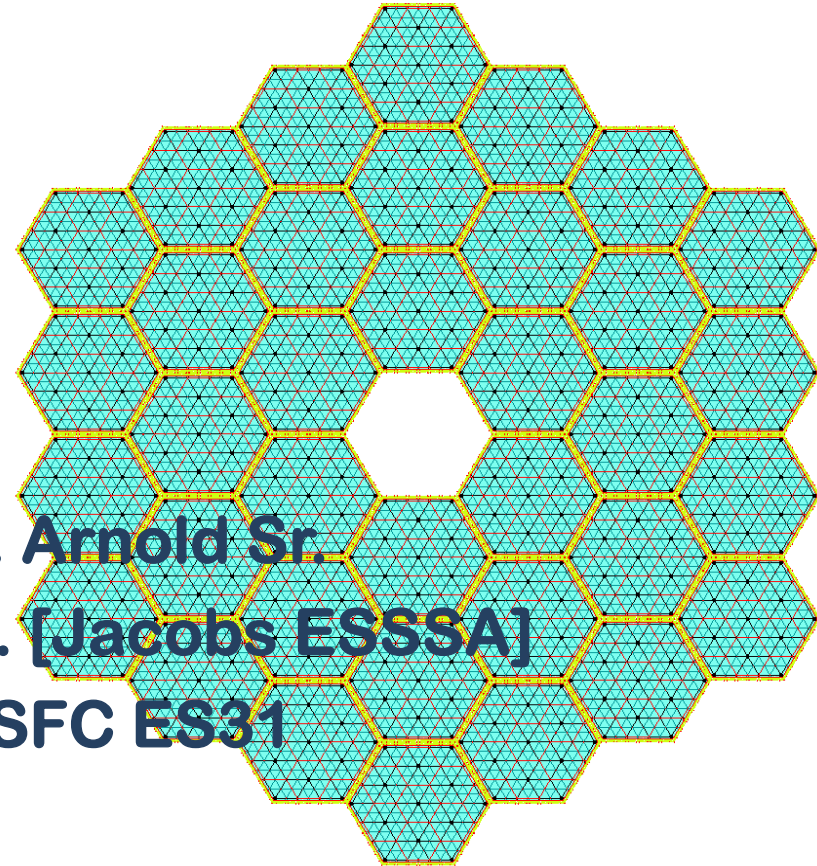
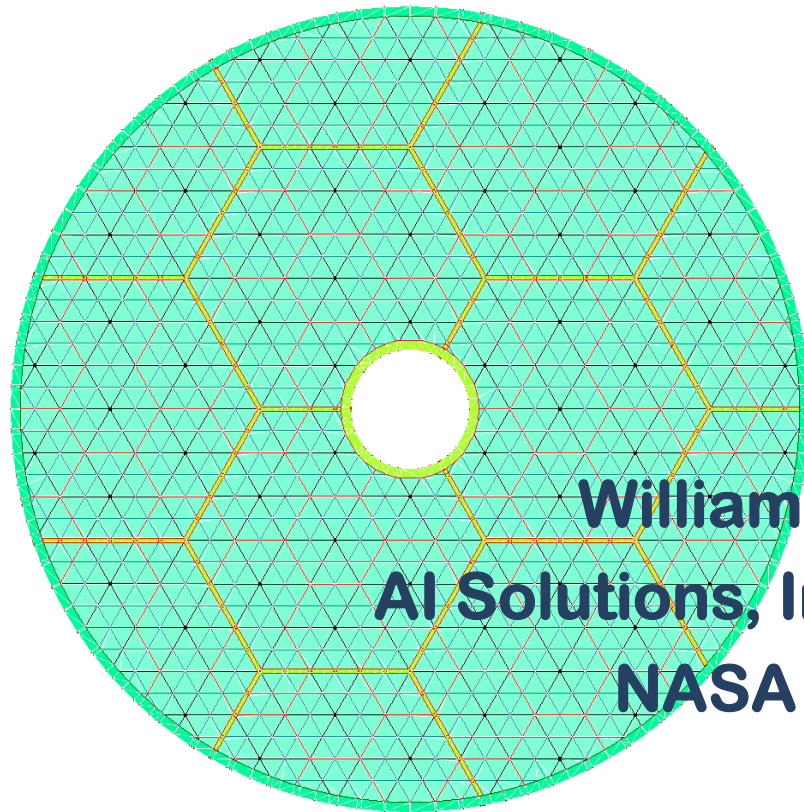




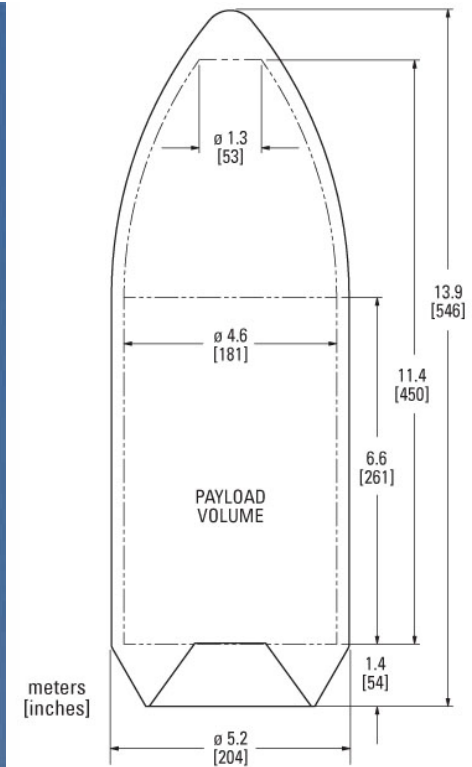
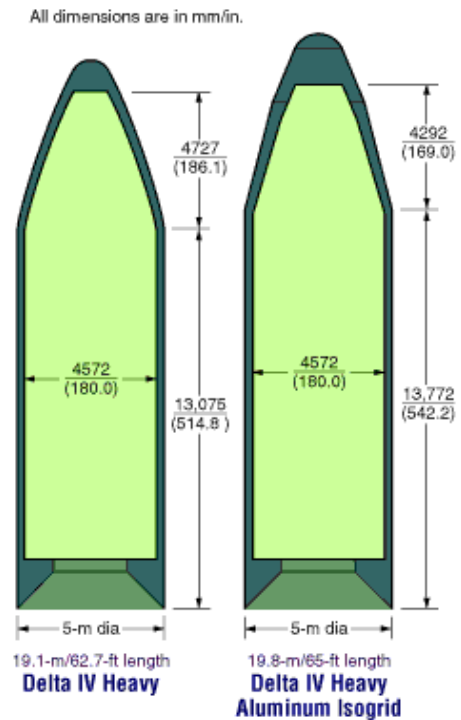
# AMTD Design Process



**William R. Arnold Sr.**  
**AI Solutions, Inc. [Jacobs ESSSA]**  
**NASA MSFC ES31**

- Objectives of AMTD (why are we doing this?)
- Influences of available launch vehicles
- What constitutes an “point design”?
- How manufacturing capabilities influence the design process.
- Mirror, suspension system and deployment mechanisms (if segmented) must be treated as a unit for a design point.

# Current Launch Vehicles





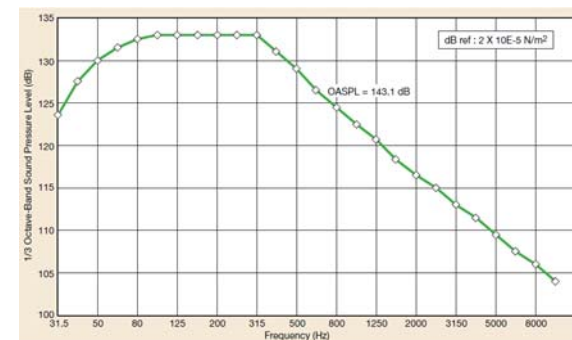
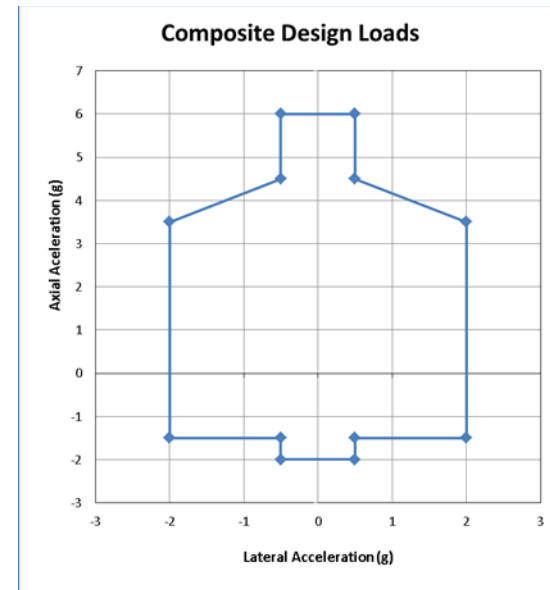
# What is an Acceptable Design Point?



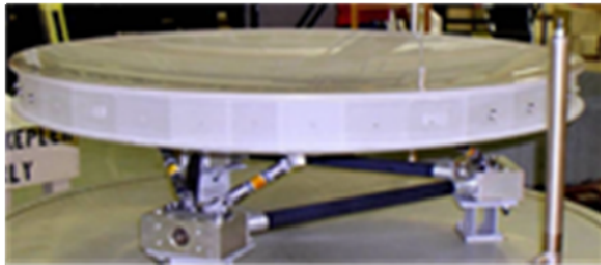
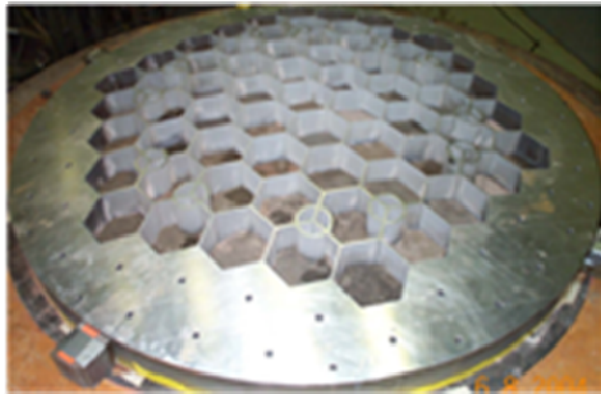
- Operational performance [It has to work]
- Launch Survival [It has to get into orbit]
- Manufacturing Considerations [it has to be made]
- Cost and Risk Estimates [It has to be affordable and reasonable risk of success]

- Optical Stability
- Thermal Stability
- Jitter rejection
- Optical performance, diffraction, quality etc.
  - Monolith versus segmented primary
  - Off axis versus On axis

- Steady State Acceleration
- Vibro-Acoustic
- Sinusoidal
- Random Vibration
  
- Support System(s)
  
- Shroud Geometry
- Payload to L2 Orbit

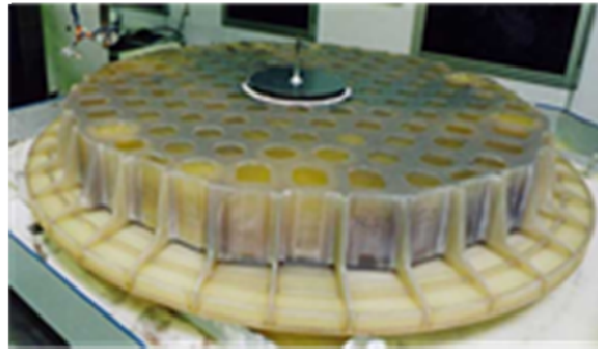


## FRIT BONDED ULE



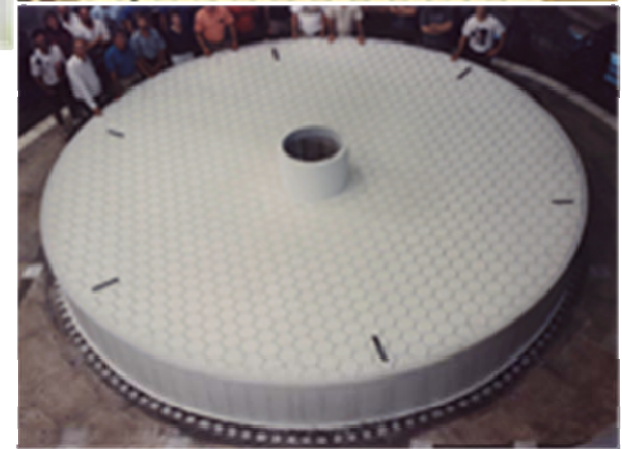
**\*LOW TEMPERATURE FUSION IS AN ALTERNATIVE ASSEMBLY, REQUIRES SLUMPING**

## POCKET MILLED ZERODUR



- Can the blank be made?
- Can the blank be transported where needed?
- Can the mirror be processed (flipped etc.)?
- Can the mirror be tested (gravity offset)?
- Can the mirror be coated?
- Can the mirror be transported where needed?

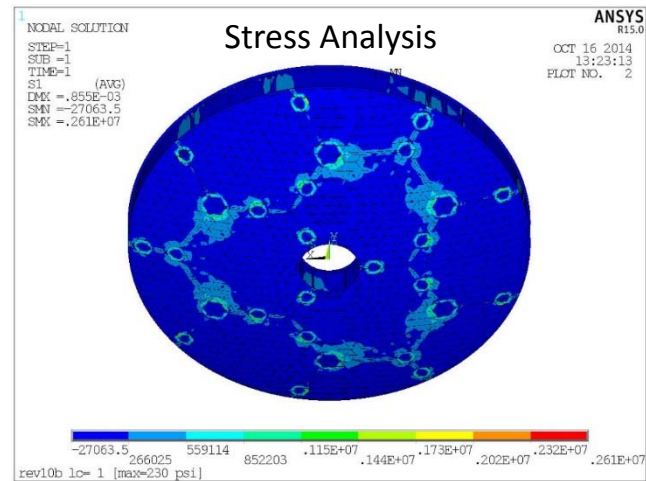
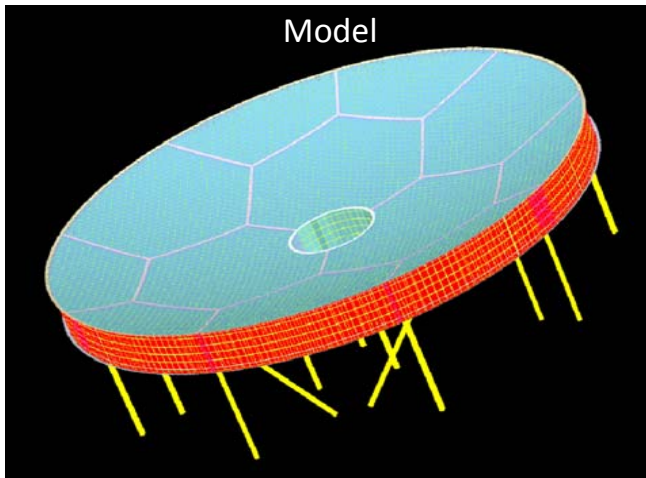
## CAST BOROSILICATE



- **Operational requirements**
  - Kinematic
  - Jitter rejection
  - Thermal and figure control
- **Launch requirements**
  - survive
- **Auxiliary Launch system**
  - Beyond certain diameter versus mirror mass
  - Key characteristics
    - Detach after launch
    - Share load evenly with operational system



# Typical Deep-Core LTF ULE

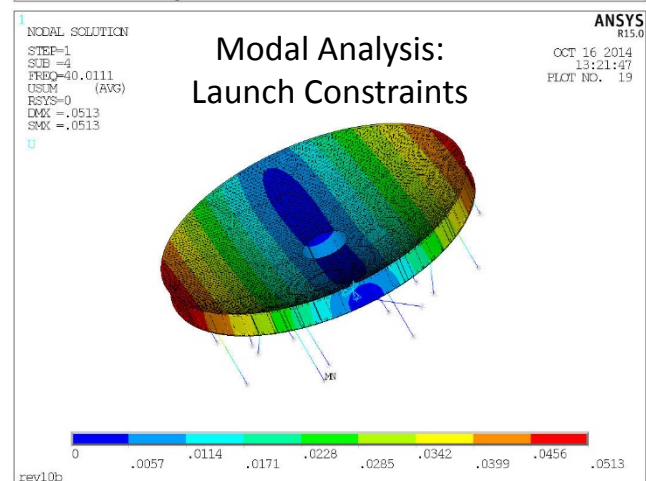


Arnold Mirror Modeler (c2014 version 2.6.1)

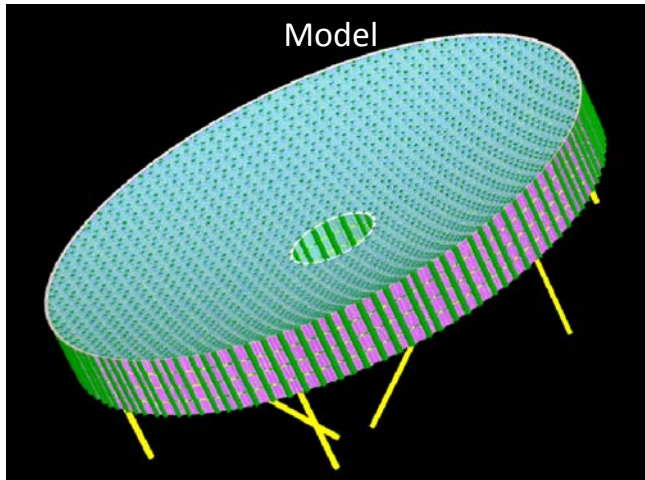
Model Statistics

|          |                          |
|----------|--------------------------|
| 54128    | num Nodes                |
| 123147   | num Elms                 |
| 1069.211 | Weight (kg)              |
| 12.43228 | Area (m <sup>2</sup> )   |
| 86.00282 | AD (kg/m <sup>2</sup> )  |
| 772.6182 | Faces (sq)               |
| 296.6559 | Core (sq)                |
| 162.8744 | Edges (m)                |
| 0.80553  | Milled (m <sup>3</sup> ) |

Modeler Statistics



# Typical Open-Back Zerodur "Milled"



Arnold Mirror Modeler (c)2014 version 2.6.13

Model Statistics

|          |                          |
|----------|--------------------------|
| 63919    | num Nodes                |
| 108553   | num Elements             |
| 1766.539 | Weight (kg)              |
| 12.38184 | Area (m <sup>2</sup> )   |
| 142.6718 | AD (kg/m <sup>2</sup> )  |
| 161.5818 | Faces (kg)               |
| 1604.896 | Core (kg)                |
| 213.0596 | Edges (m)                |
| 8.08954  | Milled (m <sup>3</sup> ) |

Archive Loaded

Status

Finished Writing out Model

Operation Duration

Lapsed Time: 00:00:06.595

Modeler Statistics

SINGLE SEGMENT

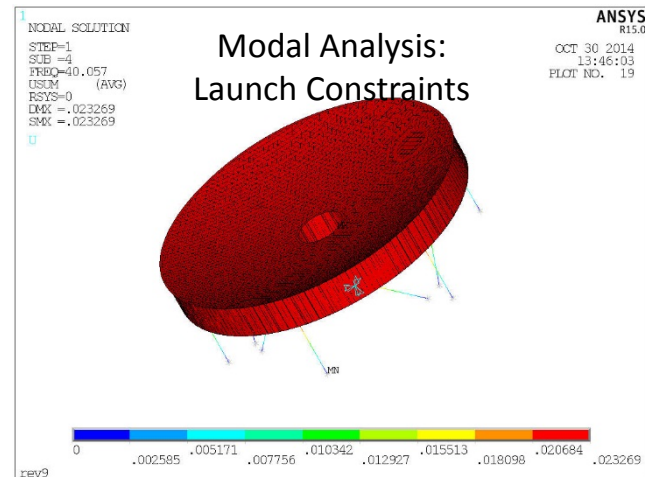
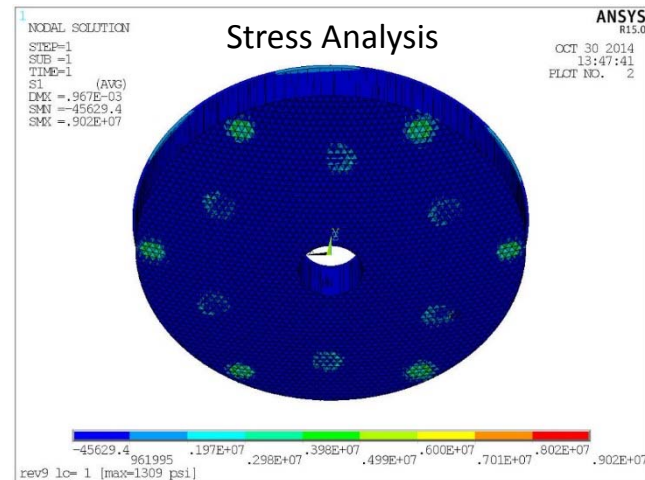
Outer Dia: 4  
Mirror Lip: 0.0254  
Petal OD: 2  
Petal ID: 0.5  
Num Petals: 6

Output Format: ANSYS, ABAQUS, NASTRAN

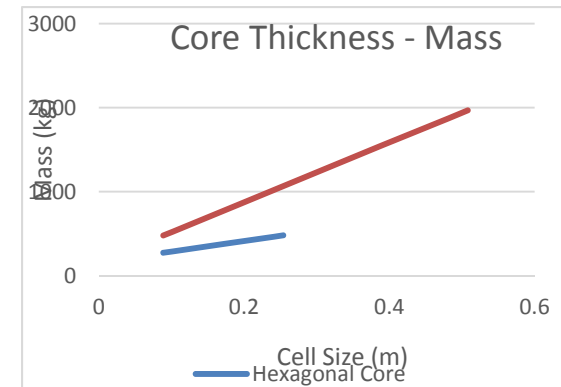
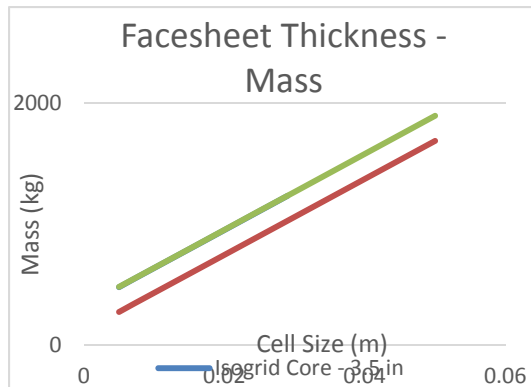
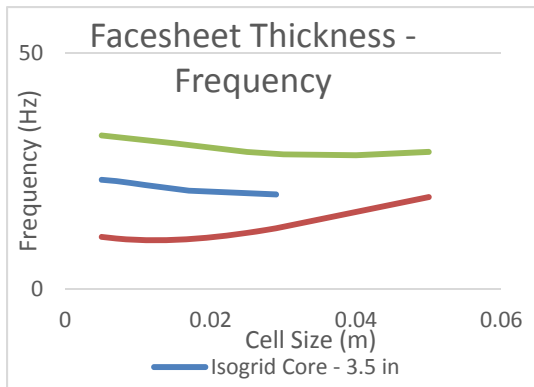
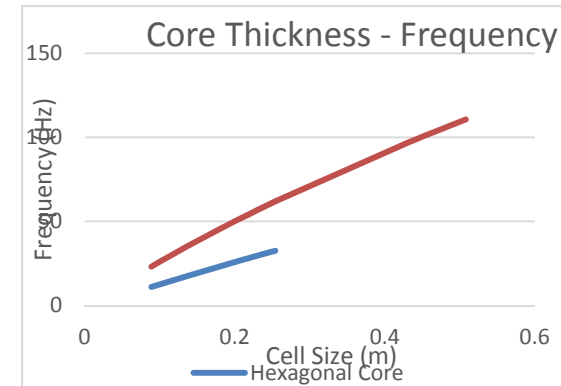
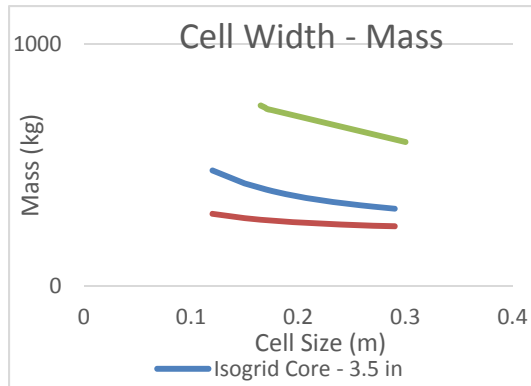
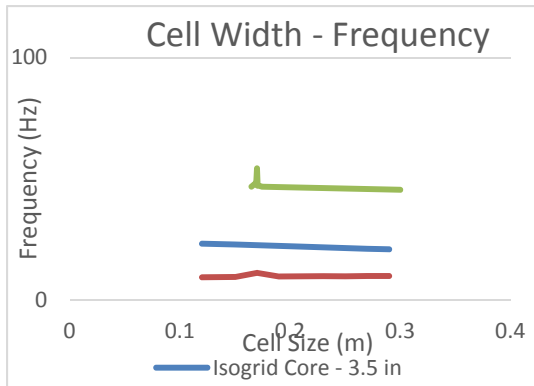
Buttons: SAVE SETTINGS, RESTORE ALL, MERGE POINTS, MERGE NODES, DOUBLE MESH, TRISECT FRONT, CREATE GRID, MAKE SUPPORT, CREATE MODEL, REFINA PADS, SLUMP MIRROR

Options: Outer Segt Lip, Inner Mirror Lip, Circular Segment, Seal Ring Outer, Seal Ring Inner, Seal Ring Mirror, Continuous Seal Rings, Segment Lip Fills, Web Ceramic Grid, Segt Coord System, Radial Petals, Isogrid Front, Isogrid Back, Backface Holes, Include Fillets, Off Center Pattern, No Backsheet, Central Hole, Omit Central Segt, Variable FaceSheet, Sofia Style Edge, Isogrid Core, ANSYS Legacy Elements

Supports: Whole Mirror, Cell Level 0, Cell Level 1, Cell Level 2, Cell Level 3, Cell Level 4, By Segment, Core Only, Back Only



# Typical Trade Studies Within a Design point



- **Costs**
  - Initial fabrication costs
  - Transportation and handling costs
  - Optical processing costs
  - Testing costs
  - Coating costs
  - Integration into satellite costs
  - Launch costs
  
- **Risks**
  - At each stage what happens if damaged

## Tools Being Developed



- **Integrated Optical Analysis System**
  - Standardized inputs
- **Thermal Analysis System**
  - Shares models with structural analyses tools
- **Structural Analysis Tools**
  - Arnold Mirror Modeler supports commercial FEA packages and both monolith and segmented mirror and support systems.
- **Cost and Risk Assessment Tools**

- Continue integration of various design tools
- Mature likely manufacturing methods
- Explore new materials or refine existing methods for 4 meter class mirrors and beyond
- Explore segmented versus monolith rationale

- The goal is the design of a realistic next generation successor to James Web.
- Applying systematic approach
- Byproducts of effort useful to all aspects of telescope design ... terrestrial or space.