JEM-EUSO Advanced Optical Design
Lens and Frame Stress And Dynamics Analysis

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NASA MSFC

- Project Mgt.
- Systems Eng.
- Optical frames
- Ground flashers

UAHuntsville

- Optics testing
- Public data release
- Simulations

Vanderbilt University

- Theory
- Simulations
- Analysis

Space Sciences Laboratory, University of California Berkeley

- Simulations
- Education & Public Outreach

UCLA

- Event Reconstruction
- Neutrino theory

Design Considerations

The lens frame/support design was conducted with consideration to several design requirements including:

Overall system mass

1st Lens Support/Frame = <150 kg (including 15% margin)
2nd Lens Support/Frame = <100 kg (including 15% margin)
3rd Lens Support/Frame = <100 kg (including 15% margin)

Lens manufacturing constraints (depth limitation in Z-axis): < 210 mm

Stress/deformation caused by change in temperature of interfacing material:

Operating Temperature: -10 to 30°C
Non-Operation Temperature: -45°C to +55°C
Lens Lateral Displacement (positional accuracy) < ± 2.5 mm
Lens Axial Displacement (coaxial tolerance) < ± 2.5 mm
Lens Tilt (parallel tolerance) < ± 2.5 mm

Stress caused by launch loads: 16.6g quasi-static (each axis independently)

Structural Natural Frequency:

Launch ≥ 25 Hz
Operational > 2 Hz

Obscuration of support structure: < 4%

Baseline vs. Advanced Design Analysis

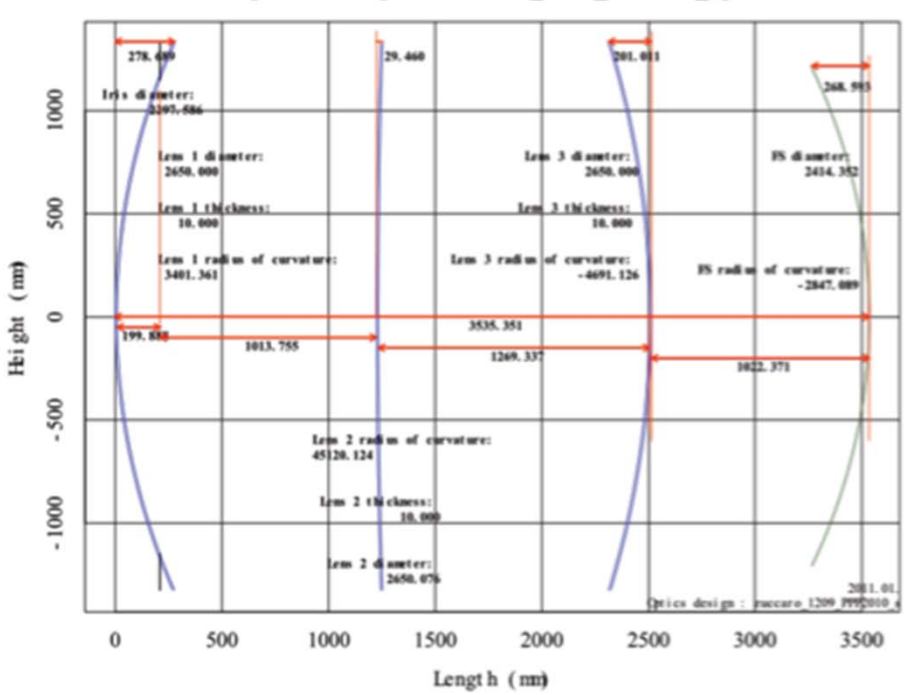
Analysis of Lens 1 in Frame 1 – This section contains the analysis of the one piece lens 1 in the frame 1 assembly. In this iteration the lens material is changed to CYTOP which makes the lens about twice as heavy as the Baseline Design's PMMA lens and the lens is monolithic vs. segmented.

Lens 2 is mounted in Frame 2 in a similar manner as Lens 3 is mounted in Frame 3 for both the Baseline and Advanced Designs. Therefore, the approach used to increase the frequency for the Frame 3/Lens 3 assembly will also be applicable to the Frame 2/Lens 2 assembly. Due to the similarity between the two assemblies, a stress analysis for the Frame 2 assembly is not expected to uncover any concerns that would not also be seen in the Frame 3 assembly analysis.

Baseline and Advanced Designs

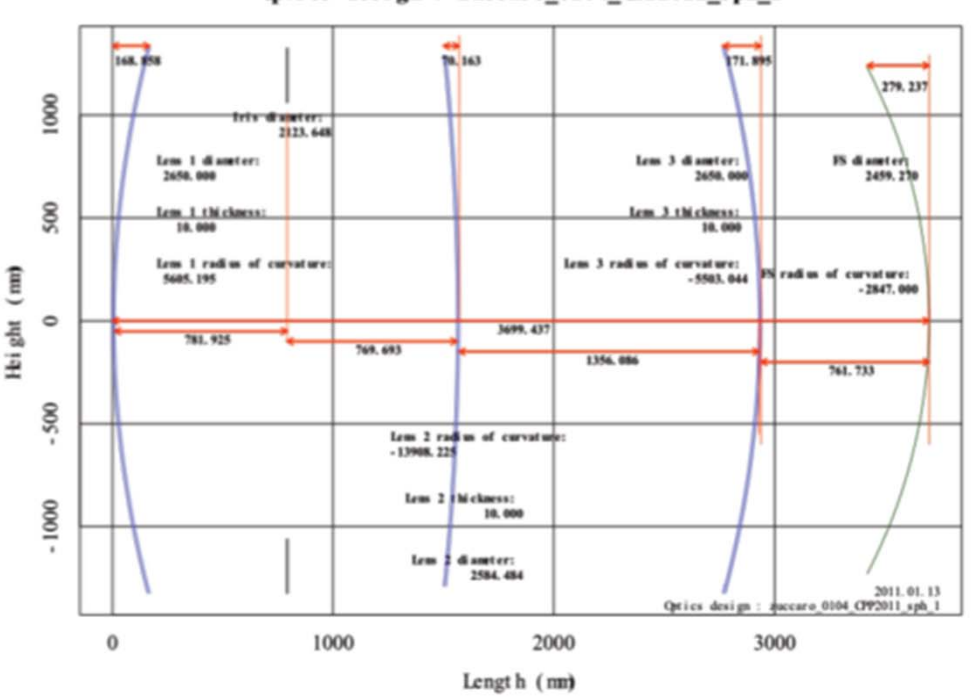
Baseline design

PMMA-PMMA-PMMA

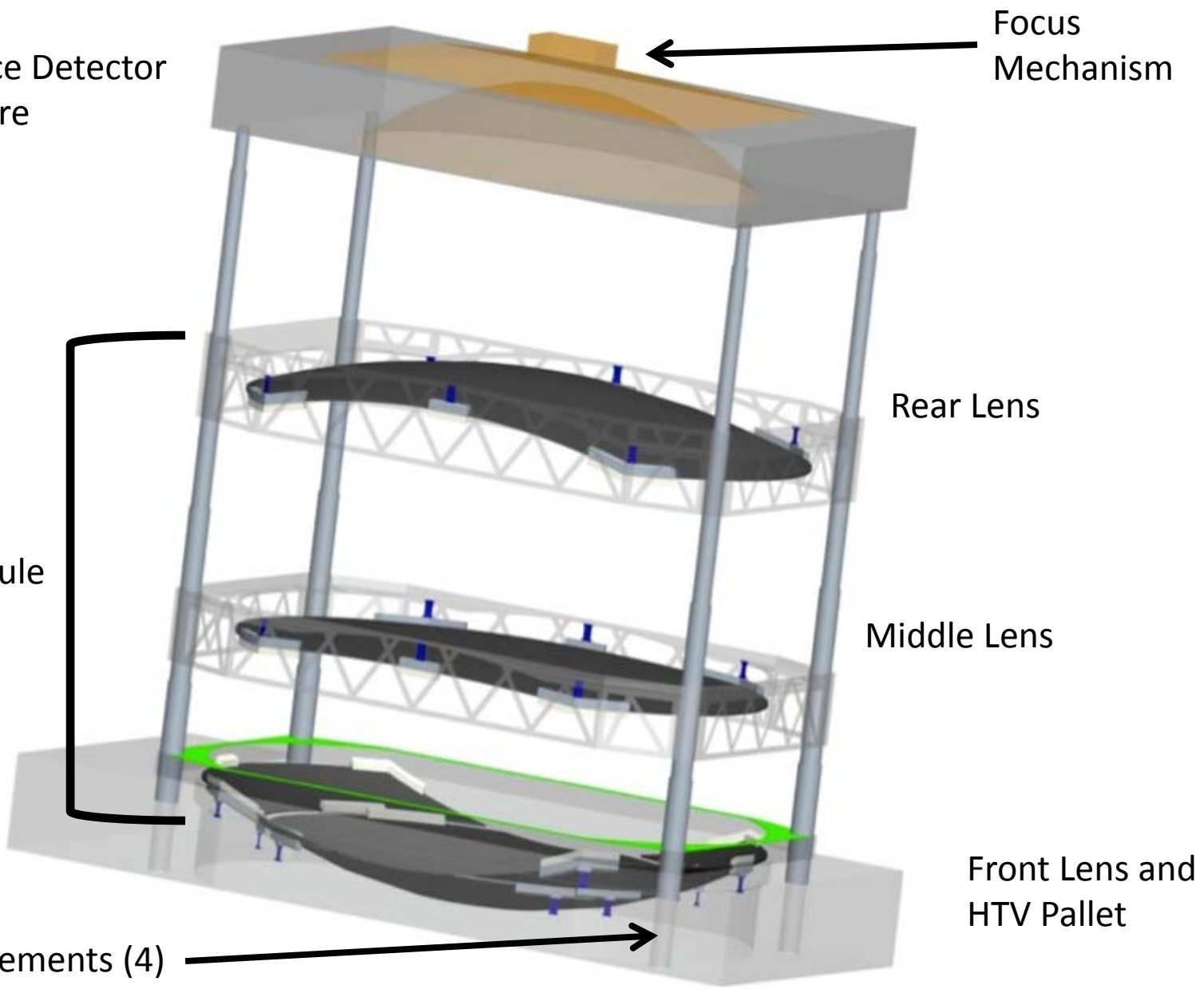


Advanced design

CYTOP-PMMA-PMMA

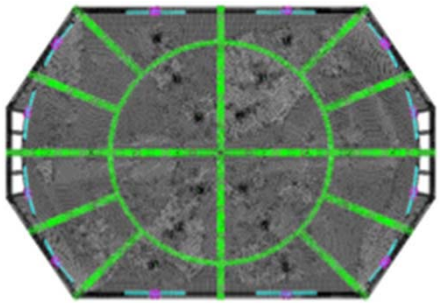


JEM-EUSO Instrument



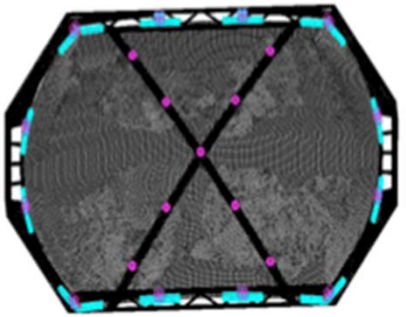
Preliminary Advanced Optical Design Frame

Frame 1

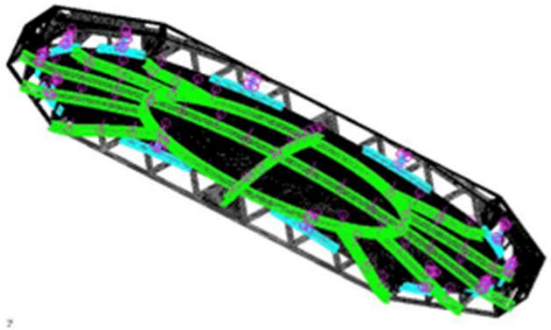


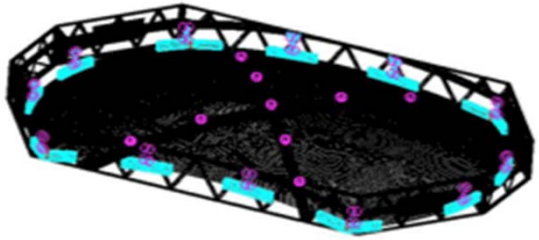
Lens 1 with Brackets (blue) beams (green) and Flexures (pink) in Frame

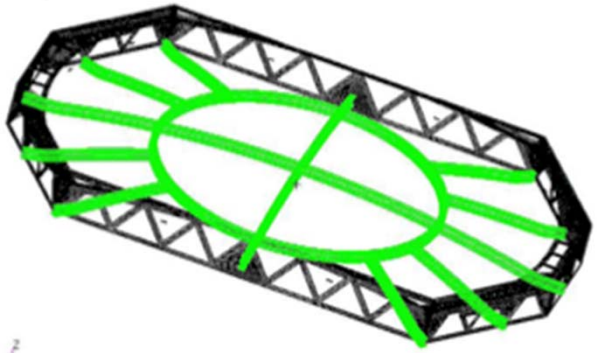
Frame 3

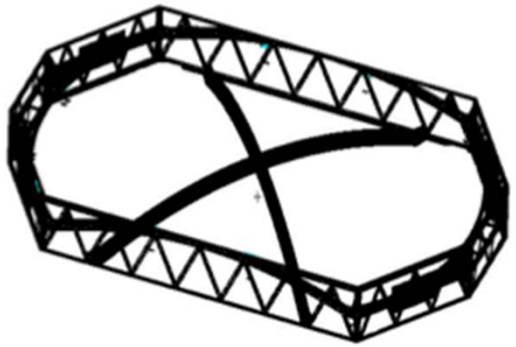


Lens 3 with Brackets (blue) and Flexures (pink) in Frame









Ti flexures
Al 6061 frames, support

Preliminary Lens Frame Design Outer Envelope

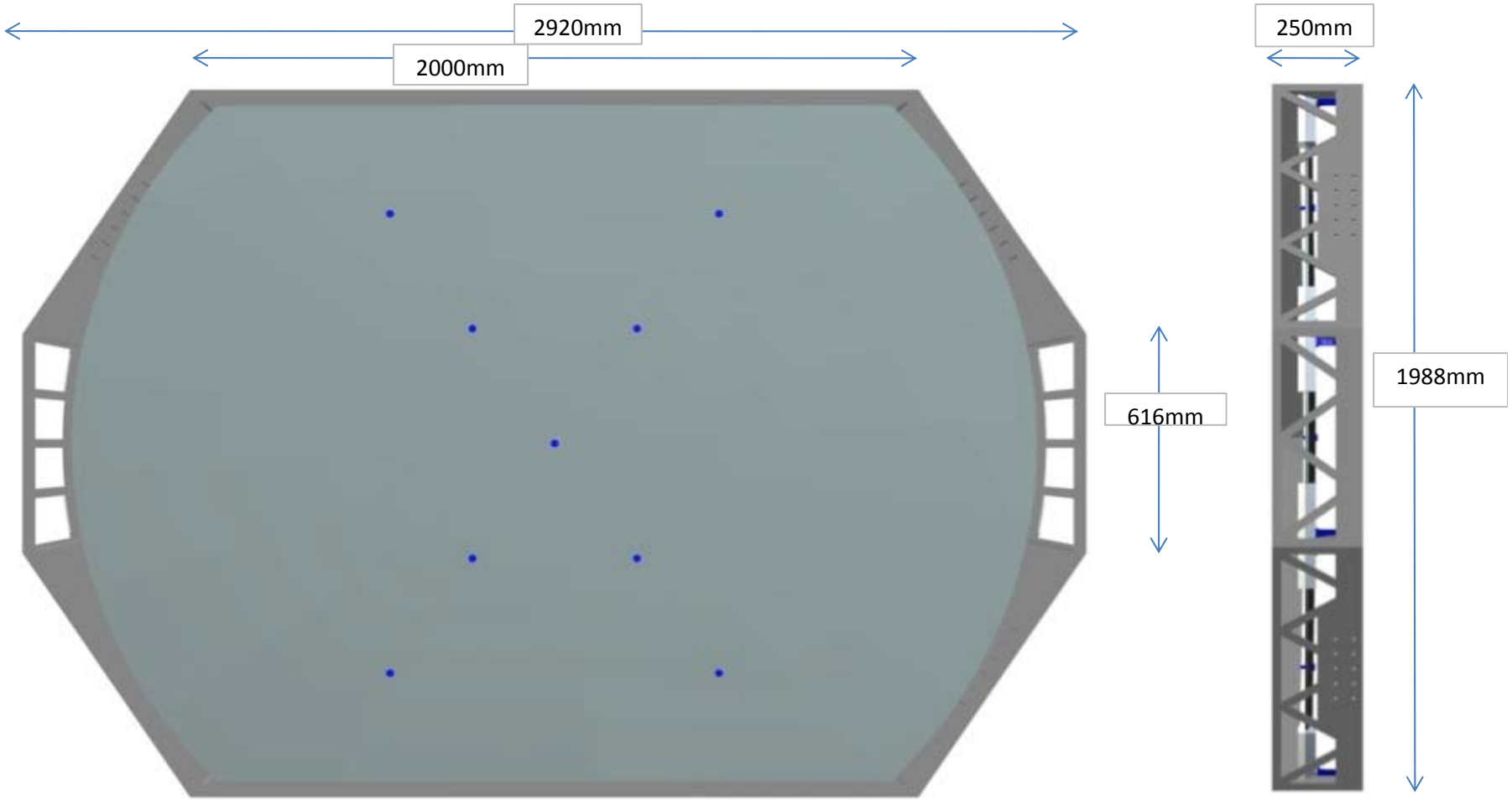


Table *Mass budget (Advanced optics and preliminary structure design).*

Parts	BEE [kg]	Margin [%]	Total [kg]	Comments
1st lens (Front)	96.2	15	110.63	CYTOP 10 mm thickness
Frame of the 1st lens	86.2	15	99.13	
Stop (iris)	-	-		Not modeled for Advanced Design – between Lens 1 & 2
2nd lens (Middle)	56.17	15	64.60	PMMA-000 10 mm thickness
Frame of the 2nd lens	64.46	15	74.13	
3rd lens (Rear)	56.7	15	65.21	PMMA-000 10 mm thickness
Frame of the 3rd lens	64.46	15	74.13	
Focusing adjust system	20	15	23.00	
Total	***444.19***		***510.82***	

Notes: Frame 1 mass can be reduced once details of the Modified EP are provided
Overall mass optimization of the OM will occur in Phase A

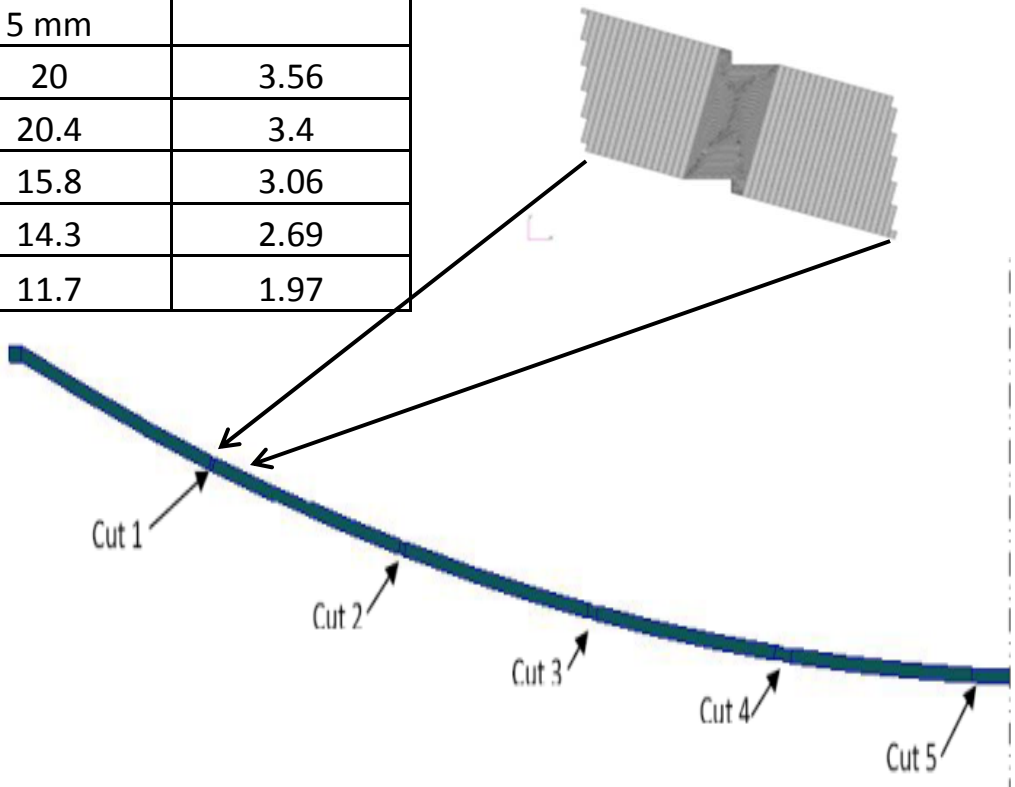
Study Parameters

- Used loads from NASDA-ESPC-2857 Rev C
  - ❑ Quasi: ±3.0 g's in X and Y, ±6.0 g's in Z, ±30.0 rad/s^2 rotation in all three axis
  - ❑ Random: ±14.188 g's assuming damping of 10, and frequency of 80 Hz to maximize load.
- Considered translation accelerations
- Random loads applied in all three directions simultaneously
- Safety factors are 2.0 for Ultimate and 1.25 for Yield
- Thermal: assembly temperature of 21°C, maximum and minimum temperatures are +40°C and -20°C.

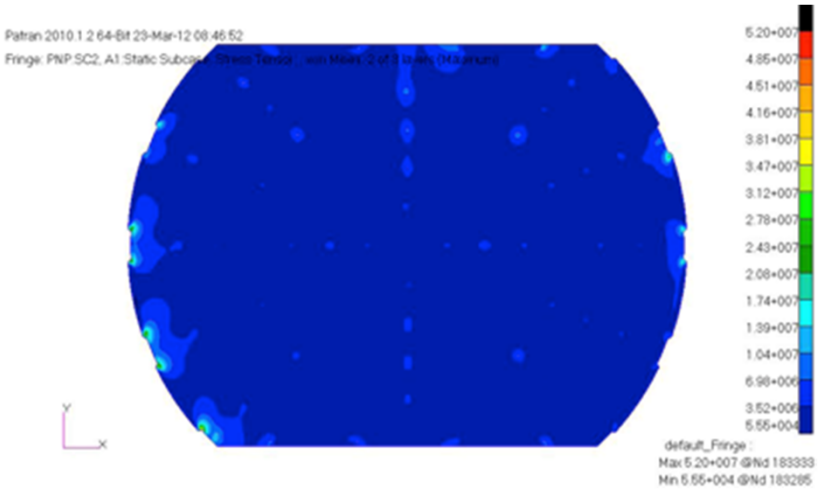
Fresnel Facet Modeling

Analysis showed the stress is increased by a factor of 3.56 due to the Fresnel facets. This factor was introduced in all stress calculations

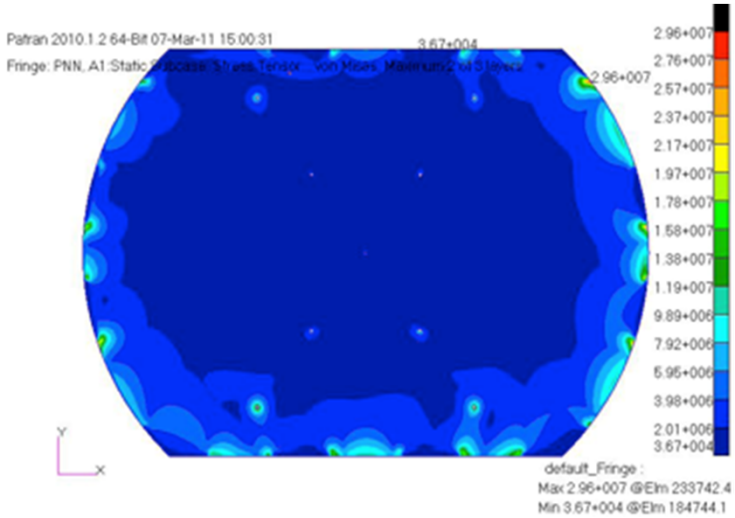
Summary of Peak Stresses for each cut location					
	Stress with no cut	Stress at 1 mm cut with lens thickness of:			Stress Concentration Factor
		40 mm	10 mm	5 mm	
Cut 1	5.62	19.3	20	20	3.56
Cut 2	6	18.2	20.4	20.4	3.4
Cut 3	5.17	15.1	15.8	15.8	3.06
Cut 4	5.32	13.7	14.3	14.3	2.69
Cut 5	5.95	10.6	11.7	11.7	1.97

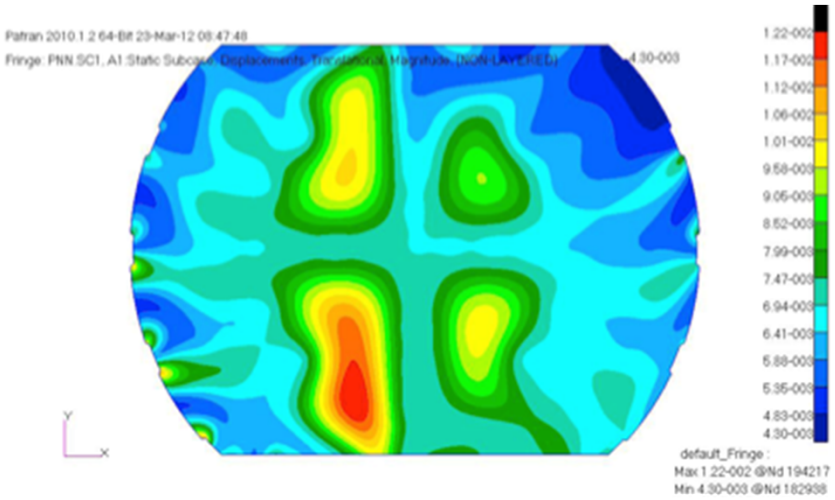


Advanced Design Lens Analysis Results

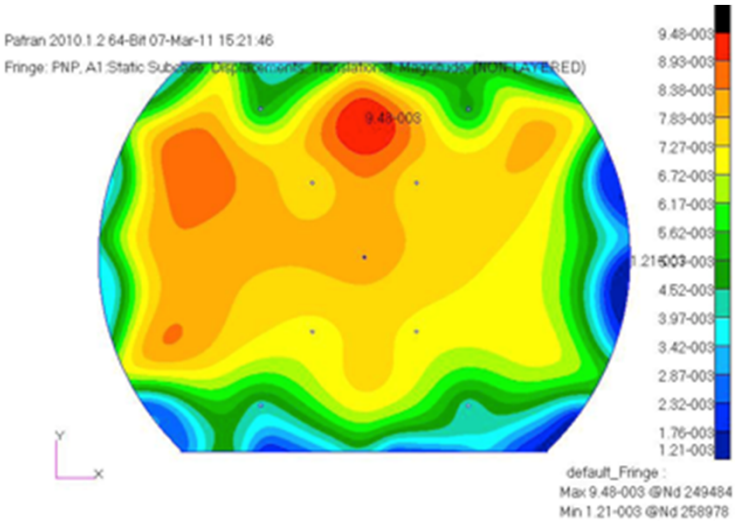


Maximum Stress (Pascals)





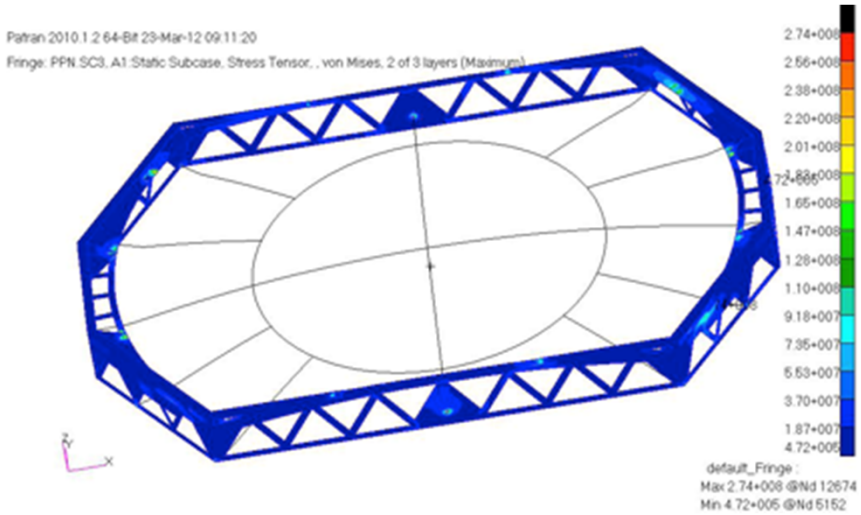
Maximum Displacement (Meters)



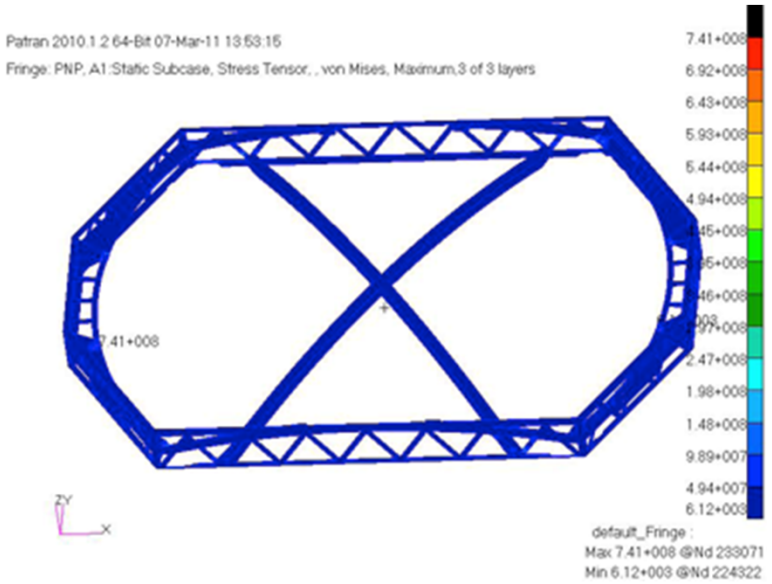
Lens 1

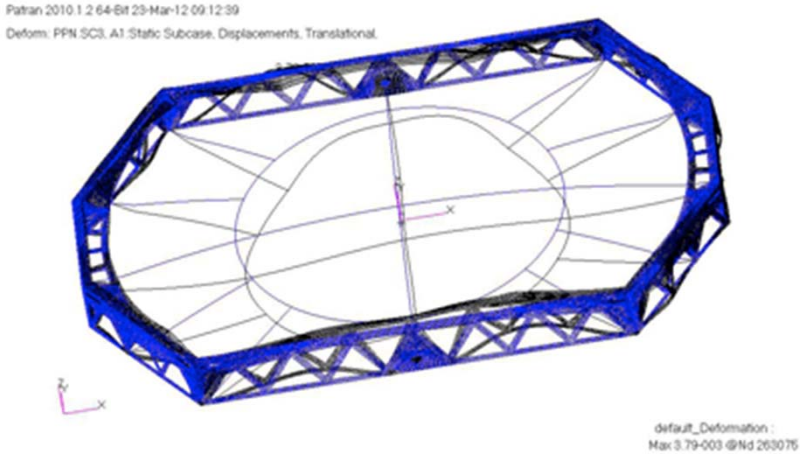
Lens 3

Advanced Design Frame Analysis Results

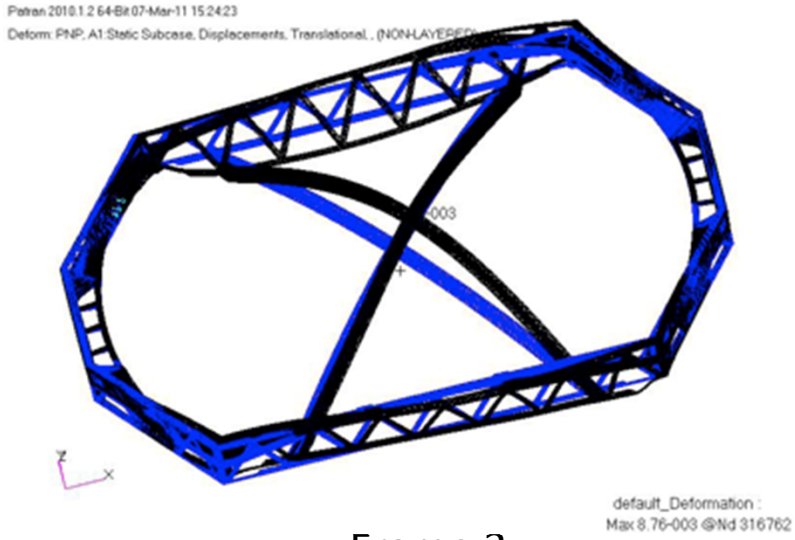


Maximum Stress (Pascals)





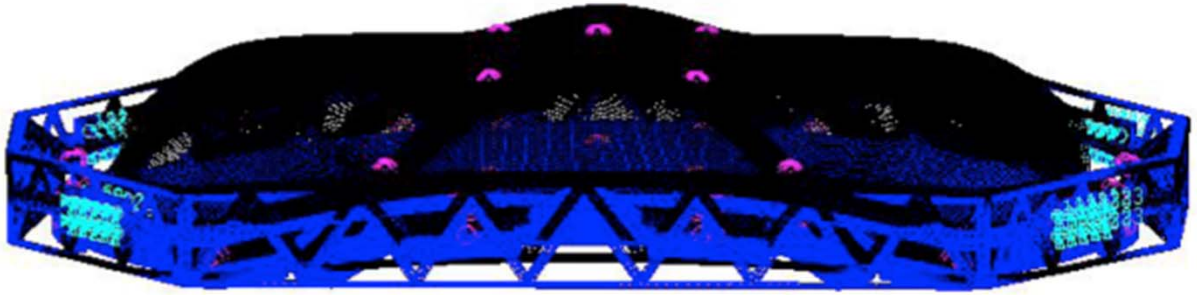
Maximum Deflection (Meters)



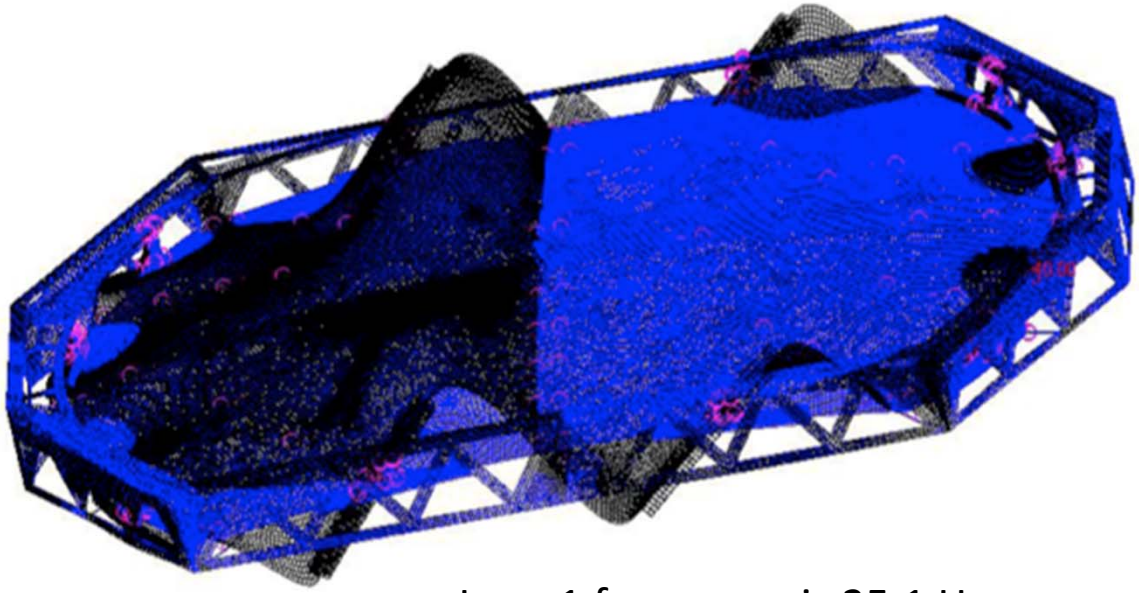
Frame 1

Frame 3

Advanced Design Structural Analysis Results
First Frequency Mode

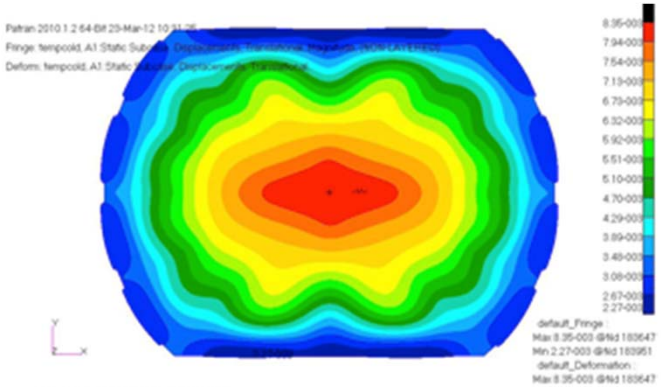


Lens 3 frequency is 25.6 Hz

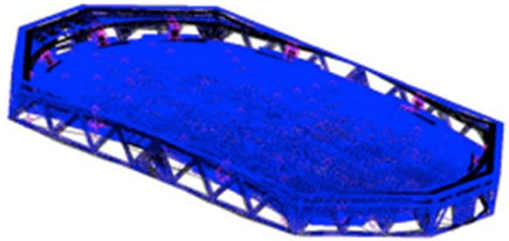


Lens 1 frequency is 25.1 Hz

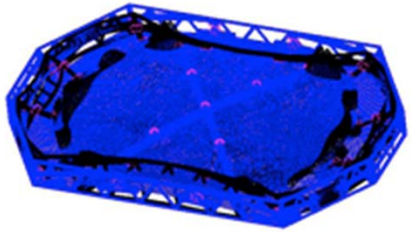
Advanced Design Thermal Analysis Results

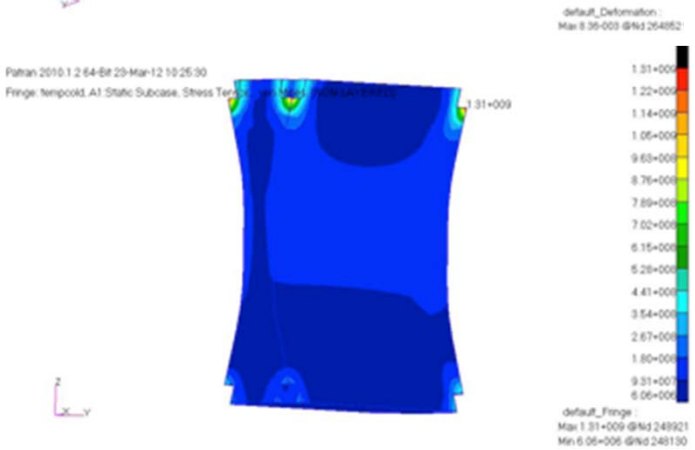


Maximum Deflection of Lens due to Thermal (Meters)

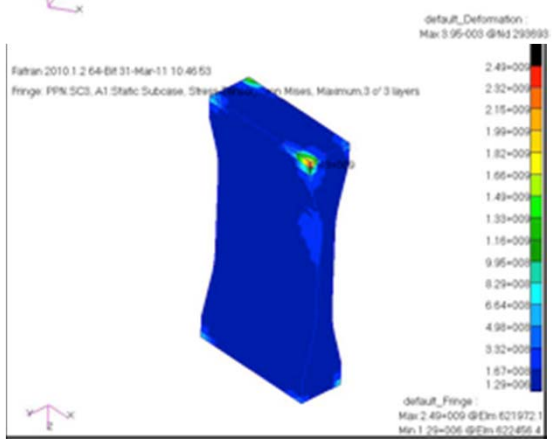


Maximum Deflection of Frame due to Thermal (Meters)





Flexure – max stress (Pascals)



Lens 1

Thermal range -20 to +40 ˚C
Assembled at room temperature

Lens 3

Conclusions

- Majority of the design is showing positive safety margins
- Few areas with negative margins
  - ❖ Address in the next iteration of analysis
  - ❖ Many are due to the modeling
  - ❖ Applying loads simultaneously is conservative
- Minor changes in design and more detailed modeling and analysis should produce positive margins
- The thermal and structural issues identified in the analysis are similar and should be resolved with the same design/model modifications
- The masts need to be included in the next iteration as well as the EP-MP