

MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES



HiWind 2024 Structural Analysis

Andrew Carlile

4/30/2024

A substantial change was made in February 2024. Changes to the FEA Upper Gondola analysis were: adding the tri-plate, adding all the panels, changing the Margin of Safety Calculation, and an update to the dummy masses including their shape and not just the mass override. In March 2024 the dummy mass models were removed and replaced by remote masses. The total masses were increased slightly. The Starlink antennae estimate was added, and the results are below.

Drawing Requirements

1. Drawings shall show the relative locations and dimensions of all structural and load-bearing gondola members

| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. | MASS (g) | MATERIAL |
|----------|---|---|------|-----------|--|
| 1 | Level2UGA | Upper Gondola FEA Structure | 1 | 519074.65 | Aluminum 6061, except Trapeze 4031 Steel |
| 2 | Antennas and Structure | Antennas and Structure | 1 | 85741.3 | C Channel Aluminum 6061, Antennae Dummy Masses Steel |
| 3 | IR_3221-SW-205850 (CSBF Lower Rotator Adaptor Fitting D27505) | CSBF Lower Rotator Adaptor Fitting D27505 | 1 | | 6061-T6 Aluminum |
| 4 | FEA-VerlInsertReinforcement | Vertical Insert Dummy Mass | 4 | 1035.92 | 6061-T6 (SS) |
| 5 | FEA-LGA Solid | LOWER GONDOLA FEA BLOCK | 1 | 1000000 | 6061-T6 (SS) |
| 6 | Starlink Antennae | ? | 1 | 13500.0 | 6061-T6 (SS) |

DFS Job #: _____
 Acct. Key: _____
 Contact: AAC
 Extension: _____

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UNLESS OTHERWISE SPECIFIED:
 DIMENSIONS ARE IN MM
 TOLERANCES:
 ANGULAR: FORMED: +2°
 MACHINED: ±0.5°
 DECIMALS
 X.X: ±0.25
 X.XX: ±0.13
 X.XXX: ±0.013
DO NOT SCALE DRAWING

MATERIAL: _____
 MASS [grams]: _____

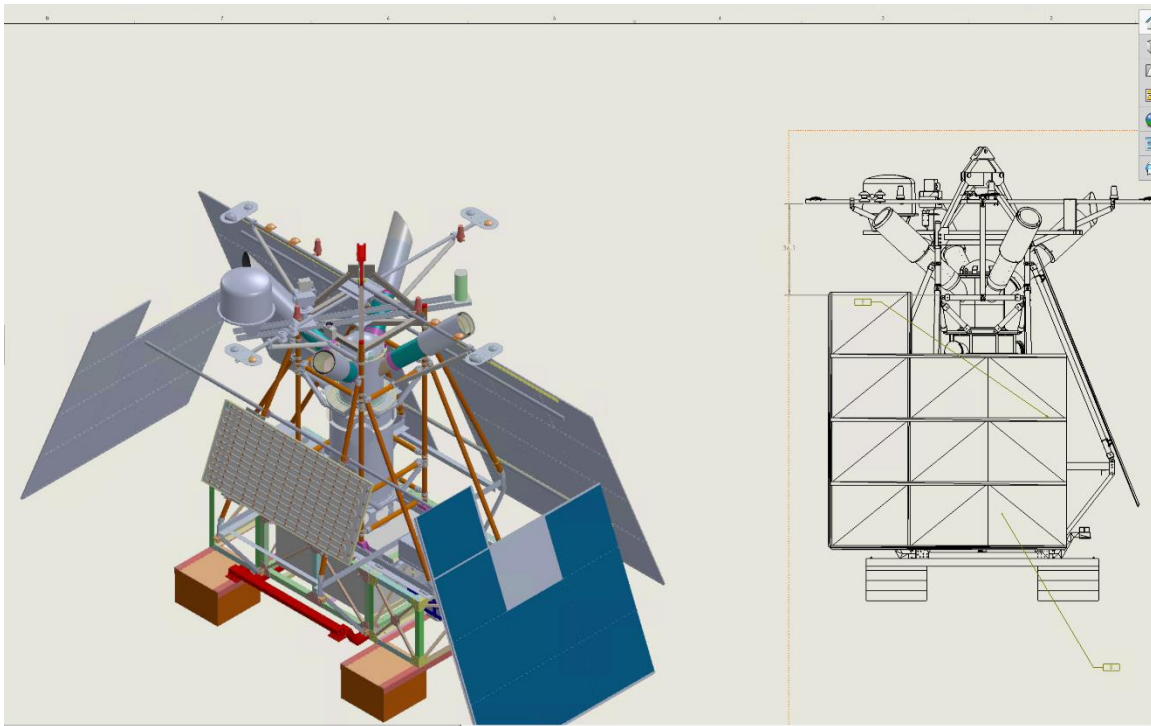
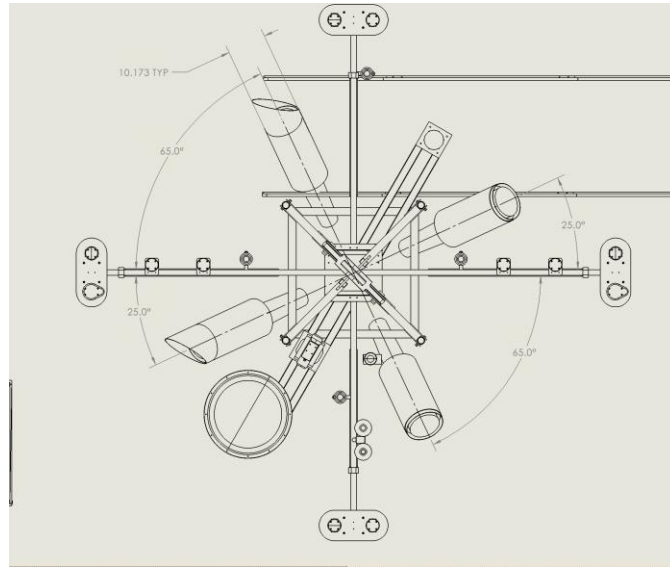
HAO High Altitude Observatory
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 Boulder, CO 80301
 303-497-1000

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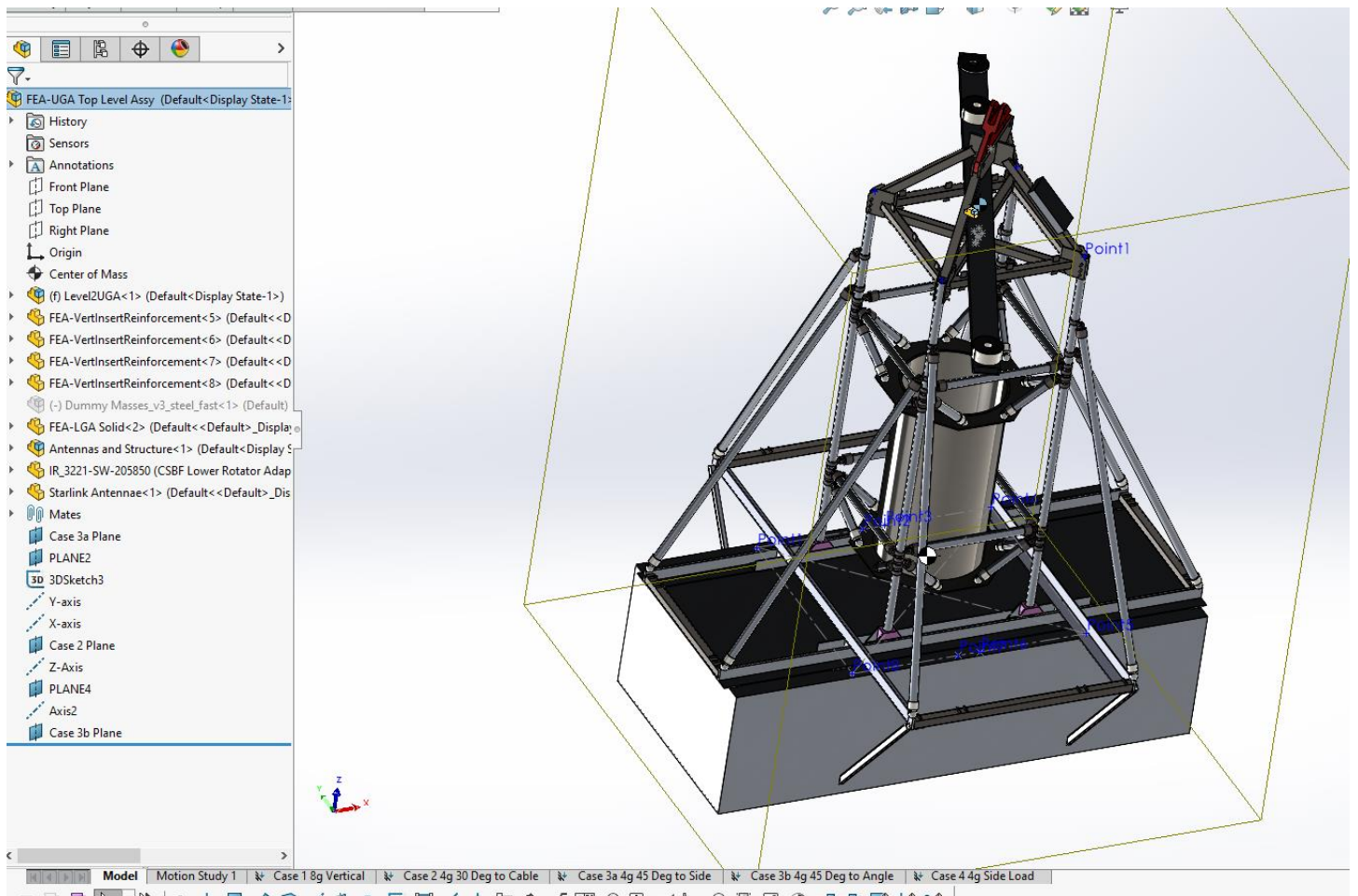
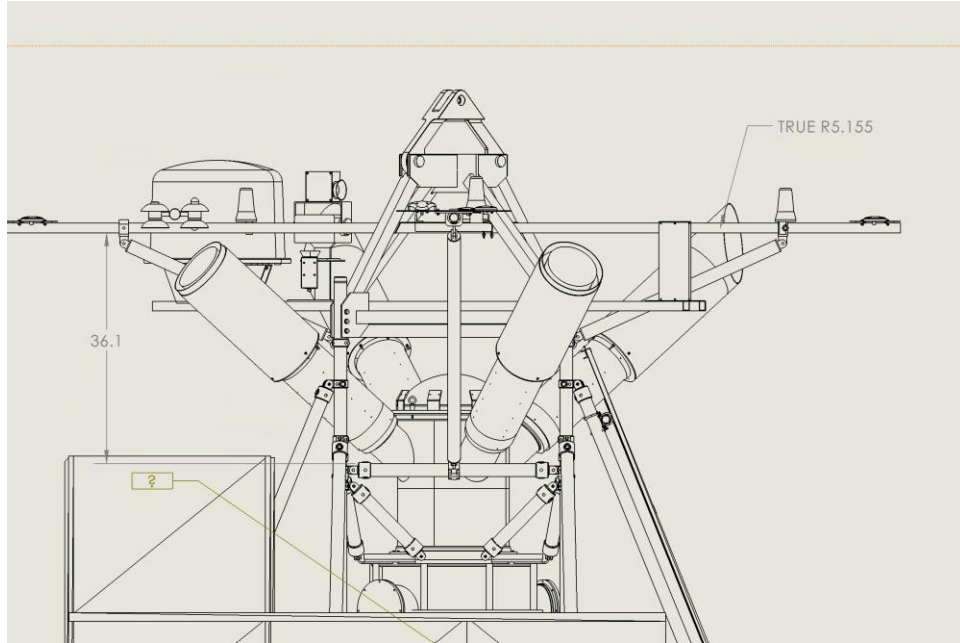
| APPROVALS | DATE | TITLE |
|--------------------|------|-------------------------|
| DRAWN: AAC | | |
| ENG APPR: | | |
| PROJ. APPR: | | STATE: Work in Progress |
| SURFACE AREA (mm²) | | SIZE: DWG. NO. |
| VIEW: 3_8_2024_FEA | | REVISION: _____ |
| SCALE: 1:30 | | SHEET 1 OF 1 |

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The observatory viewports need to be considered keep out zones for NASA and HAO. Clearance between the baffle tube and other structures should be 6 inch away from the ends of the four baffle tubes and 10 inch behind the ends to avoid scattering light. Dimensions in inches.



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| | from center of origin in the UGA model | | | |
|---|--|--------|--------|-----------|
| Mass Description | X [mm] | Y [mm] | Z [mm] | Mass [kg] |
| Model including Lower Gondola and Antennaes | | | | 1677 |
| Lower Gondola | 0 | 0 | 2423 | 1045.4 |
| Batteries added into Lower Gondola | | | | 150 |
| Radiator Total | 0 | -1000 | -1500 | 56 |
| Makeup Gas | -500 | -250 | -1500 | 30 |
| Radiator Side Panel | 0 | -1800 | -2000 | 40 |
| Left Panel | -2200 | 0 | -2000 | 40 |
| Right Panel | 2200 | 0 | -2000 | 40 |
| Front Panel | 0 | 1800 | -2000 | 40 |
| Starlink | attached | | | |
| Total Antennaes on Both Faces of tube | | | | 60 |
| | | | | |
| total HiWind including remote masses | total HiWind | | kg | 1923 |

2. Drawings shall identify all the materials used for the construction depicted by the drawing
 The tubes are aluminum, with Kee Clamp cast iron for the clamps and connections. The upper gondola is mild steel, and all of the hardware is at least grade 8 steel.

3. Material specifications shall be included in all drawings
 All parts in FEA are of one of these 3 materials. The steel cable estimate is described in section 6.

| | | | | | | | | | |
|---|---------|--|--|--|--|--|--|--|--|
| Material Properties | | | | | | | | | |
| Aluminum 6061 Pu | 310 MPa | | | | | | | | |
| Aluminum 6061 Py | 276 MPa | | | | | | | | |
| Aluminum 6061-T6; 6061-T651 (matweb.com) | | | | | | | | | |
| Cast Iron Pu | 344 MPa | | | | | | | | |
| Cast Iron Py | 276 MPa | | | | | | | | |
| https://www.matweb.com/search/datasheet.aspx?matguid=ec56a89f37f74e2f867a64b0f87f1e9d | | | | | | | | | |
| Steel 4130 Pu | 670 MPa | | | | | | | | |
| Steel 4130 Py | 435 MPa | | | | | | | | |
| Overview of materials for Medium Alloy Steel (matweb.com) | | | | | | | | | |
| Calculated in Workbook | | | | | | | | | |
| Calculated in SolidWorks | | | | | | | | | |

4. At least one complete assembly drawing shall be provided
 HAO cannot currently provide this.

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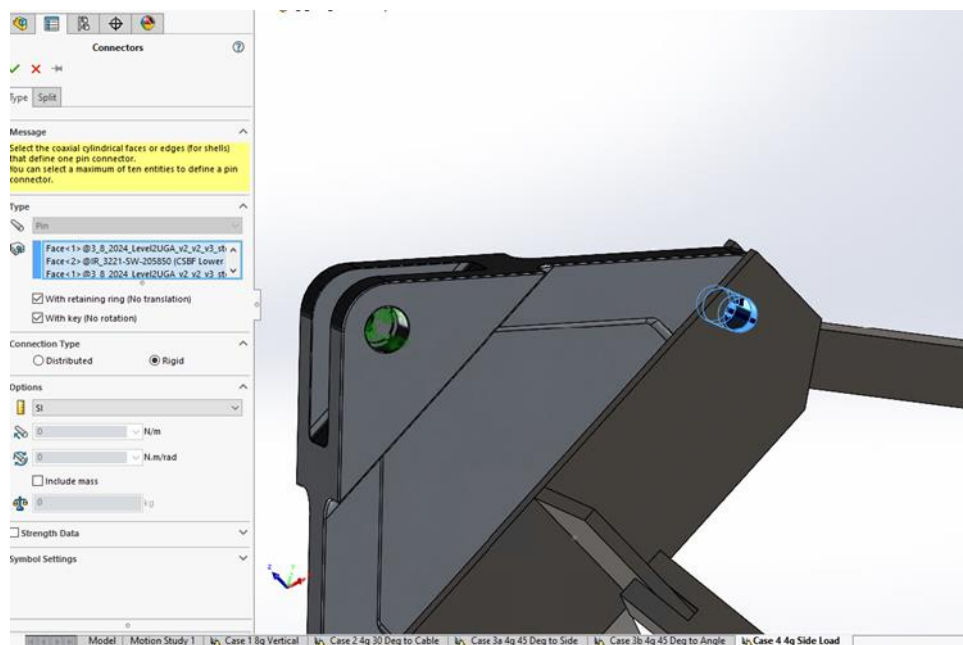
5. Working drawings and specifications for all purchased and fabricated mechanical components and assemblies that are part of the gondola (e.g., rotators, swivels, turnbuckles, clevises, rings, and universal joints) shall be provided

HAO can provide most of these drawings at a later date.

6. A stress analysis of all major structural members, including decks and ballast attachment points shall be provided and shall identify the boundary conditions, components, equipment, and weights comprising the loads

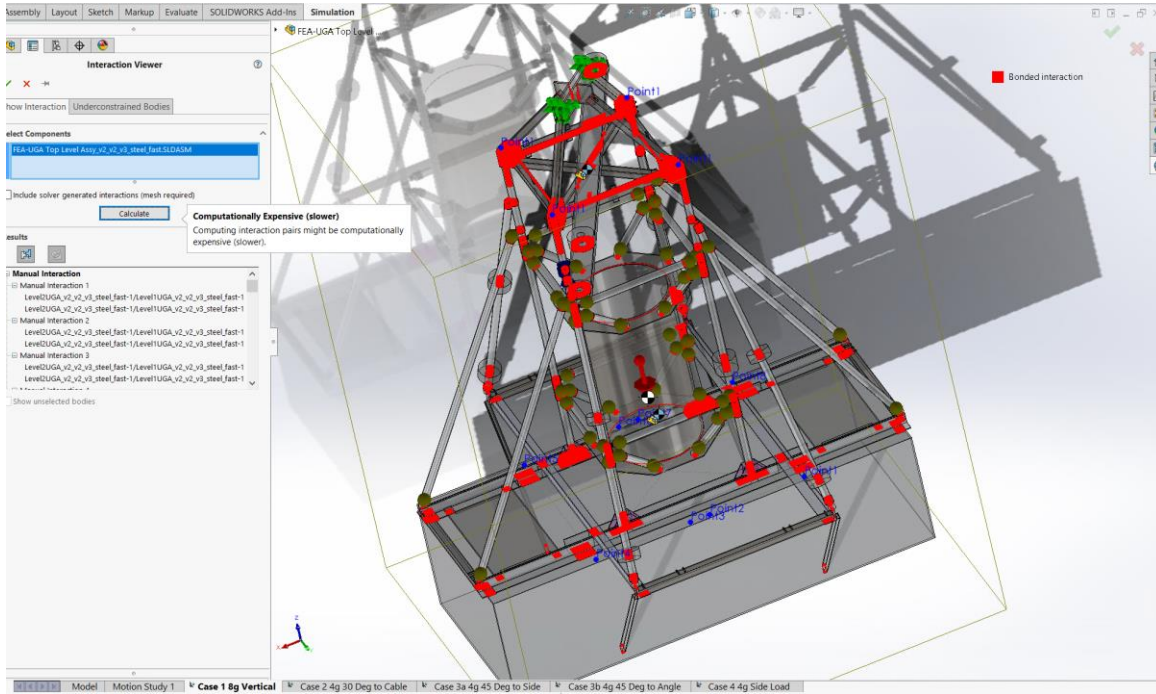
Upper Gondola Attachment Points and Boundary Conditions

The upper gondola attaches to the balloon with the trapeze. The attachment point to the balloon is modeled as a fixed constraint at the top of the trapeze, shown below.



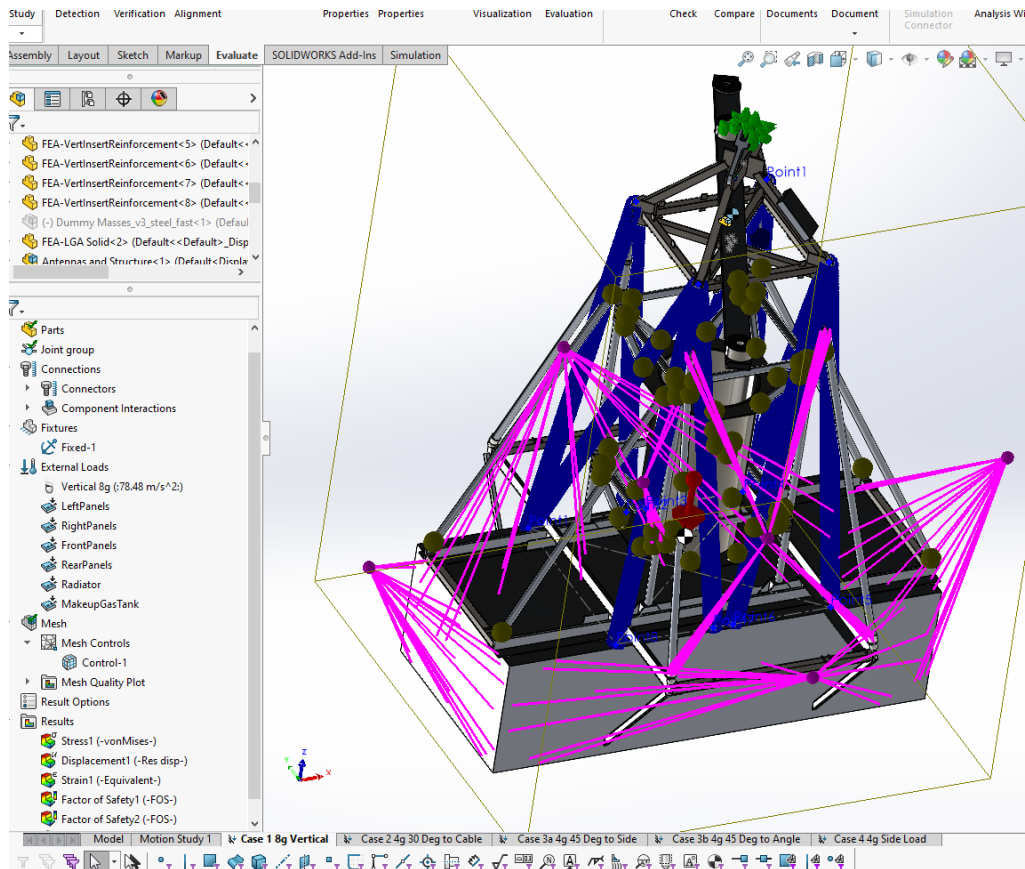
The manually added connectors, either link connector or spring (cable estimate), are shown below.

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Dummy Mass Changes

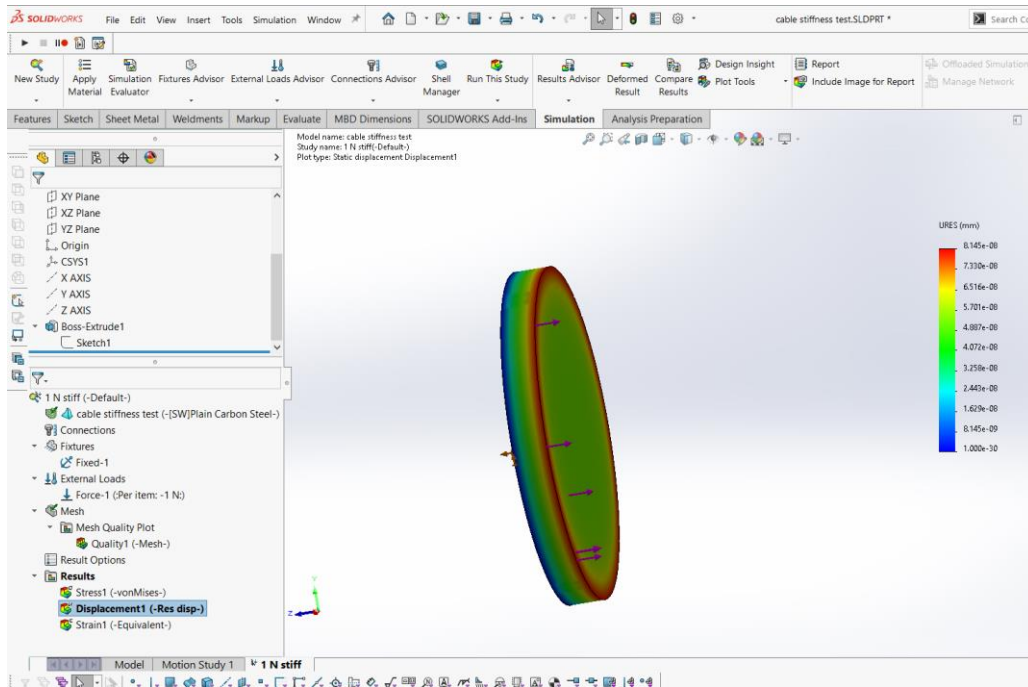
As of March 2024, the dummy mass models have been changed to remote masses, except for the antennas and lower gondola assembly.



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Support Cable Estimation

In order to create the cables as a connection in the FEA model a simple steel model was created with a 3/8” diameter and a 1 N load applied. Then the stiffness value was used to create spring connections in the upper gondola analysis.



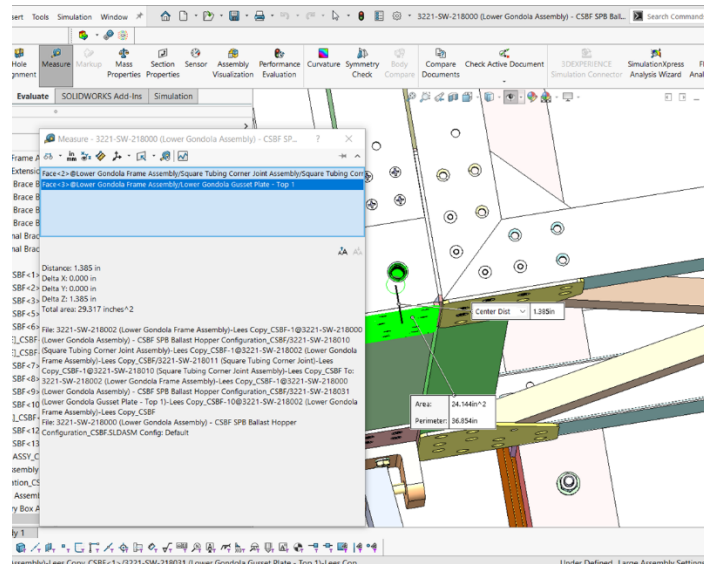
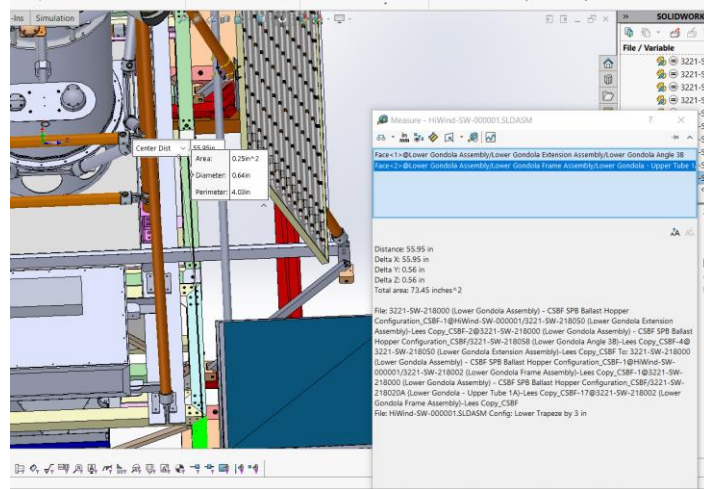
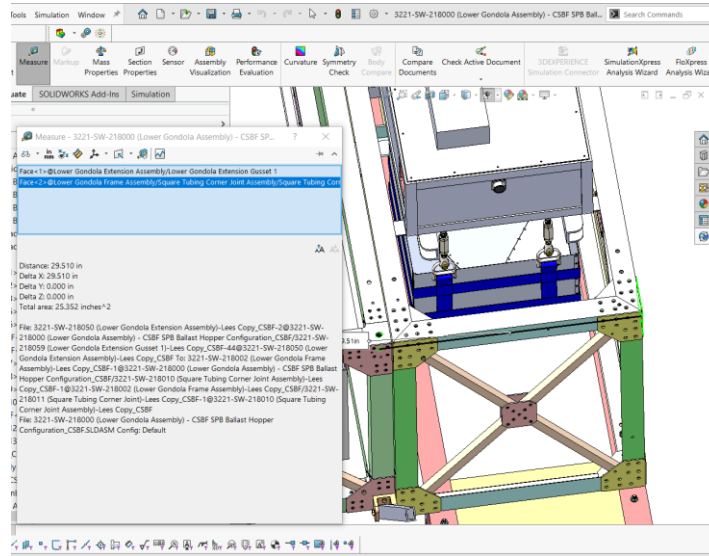
| 3/8 steel cable stiffness | | | |
|---------------------------|---------------|--|--------------|
| | | | |
| | 1 N | | |
| | 8.15E-08 mm | | |
| | | | |
| | 1.23E+07 N/mm | | 1.23E+10 N/m |

- ☐ AISI Type 316L stainless steel
 - ☐ AISI Type A2 Tool Steel
 - ☐ Alloy Steel
 - ☐ Alloy Steel (SS)
 - ☐ ASTM A36 Steel
 - ☐ Cast Alloy Steel
 - ☐ Cast Carbon Steel
 - ☐ Cast Stainless Steel
 - ☐ Chrome Stainless Steel
 - ☐ Galvanized Steel
 - ☐ **Plain Carbon Steel**
 - ☐ Stainless Steel (ferritic)
 - ☐ Wrought Stainless Steel
- ☐ Iron
- ☐ Aluminium Alloy

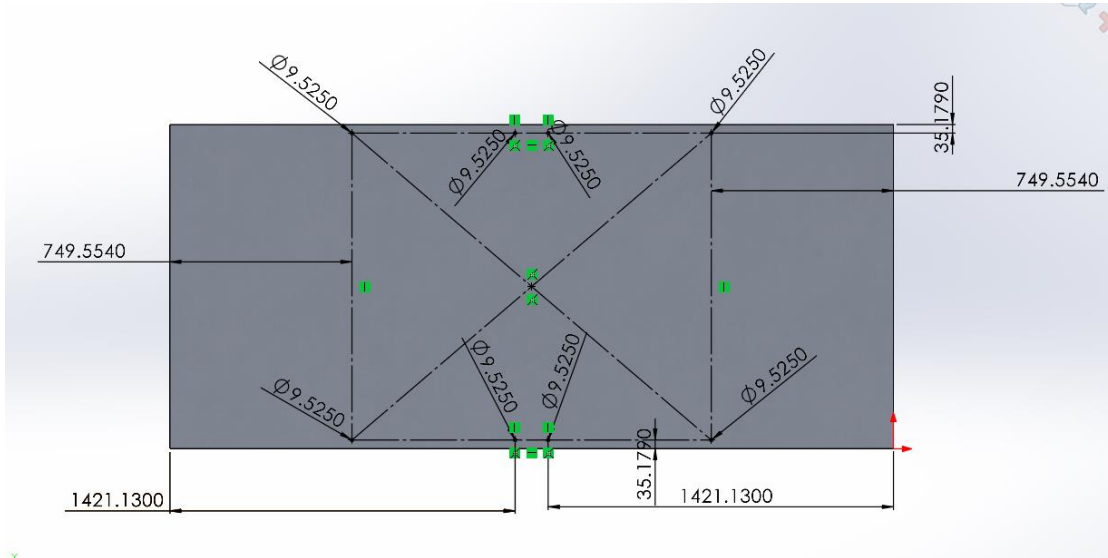
| Property | Value | Units |
|-------------------------------|-----------|-------------------|
| Elastic Modulus | 2.1e+11 | N/m ² |
| Poisson's Ratio | 0.28 | N/A |
| Shear Modulus | 7.9e+10 | N/m ² |
| Mass Density | 7800 | kg/m ³ |
| Tensile Strength | 399826000 | N/m ² |
| Compressive Strength | | N/m ² |
| Yield Strength | 220594000 | N/m ² |
| Thermal Expansion Coefficient | 1.3e-05 | /K |
| Thermal Conductivity | 43 | W/(m-K) |
| Specific Heat | 440 | J/(kg-K) |
| Material Damping Ratio | | N/A |

The connection points for the spring connection are shown below:

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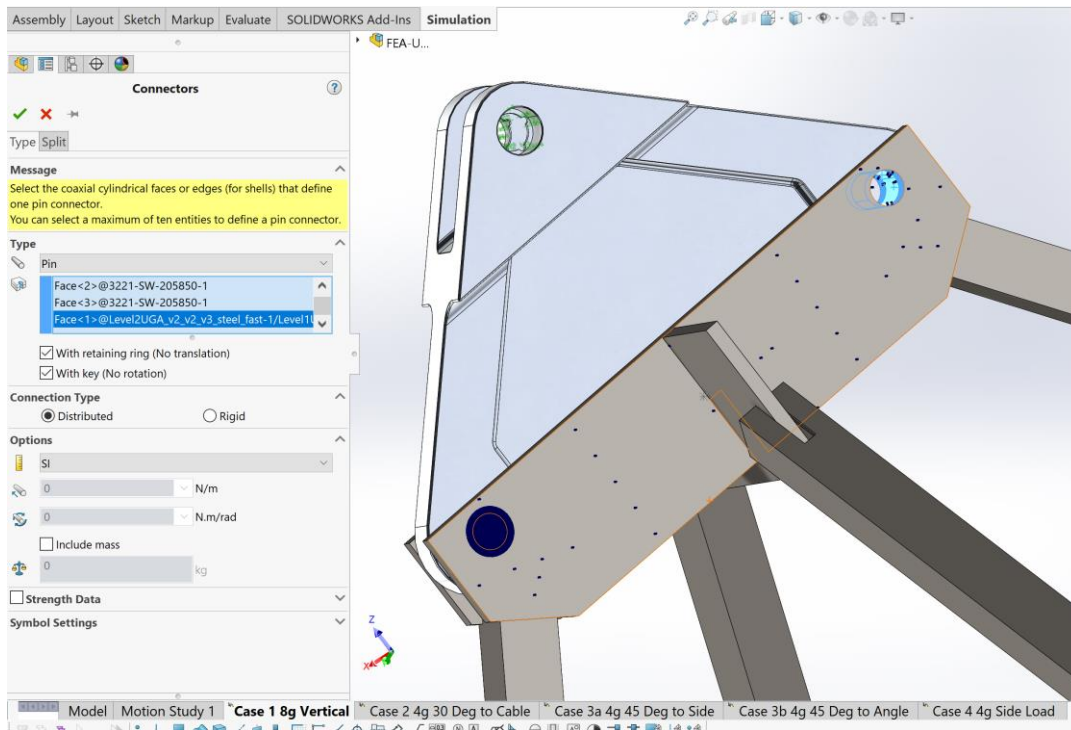


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Tri-plate Attachment Fixed Surfaces and Connections to Trapeze

The tri-plate has been imported using the SW default 6061-T6 material. The top holes are fixed, and the connection to the trapeze is set as a solid pin linking the faces, shown below.



Key details from 820-PG-8700.0.1 Gondola Structural Design Requirements

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3.3 Design Limit Loads (DLL)

Gondolas shall be designed so that all load-carrying structural members, joints, connectors, decks, and suspension systems show a *positive* margin of safety ($MS > 0.0$) when subjected to the design limit loads listed below in Table 2 and the desired design factor(s) of safety given in Table 3. Note: some components can only be shown to have positive MS against ultimate strength (e.g. composites).

Table 2: Design Limit Loads

| Structural Flight Hardware | Design Limit Loads (DLL) G's | | |
|----------------------------|------------------------------|--------|------------|
| | Vertical | 45 Deg | Horizontal |
| | 8 | 4 | 4 |

NOTE:

Metallic materials with a fracture strain of 5% or less, at worst case temperature limit, shall be considered brittle and an additional factor of 1.5 shall be applied to the Design Limit Loads. That is, the particular element that is fabricated using a brittle material must be able to sustain a 12g vertical load, a 6g load applied at 45 degrees off vertical, and a 6g horizontal load without failure.

3.4 Factors of Safety

Design factors of safety (FS) for the gondola structural components and its suspension system are given in Table 3. The Design FS are based upon the worst-case termination event and historic flight profiles. It is paramount that the gondola design ensures that no scientific equipment, CSBF equipment, or ballast separate from the flight system during any phase of flight operation.

Table 3: Design Factors of Safety

| TYPE OF HARDWARE | DESIGN FACTOR OF SAFETY | | |
|---|---|----------|------------|
| | Yield | Ultimate | Proof Test |
| Metallic Structures | | | |
| Flight Structure - metallic only | 1.25 | 1.4 | N/A |
| Preloaded Joints | 1.25 | 1.4 | N/A |
| Fasteners | 1.25 | 1.4 | N/A |
| Welds | N/A | 1.5 | 1.2 |
| Suspension Systems | | | |
| Wire Rope Cables, Slings, Cable assemblies, Shackles, Turnbuckles, etc. | N/A | 1.4 | * |
| Soft-body Structures | | | |
| Slings, Webbing | N/A | 2.0 | * |
| Composite Flight Structure | | | |
| Uniform Material | N/A | 1.5 | 1.2 |
| Bonded Joints/Inserts | N/A | 2.0 | 1.2 |
| Stability/Buckling | | | |
| Stability/Buckling – metallic only | N/A | 1.4 | N/A |
| Stability/Buckling – composite | N/A | 1.5 | N/A |
| Pressure Vessel Systems | Ref: GSFC-STD-8009, ANSI/AIAA S-080A-2018 | | |
| *: based upon NASA review of GP hardware | | | |

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3.5 Margins of Safety

The strength of the gondola system shall be demonstrated by showing a positive margin of safety (MS) for individual components and assembly interfaces for the given loading environment when the factors of safety given in Table 3 are applied.

The margins of safety are determined by multiplying the design limit load (or stress) by the appropriate factor of safety and comparing it to either the yield or ultimate material allowable strength as shown in the following equations:

$$MS_u = \frac{P_u}{FS_u P} - 1$$

and

$$MS_y = \frac{P_y}{FS_y P} - 1$$

where

- FS_u is the ultimate Factor of Safety
- FS_y is the yield Factor of Safety
- P is the limit load (or stress) calculated in the analysis
- P_u is the load (or stress) at which material failure will occur
- P_y is the load (or stress) at which material yielding will occur
- MS_u is the Margin of Safety against ultimate failure
- MS_y is the Margin of Safety against material yielding

At pre-loaded interfaces, the analysis shall show positive margins for all components which comprise the interface – fittings, bolts, rivets, etc., when subjected to the loads given in Section 3.3 and the margins given in Section 3.4. Fitting analysis of critical components shall meet Section 4.4.2, Certification of Fasteners.

6.1 Load Case 1 8g Vertical

4.2.1 Load Case #1

A load 8 times the weight of the payload applied vertically at the suspension point.

Rationale: Vertical load path for parachute opening shock immediately after termination. Optionally, pin base and apply vertical load.

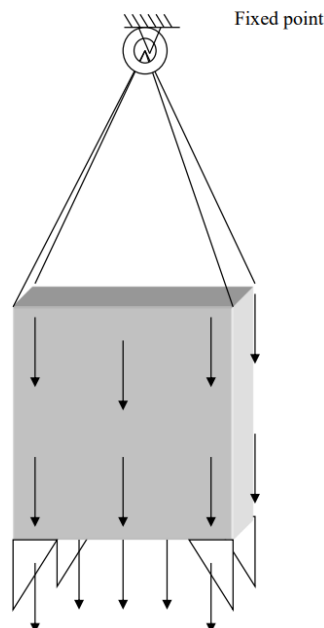
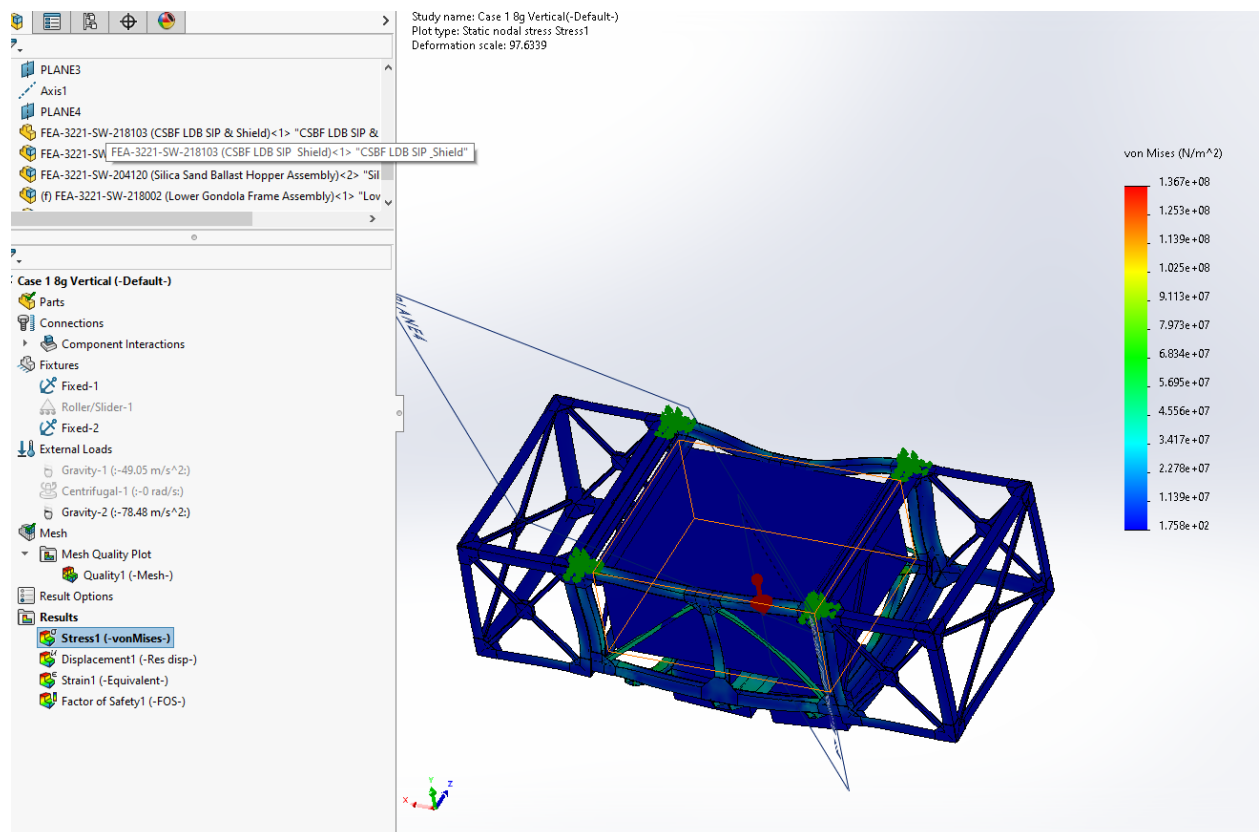
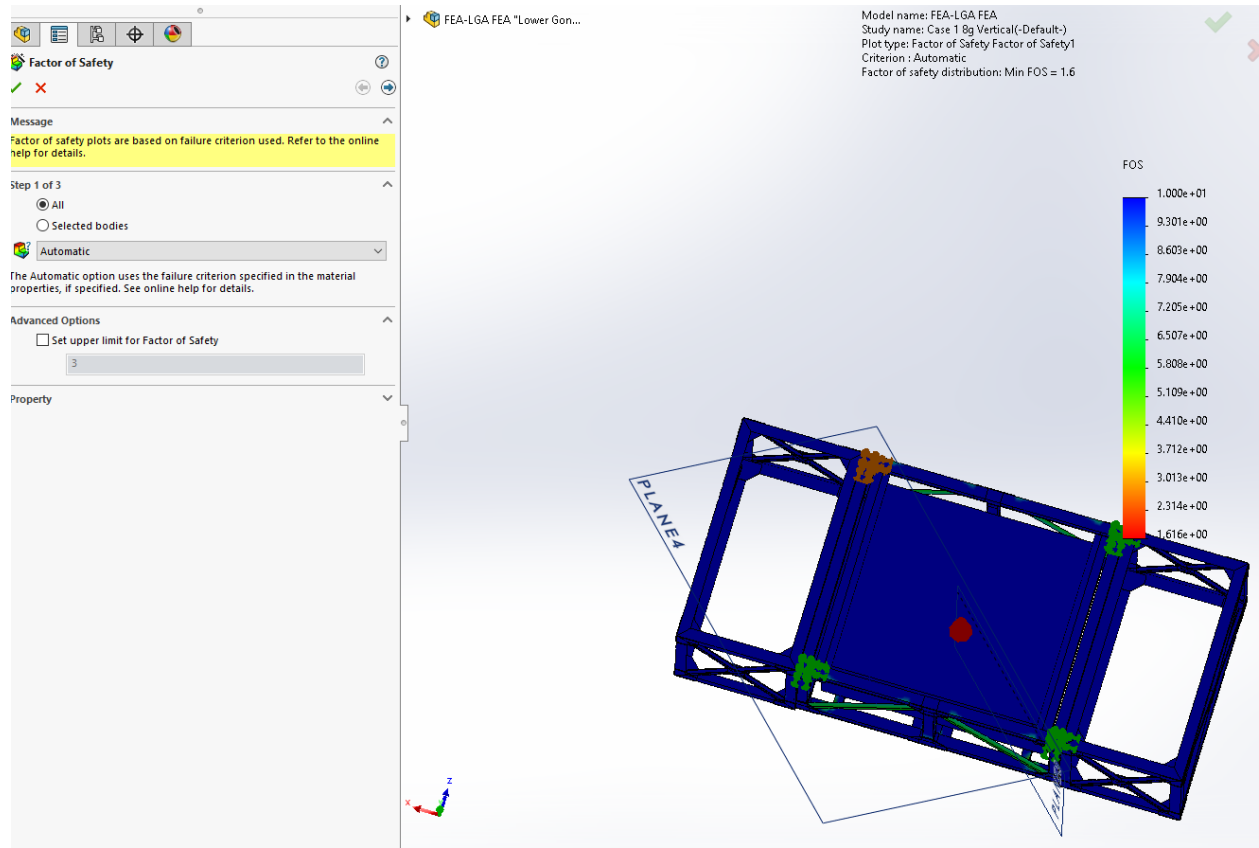


Figure 2: Load Case #1 – Gondola Vertical Loading

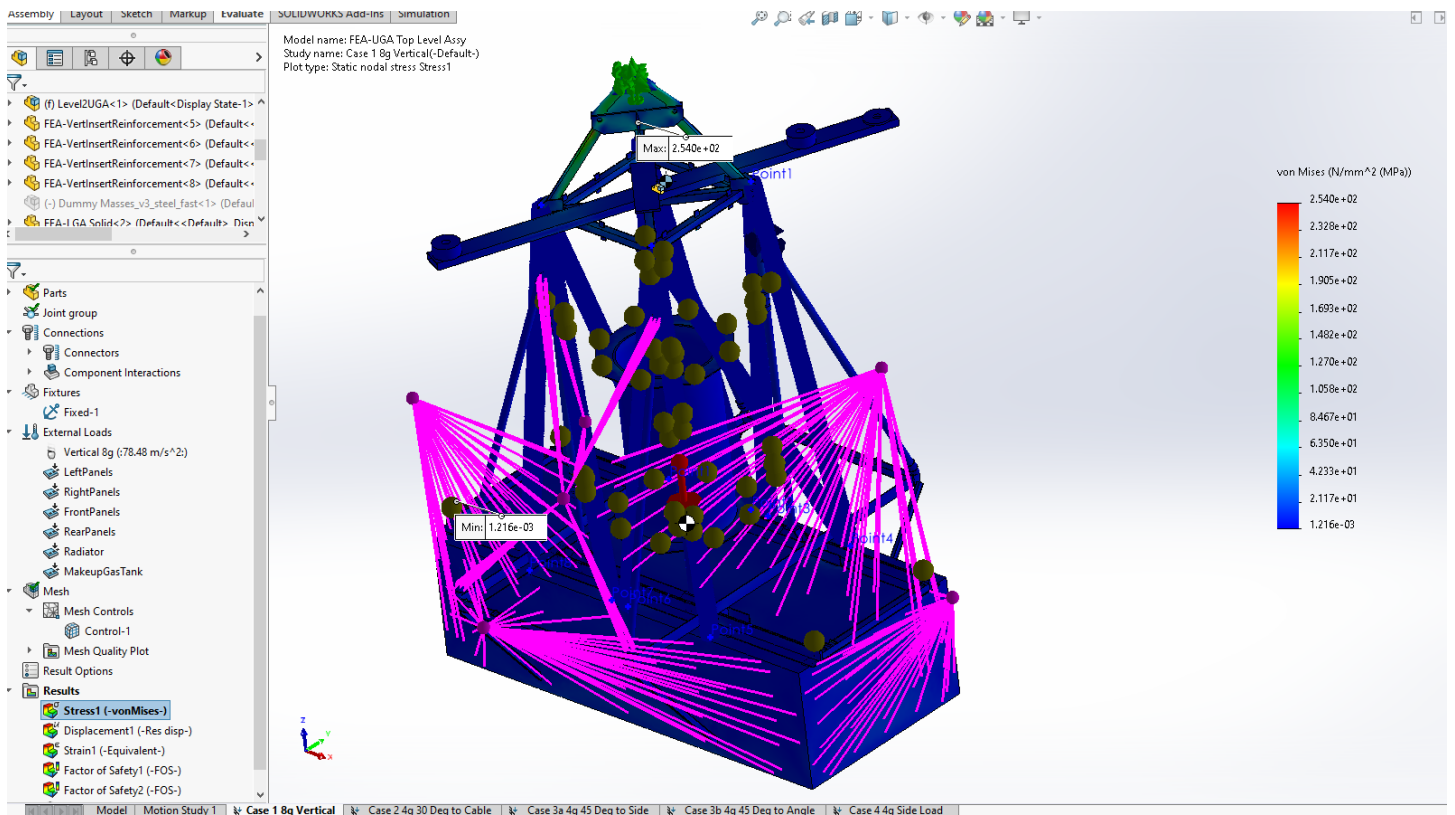
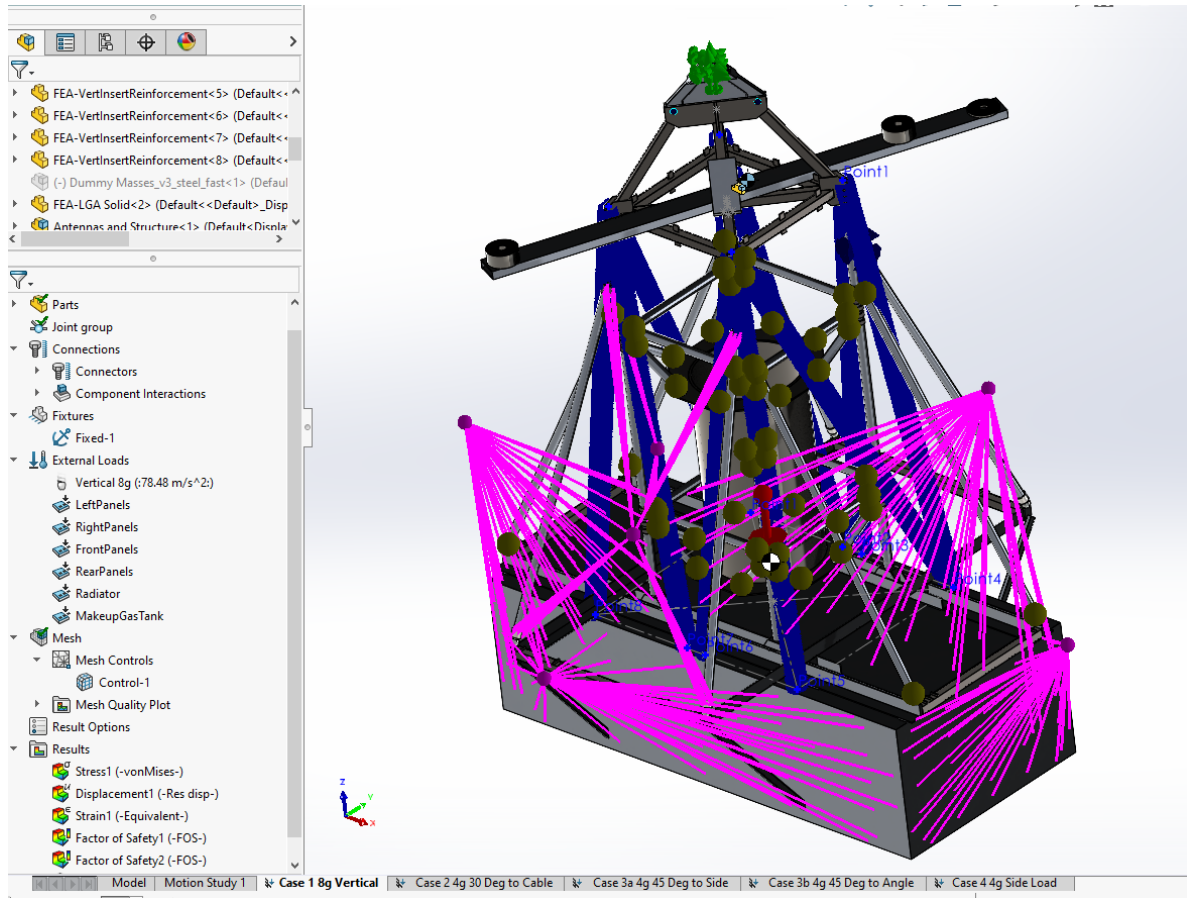
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Load Case 1 Lower Gondola

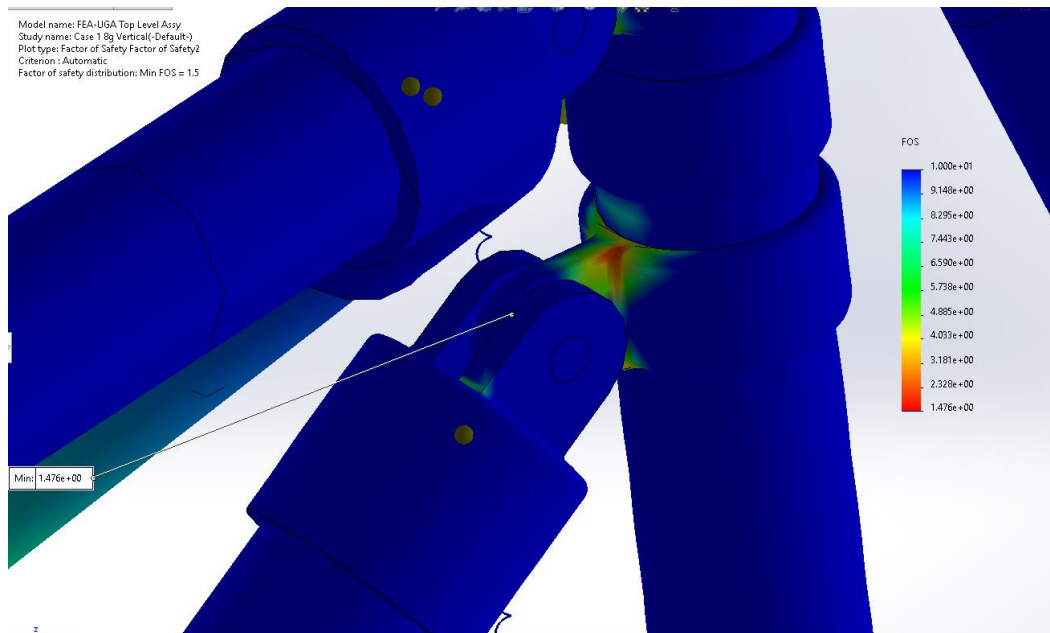
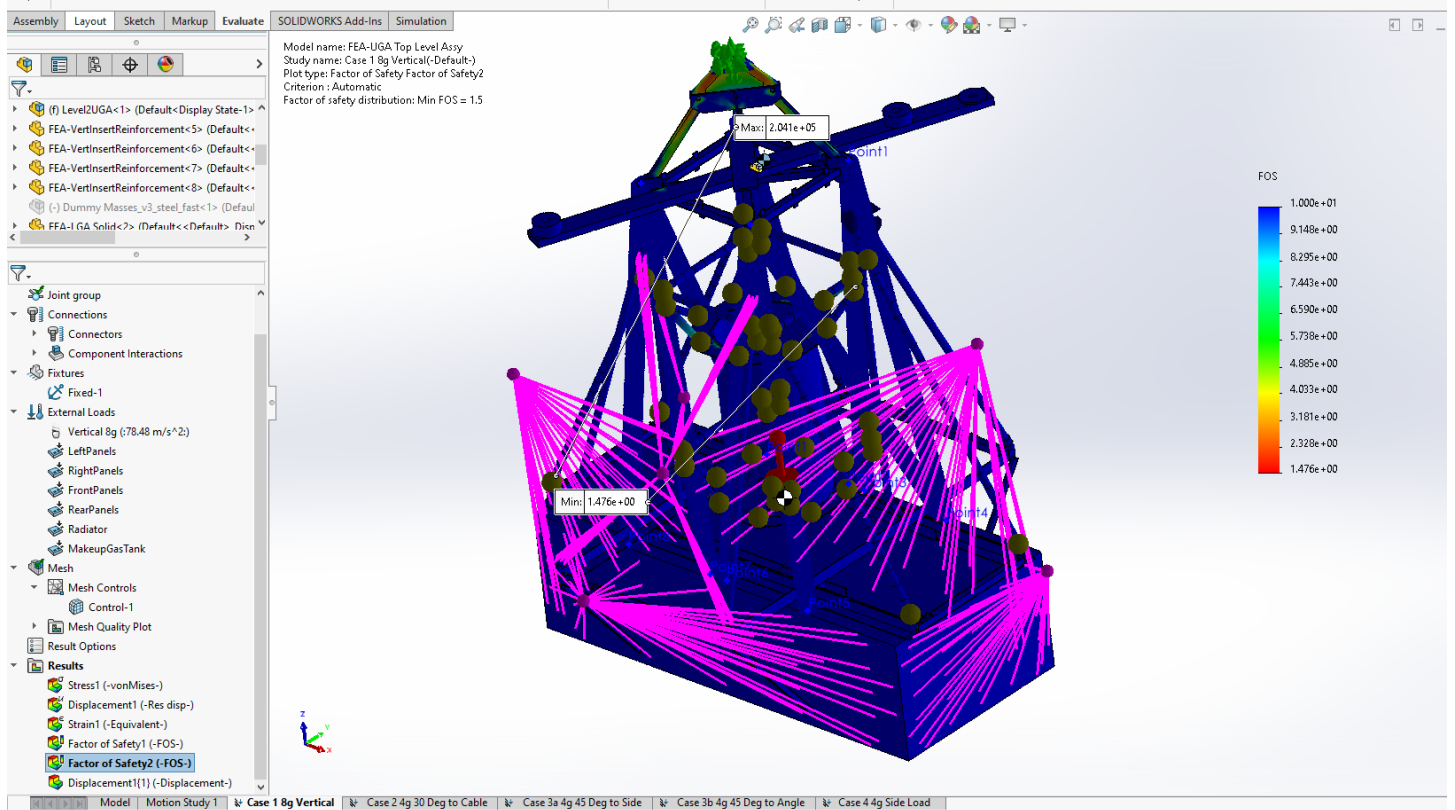


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Load Case 1 Upper Gondola



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The KeeClamp joining member has a low FOS, the min FOS from the assembly and the max stress of a node in any part will be used in the Safety Factor calculation. Steel is used in the Margin of Safety calculation as the material, as the fastener taking the load is steel.

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Load Case 1 Summary

| Case 1 8g Vertical | | | | | | | | |
|----------------------|-----|------|-----|-----------|---|------------------|--|------------------|
| | | | | From NASA | | Maximum From FEA | | Minimum From FEA |
| Upper Gondola | | | | | | | | |
| | MSu | 1.11 | FSu | 1.25 | P | 2.54E+02 MPa | | 1.48 FOS |
| | MSy | 0.22 | FSy | 1.40 | P | 2.54E+02 MPa | | 1.48 FOS |
| Lower Gondola | | | | | | | | |
| | MSu | 2.92 | FSu | 1.25 | P | 1.37E+02 MPa | | 1.62 FOS |
| | MSy | 1.27 | FSy | 1.40 | P | 1.37E+02 MPa | | 1.62 FOS |

6.2 Load Case 2 4g Angle to Cable

4.2.2 Load Case #2

For multiple-cable suspension systems, each cable must have an ultimate strength greater than 4 times the weight of the payload divided by the sine of the angle that the cable makes with horizontal ($\alpha > 30$ degrees) in a normal flight configuration.

Rationale: The load path through the gondola are directed through the cables so the loads are analyzed acting through the structure.

Note: In reality, the load would be reacted through the gondola inertia and not the feet. For this reason, failure modes due to tension in the feet are not considered.

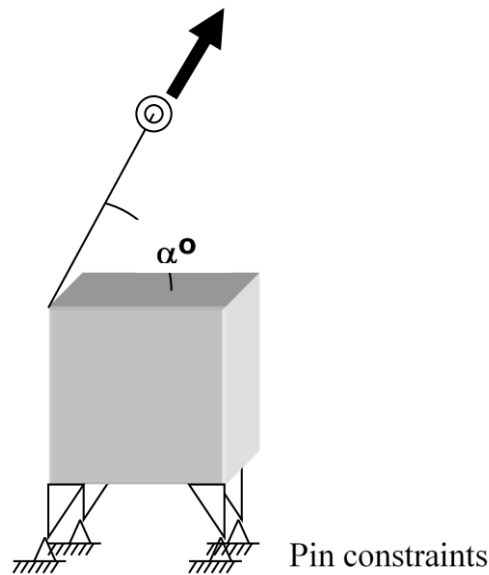
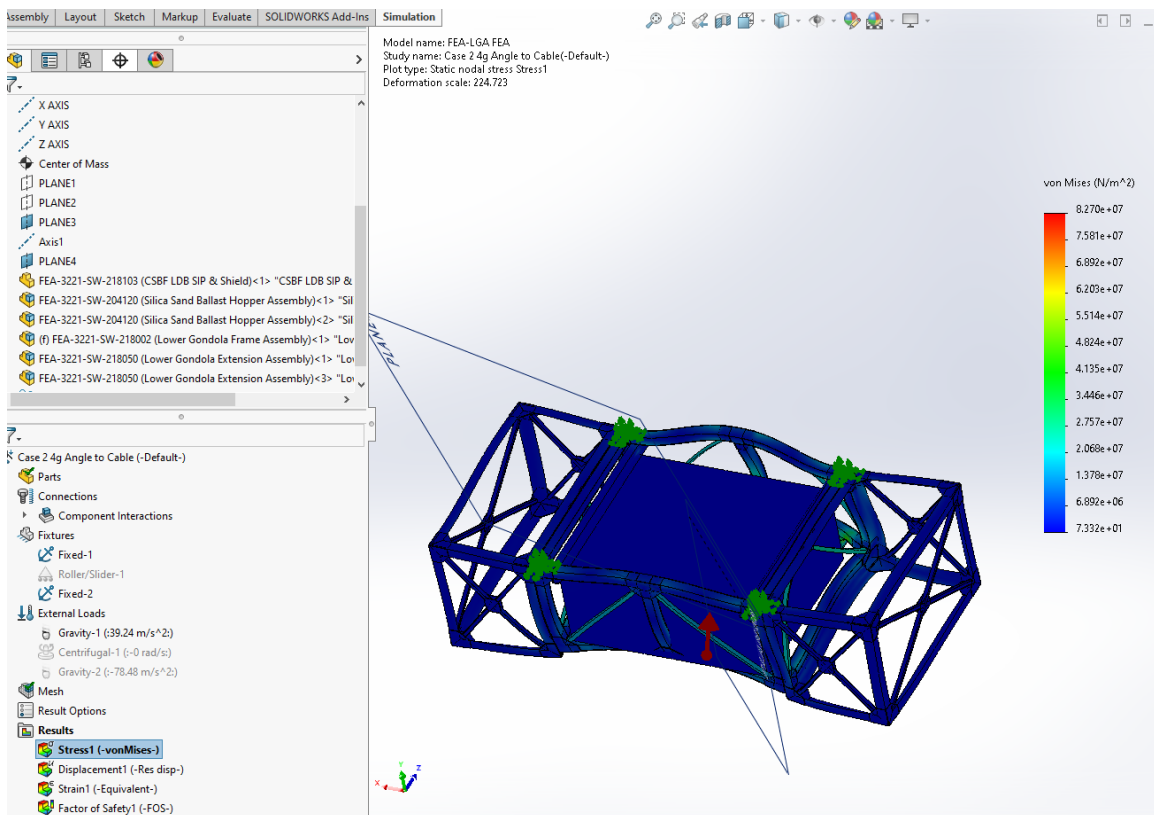
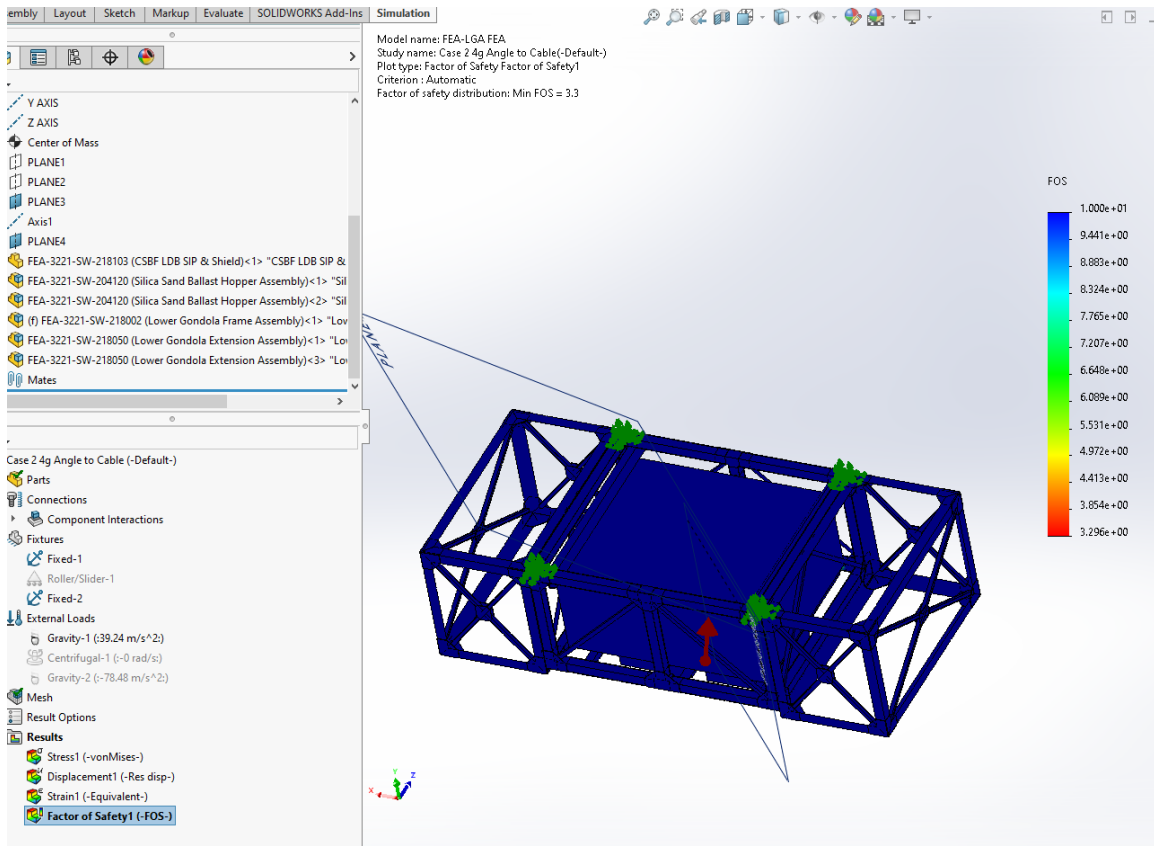


Figure 3: Load Case #2 – Gondola Single Cable Loading

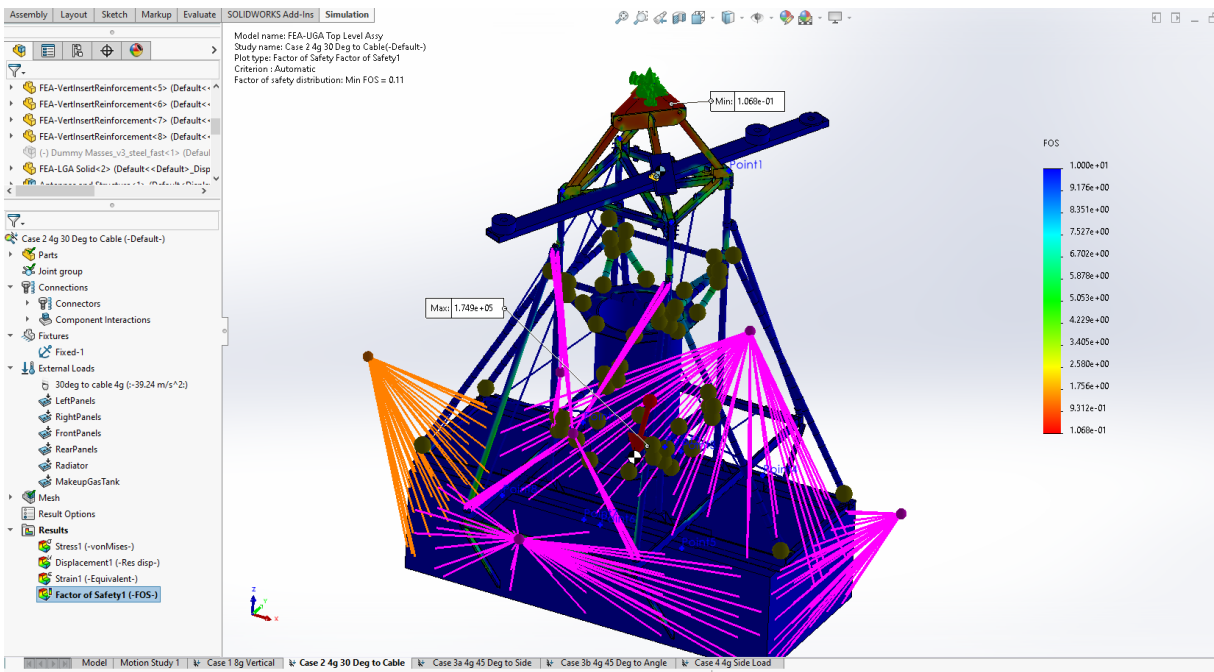
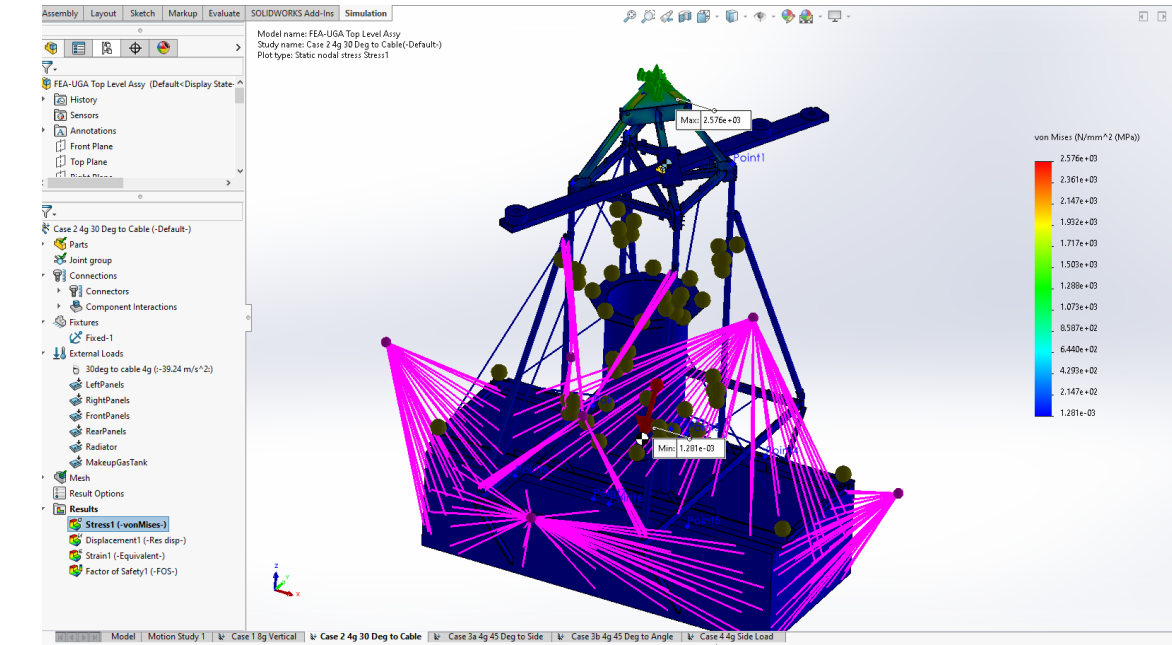
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Load Case 2 Lower Gondola



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Load Case 2 Upper Gondola



Load Case 2 Summary

The upper gondola does not pass this case. The lowest factor of safety is in the triplate.

| Case 2 4g 30 Degree to Cable | | | | From NASA | Maximum From FEA | Minimum From FEA | |
|------------------------------|-----|-------|-----|-----------|------------------|------------------|-----|
| Upper Gondola | | | | | | | |
| | MSu | -0.90 | FSu | 1.25 | P 2.58E+03 MPa | 0.11 | FOS |
| | MSy | -0.92 | FSy | 1.40 | P 2.58E+03 MPa | 0.11 | FOS |
| Lower Gondola | | | | | | | |
| | MSu | 5.48 | FSu | 1.25 | P 8.27E+01 MPa | 3.30 | FOS |
| | MSy | 2.76 | FSy | 1.40 | P 8.27E+01 MPa | 3.30 | FOS |

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6.3 Load Case 3a,b 4g 45 Degree to Vertical

4.2.3 Load Case #3

A load 4 times the weight of the payload applied at the suspension point and 45 degrees to the vertical. This load factor must be accounted for in the direction perpendicular to the gondola's short side, long side, and in the direction of the major rigid support members at the top of the gondola structure. If flexible cable suspension systems are used, they shall withstand uneven loading caused by cable buckling.

Rationale: Assumes that the gondola rotates 45 degrees descends off-axis during termination and only one or two cables are loaded at parachute opening. It is to assure that the structure and attachments can handle this initial load.

Note: In reality, the load would be reacted through the gondola inertia and not the feet. For this reason, failure modes due to tension in the feet are not considered.

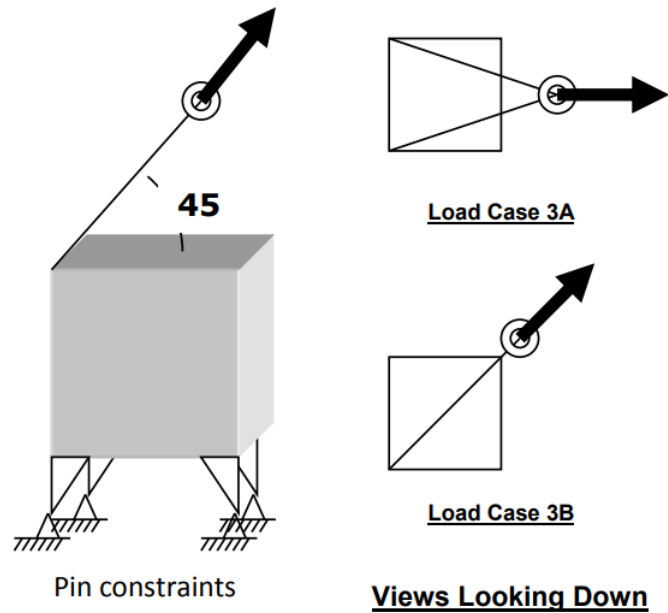
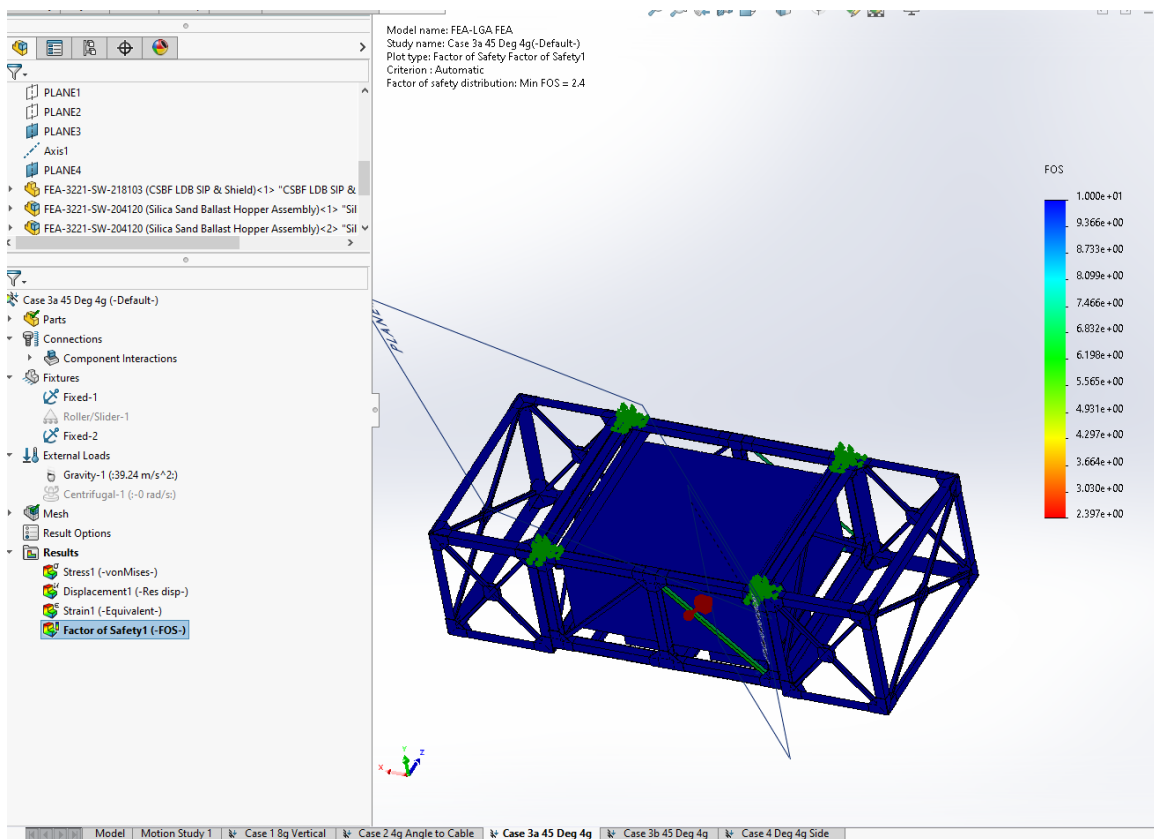
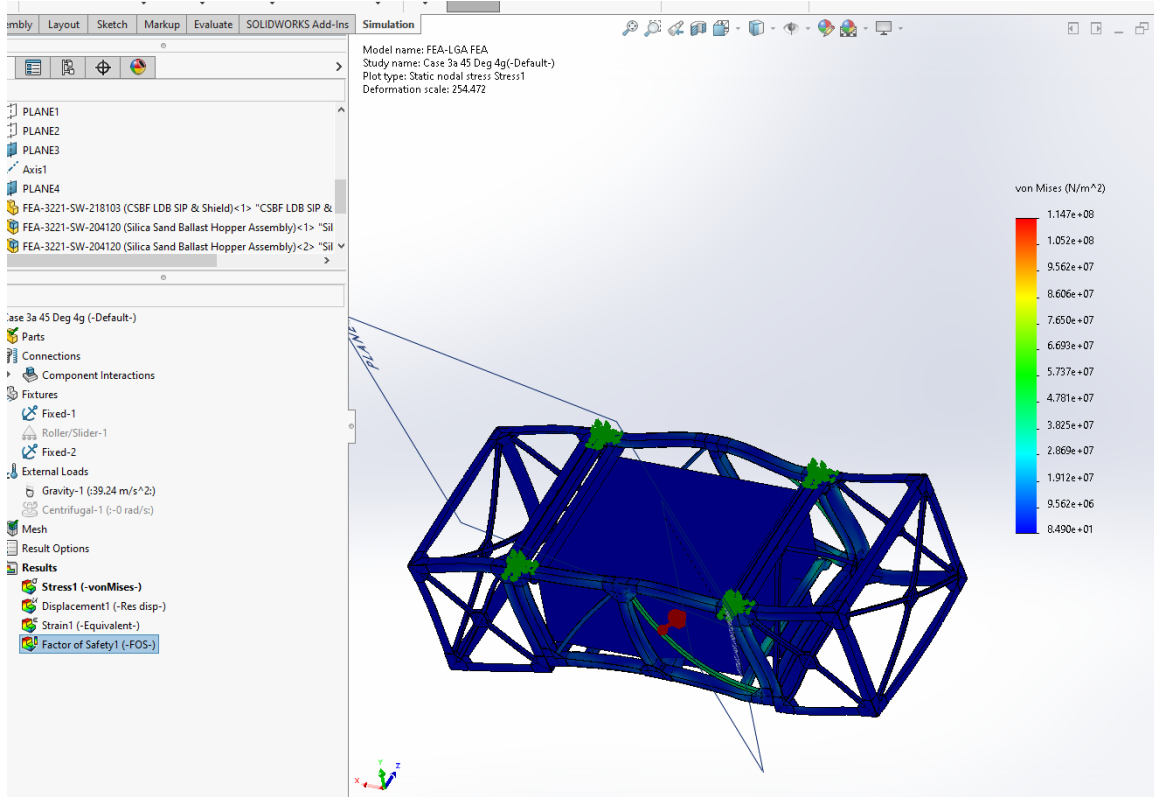


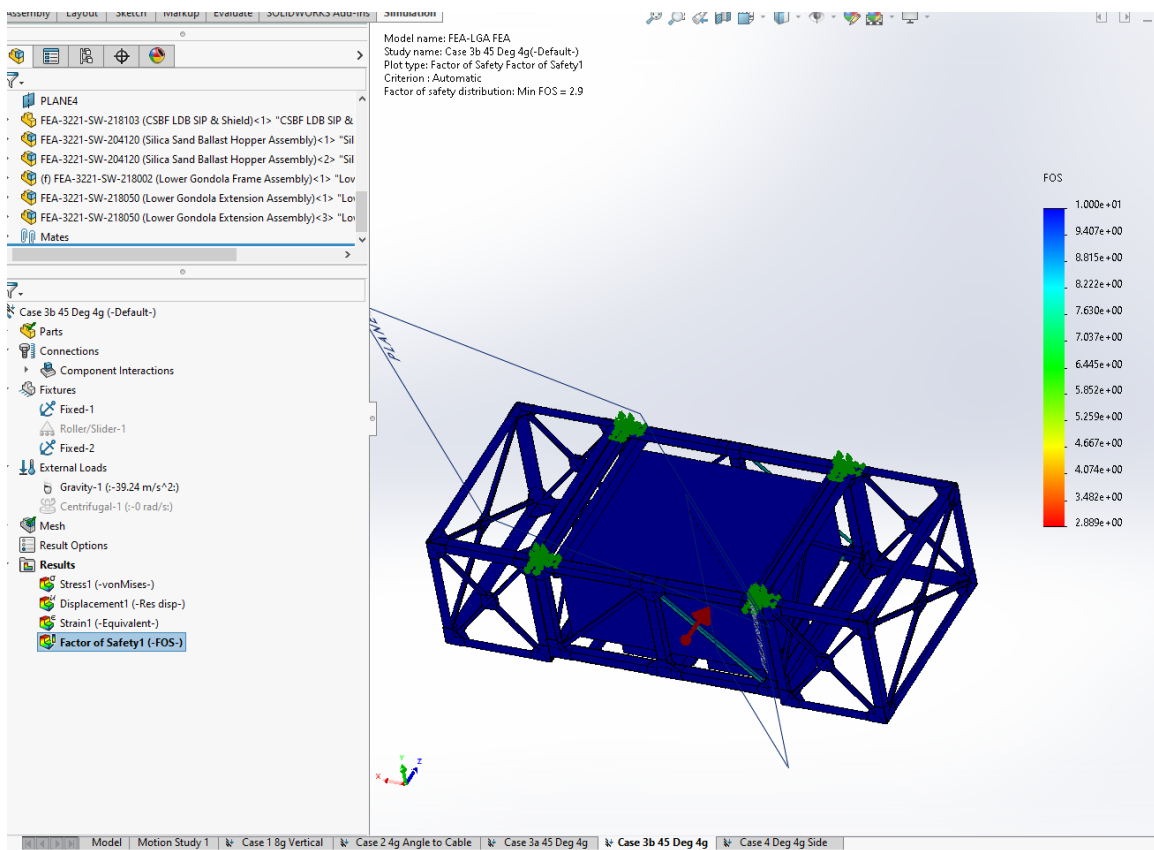
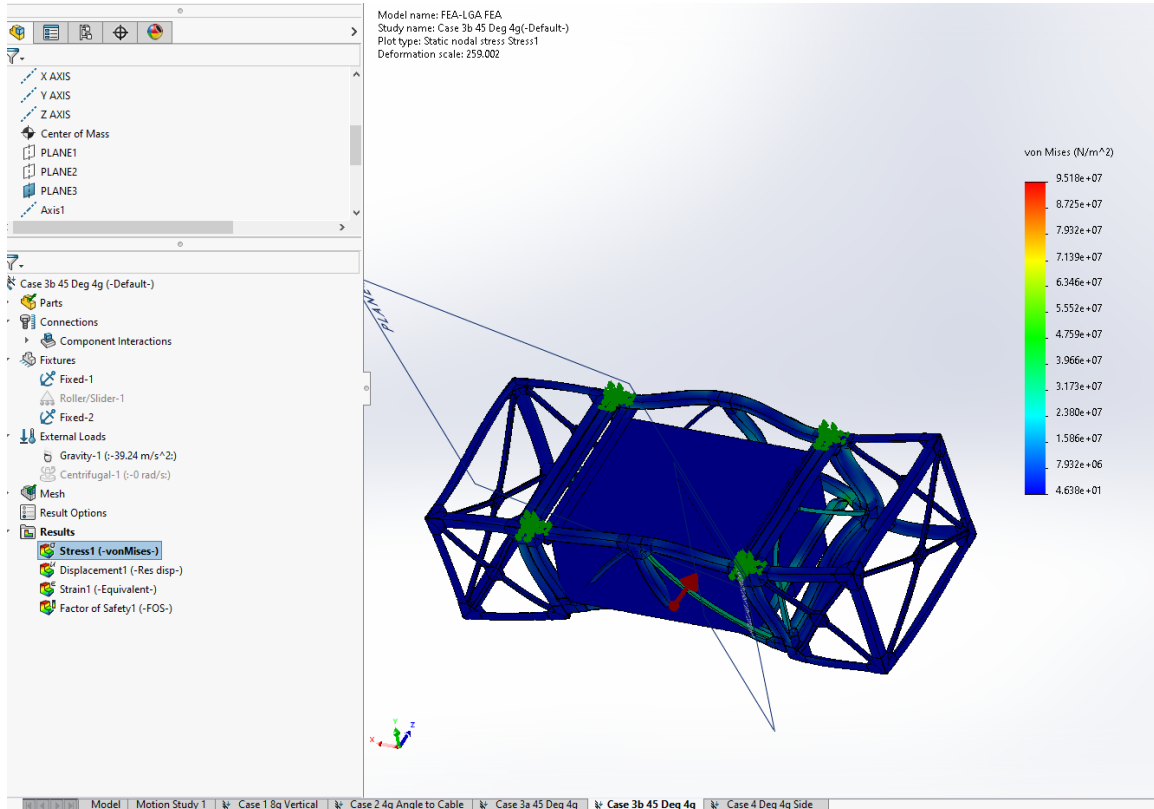
Figure 4: Load Case #3 – Off-Vertical Gondola Loading

Load Case 3a,b Lower Gondola

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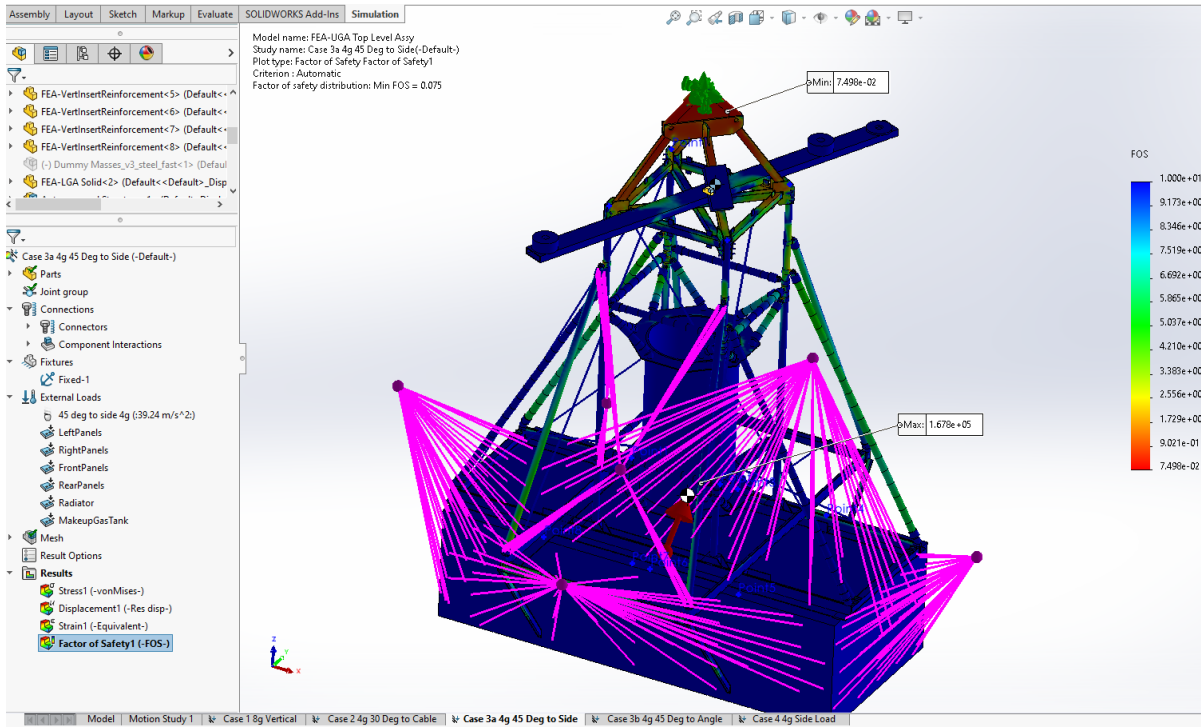
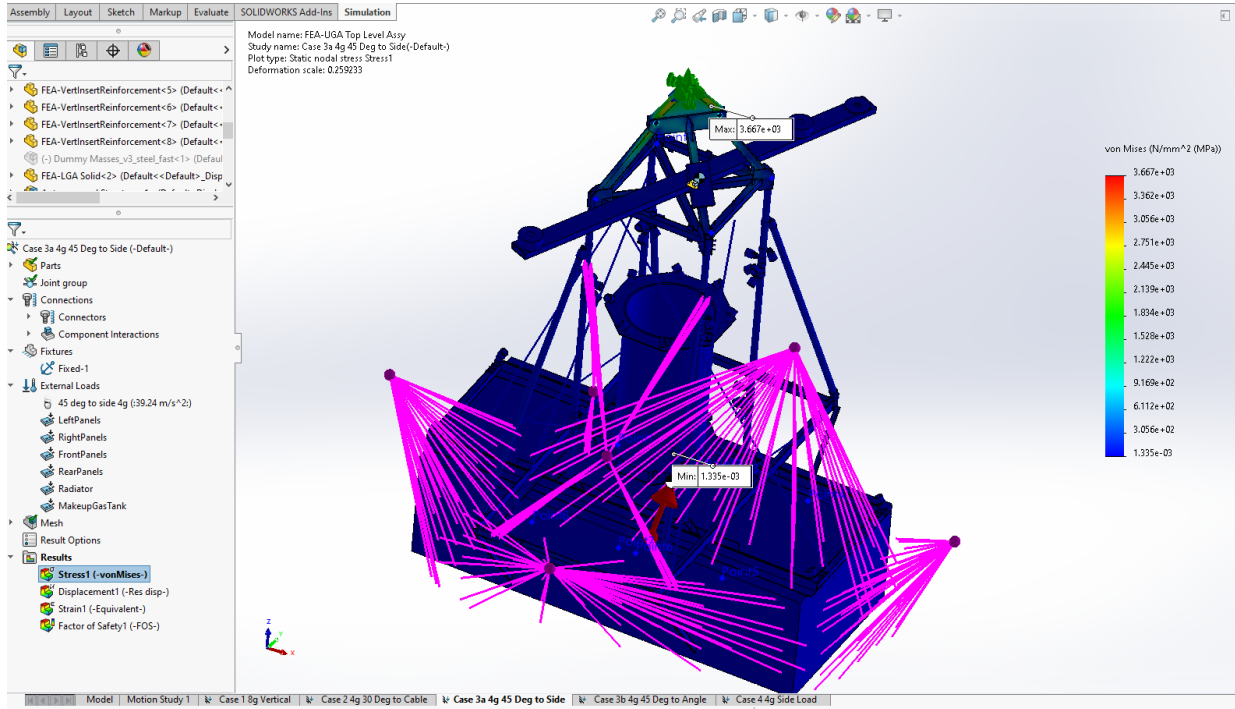


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MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

Load Case 3a Upper Gondola

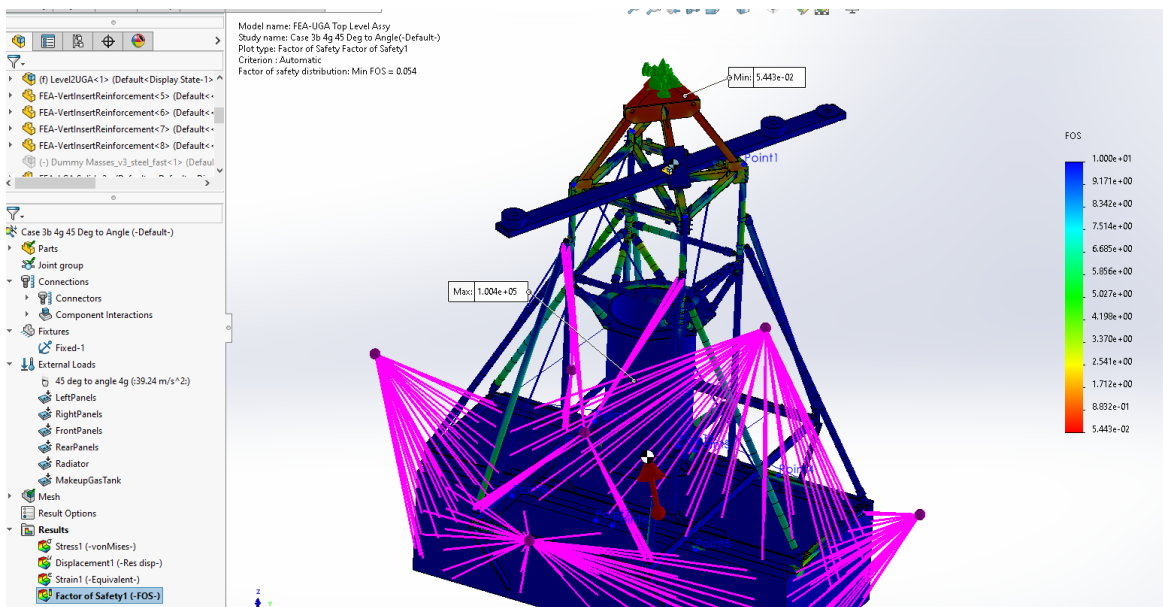
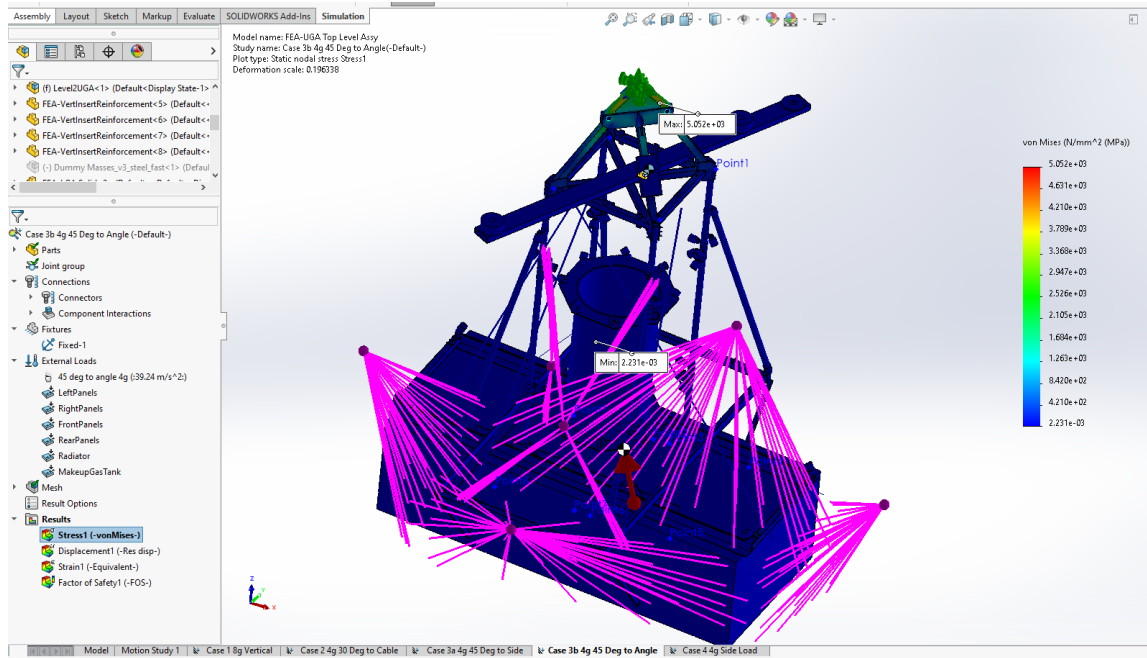


MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

Load Case 3a Summary

| | | From NASA | Maximum From FEA | Minimum From FEA | | |
|----------------------|-------|-----------|------------------|------------------|-----|--|
| Upper Gondola | | | | | | |
| MSu | -0.93 | FSu 1.25 | P 3.67E+03 MPa | 0.08 | FOS | |
| MSy | -0.95 | FSy 1.40 | P 3.67E+03 MPa | 0.08 | FOS | |
| Lower Gondola | | | | | | |
| MSu | 3.67 | FSu 1.25 | P 1.15E+02 MPa | 2.30 | FOS | |
| MSy | 1.71 | FSy 1.40 | P 1.15E+02 MPa | 2.30 | FOS | |

Load Case 3b Upper Gondola



MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

Load Case 3b Summary

| Case 3b 45 Degree to Vertical | | | | | | | | |
|-------------------------------|-----|-------|-----|-----------|---|------------------|--|------------------|
| | | | | From NASA | | Maximum From FEA | | Minimum From FEA |
| Upper Gondola | | | | | | | | |
| | MSu | -0.95 | FSu | 1.25 | P | 5.05E+03 MPa | | 0.05 FOS |
| | MSy | -0.96 | FSy | 1.40 | P | 5.05E+03 MPa | | 0.05 FOS |
| Lower Gondola | | | | | | | | |
| | MSu | 4.63 | FSu | 1.25 | P | 9.52E+01 MPa | | 2.80 FOS |
| | MSy | 2.26 | FSy | 1.40 | P | 9.52E+01 MPa | | 2.80 FOS |

6.4 Load Case 4 4g Side Load

4.2.4 Load Case #4

A lateral load of 4 times the weight of the payload applied to all components and equipment attached to and/or onboard the gondola structure or any portion of the flight system below the balloon at both principal lateral axes.

Rationale: Assumes that the gondola rotates 90 degrees descends off-axis during termination and inertial side loads are applied to components attached to the structure.

Note: Some components are analyzed individually and some are analyzed as part of the structural model. In non-symmetric situations, 4g is applied in both horizontal axis.

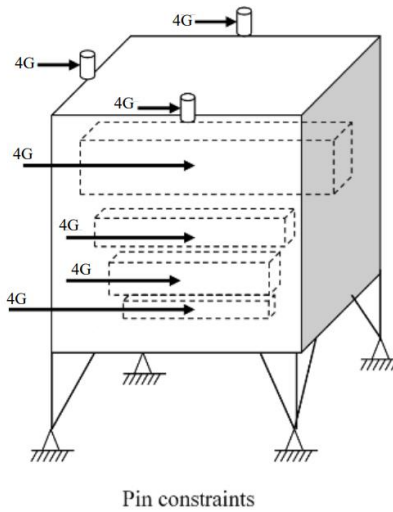
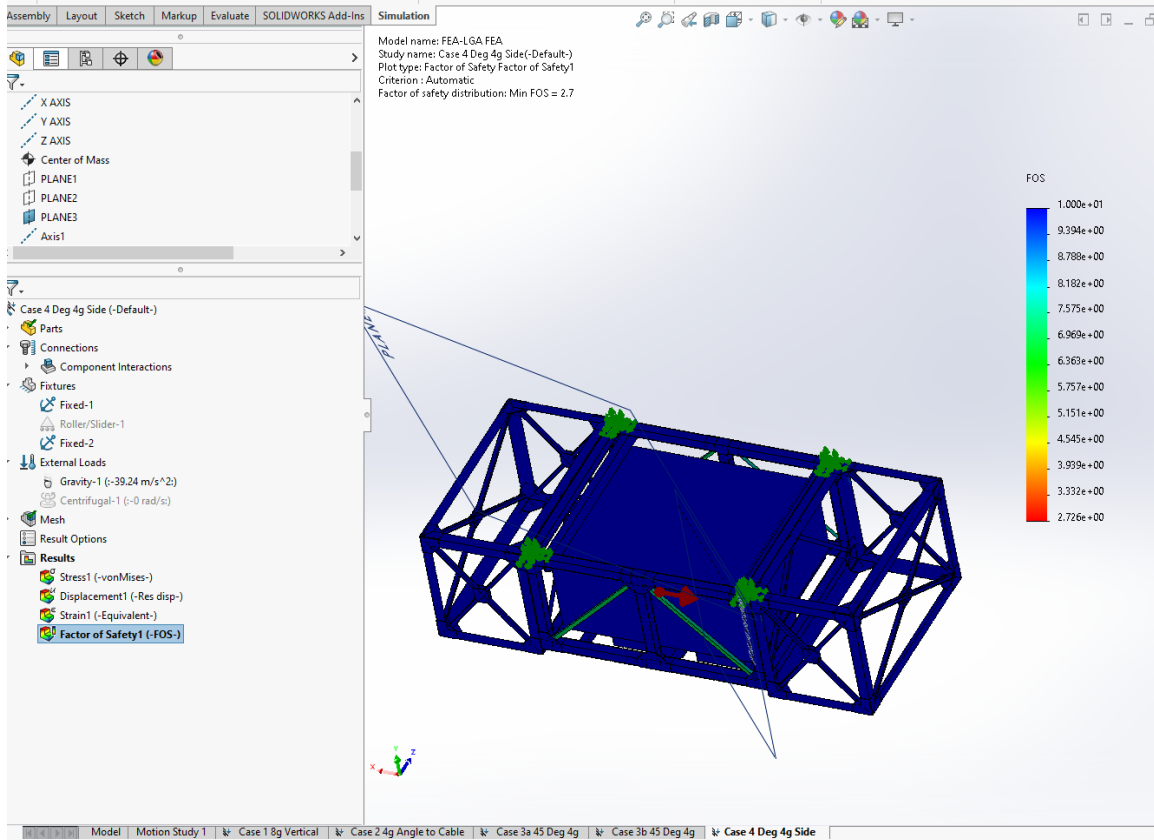
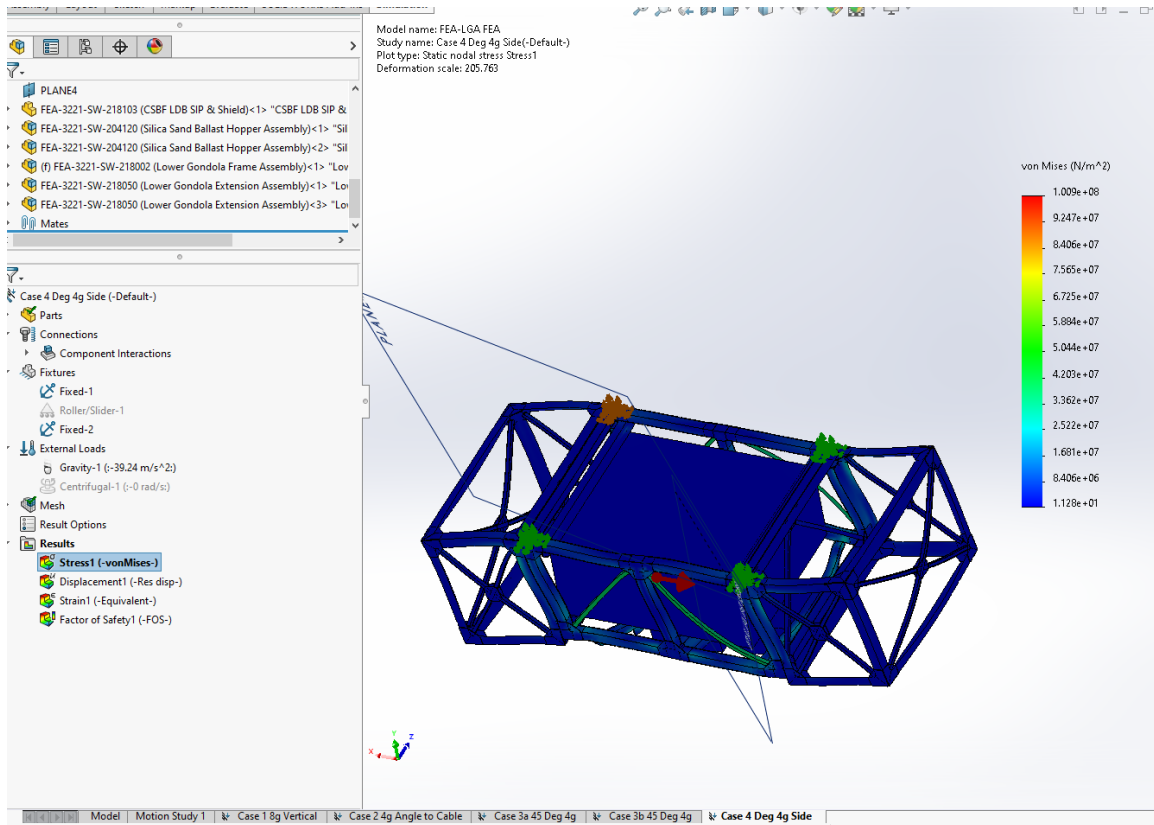


Figure 5: Load Case #4 – Gondola Lateral Loading

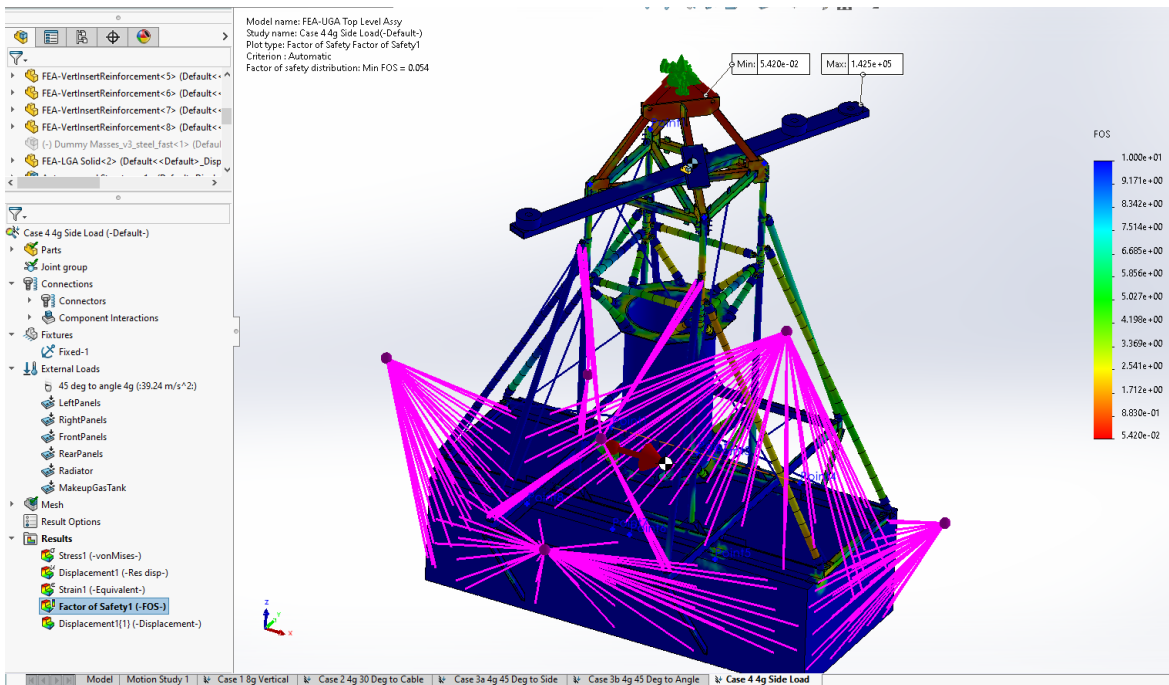
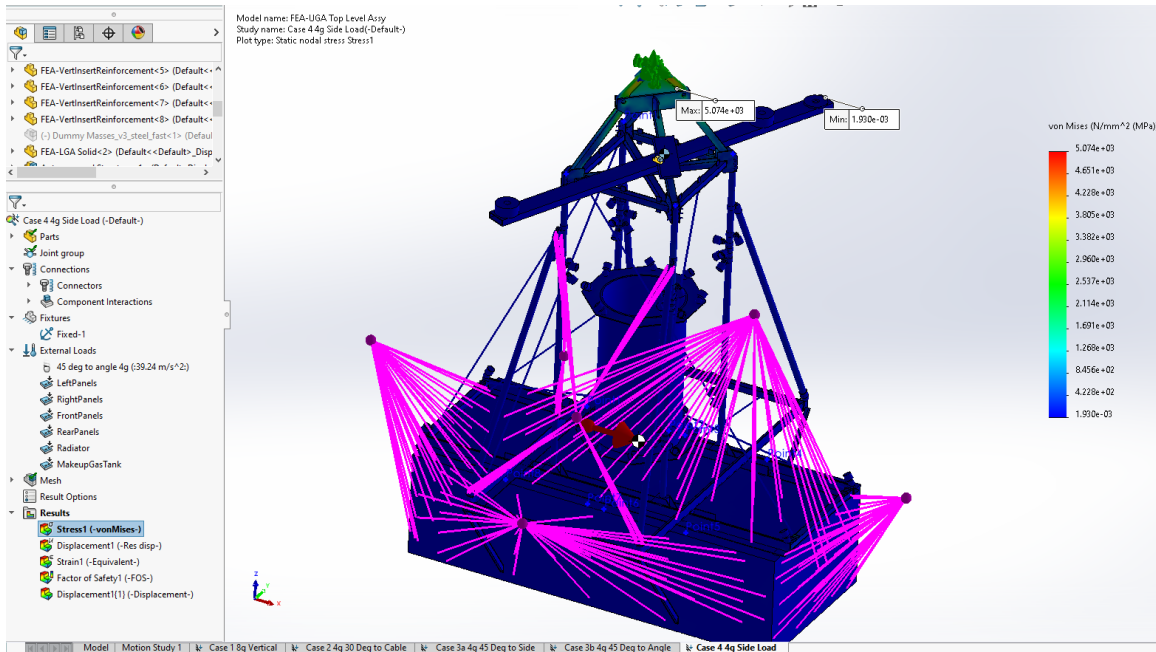
MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

Load Case 4 Lower Gondola



MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

Load Case 4 Upper Gondola



Load Case 4 Summary

| Case 4 4g Side Load | | | From NASA | | Maximum From FEA | | Minimum From FEA | |
|----------------------|-----|-------|-----------|------|------------------|--------------|------------------|-----|
| Upper Gondola | | | | | | | | |
| | MSu | -0.95 | FSu | 1.25 | P | 5.10E+03 MPa | 0.05 | FOS |
| | MSy | -0.96 | FSy | 1.40 | P | 5.10E+03 MPa | 0.05 | FOS |
| Lower Gondola | | | | | | | | |
| | MSu | 4.31 | FSu | 1.25 | P | 1.01E+02 MPa | 2.73 | FOS |
| | MSy | 2.08 | FSy | 1.40 | P | 1.01E+02 MPa | 2.73 | FOS |

MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

6.5 Load Case 5 1.4x Weight on Flight Hardware

4.2.5 Load Case #5 – Flight Hardware to MGSE Interface Verification

A load 1.4 times the weight of the payload applied independently to the gondola in all three orthogonal directions. The mechanical ground support equipment (MGSE) (cart/casters/stand/etc) interface shall be pinned or fixed depending on the interface design.

Our design files are not capable of supporting this analysis.

Summary of Safety Factor Calculations

The lower gondola meets quite a few of the margin of safety requirements, but the upper gondola only passes load case 1. This gondola overall does not meet the calculated safety requirements in this report, additionally HAO does not have a complete submission.

MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

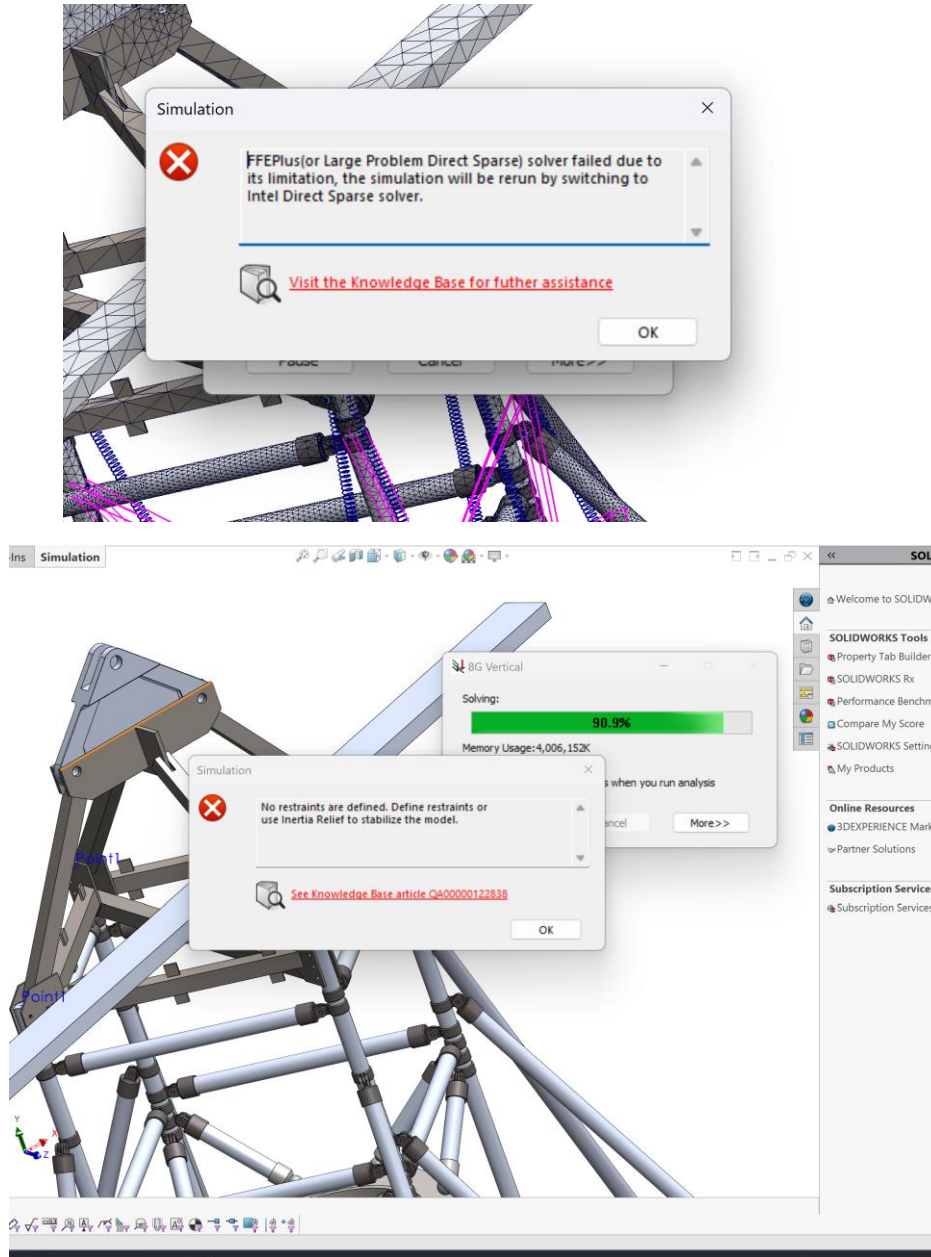
| Case 1 8g Vertical | | | | | | | | | |
|--------------------------------------|-----|-------|--|--------------|------|---------------------|--------------|---------------------|-----|
| | | | | From NASA | | Maximum From FEA | | Minimum From FEA | |
| Upper Gondola | | | | | | | | | |
| | MSu | 1.11 | | FSu | 1.25 | P | 2.54E+02 MPa | 1.48 | FOS |
| | MSy | 0.22 | | FSy | 1.40 | P | 2.54E+02 MPa | 1.48 | FOS |
| Lower Gondola | | | | | | | | | |
| | MSu | 2.92 | | FSu | 1.25 | P | 1.37E+02 MPa | 1.62 | FOS |
| | MSy | 1.27 | | FSy | 1.40 | P | 1.37E+02 MPa | 1.62 | FOS |
| Case 2 4g 30 Degree to Cable | | | | | | | | | |
| | | | | From NASA | | Maximum From FEA | | Minimum From FEA | |
| Upper Gondola | | | | | | | | | |
| | MSu | -0.90 | | FSu | 1.25 | P | 2.58E+03 MPa | 0.11 | FOS |
| | MSy | -0.92 | | FSy | 1.40 | P | 2.58E+03 MPa | 0.11 | FOS |
| Lower Gondola | | | | | | | | | |
| | MSu | 5.48 | | FSu | 1.25 | P | 8.27E+01 MPa | 3.30 | FOS |
| | MSy | 2.76 | | FSy | 1.40 | P | 8.27E+01 MPa | 3.30 | FOS |
| Case 3a 45 Degree to Vertical | | | | | | | | | |
| | | | | From NASA | | Maximum From FEA | | Minimum From FEA | |
| Upper Gondola | | | | | | | | | |
| | MSu | -0.93 | | FSu | 1.25 | P | 3.67E+03 MPa | 0.08 | FOS |
| | MSy | -0.95 | | FSy | 1.40 | P | 3.67E+03 MPa | 0.08 | FOS |
| Lower Gondola | | | | | | | | | |
| | MSu | 3.67 | | FSu | 1.25 | P | 1.15E+02 MPa | 2.30 | FOS |
| | MSy | 1.71 | | FSy | 1.40 | P | 1.15E+02 MPa | 2.30 | FOS |
| Case 3b 45 Degree to Vertical | | | | | | | | | |
| | | | | From NASA | | Maximum From FEA | | Minimum From FEA | |
| Upper Gondola | | | | | | | | | |
| | MSu | -0.95 | | FSu | 1.25 | P | 5.05E+03 MPa | 0.05 | FOS |
| | MSy | -0.96 | | FSy | 1.40 | P | 5.05E+03 MPa | 0.05 | FOS |
| Lower Gondola | | | | | | | | | |
| | MSu | 4.63 | | FSu | 1.25 | P | 9.52E+01 MPa | 2.80 | FOS |
| | MSy | 2.26 | | FSy | 1.40 | P | 9.52E+01 MPa | 2.80 | FOS |
| Case 4 4g Side Load | | | | | | | | | |
| | | | | From NASA | | Maximum From FEA | | Minimum From FEA | |
| Upper Gondola | | | | | | | | | |
| | MSu | -0.95 | | FSu | 1.25 | P | 5.10E+03 MPa | 0.05 | FOS |
| | MSy | -0.96 | | FSy | 1.40 | P | 5.10E+03 MPa | 0.05 | FOS |
| Lower Gondola | | | | | | | | | |
| | MSu | 4.31 | | FSu | 1.25 | P | 1.01E+02 MPa | 2.73 | FOS |
| | MSy | 2.08 | | FSy | 1.40 | P | 1.01E+02 MPa | 2.73 | FOS |

MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

Narrative on Analysis Types

The tri-plate being fixed and using the gravity vector load with the dummy masses was used because the inertial relief style of analysis has serious problems meshing and converging on a solution. The high quality mesh never completed an analysis run.

Analysis Errors



Exception code 0xc0000005 thrown at address 0x1405f7612.

Please send crash data file Z:\2023 Final FEA Design and Analysis\SIMSTACK-V32,5,0,13-240222-135014.dmpl is under such a force

or under marginally imbalance forces, application of Inertia

Relief may alter the characteristics of your model.

MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

Would you like to continue? "Yes" to SOLIDWORKS technical support.

Please press OK to terminate solution

Warning: There is a significant external imbalanced force in Z-direction which will be balanced by the application of opposing inertia forces. Unless your model is under such a force or under marginally imbalance forces, application of Inertia Relief may alter the characteristics of your model.

Would you like to continue?

7. For critical or single-point failure items material certifications shall be provided in accordance with Section 4.4, Material Requirements for Critical Hardware
To be submitted at a later date.

8. A statement certifying that the aforementioned requirements have been met; the statement shall be signed by the principal investigator and the engineer responsible for the design and analysis of the gondola structure. Qualifications of the engineer responsible shall be submitted in the form of a brief résumé

HAO cannot provide a statement saying these requirements have been met because they are **not**. Only Load Case 1 is acceptable.

MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

Andrew Carlile

PO Box 21385, Boulder, CO 80308 | (918) 931-7845 | acarile@live.com

LinkedIn Profile: <https://www.linkedin.com/pub/andrew-carlile/28/b86/159>

EDUCATION

| | | |
|--|-----------------|-----------------|
| Georgia Institute of Technology | | Atlanta, GA |
| Master of Science Mechanical Engineering | GPA 3.25 | May 2015 |
| University of Oklahoma | | Norman, OK |
| Bachelor of Science Aerospace Engineering | GPA 3.33 | May 2011 |
| Minor in Mathematics, Cum Laude Honors Graduate Passed FE Exam 2011 | | |
| University of Arizona | | Online |
| Master's Certificate Optical Science | GPA 3.4 | May 2023 |

DESIGN, ANALYSIS, AND MANUFACTURING SKILLS

- Professional experience with: **Dassault:** SolidWorks and Enovia **Autodesk:** Inventor, Fusion, and Vault **PTC:** Creo **Zemax:** Optic Studio
- Programming in: MATLAB M-Files, C (Visual Studio), C# (Visual Studio), C++, Beckhoff **TwinCAT**, LabView
- Simulation experience with: ANSYS Workbench, ANSYS CFX, Dymola, Autodesk Inventor Simulation, SolidWorks FEA and Flow Simulation
- Electronics design, sensor integration, motion control, control, and safety systems, primarily in SolidWorks electrical
- Designed composite parts, machined parts, additive manufactured **parts**
- Part documentation, tolerance analysis, and manufacturing planning (Design for Assembly, Design for Manufacturing), System layout and assembly experience

RESEARCH

- "Water Risk Analyses and Strategies for Automotive Manufacturing." Thesis for **Master's** research, research on sustainable manufacturing, in particular water and energy usage
- "Comparison of Water Strategy Tools for Automotive Manufacturing." Society of Automotive **Engineers - SAE** Paper: 2014-01-1958 Published 04/01/2014
- "The Visible Spectro-Polarimeter of the Daniel K. Inouye Solar Telescope." Solar Physics, de **Wijn**, A. G. and Casini, R. and Carlile, A. and Lecinski, A. R. and Sewell, S. and Zmarzly, P. and **Eigenbrodt**, A. D. and Beck, C. and **Wöger**, F. and **Knölker**, M. 2022

LEADERSHIP

- Lead design, commissioning, and operation of largest production line at GE/Suez/Veolia Analytical Instruments in Boulder, CO
- Lead engineer for multiple UCAR/NCAR projects in Boulder, CO: ChroMag, **Chromis**, KSO **Lyo**-filter

Experience

ENGINEER III | UCAR/NCAR/HAO | 2018-CURRENT

- Mechanical and electrical design of scientific instruments, Beckhoff **TwinCAT** and LabView programming
- Thermodynamic and structural analysis of instruments. FEA in SolidWorks Simulation in addition to non-FEA calculations
- Engineer in charge of mechanical and electrical integrations of the **ViSP** instrument into the DKIST observatory
- Control system tuning, optical alignments, proposal writing, and strain gauge testing of optical component stress
- Basic optical engineering, such as alignments and mechanical tolerance analysis **affects on system performance**
- Lead Mechanical Engineer and point of contact for High Altitude Balloon Instrument (DIMS)

AUTOMATION ENGINEER | GE & SUEZ | 2015-2018. CURRENT CONTRACT WORK

- Project management and design of new production line and new product launch
- PLC Programming: IEC 61131-3 based C in Beckhoff **TwinCAT** 3, C#, human machine interfaces in **TwinCAT** 3
- Industrial networking with Ethernet IP, **EtherCAT** and **ModBus**; Sensor monitoring solutions through GE **InSight**
- Mechanical, electrical, and fluid design. Thermodynamic and structural analysis of production systems, ceramic structures, and frames. FEA in SolidWorks Simulation.
- Contract work for PLCs programming and water systems

GRADUATE RESEARCH ASSISTANT | GEORGIA TECH | 2013-2015

- Researcher for Ford Motor Company on sustainability and water issues in manufacturing
- Examining effect of manufacturing types, water reporting, and environmental issues

MECHANICAL ENGINEER II | DEMATIC AG | 2011-2013

- Hired as Engineer I, received promotion to Engineer II
- Design of new products, iLogic automation, FEA Structural Analysis, manufacturing planning, and system integration
- Responsible for top level and component level design of various products, specifically the release of model UL1200



9. Any changes to analytical models following submittal of deliverable shall be submitted to NASA as soon as practical. Scope and timing of changes may impact review and certification for flight. Not applicable.

10. Triplate Analysis Requested April 2024

Request email, from Justin Marsh:

Marsh, Justin L. (WFF-820.0)[PERATON INC]

Wed, Apr 24, 7:46 AM (6 days ago)

to me, Qian

Andrew,

MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

The structural review team asked that I do an independent analysis of the trapeze for all load cases. I've finished with that and it shows good margins. They're requesting that you perform a similar analysis to verify my results. I believe they'll ask for this to be presented at the final PIR as a way to allow us to certify the gondola for flight in FY25.

Thanks,

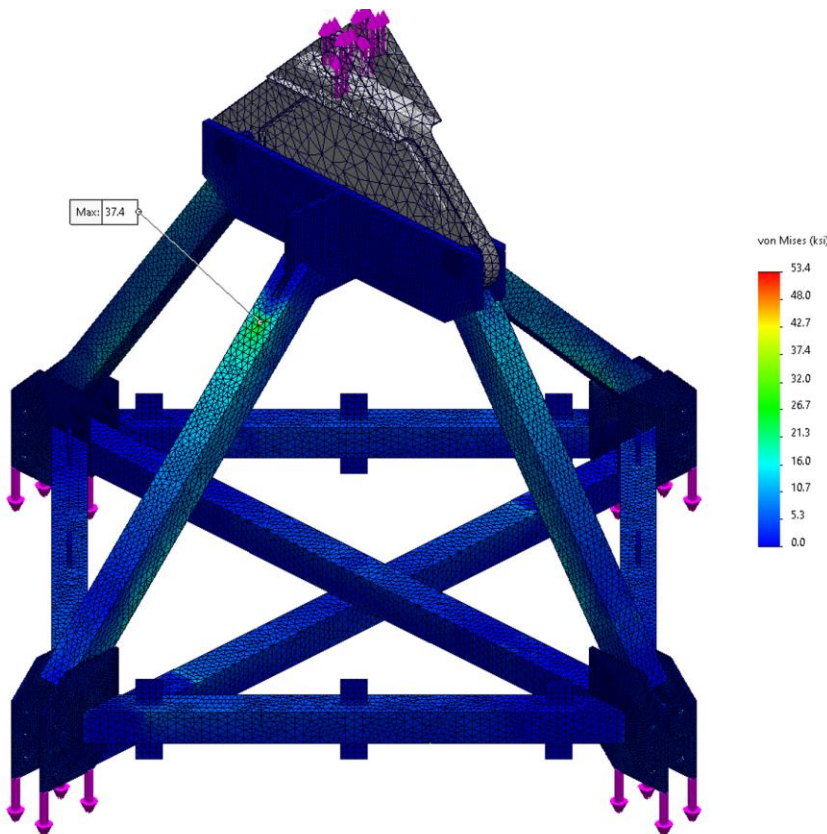
Justin

Narrative on Trapeze Analysis from HAO (Andrew Carlile):

This analysis doesn't consider any of the antennae specific loads and combines those antennae loads with the total mass. The tri-plate is aluminum, so it is the softest part in the entire assembly and its bending will affect the load paths. This model is a simple check to be compared with Justin's results with similar assumptions.

Trapeze 8g Case

From Justin:



8G Vertical (DIRECT LOAD)

- Force = 33,600lbf
 - 4,200lbs below trapeze
- Inertial Relief
 - Equal force distribution at bottom of trapeze
- Tri-Plate Rigid

SAP Reported Material Properties

- $F_{ty} = 750 \text{ Mpa} = 108.8 \text{ ksi}$
- $F_{tu} = 1,000 \text{ Mpa} = 145.0 \text{ ksi}$
 - *Carlile reports: $F_{ty} = 435 \text{ Mpa} / F_{tu} = 670 \text{ Mpa}$*

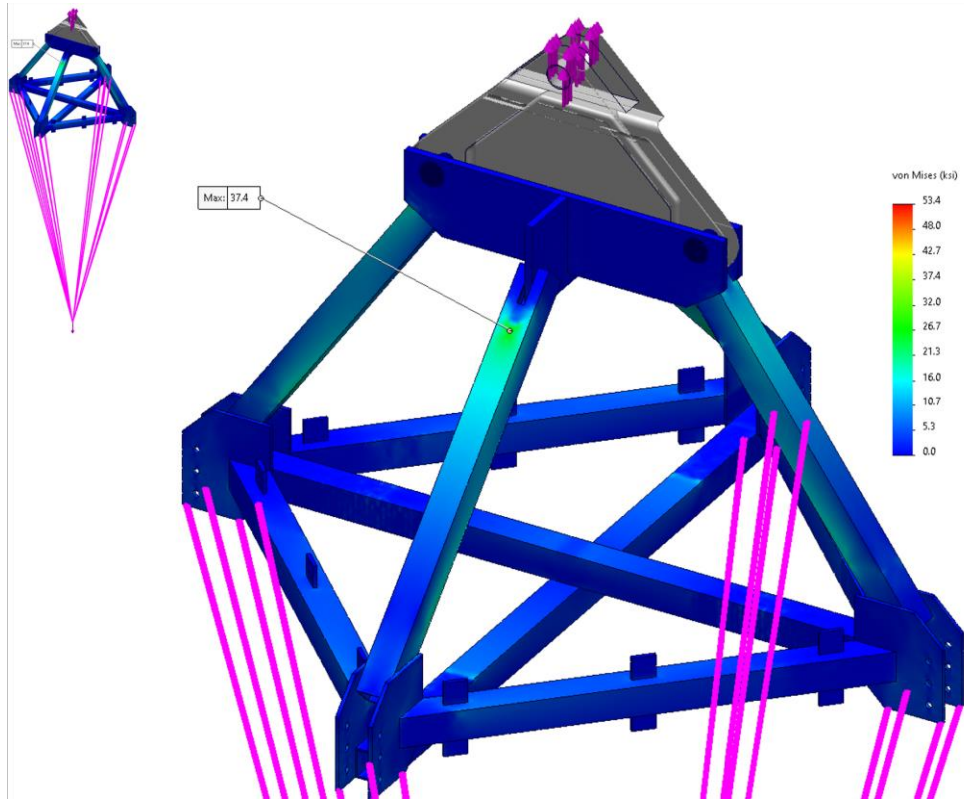
FEA Material Properties

- $F_{ty} = 460 \text{ Mpa} = 66.7 \text{ ksi}$
- $F_{tu} = 731 \text{ Mpa} = 106.0 \text{ ksi}$

Margins

- $\sigma_{\text{max}} = 37.4 \text{ ksi}$
- $M_{sy} = 0.35$
- $M_{su} = 0.86$

MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES



8G Vertical (REMOTE LOAD)

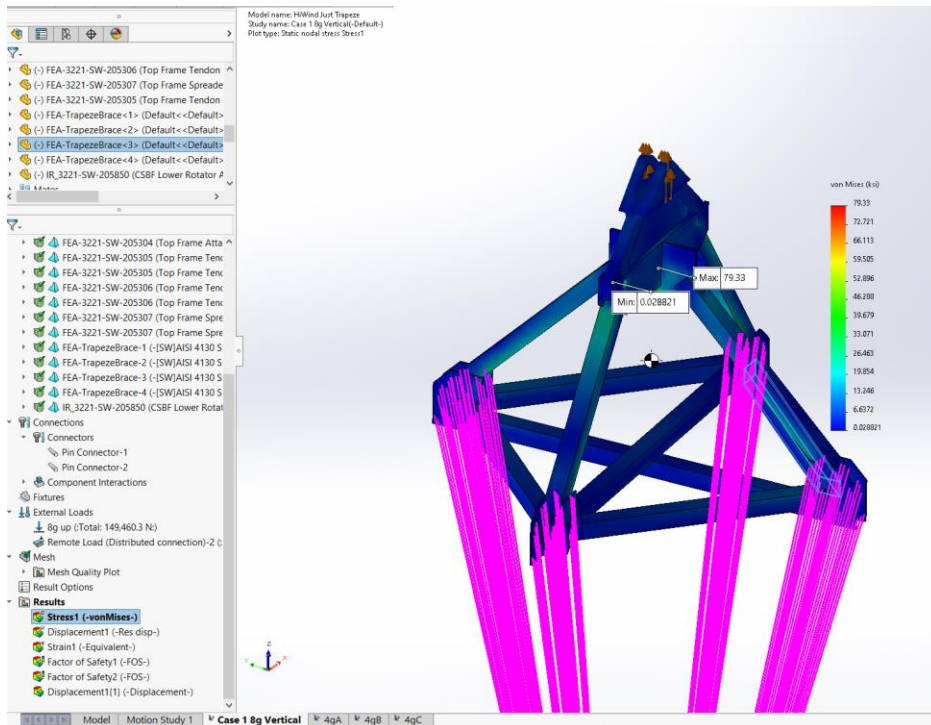
- Force = 33,600lbf
 - 4,200lbs below trapeze
- Inertial Relief
 - Equal force distribution at bottom of trapeze
- Tri-Plate Rigid
- Remote Load @ CG

Margins

- $\sigma_{max} = 37.4$ ksi
- $M_{sy} = 0.35$
- $M_{su} = 0.86$

EXAMPLE TO SHOW REMOTE LOAD BEHAVES SAME AS DIRECT LOAD

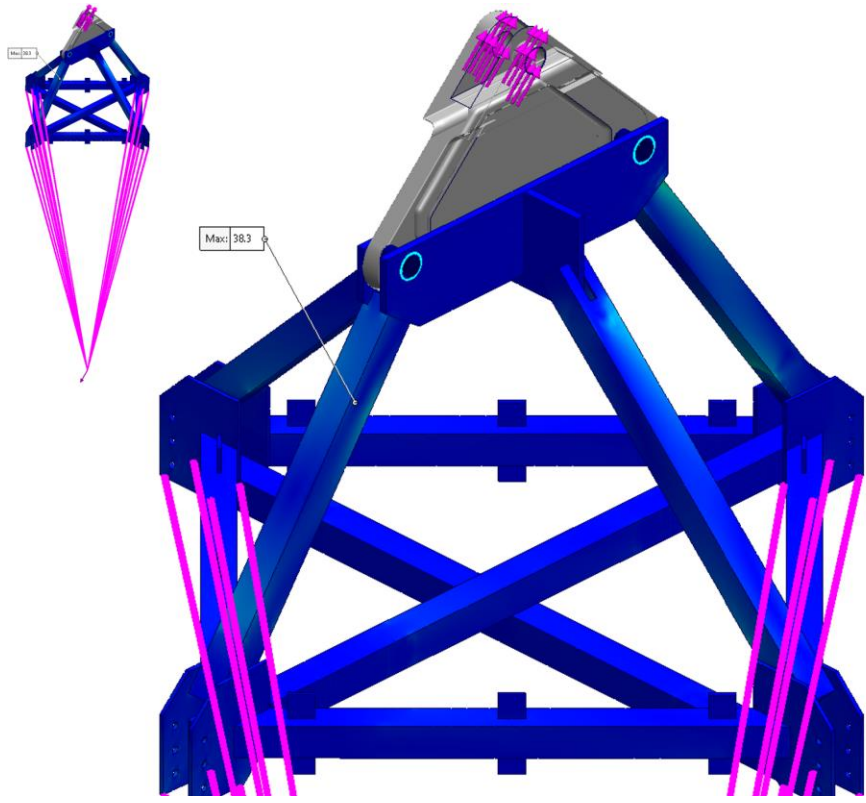
From HAO:



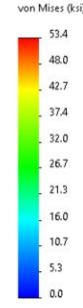
Trapeze 4gA Case

From Justin:

MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES



- 4G @ 45° (A)
- Force = 16,800lbf
 - 4,200lbs below trapeze
 - Inertial Relief
 - Equal force distribution at bottom of trapeze
 - Tri-Plate Rigid
 - Remote Load @ CG
- Margins
- $\sigma_{max} = 38.3$ ksi
 - $M_{sy} = 0.32$
 - $M_{su} = 0.81$



From HAO:

Setup of remote load:

Remote Loads/Mass

Type: Split

Message: In case of Rigid Connection, motion of each node within the connection region is dictated by translation and rotation of the remote point. Also the connection region will not deform. Distributed Connection allows the remote point constrained to translate and rotate with average motion of nodes within the connection region.

Selection:

- Face+1>@FEA-3221-SW-205304 (Top Frame Attachment Flange)-Lees Copy-6
- Face+2>@FEA-3221-SW-205304 (Top Frame Attachment Flange)-Lees Copy-2
- Face+2>@FEA-3221-SW-205304 (Top Frame Attachment Flange)-Lees Copy-7
- Face+2>@FEA-3221-SW-205304 (Top Frame Attachment Flange)-Lees Copy-8
- Face+2>@FEA-3221-SW-205304 (Top Frame Attachment Flange)-Lees Copy-1

Reference Coordinate System:

- Global
- User defined
- Coordinate System1

Location:

- mm
- X: 0
- Y: 0
- Z: 0

Translational Components:

- X: 17365.075 N
- Y: 17365.075 N
- Z: 52842.2 N

Rotational Components:

- Mx
- My
- Mz

Connection Type:

- Distributed
- Rigid

Weighting Factor: Default (Constant)

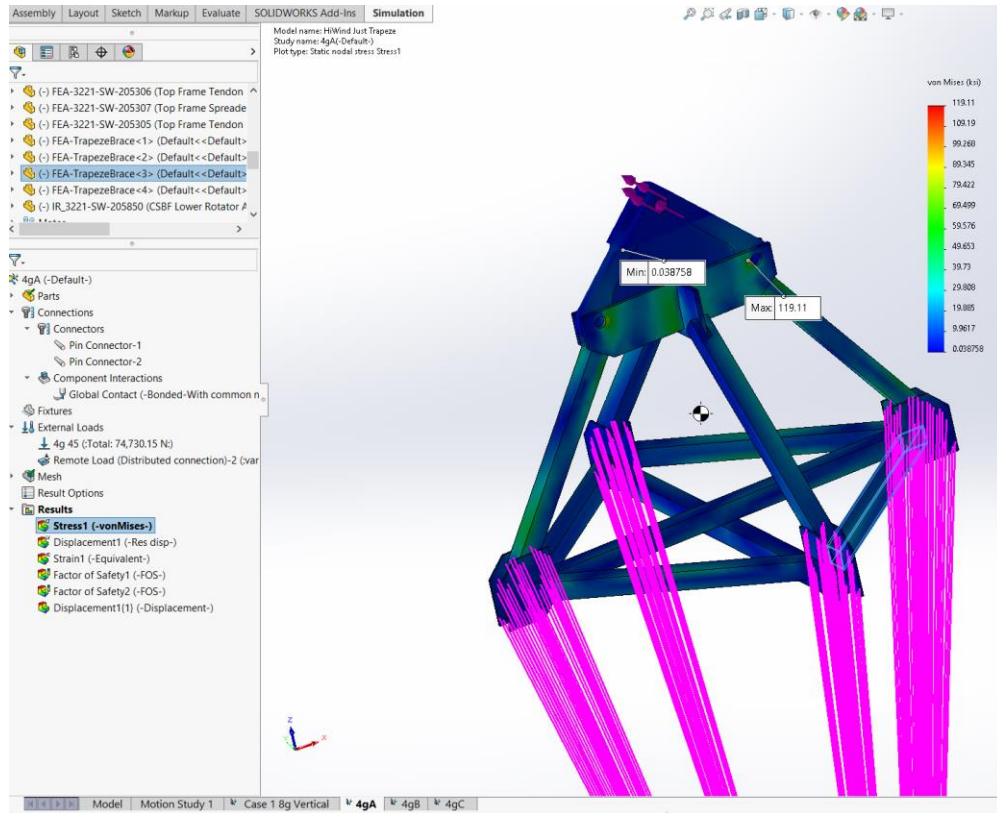
Mass: Mass

Symbol Settings

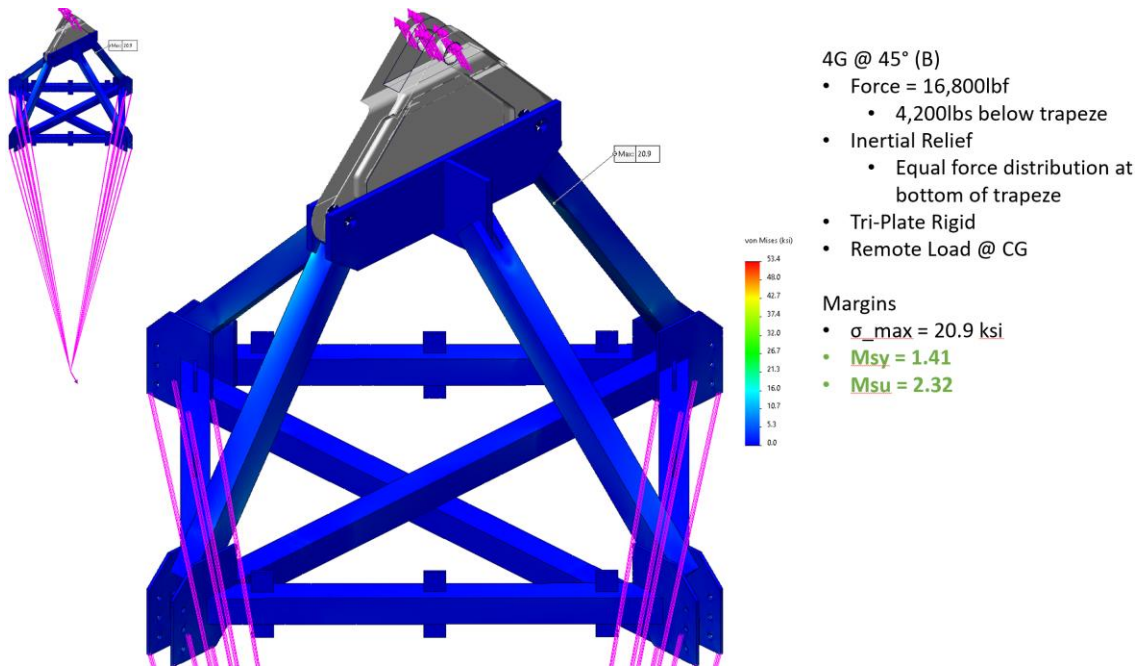
3D Model Data Table:

| | |
|--------------------------|------------|
| X-Location (mm): | 0 |
| Y-Location (mm): | 0 |
| Z-Location (mm): | 0 |
| Force - X-Direction (N): | 17,365.075 |
| Force - Y-Direction (N): | 17,365.075 |
| Force - Z-Direction (N): | 52,842.2 |

MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

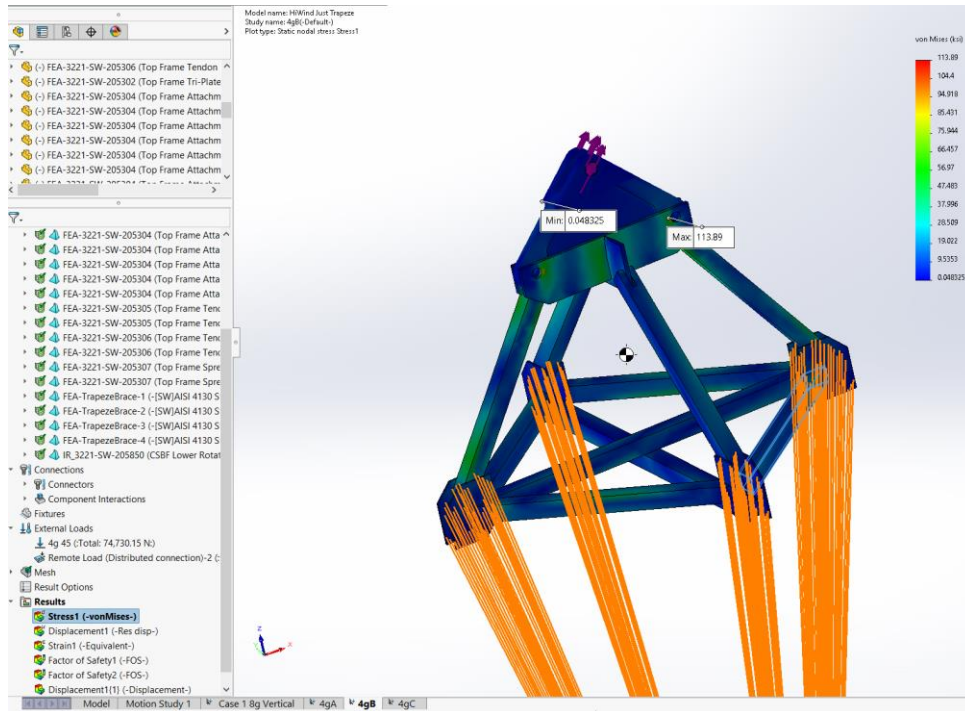


Trapeze 4gB Case
From Justin:

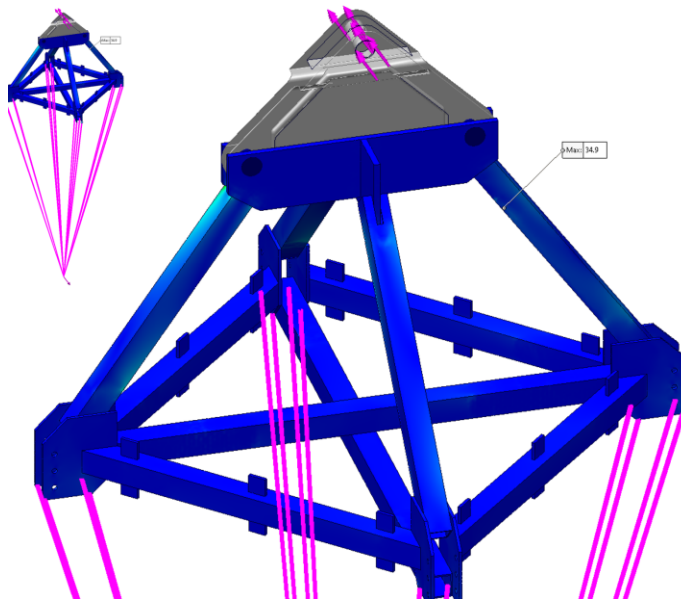


From HAO:

MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES



Trapeze 4gC Case
From Justin:



4G @ 45° (C)

- Force = 16,800lbf
 - 4,200lbs below trapeze
- Inertial Relief
 - Equal force distribution at bottom of trapeze
- Tri-Plate Rigid
- Remote Load @ CG

Margins

- $\sigma_{max} = 34.9$ ksi
- $M_{sy} = 0.45$
- $M_{su} = 0.99$

From HAO:

MEETS LOAD CASE 1 AND SOME OTHER SAFETY REQUIREMENTS CALCULATED BY HAO, IS AN INCOMPLETE REPORT AND FAILS MOST LOAD CASES

