FEA of Coil Supports

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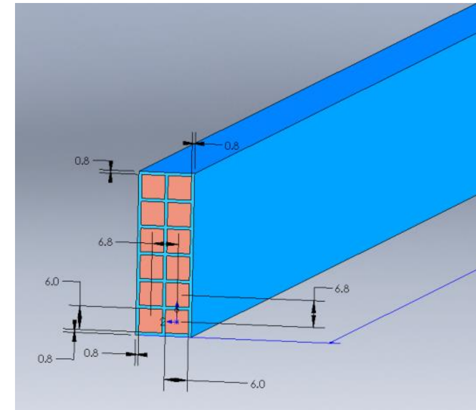
June 2013 – Oct 2013

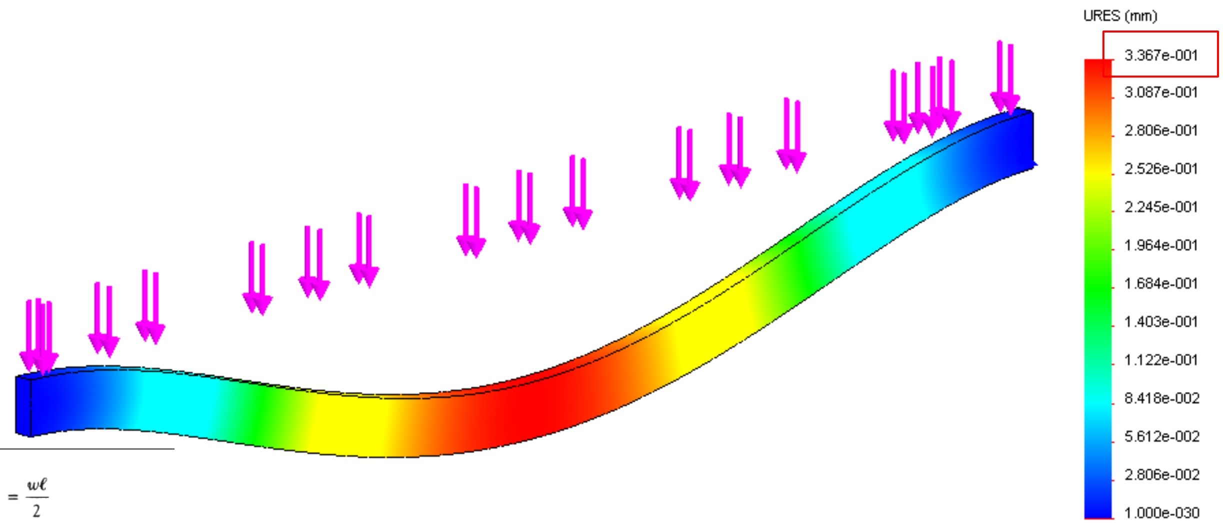
Model	
File Name	CompositeBeamTest
File Configuration	Default
Model Type	Solid
Loads	1000 N/m, uniform
Restraints	Fixed ends
Contacts	Bonded

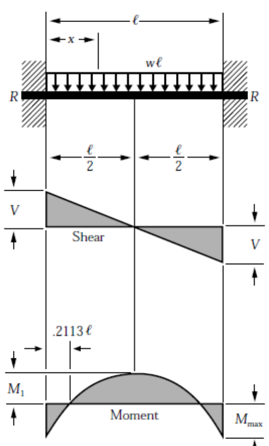
1. Create a composite beam that represents the geometry of the coils (copper + GFRP)



Filler: “Generic GFRP”; E=49 GPa

2. Simulate that beam to determine the deflection under simple boundary conditions





$R = V$ . . . . $= \frac{w\ell}{2}$

V_x . . . . $= w\left(\frac{\ell}{2} - x\right)$

M_{max} (at ends) . . . . $= \frac{w\ell^2}{12}$

M_1 (at center) . . . . $= \frac{w\ell^2}{24}$

M_x . . . . $= \frac{w}{12}(6\ell x - \ell^2 - 6x^2)$

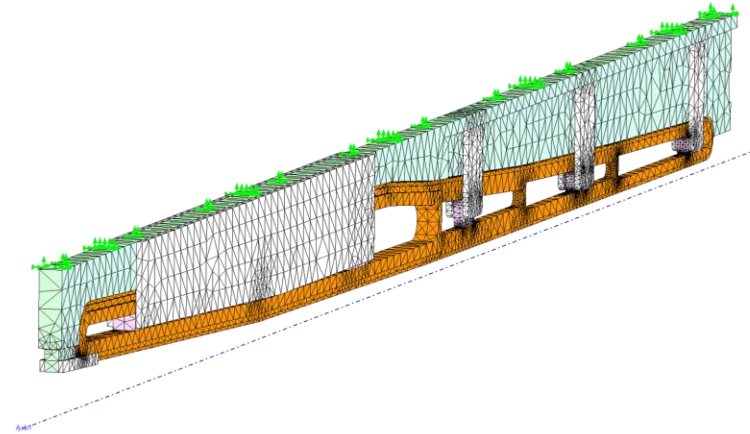
Δ_{max} (at center) . . . . $= \frac{w\ell^4}{384EI}$

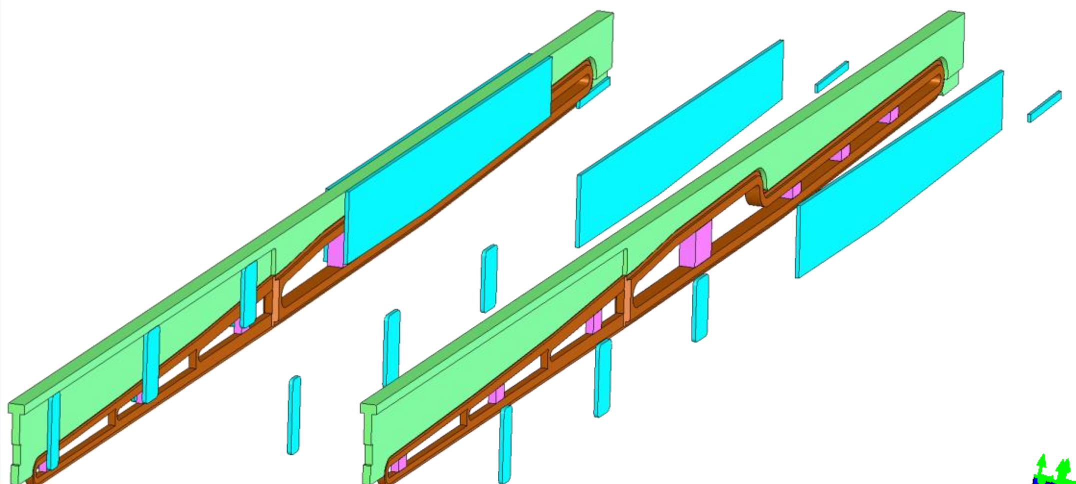
Δ_x . . . . $= \frac{wx^2}{24EI}(\ell - x)^2$

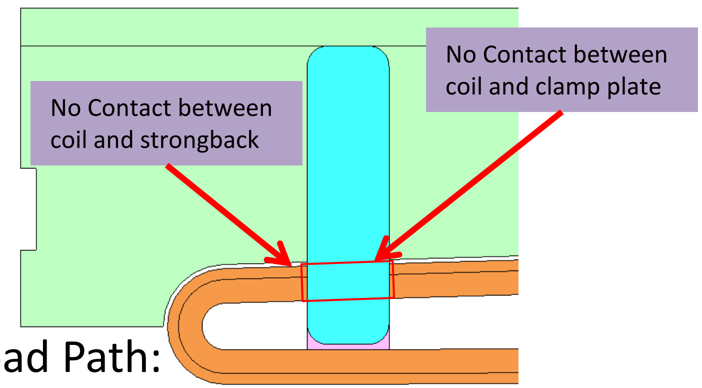
3. Use linear elastic model to determine effective stiffness, E_{eff}

E_{eff} = 89.5 GPa

Model	
File Name	Coil+Carrier Assy.SLDASM
File Configuration	FEA
Model Type	Solid, Static
Loads	Gravity + Toroid Force (3000 lb)
Restraints	Spine Fixed
Contacts	Bonded

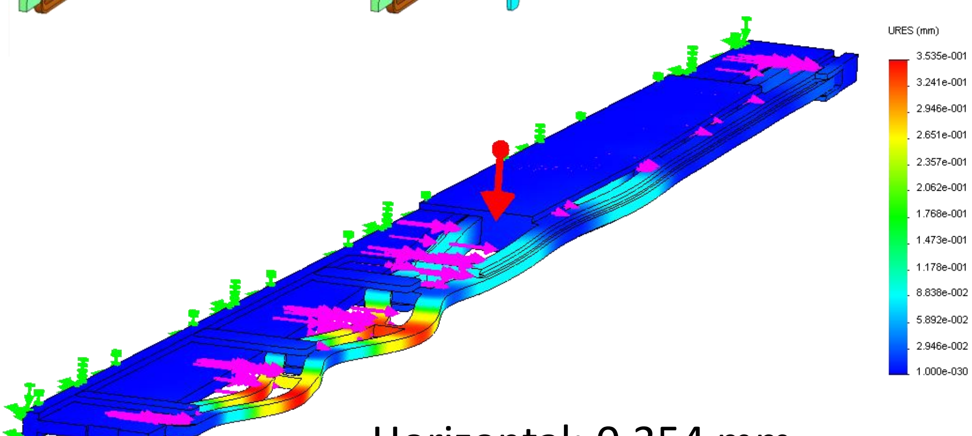




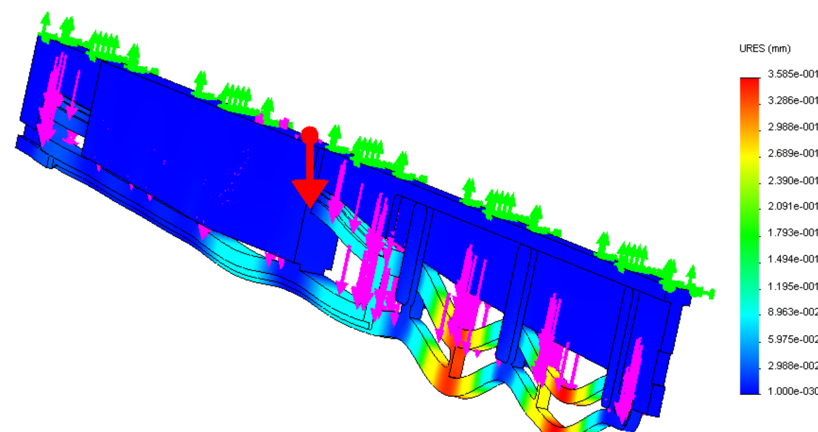


Load Path:

Coil → Blocks → Plates → Strongback

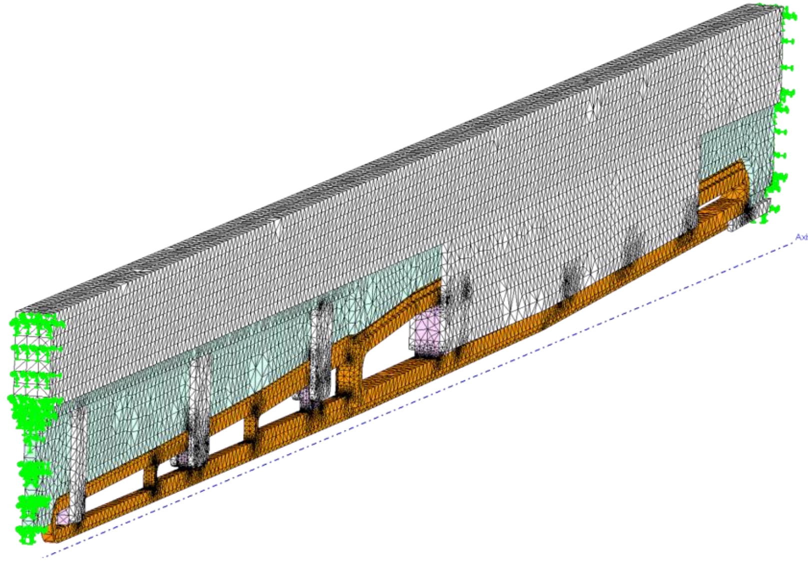


Horizontal: 0.354 mm

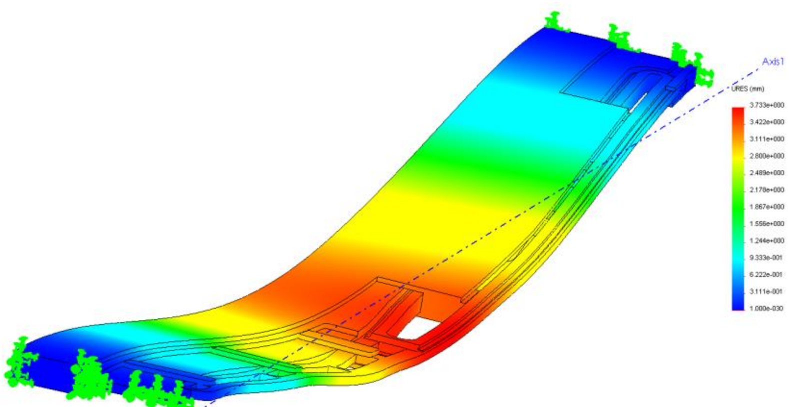


12.9 deg from vertical – 0.359 mm

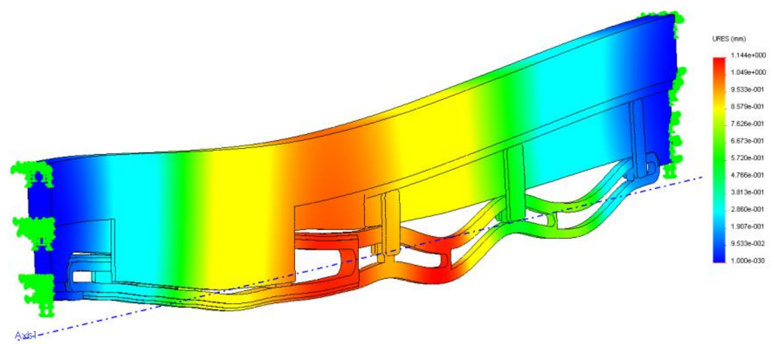
Model	
File Name	Coil+Carrier Assy.SLDASM
File Configuration	FEA (revised)
Model Type	Solid, Static
Loads	Gravity + Toroid Force (3000 lb)
Restraints	Ends Fixed
Contacts	Bonded



- More realistic supports – Clamped Ends
- Added 8” extra depth to spine of stongback to counterbalance new boundary condition
  - This brings the overall diameter of the 7 coil+carrier assemblies to ~60”
- This is a workable concept that will be further detailed and analyzed.



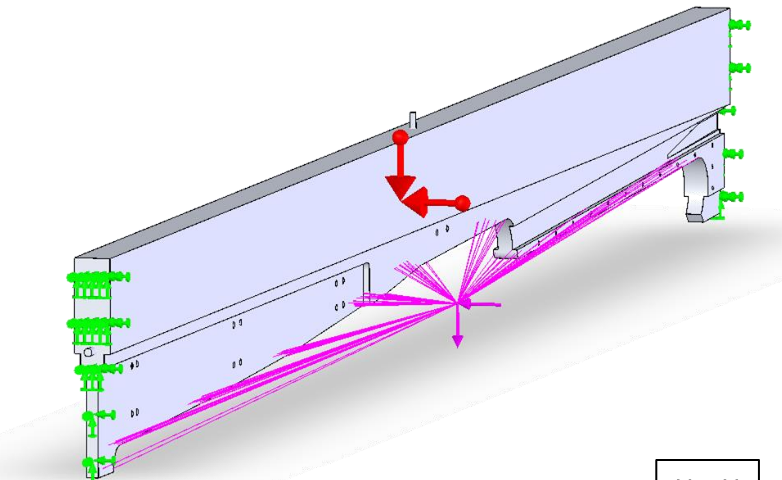
Horizontal: 3.73 mm



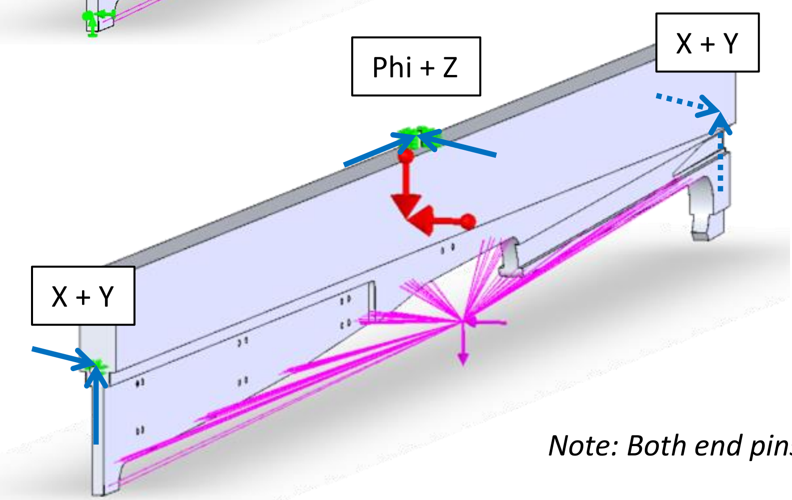
12.9 deg from vertical: 1.14 mm

Model	
File Name	Moller_Coil Strongback.sldprt
File Configuration	FEA, and FEA (6Strut)
Model Type	Solid, Static
Loads	Gravity + Coil Weight (265 kg) + Toroid Force (3000 lb)
Restraints	Ends Fixed, and 3 pin kinematic
Contacts	none

Compare clamped ends to kinematic 6-strut support



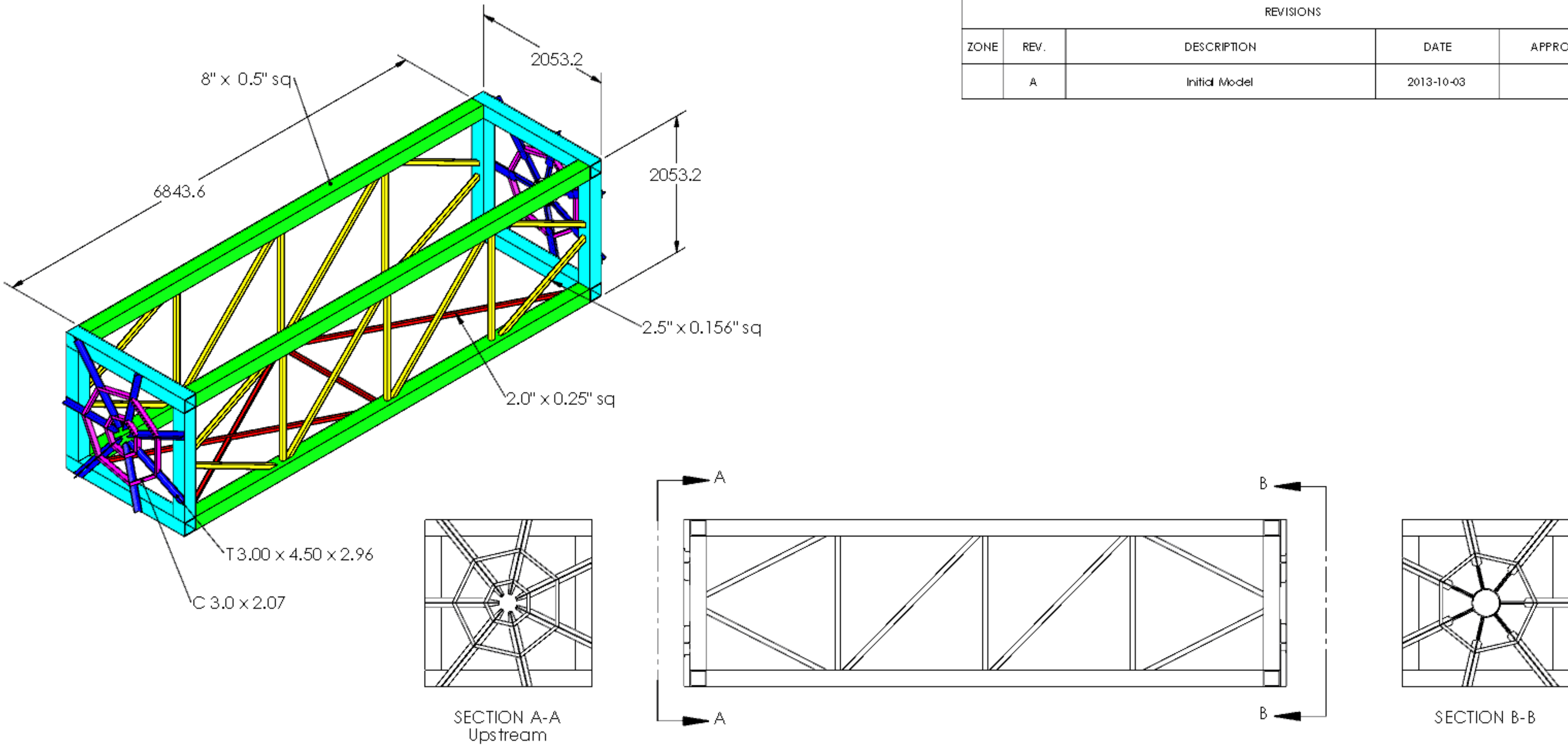
	Clamped Vertical	Clamped Horizontal
Displacement mag. [mm]	1.139	3.997



	6-Strut Vertical	6-Strut Horizontal
Displacement mag. [mm]	2.942	3.625

Note: Both end pins co-axial. All 3 pin axes intersect predicted CG of coil+carrier assembly

Model	
File Name	Moller Hybrid Support Stand Weldment ASSY.SLDASM (Rev A)



REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APPROVED
	A	Initial Model	2013-10-03	

METRIC

WEIGHT IN KILOGRAMS.

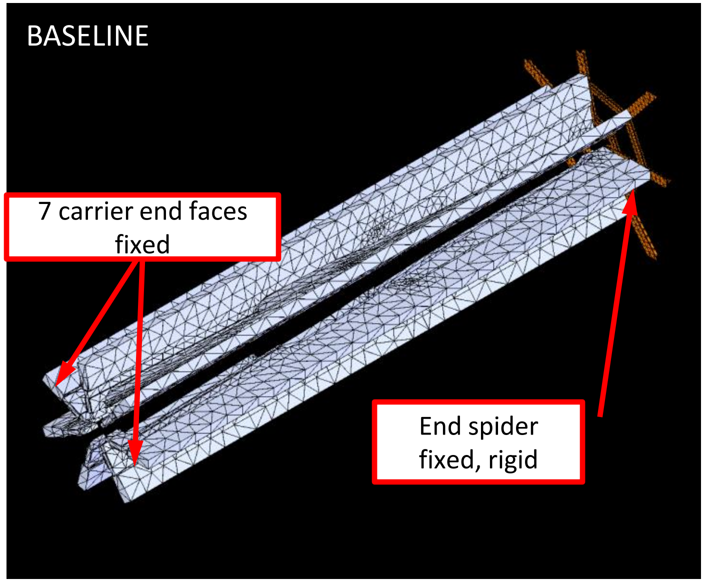
1318.686

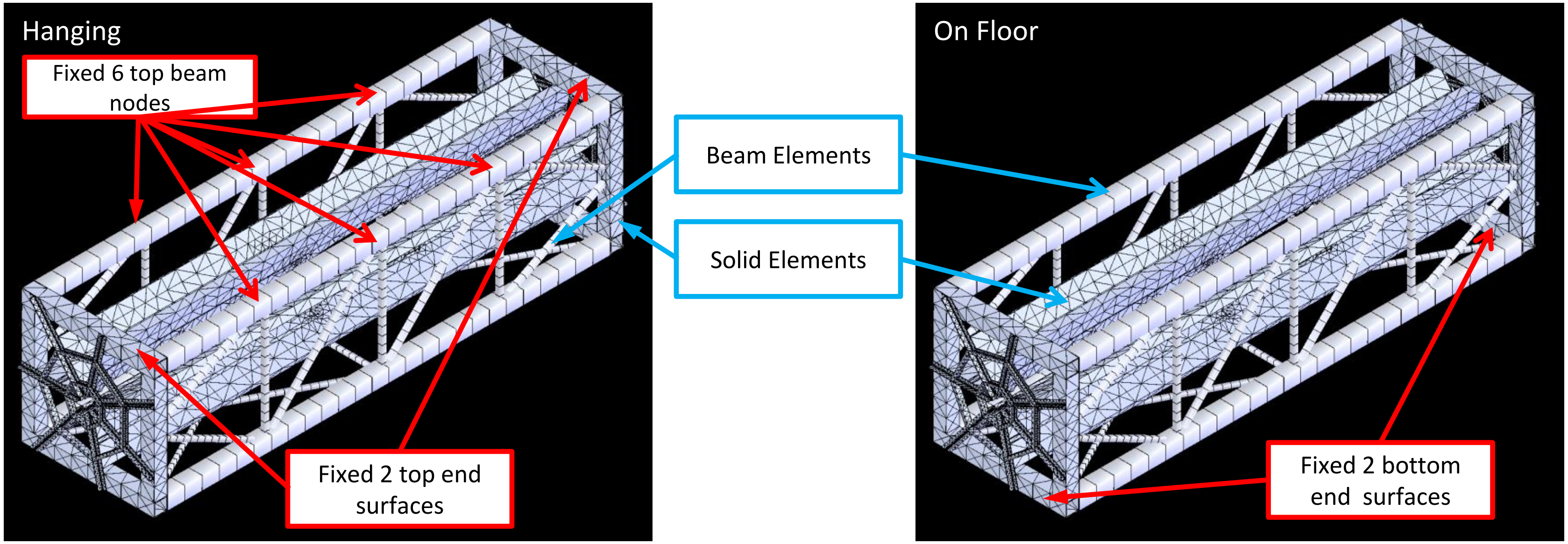
THIRD ANGLE PROJECTION

MATERIAL: SEE PARTS LIST	SHOP NOTES: - DO NOT SCALE DRAWING. - BREAK ALL SHARP EDGES. SURFACE FINISH: NONE / MAXIMUM, ALL MACHINED SURFACES	MASSACHUSETTS INSTITUTE OF TECHNOLOGY LABORATORY FOR NUCLEAR SCIENCE **BATES LINEAR ACCELERATOR CENTER**	
APPROVALS: / DATE: ORIGINATOR: - DRAWN BY: J. Bessuille 10/13 CHECKED BY: - APPROVED BY: -	UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS. **DECIMALS:** X= ±0.25 X.X= ±.125 X.XX= ±.025 **ANGLES:** = ±0°30'	**MOLLER Hybrid Toroid Support Stand Weldment**	
NEXT ASSEMBLY: -	SolidWorks GENERATED DRAWING. FILE LOCATION AND NAME:	SCALE: 1:50 / PROJECT #: / SIZE: B / DRAWING #:	SHEET #: 1 OF 1 / REV: A+

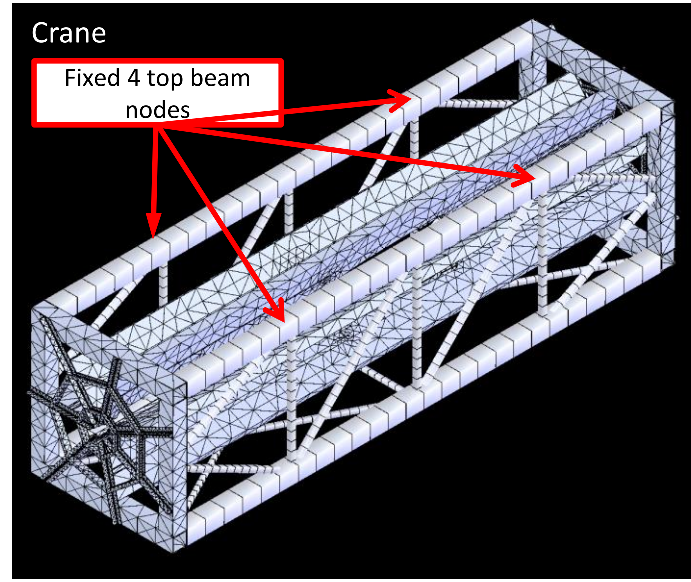
Model	
File Name	Moller Hybrid Support Stand Weldment ASSY.SLDASM (Rev A)
File Configuration	FEA2
Study Name	Hanging, Floor, and Baseline
Model Type	Solid, Static, mixed solid/beam
Loads (common)	Gravity + Toroid Force (3000 lb)
Restraints	various
Contacts	bonded solid-solid , bonded beam-solid

First pass at analyzing Frame

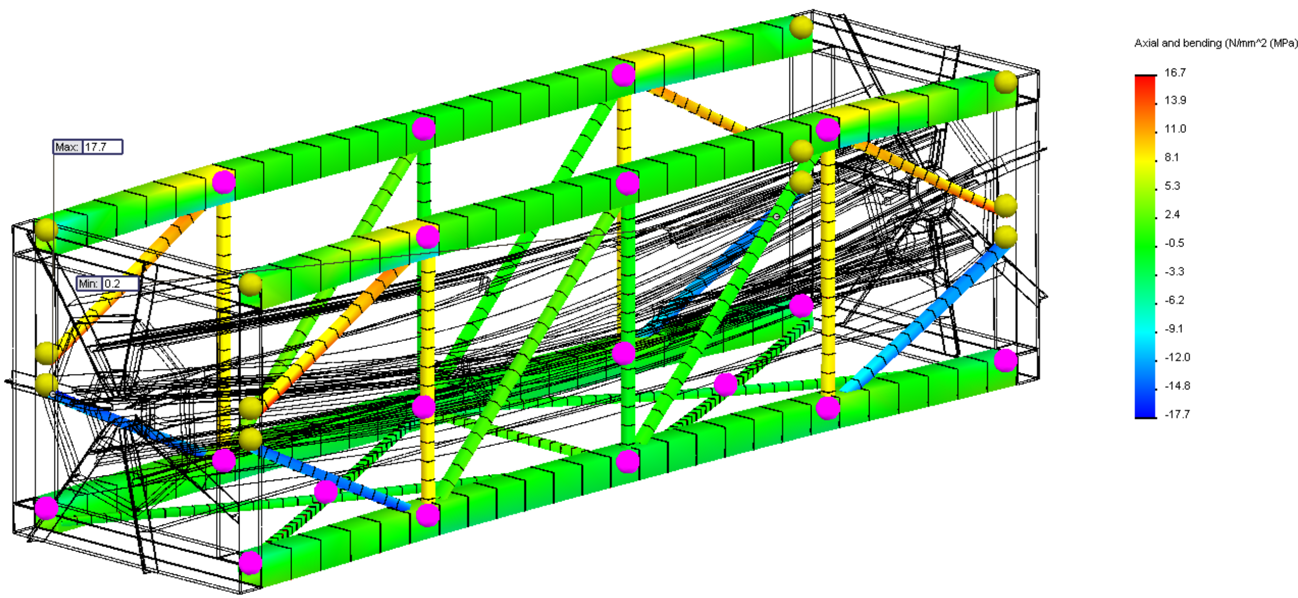


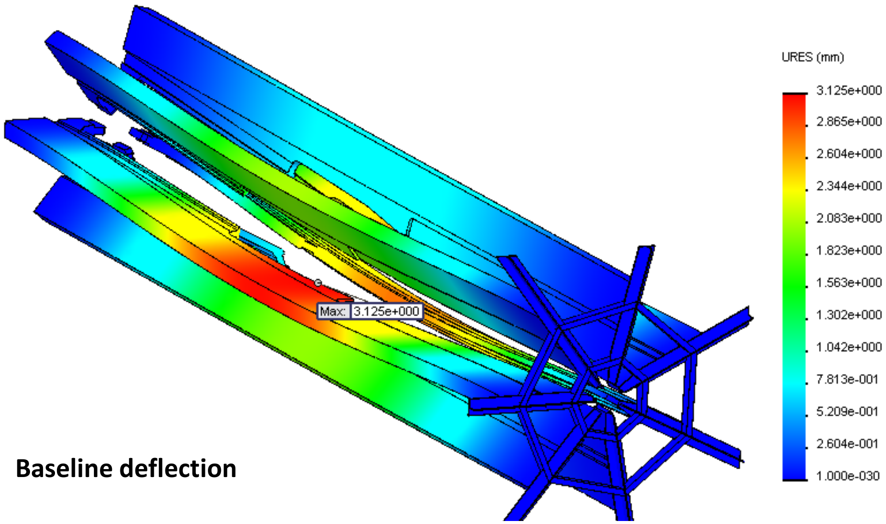


Model	
File Name	Moller Hybrid Support Stand Weldment ASSY.SLDASM (Rev A)
File Configuration	FEA2
Study Name	Crane
Model Type	Solid, Static, mixed solid/beam
Loads (common)	Gravity + Toroid Force (3000 lb)
Restraints	4 Nodes
Contacts	bonded solid-solid , bonded beam-solid



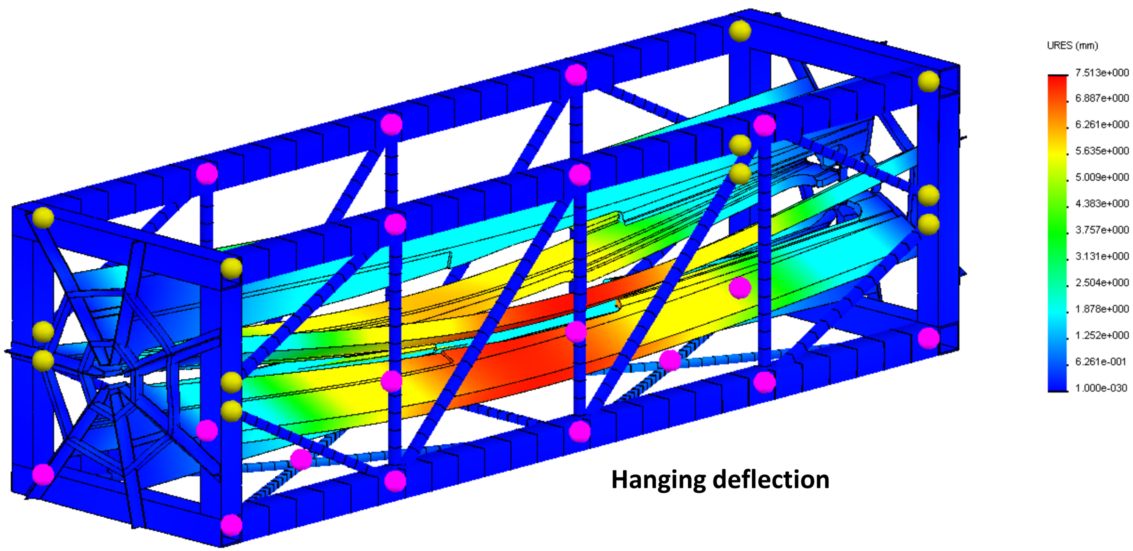
Quick check of stresses in beams: Worst case while lifting with crane





Baseline deflection

Condition	Deflection [mm]
Baseline	3.125
Hanging	7.513
Floor	7.523
Crane	8.858

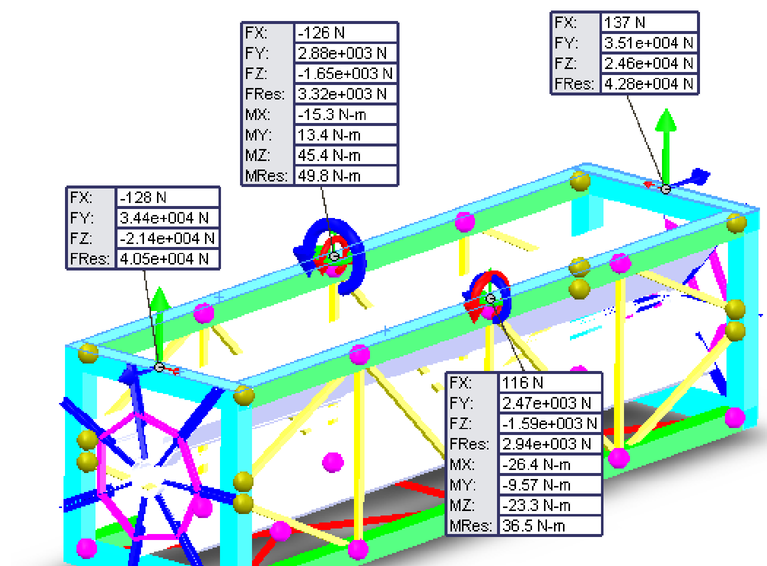


Hanging deflection

→ Why are the floor and hanging deflections so similar? The main difference between the models is that with the hanging condition, the upper z-beams are supported along their length, while for the floor condition, only the frame ends are supported. Looking at the reaction forces for the hanging case, we see that the vertical load carried by the z-beams is more than an order of magnitude less that that supported by the ends.

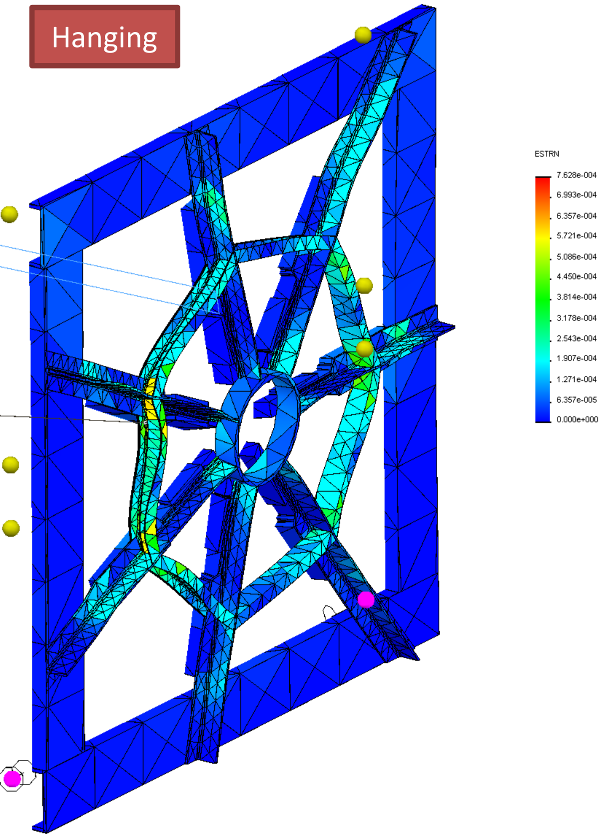
Beam rxn = (2.88+2.47)e3 N = 545 kgf

End rxn = (3.51+3.44)e4 N = 7085 kgf



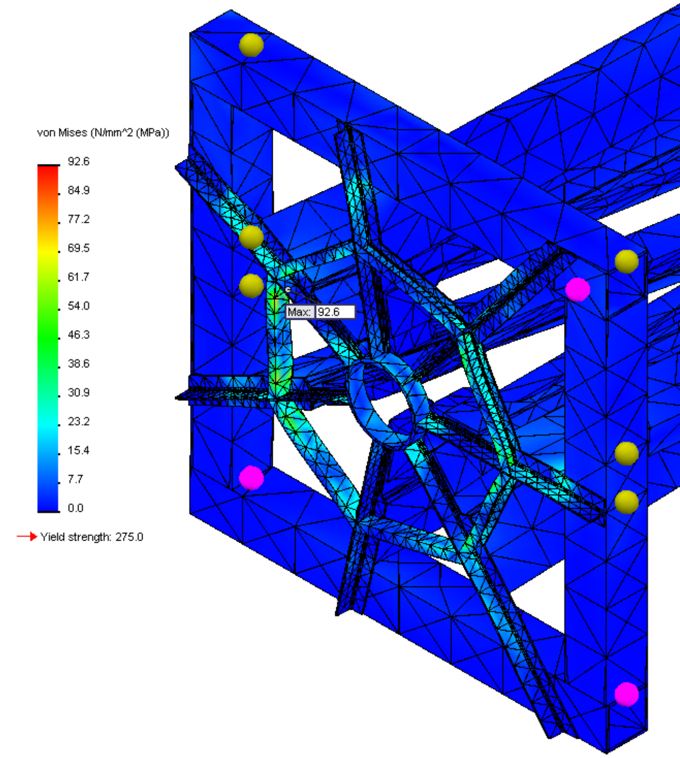
Hanging reactions

Hanging



→ Right: The highest stress was seen at the DS end of the hanging condition. At 92.6 MPa, it is well below the yield strength of 6061-T6 (275 MPa) but is still an area of concern. Because the mesh size here is relatively coarse (compared to salient dimensions of the parts), further studies should refine the mesh in these areas.

← Left: A look at the strain at the DS end shows a great deal of twisting on the fingers and heptagon supports. Since these members transfer the coil end support conditions (i.e. slope) to the frame, reducing strain here will improve overall deflection. Increasing torsional stiffness should reduce twisting



→ The beam stresses are very low (-3.0 – 2.3 MPa) in the hanging and floor-supported models. This is because the ends of the frame, where the coil load is borne, are directly supported by either the vacuuim chamber (hanging) or the ground (floor). It is likely some of these members can be made smaller / thinner.