SunEarth Maximum Load Determination for the Front and Rear Leg Structures

Objective: To determine the maximum side and axial loads for SunEarth's aluminum front and rear leg support structures.

Modeling Assumptions and Details: The aluminum tube front and rear leg structures were modeled using a combination of plate, solid, and beam elements. The aluminum extruded sections were modeled using plate elements. The weldments and upper aluminum extrusion components were modeled using brick (solid) elements. The screws and bolts were simulated with beam elements. The beam elements were attached to the plate and solid elements with rigid links. Contact behavior was enforced with gap elements.

Maximum side and compression loads were applied at the top of the model. The model was run as a geometric and material nonlinear analysis. This type of simulation incorporates both buckling and plasticity behavior. To determine the failure load of the structure, the analysis is allowed to execute until the solution diverges. Solution divergence is considered the failure point or the "buckling" load of the structure. This type of analysis is more rigerous than linear, eulerian buckling since material nonlinearity is incorporated into the analysis.

All analysis work was performed using MSC.Nastran V2001.0.9 and MARC V2003. An iterative nonlinear solution technique was required due to the use of gap elements, generalized contact and material plasticity.

Results: Results from this investigation are summarized in two tables on pages 2 and 3 of this report.

Executive Summary:

The Front Leg structure's maximum loads are summarized as follows:

1. Maximum side load is approximately 1,500 lbf. The failure mechanism is plastic tearing and buckling.
2. a) Maximum compression/tension axial load is 4,500 lbf. The failure mechanism is the tek-screw bearing area.

   b) Maximum compression/tension axial load is 4,900 lbf. The failure mechanism is the upper bolted bearing area.

   c) Maximum compression/tension axial load is 5,700 lbf. The failure mechanism is the tek-screw shear area.

   d) Maximum compression axial load is 7,500 lbf. The failure mechanism is plastic buckling.

The Rear Leg structure's maximum loads are summarized as follows:

1. Maximum compression axial load is 1,600 lbf for the 98.6 inch long leg. The failure mechanism is column buckling.
2. a) Maximum compression/tension axial load is 4,300 lbf. The failure mechanism is the lower bolted bearing area.

   b) Maximum compression/tension axial load is 4,500 lbf. The failure mechanism is the tek-screw bearing area.

   c) Maximum compression/tension axial load is 4,900 lbf. The failure mechanism is the upper bolted bearing area.
3. Maximum compression axial load is 5,600 lbf for the 63.6 inch long leg. The failure mechanism is column buckling.
4. Maximum compression/tension axial load is 5,700 lbf. The failure mechanism is the tek-screw shear area.
5. Maximum compression axial load is 6,900 lbf for the 39.6 inch long leg. The failure mechanism is column buckling.

Table 1: Results Summary of Maximum Load Capability of the Front Leg Structure			
Load Case	**Structural Member**	**Failure Mechanism**	**Documentation of Failure Mechanism**
Side Load	Main column structure	Plastic buckling of the column due to extensive plastic deformation. Front leg plastically collapses at 1,500 lbf in either direction.	Finite element analyses work documents this value.
Axial Tension/Compression	#10 tek-screw bearing area	Screw bearing load is limited to 1,500 lbf. The structure has three screws, thus 4,500 lbf.	Hand calculation based on the cross-sectional bearing area of the screw and the ultimate bearing strength of the 6063-T6 aluminum. See Appendix for details.
Axial Tension/Compression	Upper swivel hinge bracket bolted connection to aluminum tube	The bearing area of the bolt limits the ultimate load to 4,900 lbf.	Hand calculation based on the cross-sectional bearing area of the bolt onto the aluminum extrusion and the ultimate bearing strength of the 6063-T6 aluminum. See Appendix for details.
Axial Tension/Compression	#10 tek-screws	Shear area failure at 1,900 lbf per screw. The structure has three screws, thus 5,700 lbf.	Hand calculation based on the screw's diameter and shear strength. See Appendix for details.
Axial Compression	Main column structure	Plastic buckling at 7,500 lbf.	Finite element analyses work documents this value.
Axial Tension/Compression	Upper swivel bracket	Limited by bolted connection to aluminum extrusion. Maximum bearing load is 9,800 lbf.	The cross-section bearing area of the extrusion far exceeds the bolt bearing area onto the aluminum tube.

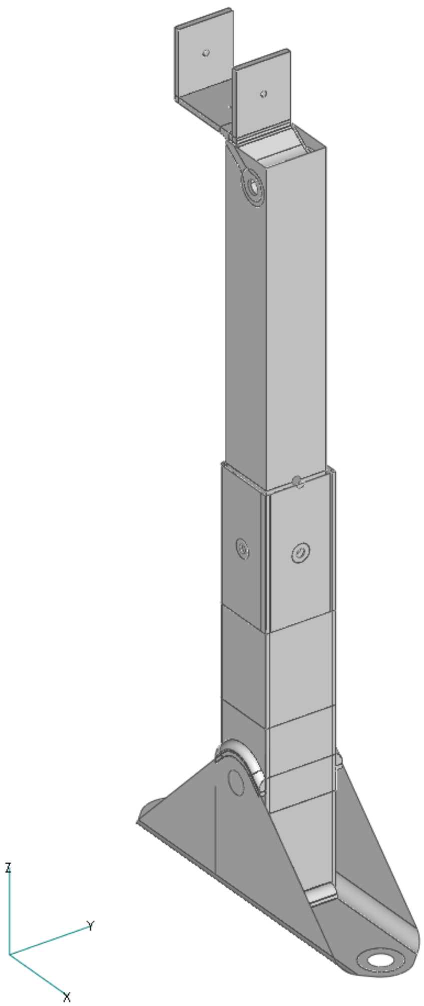
Table 2: Results Summary of Maximum Load Capability of the Rear Leg Structure

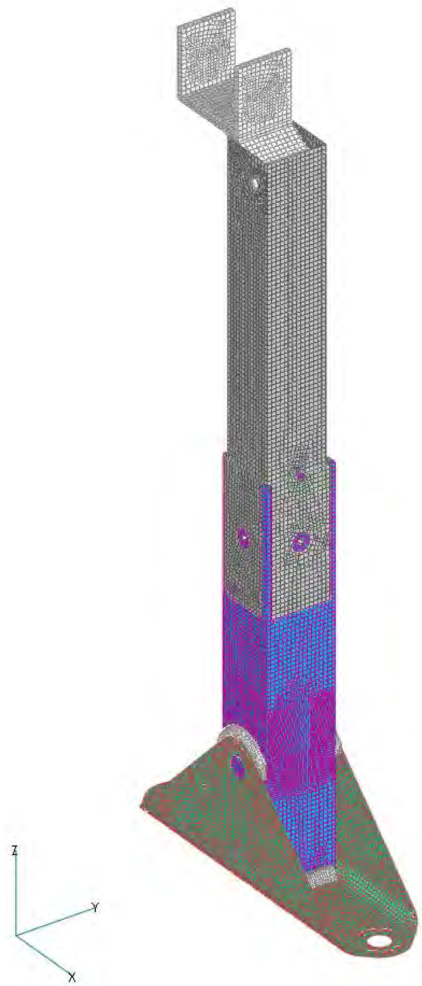
Load Case	Structural Member	Failure Mechanism	Documentation of Failure Mechanism
Axial Compression	98.6 inch long Rear Leg Structure	Column buckling at 1,600 lbf.	Column buckling predicted by finite element analysis.
Axial Tension/Compression	Lower bolted connection to aluminum tube	The bearing area of the bolt limits the ultimate load to 4,300 lbf.	Hand calculation based on the cross-sectional bearing area of the bolt onto the aluminum extrusion and the ultimate bearing strength of the 6063-T6 aluminum. See Appendix for details.
Axial Tension/Compression	#10 tek-screw bearing area	Screw bearing load is limited to 1,500 lbf. The structure has three screws, thus 4,500 lbf.	Hand calculation based on the cross-sectional bearing area of the screw and the ultimate bearing strength of the 6063-T6 aluminum. See Appendix for details.
Axial Tension/Compression	Upper swivel hinge bracket bolted connection to aluminum tube	The bearing area of the bolt limits the ultimate load to 4,900 lbf.	Hand calculation based on the cross-sectional bearing area of the bolt onto the aluminum extrusion and the ultimate bearing strength of the 6063-T6 aluminum. See Appendix for details.
Axial Compression	63.6 inch long Rear Leg Structure	Column buckling at 5,600 lbf.	Column buckling predicted by finite element analysis.
Axial Tension/Compression	#10 tek-screws	Shear area failure at 1,900 lbf per screw. The structure has three screws, thus 5,700 lbf.	Hand calculation based on the screw's diameter and shear strength. See Appendix for details.
Axial Compression	39.6 inch long Rear Leg Structure	Column buckling at 6,900 lbf.	Column buckling predicted by finite element analysis.
Axial Tension/Compression	Upper swivel bracket	Limited by bolted connection to aluminum extrusion at 9,800 lbf.	The cross-section bearing area of the extrusion far exceeds the bolt bearing area onto the aluminum tube.

Table 3: Suggestions for Improvements in Load Bearing Capacity of the Front and Rear Leg Structures.

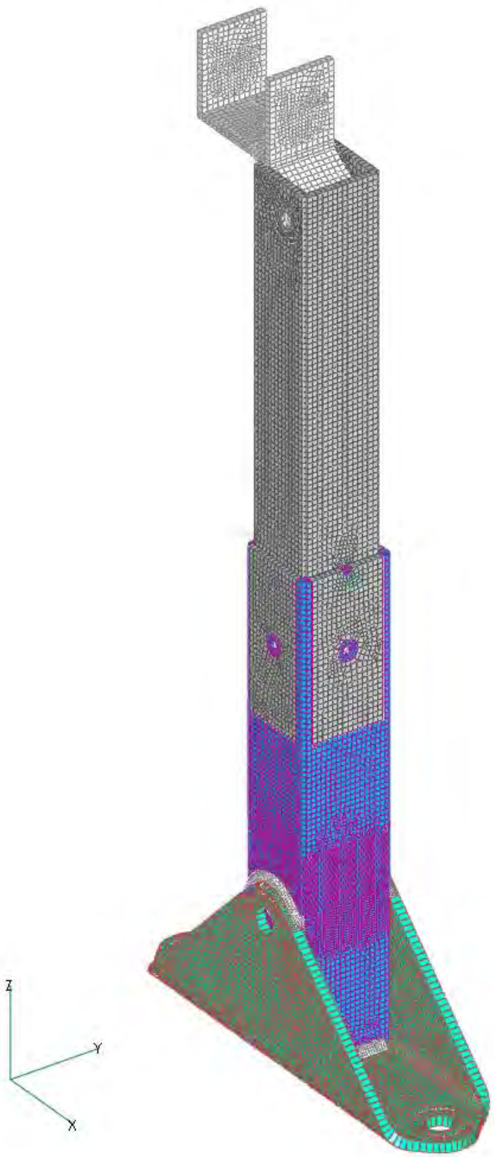
Load Case	Structural Member	Design Suggestion
Axial Compression	Rear Leg Structures	Increase wall thickness of aluminum extrusions.
Axial Tension/Compression	Rear Leg Structures	Increase the number of tek-screws and use steel inserts for the through bolted connections at the top and bottom of the Rear Leg Structure to distribute the bolt bearing load.
Side Load	Front Leg Structure	Increase the wall thickness of the lower aluminum extrusion.
Axial Compression	Front Leg Structure	Increase the wall thickness of the upper aluminum extrusion.
Axial Tension/Compression	Front Leg Structure	Same design concept as in the Rear Leg Structure.

Front Leg Geometry and Mesh Details





Geometry and mesh details of structure.



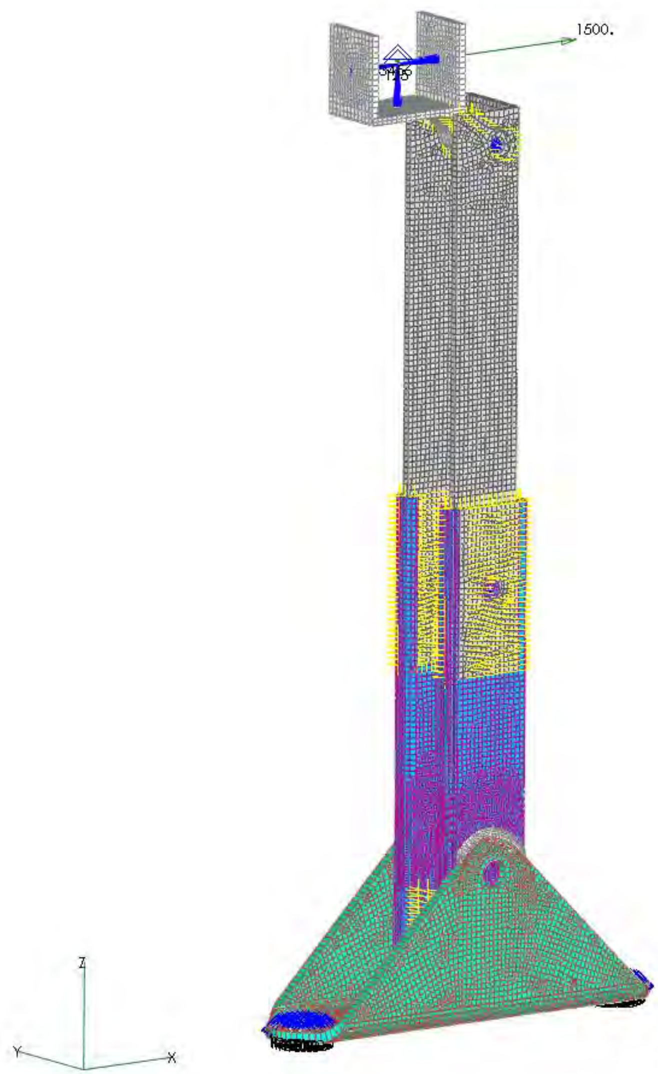
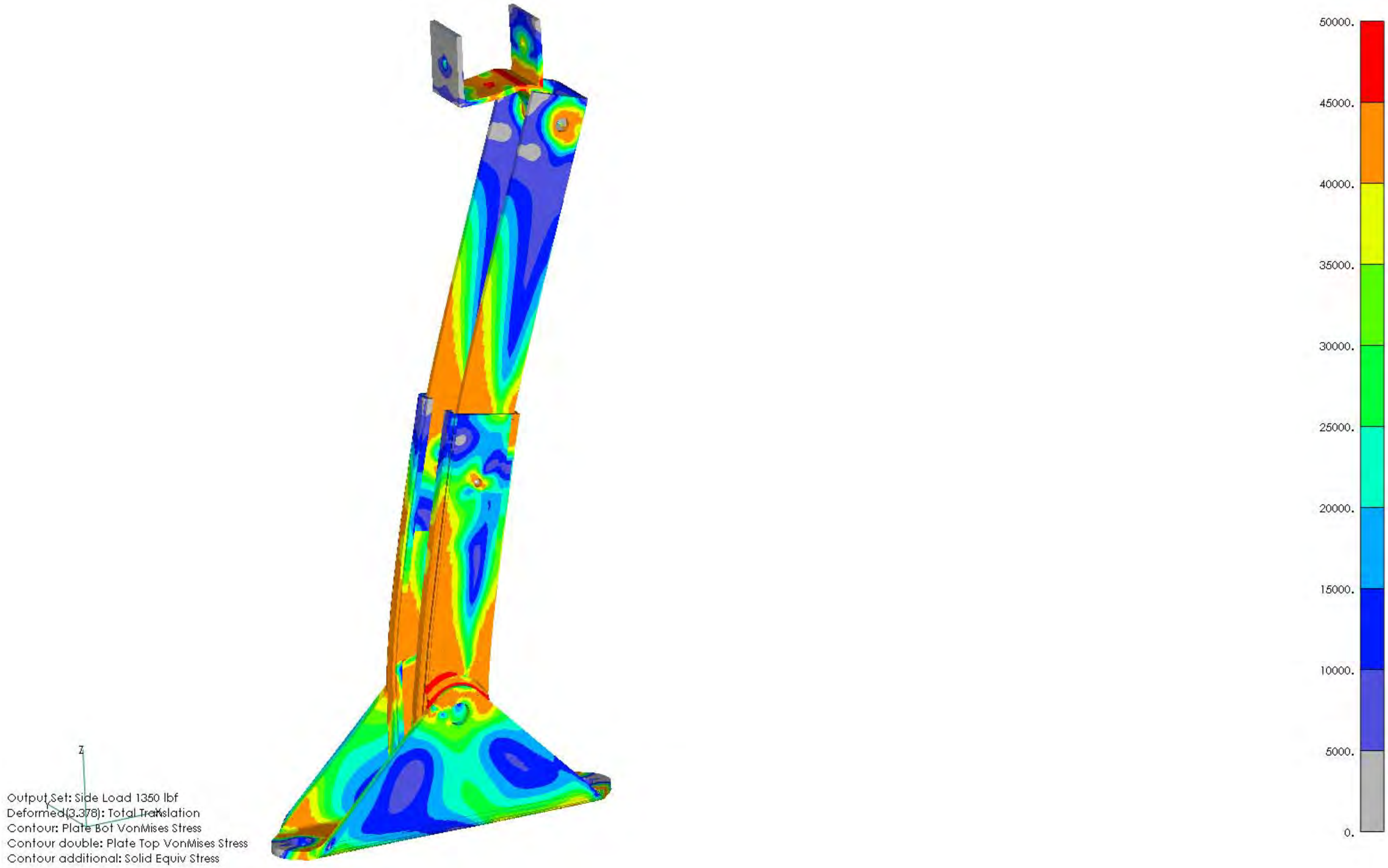
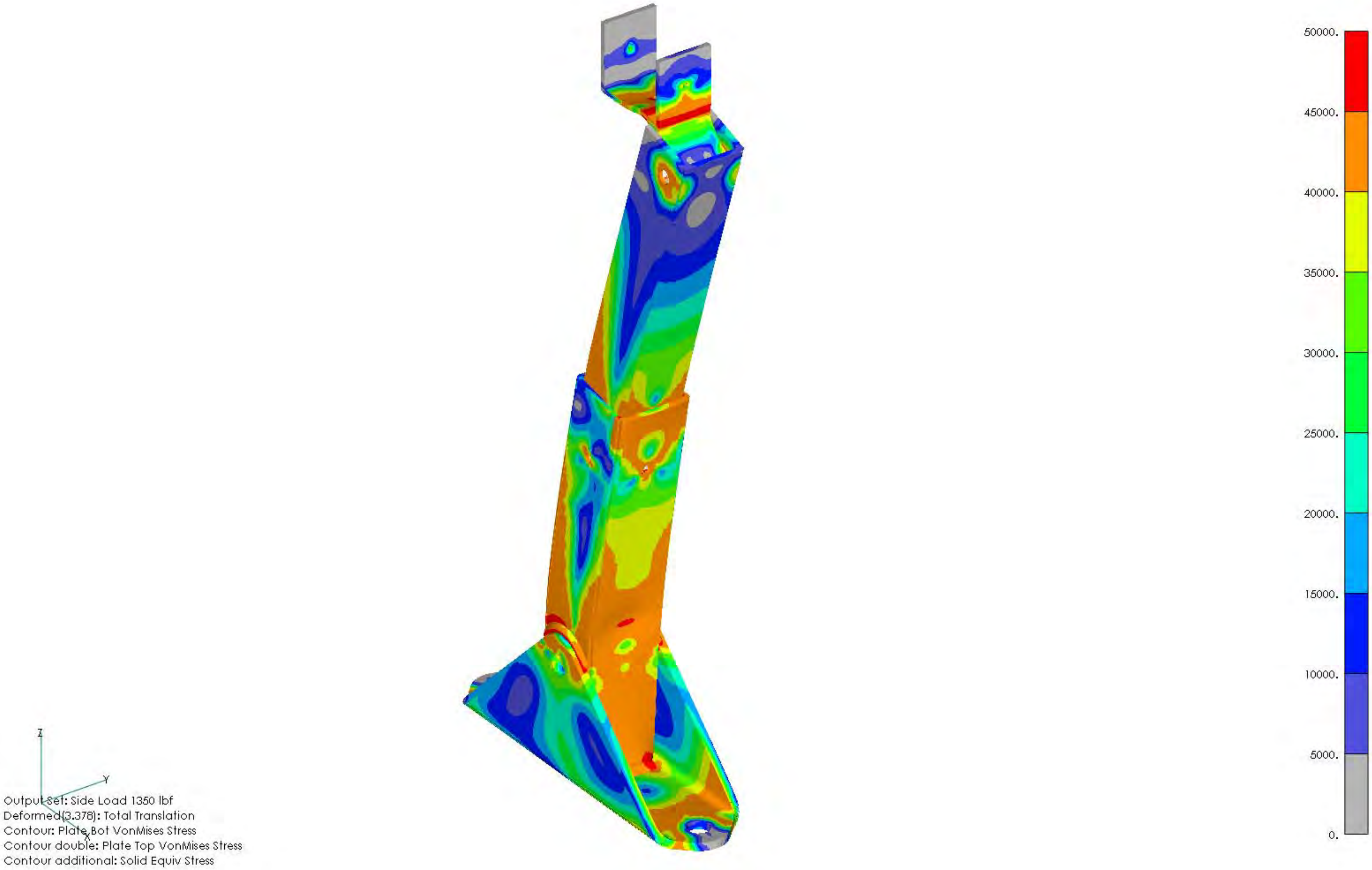


Plate elements were used for the alumium tubes. Solid elements were used to model the weldments and the upper aluminum extrusion segment. Gap elements (light yellow lines) were extensively used to simulate the contact behavior between the tubing. Beam elemets were used for the screws and bolt.

Front Leg Structure: Stress Results Under Maximum Side Load



The front leg can withstand a maximum side load of approximately 1350 lbf before failure is predicted by plastic collaspe. A more detailed analysis using the MARC V2003 solver predicts a plastic collapse at 1,500 lbf. This higher number is used since the MARC solver is more robust in its solution approach.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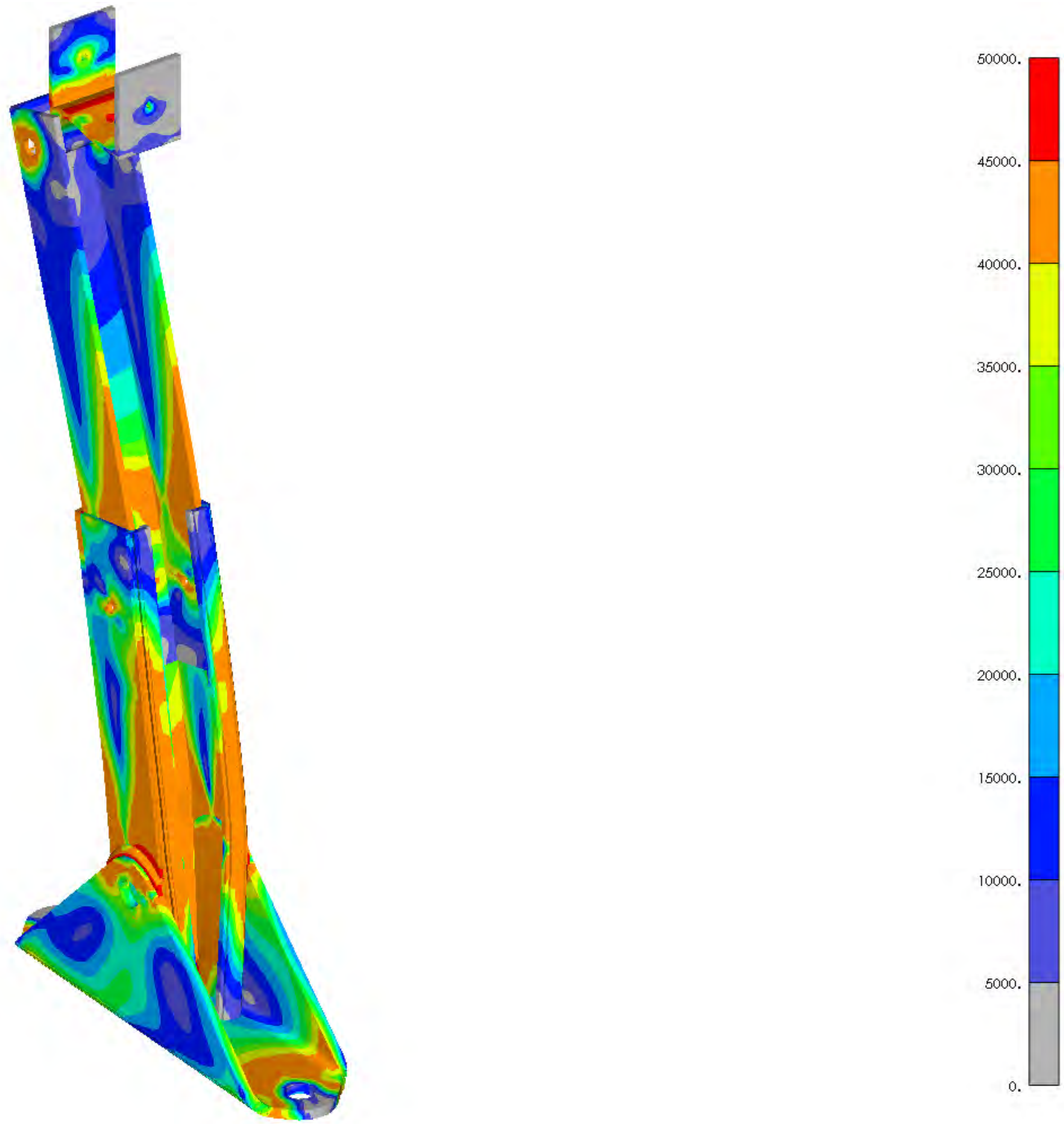
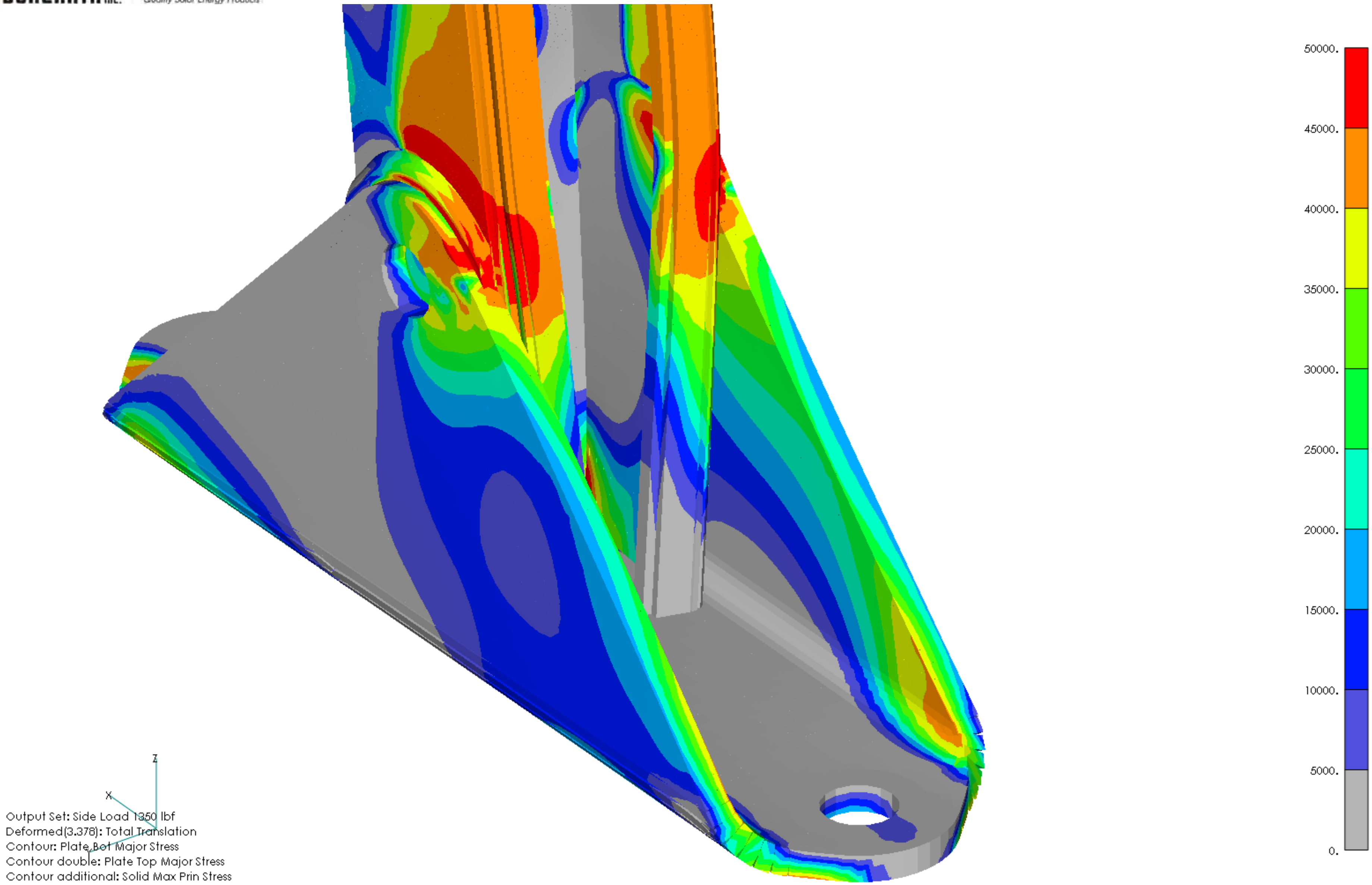
40000.
35000.
30000.
25000.
20000.
15000.
10000.
5000.
0.
Z
Y
X
Output Set: Side Load 1350 lbf
Deformed(3.378): Total Translation
Contour: Plate Bot VonMises Stress
Contour double: Plate Top VonMises Stress
Contour additional: Solid Equiv Stress



Output Set: Side Load 1350 lbf
Deformed(3.378): Total Translation
Contour: Plate Bot VonMises Stress
Contour double: Plate Top VonMises Stress
Contour additional: Solid Equiv Stress



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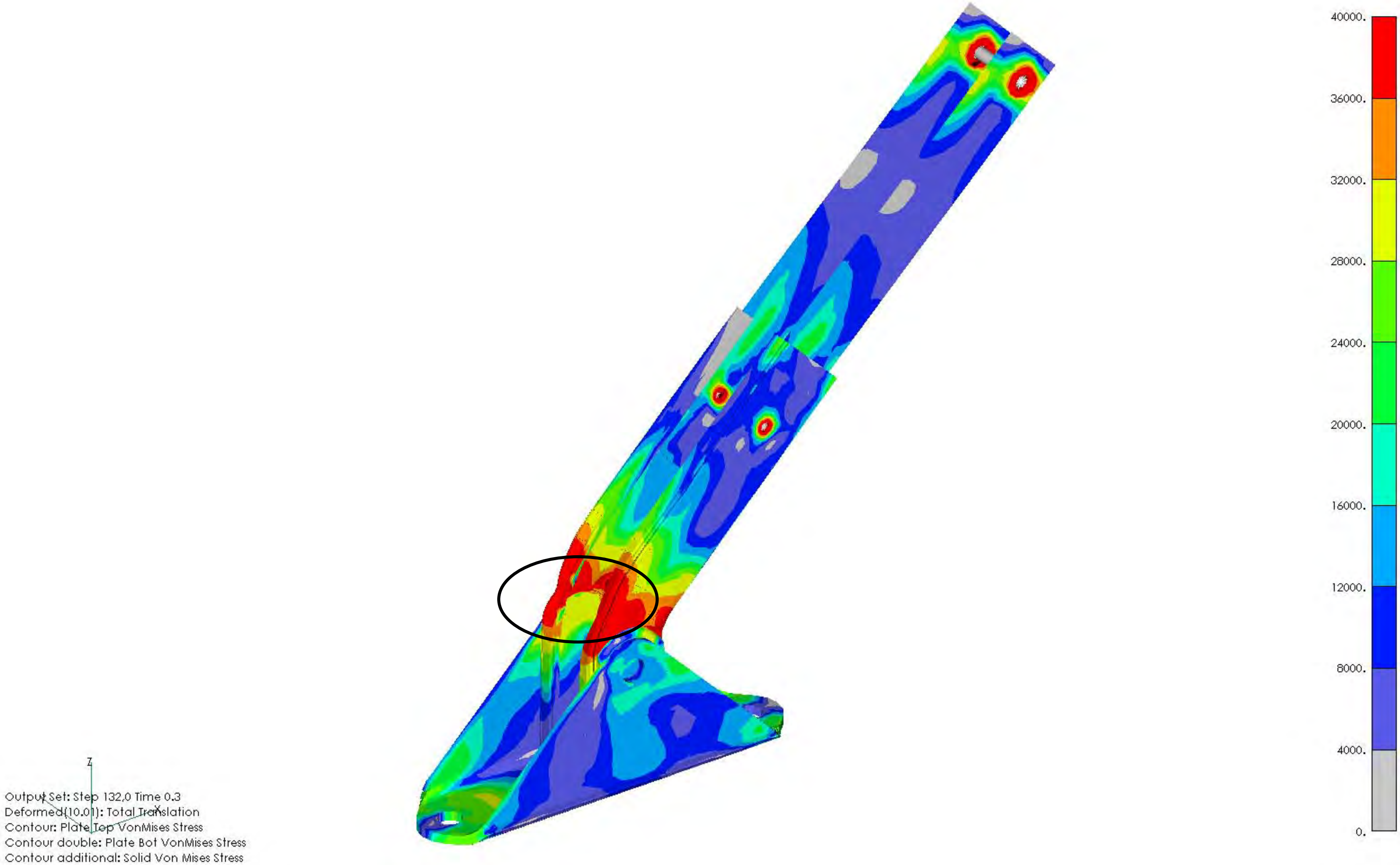
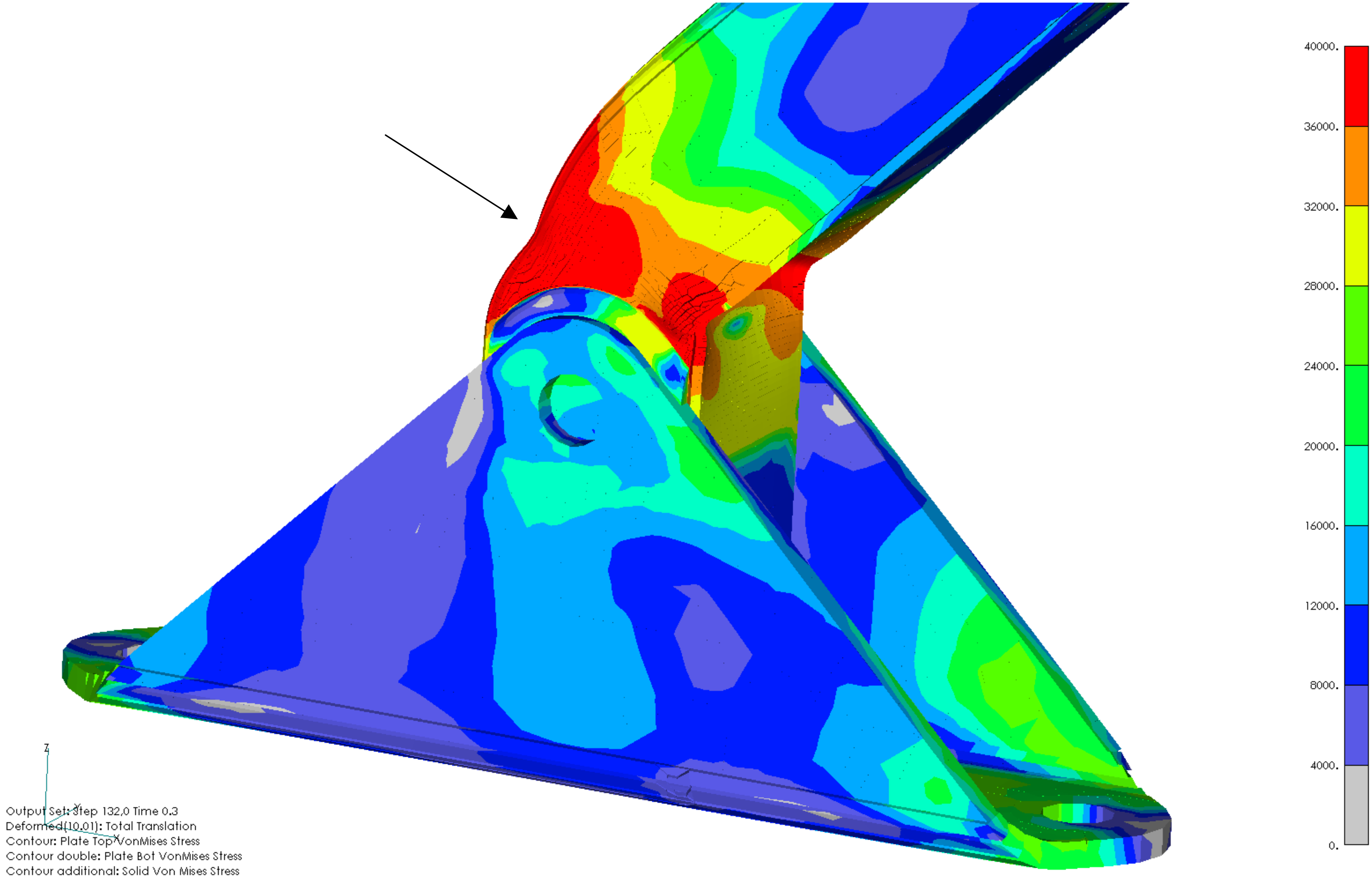
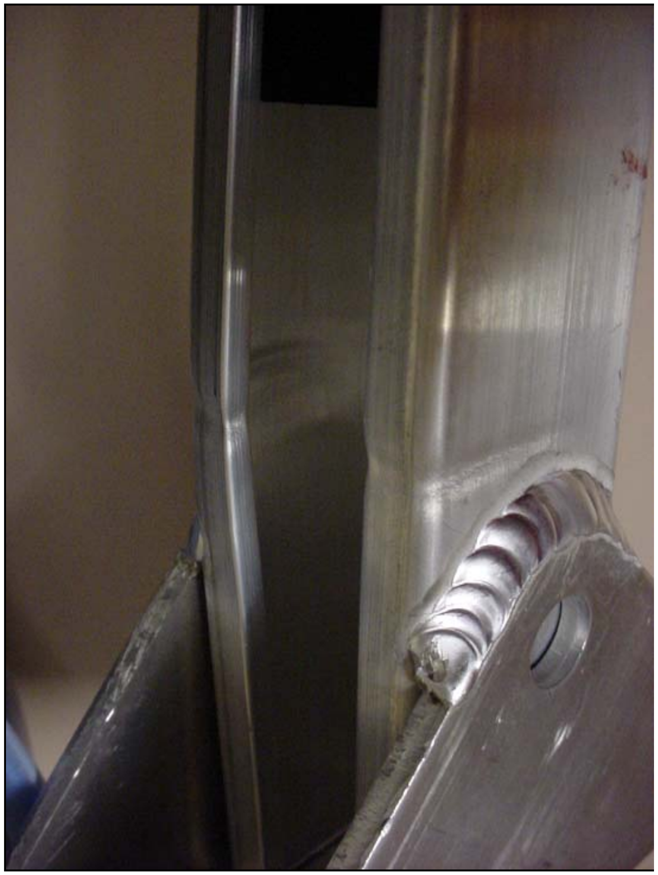
Plastic stresses far above the material's ultimate stress are estimated.

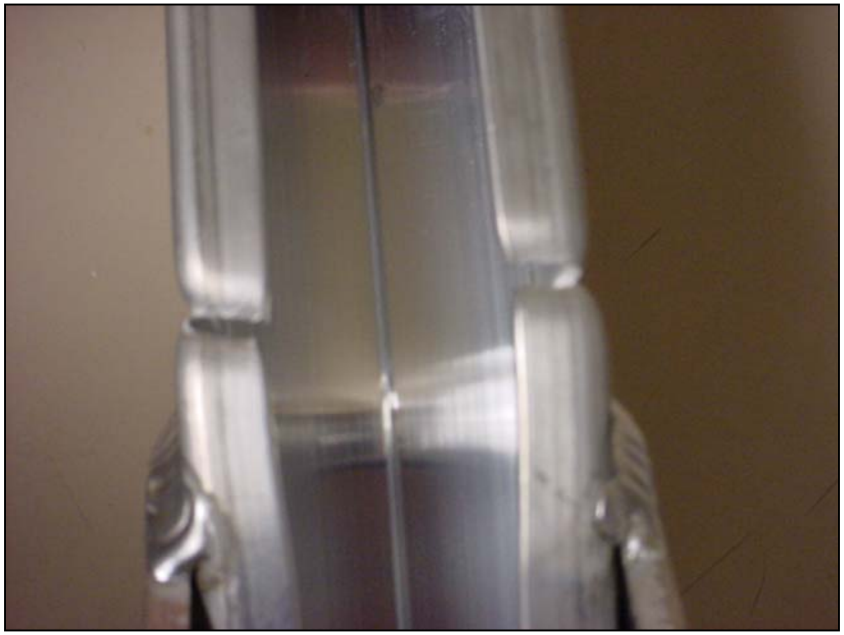


Leveraging the prior work, the model was modified slightly to run using MSC.Software's MARC V2003 solver. This solver is tailored to solver large-deformation problems. The above image shows the Front Leg structure under a 1,500 lbf load. Tearing of the lower aluminum extrusion is predicted in the circled regions. Ultimate failure of the structure is therefore predicted around the 1,500 lbf load range.

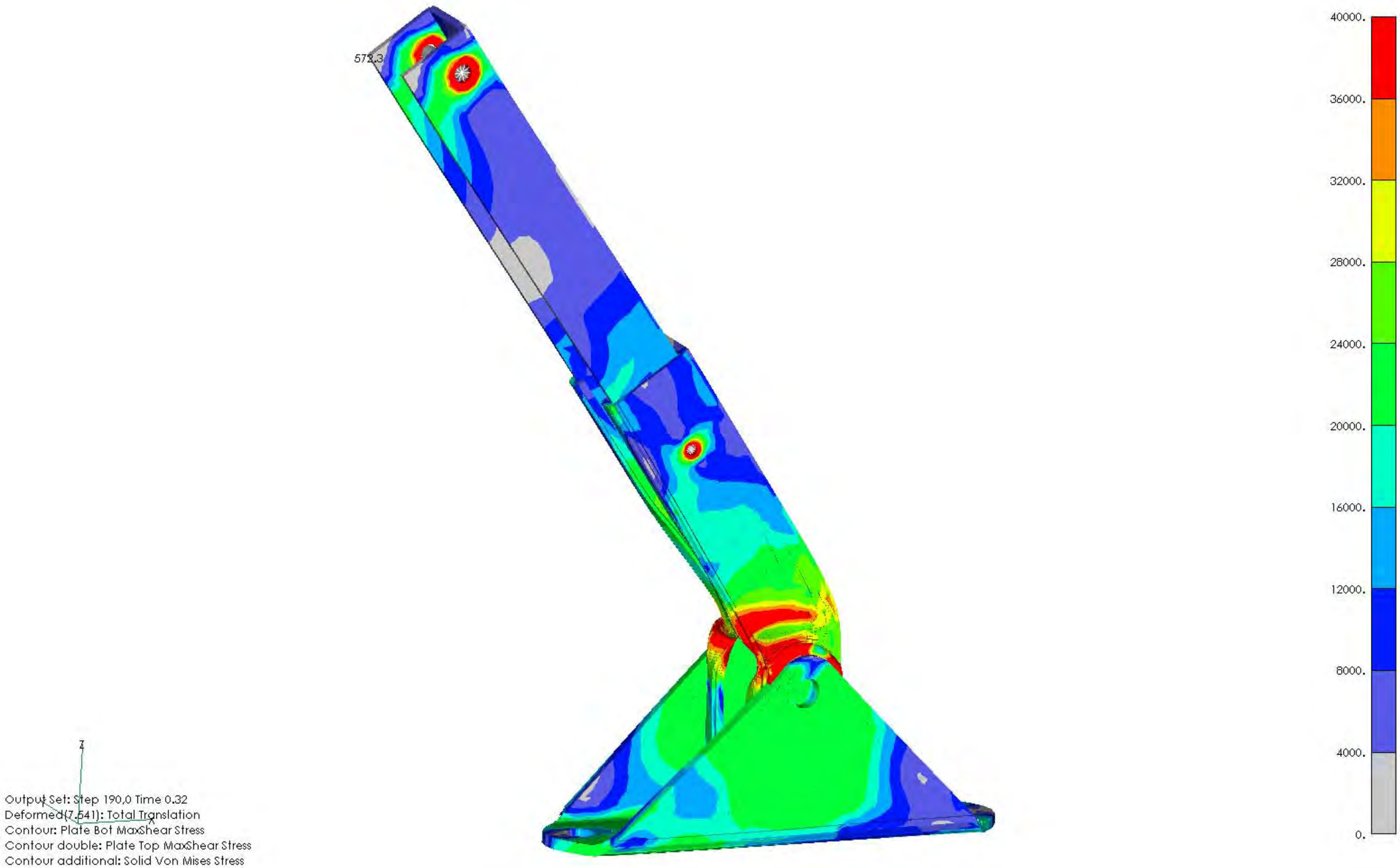


A close-up view of the MARC V2003 large-deformation plasticity analysis. Tearing would be predicted at the above indicated point.

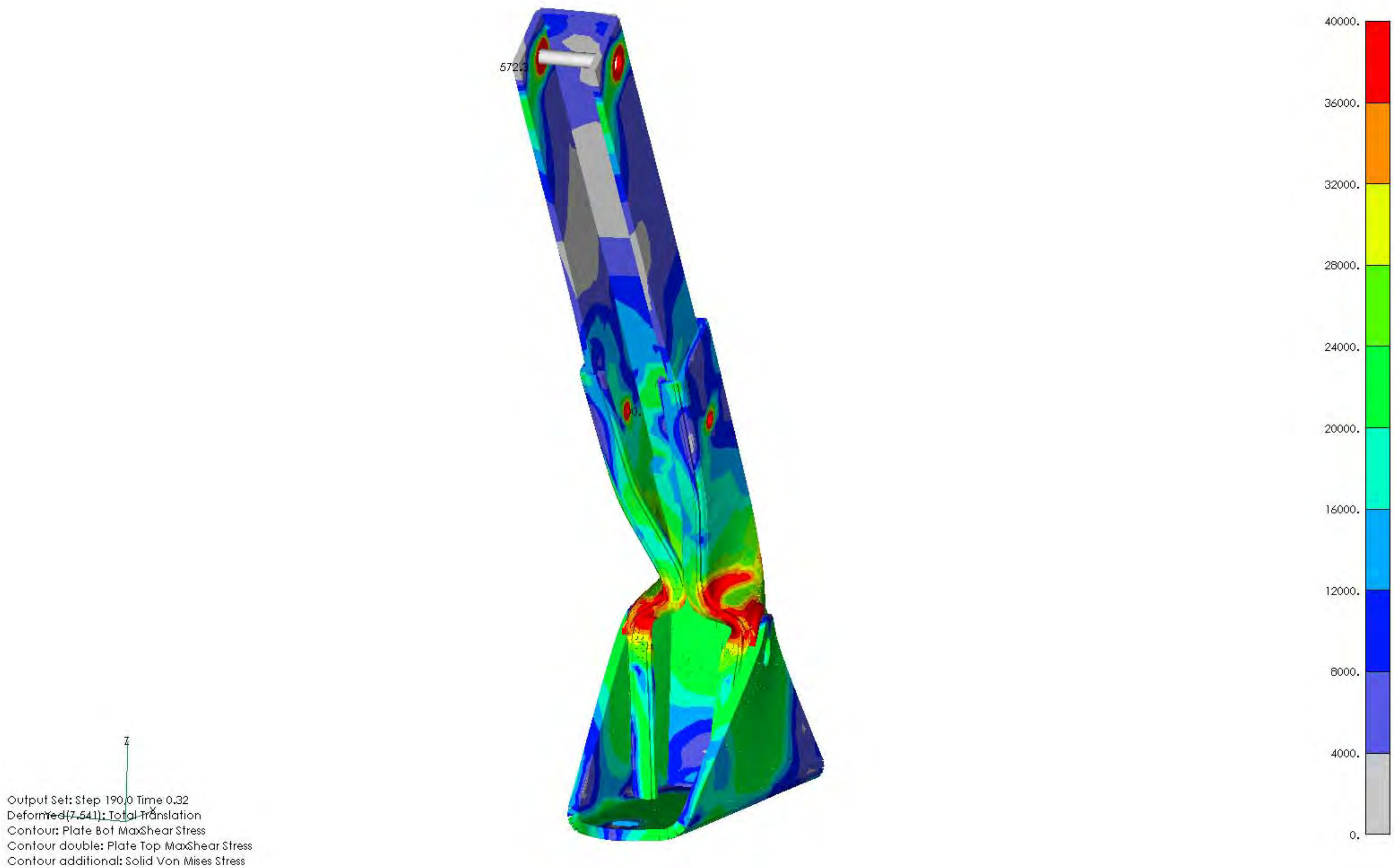




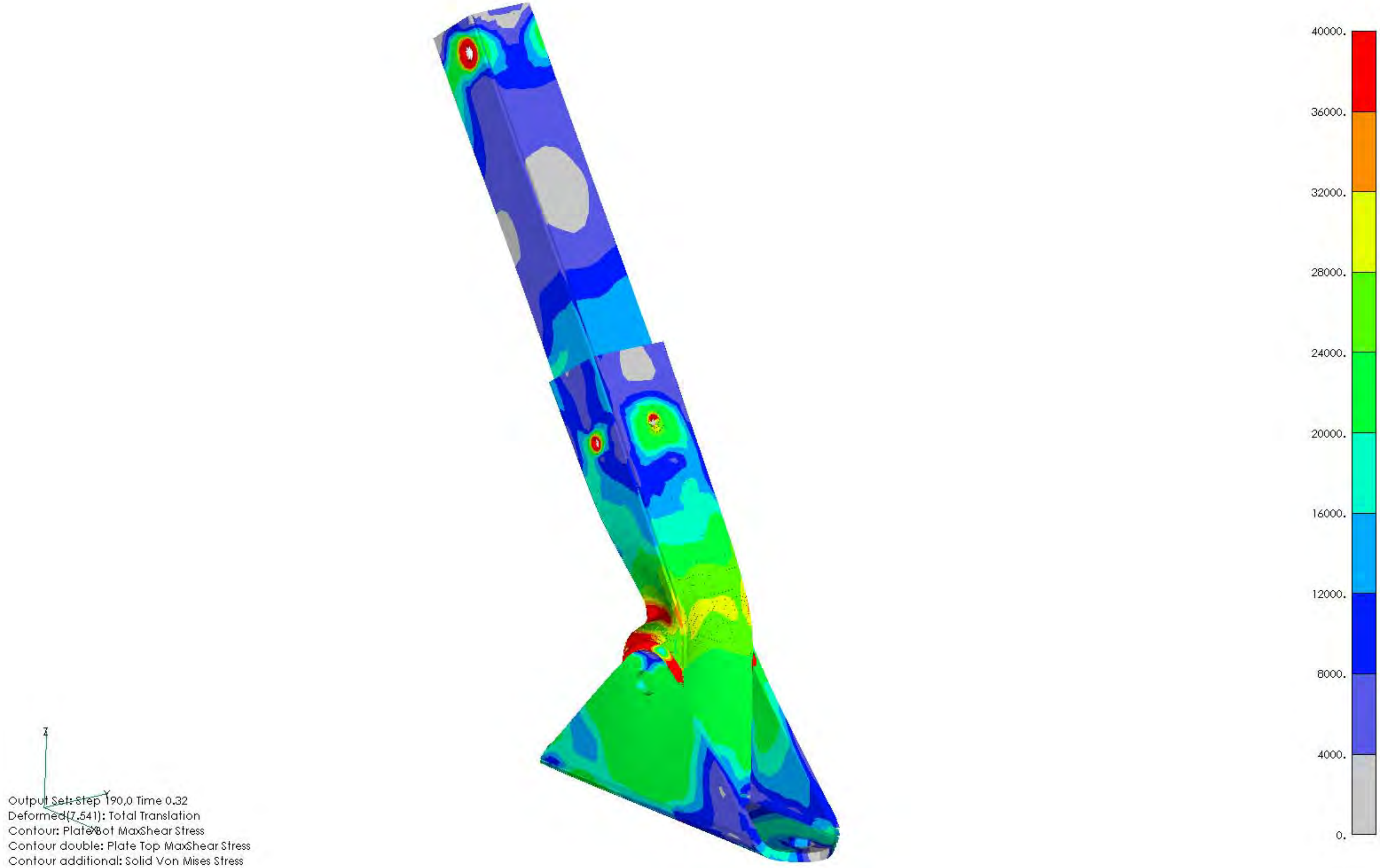
Experimental verification of the tearing mechanisms in the Front Leg structure. The failure mechanism matches the FEA results.



In the opposite direction, the same failure load prediction was calculated. At around 1,500 lbf, the structure will plastically collapse.



The Front Leg structure buckles above the lower bracket welded region.


Output Set: Step 190,0 Time 0.32
Deformed(7.541): Total Translation
Contour: Plate Bot MaxShear Stress
Contour double: Plate Top MaxShear Stress
Contour additional: Solid Von Mises Stress
40000.
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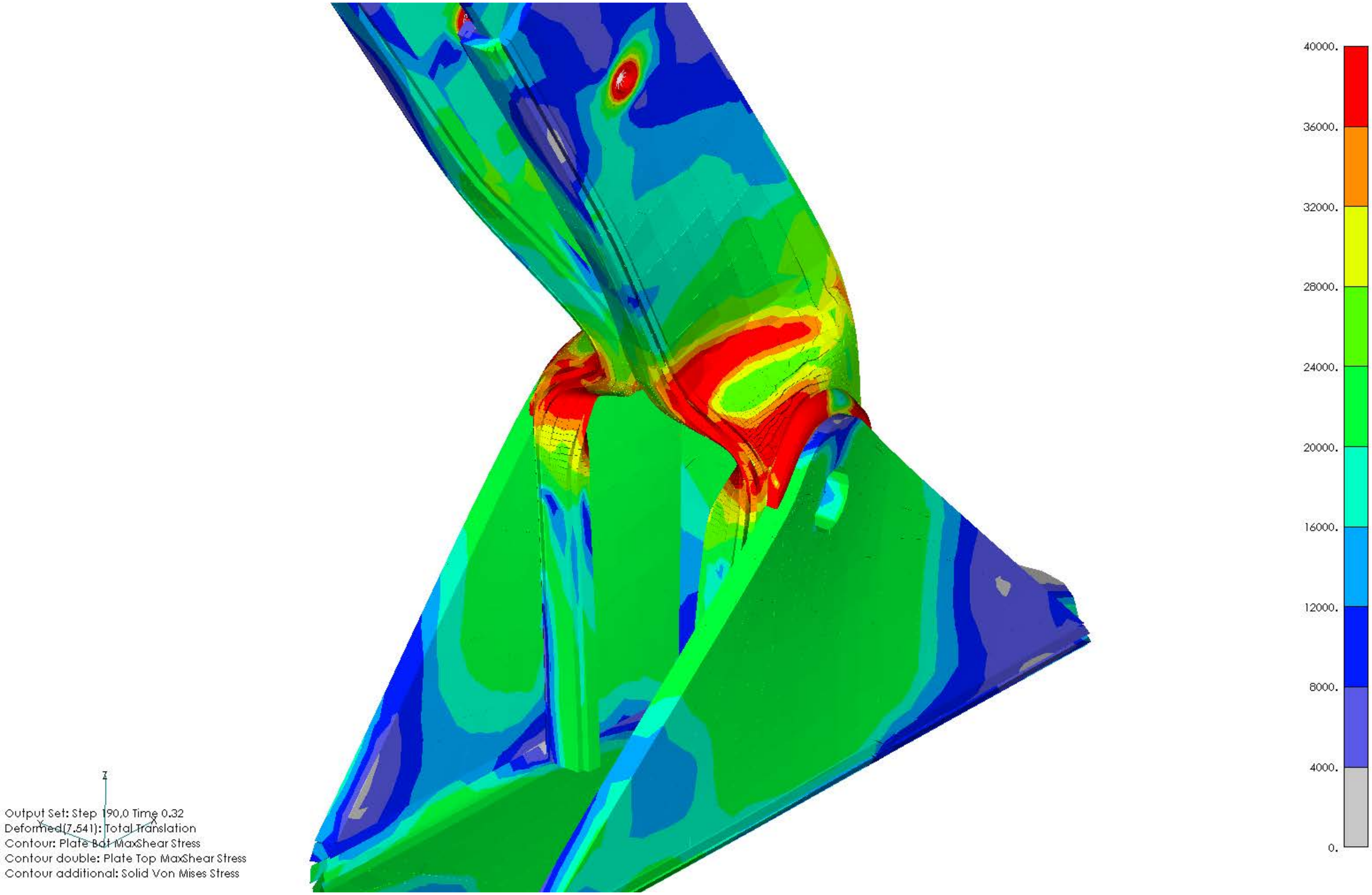
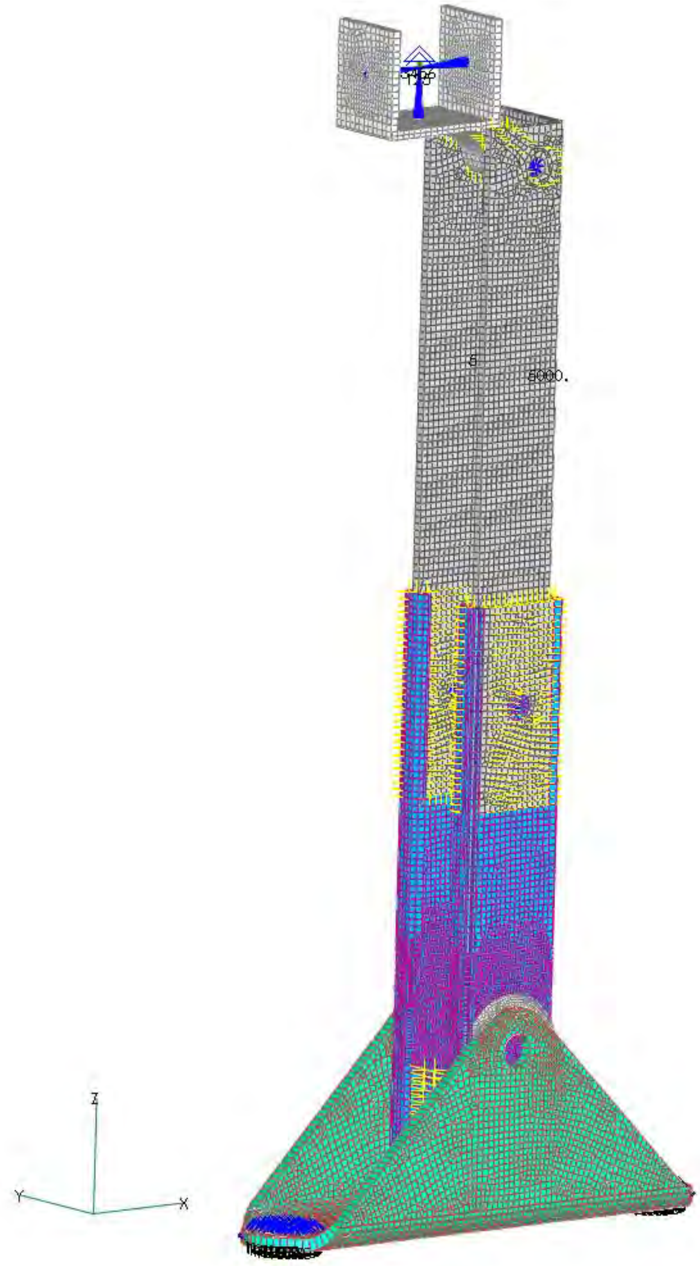
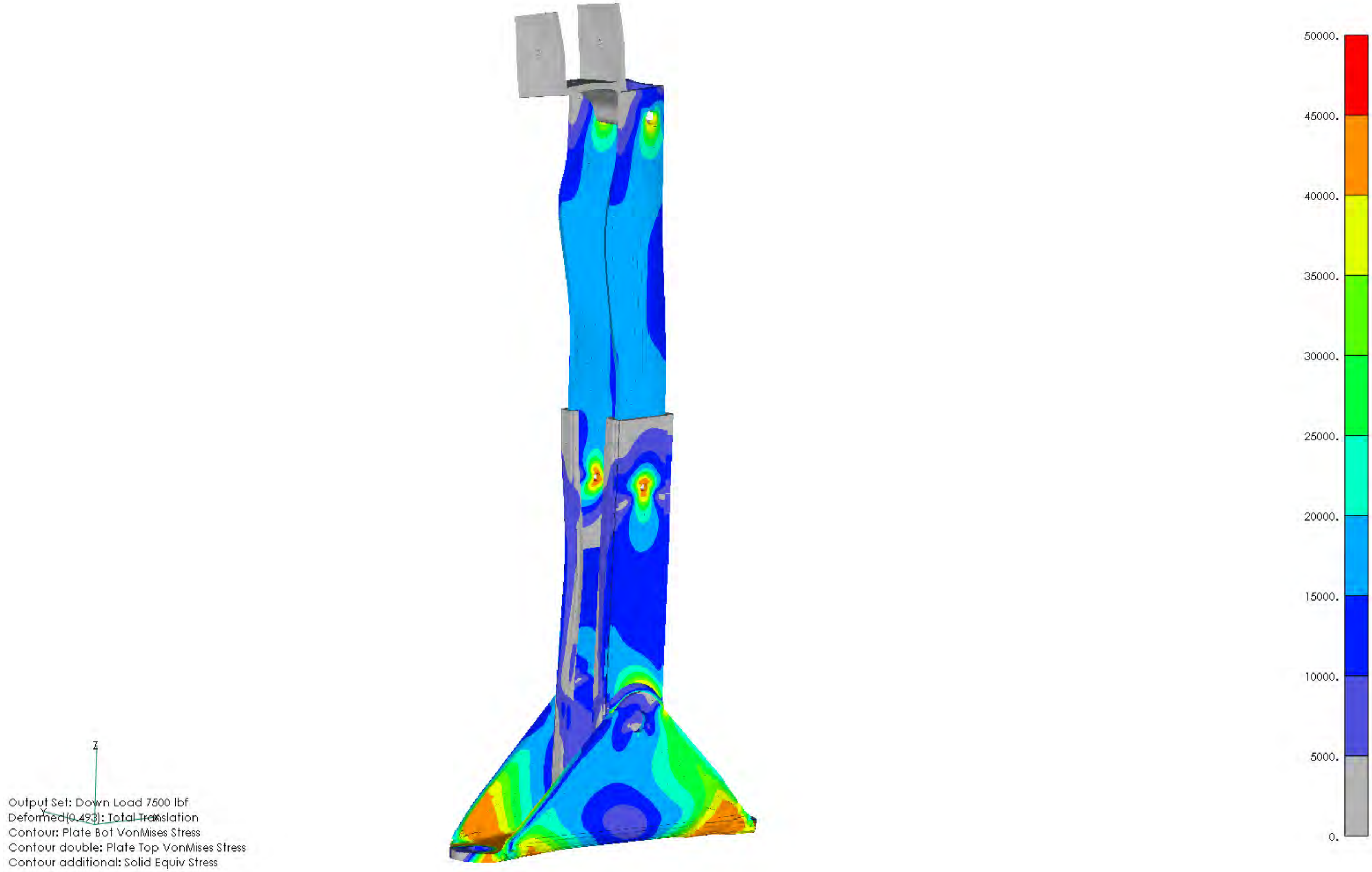


Close-up view of buckled region.

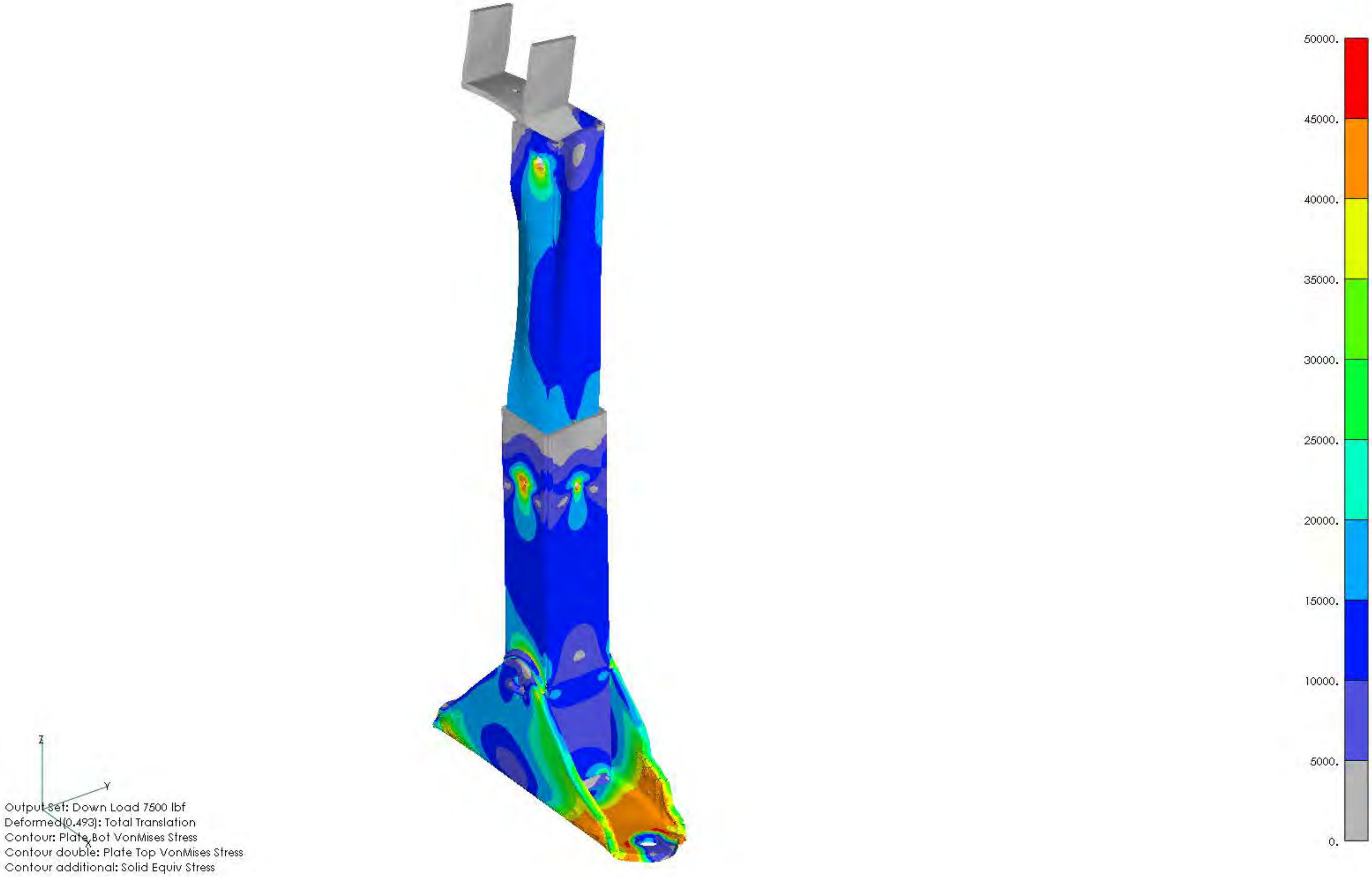
Front Leg Structure: Stress Results for Maximum Compression Load



The compression load was applied down the axes of the front leg through the bolt.



The front leg collaspes under a compression load of 7500 lbf. This is an elastic buckling behavior since very little plastic damage has occurred to the structure.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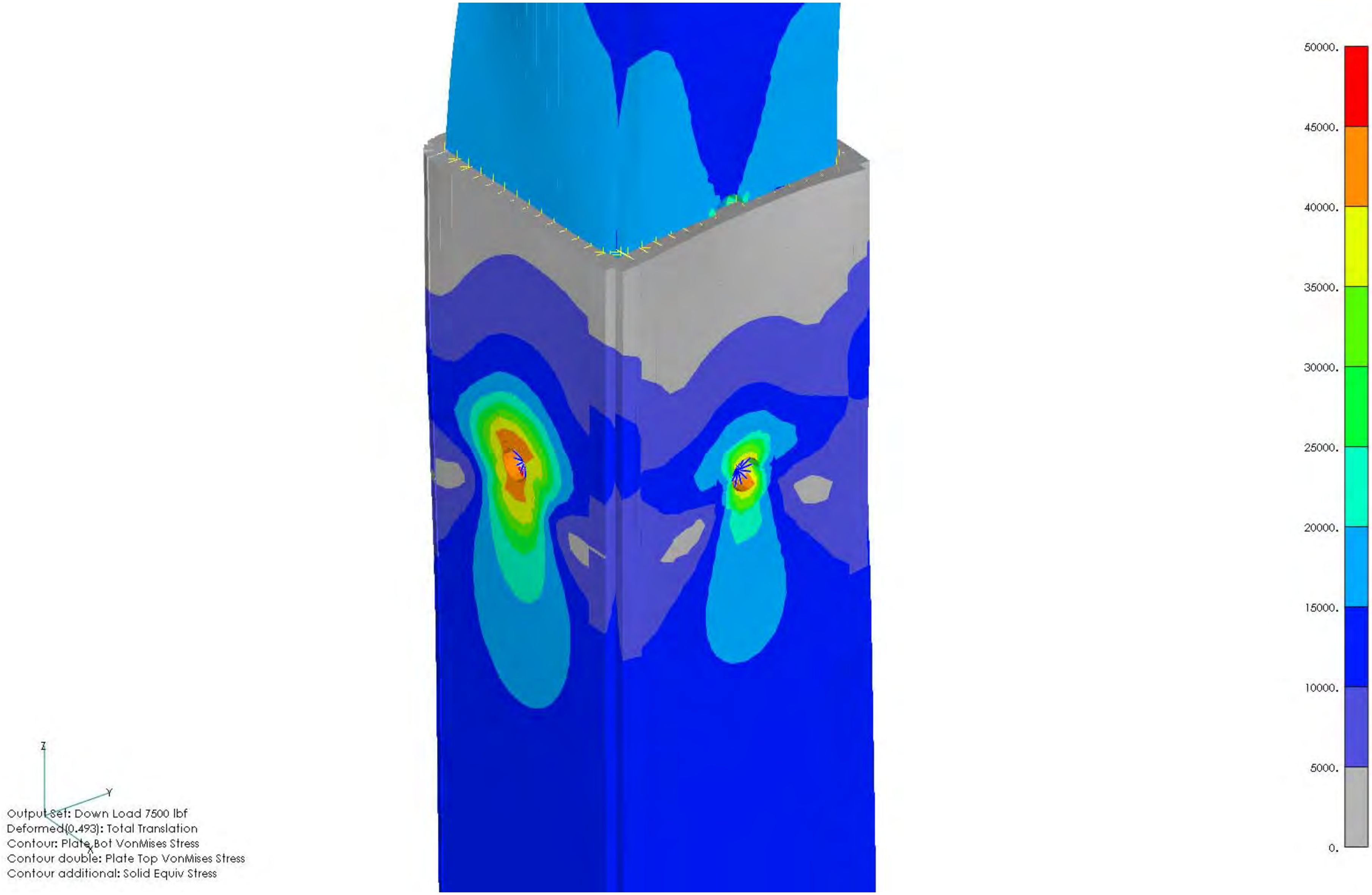
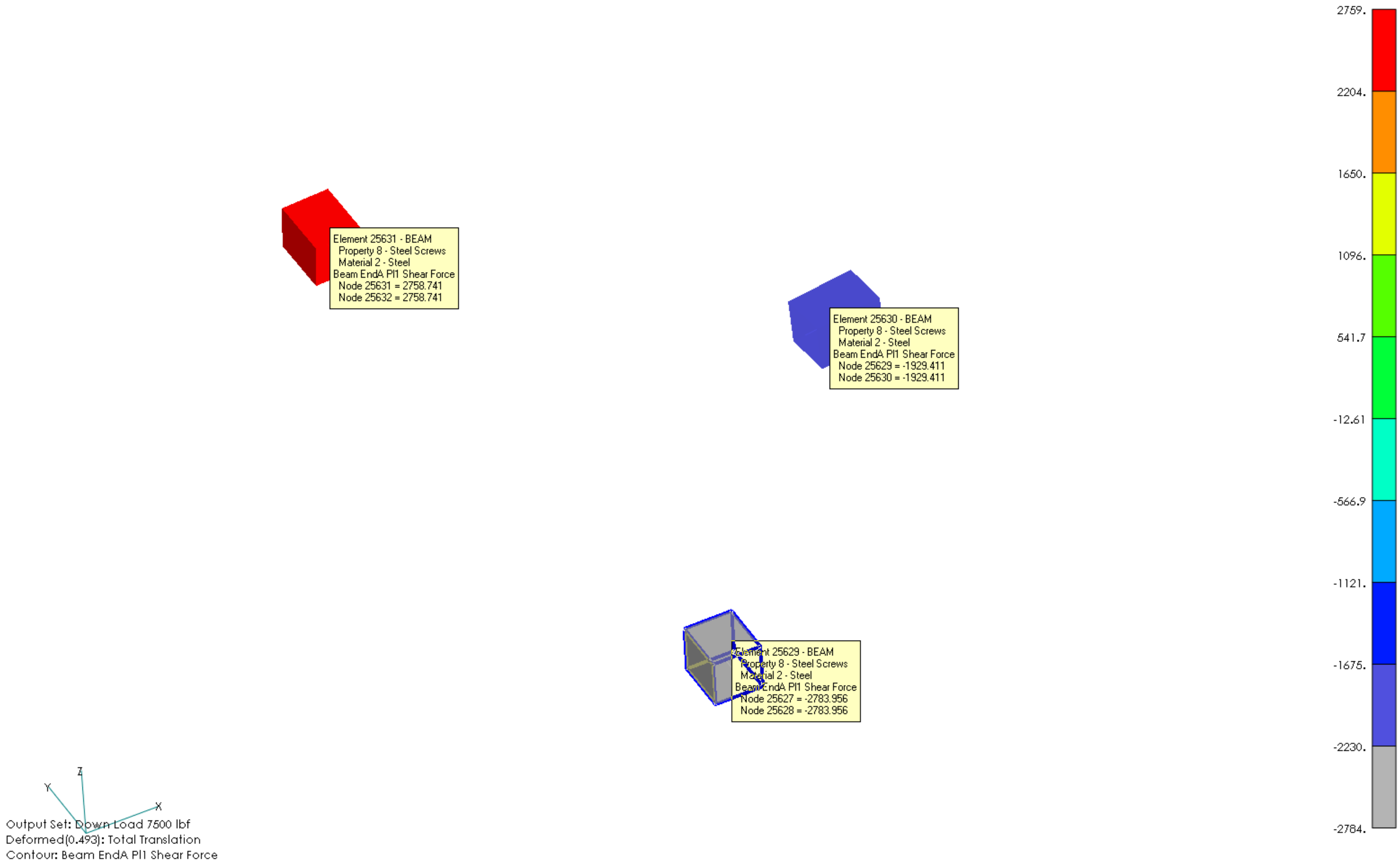
15000.
10000.
5000.
0.
Z
Y
X
Output Set: Down Load 7500 lbf
Deformed(0.493): Total Translation
Contour: Plate Bot VonMises Stress
Contour double: Plate Top VonMises Stress
Contour additional: Solid Equiv Stress



The #10 screws do not cause tearing of the aluminum tube structure under the compression load.



The #10 SS screws bear a shearing force of 2800 lbf on the side and 1900 lbf on the center screw. Assuming a nominal screw diameter of 0.19 inch and a shear failure stress of 69,000 psi (see Appendix), the maximum load shear load for each screw is 1,900 lbf. Consequently, under this compression load, the screws are not sufficiently sized.

Rear Leg Structure: Geometry and Mesh Details

Geometry of the long leg structure. All three models had a similar geometric basis.

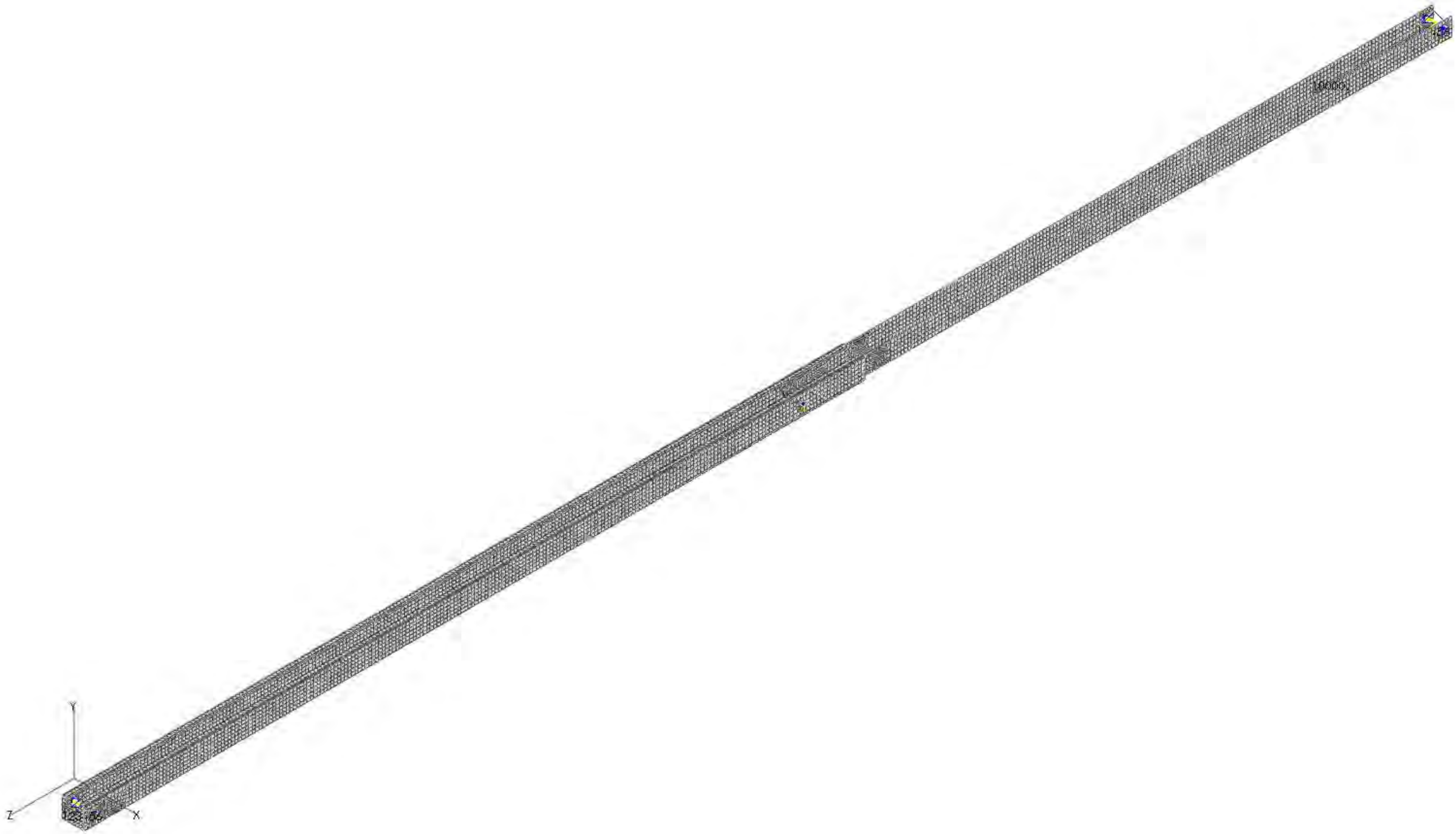
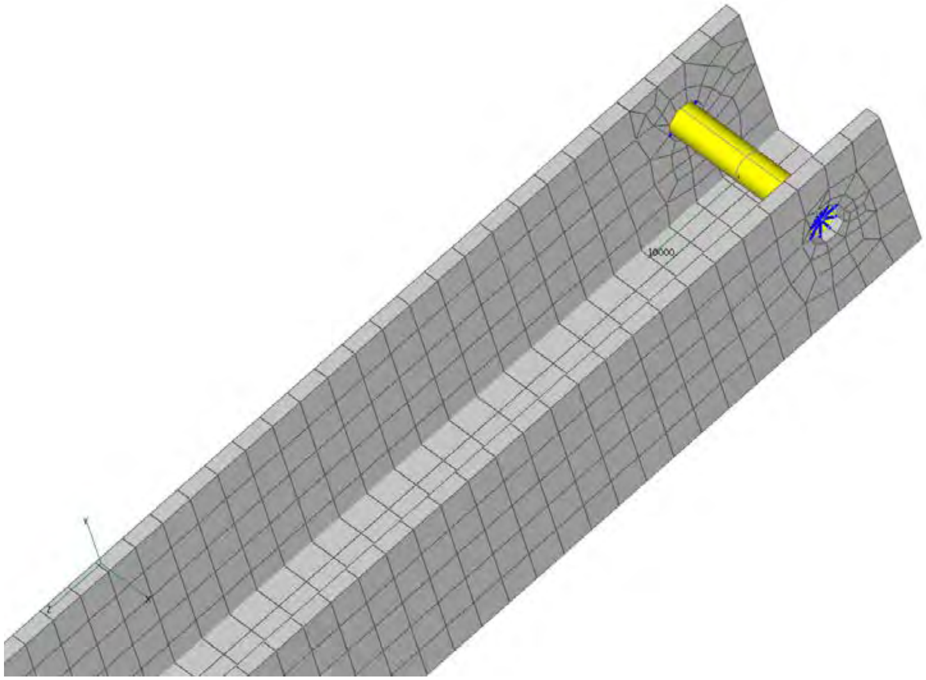
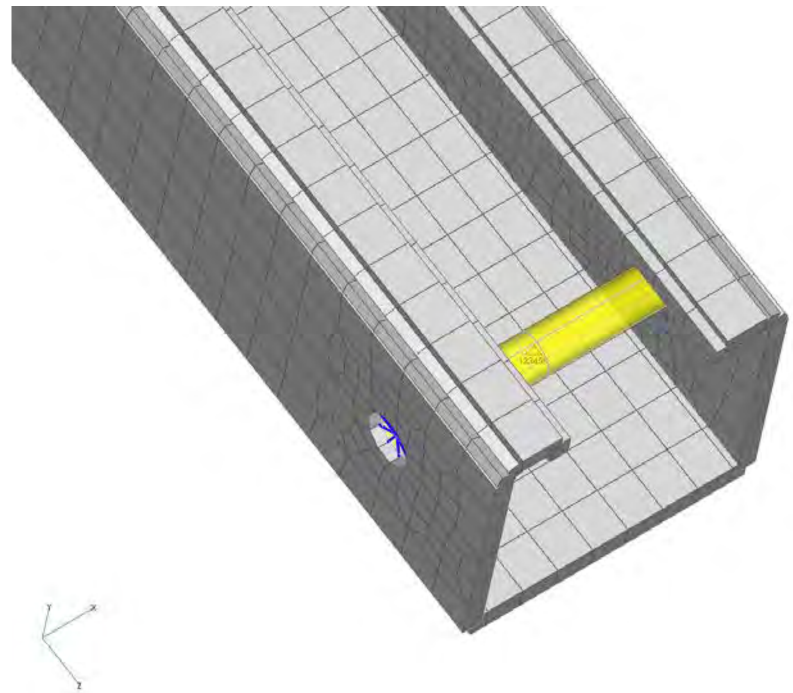
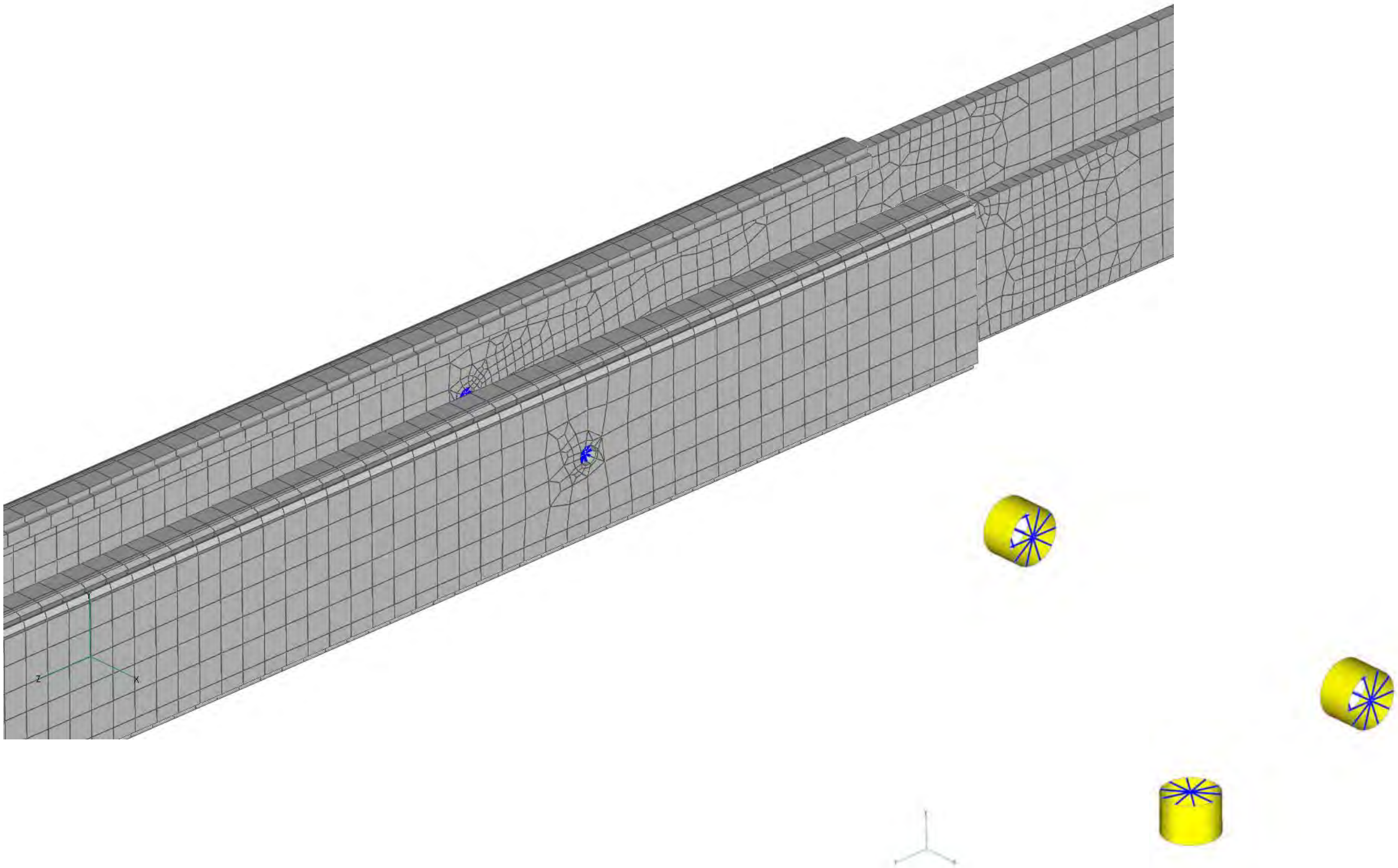


Plate elements were used for the aluminum tubes. Beam elements were used for the bolts. All three models were constructed in a similar fashion.

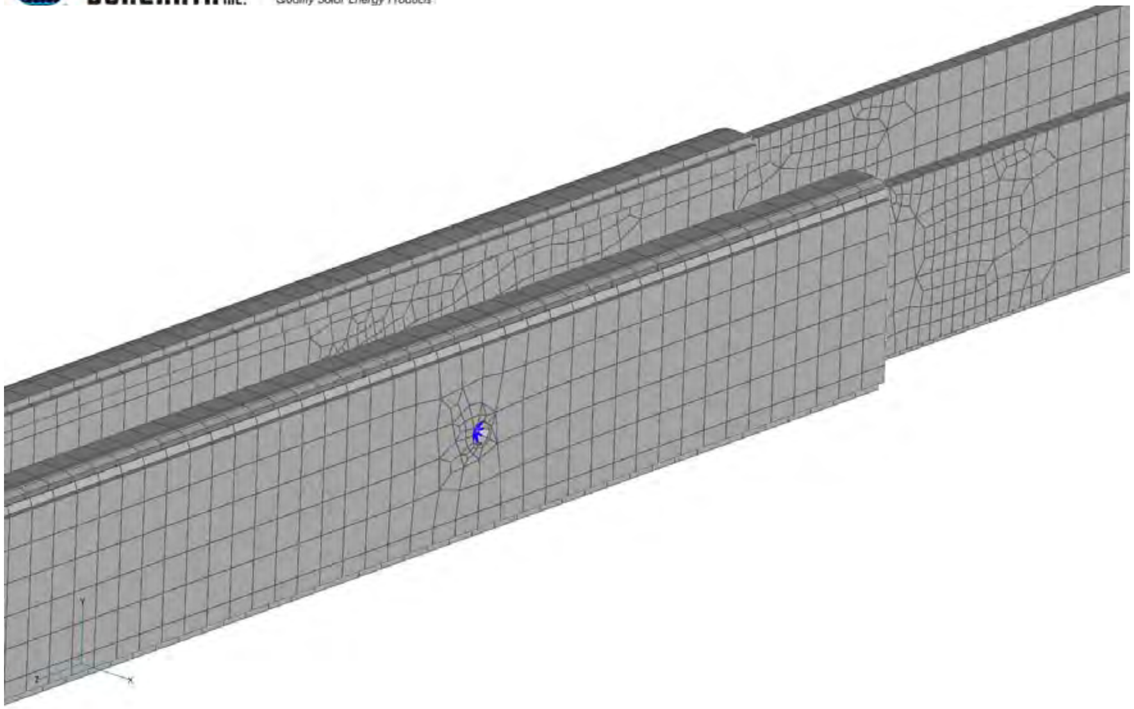


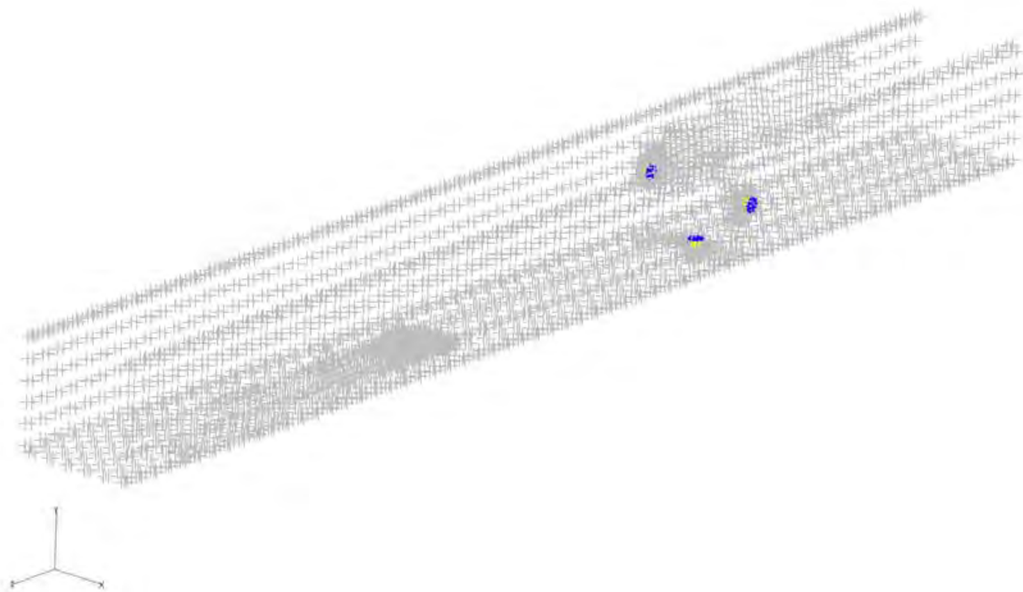


The column load was applied through a beam element and applied down the center of the column. The column was restrained at a bolt (beam element) through the bottom connection.

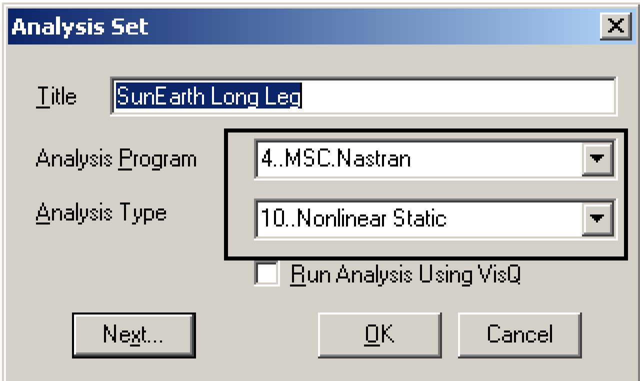


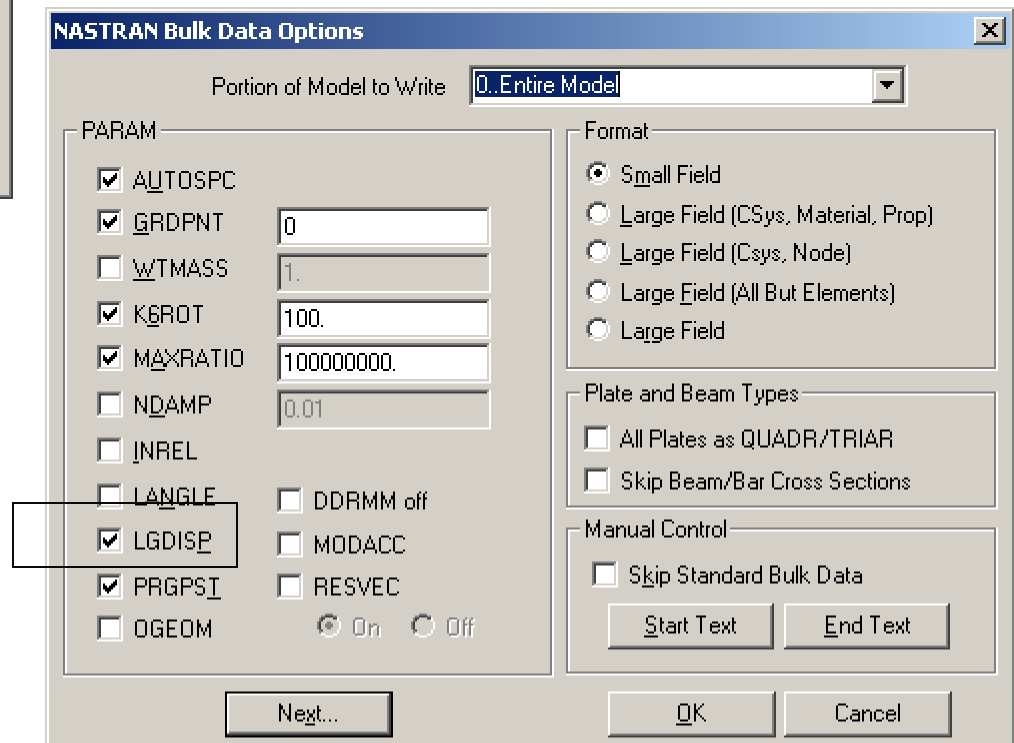
The #10 SS screws were modeled using beam elements. These elements were then connected to the plate elements via rigid links.





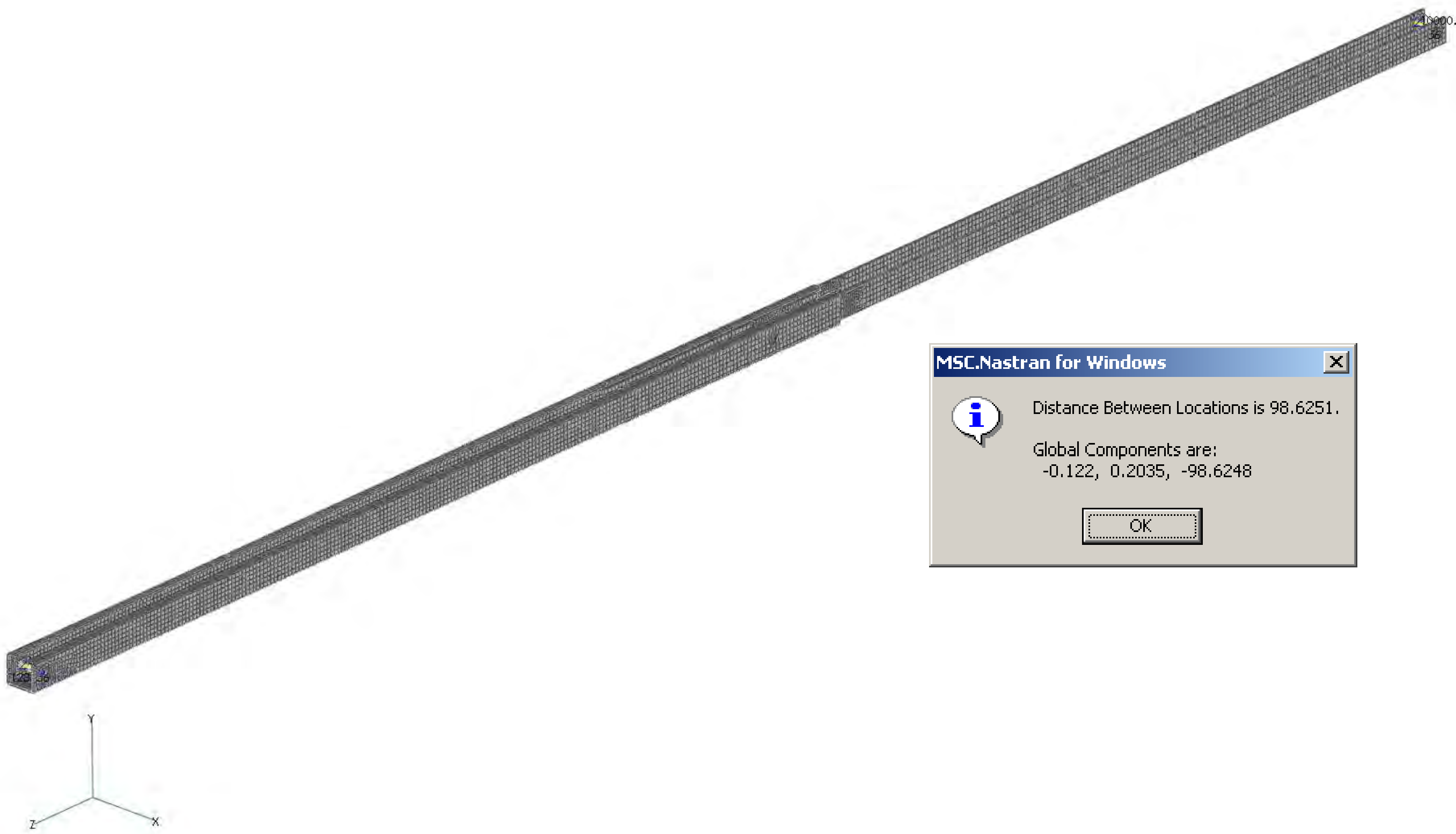
Gap elements (shown above as the gray lines) were used to enforce contact between the lower and upper aluminum tubes.



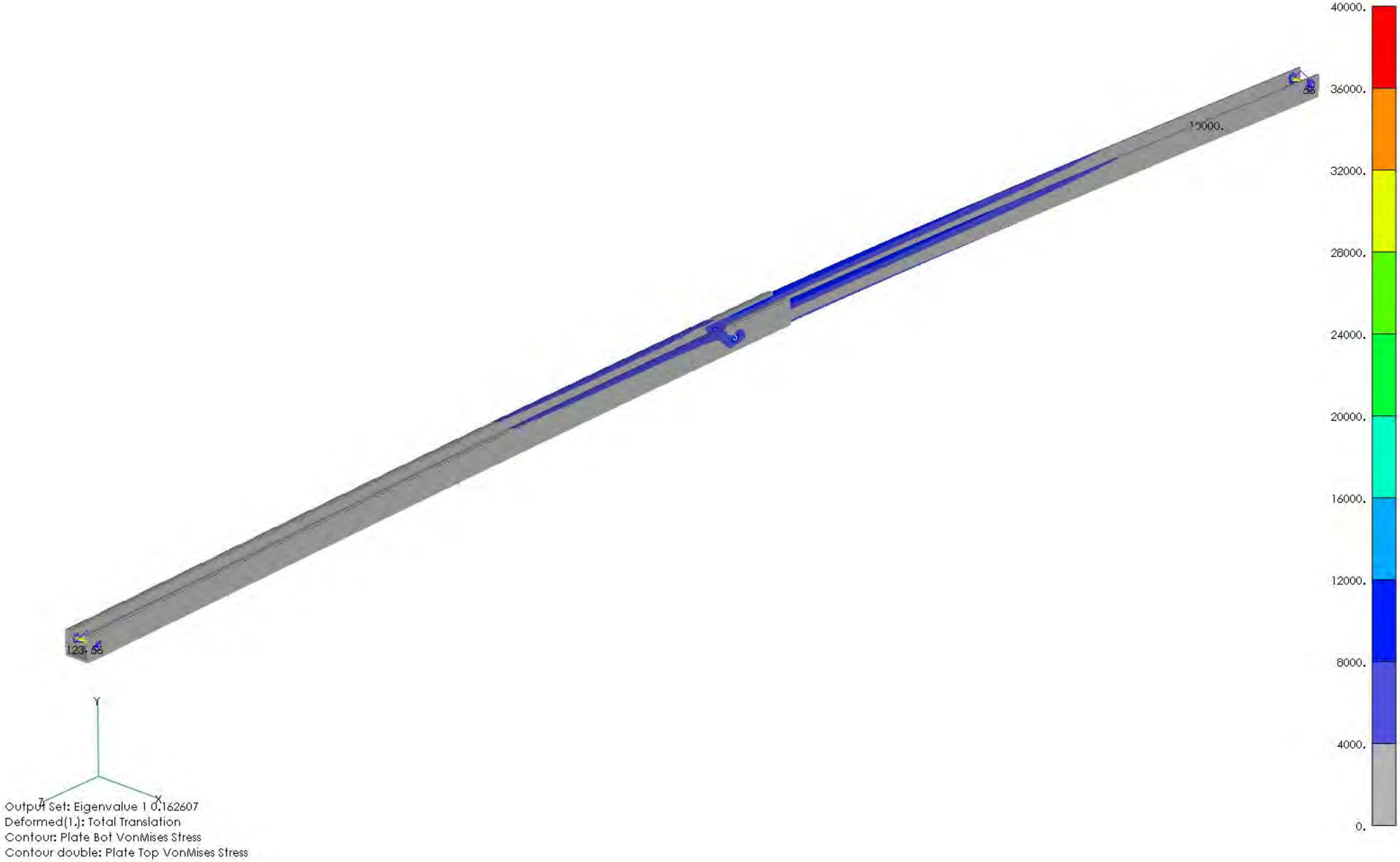


Documentation of analysis procedure used in the three simulations. The nonlinear, large displacement option was enforced.

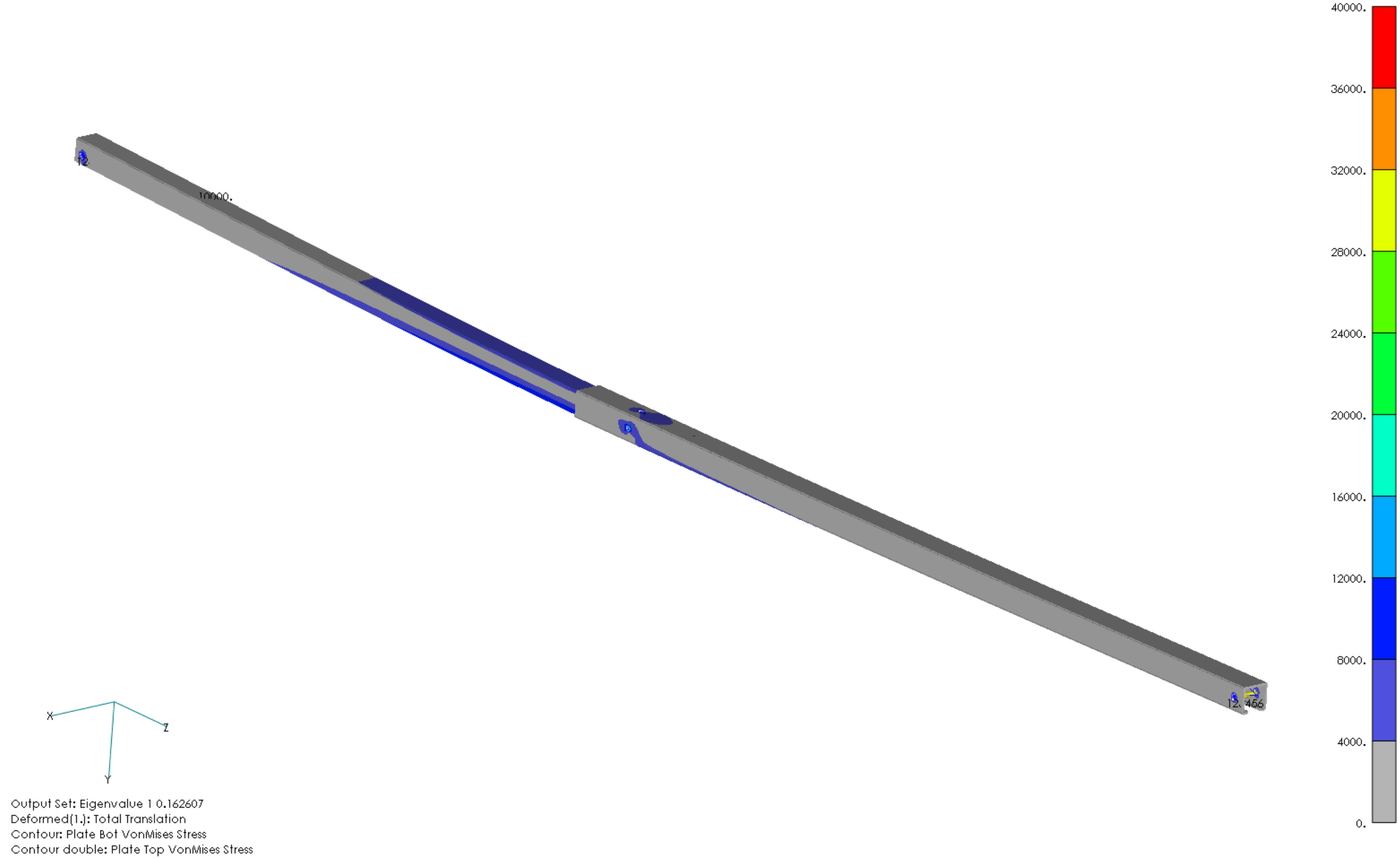
Rear Leg Structure: 98.6 inch Length Buckling Results



The long leg had a length from bolt-to-bolt of 98.6 inches.



Long leg FEA model. The buckling load is 0.162*10,000 lbf = 1,620 lbf.


40000.
36000.
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10000.
X
Y
Z
Output Set: Eigenvalue 1 0.162607
Deformed(1.): Total Translation
Contour: Plate Bot VonMises Stress
Contour double: Plate Top VonMises Stress

$$I_C := 0.198 \cdot in^4$$

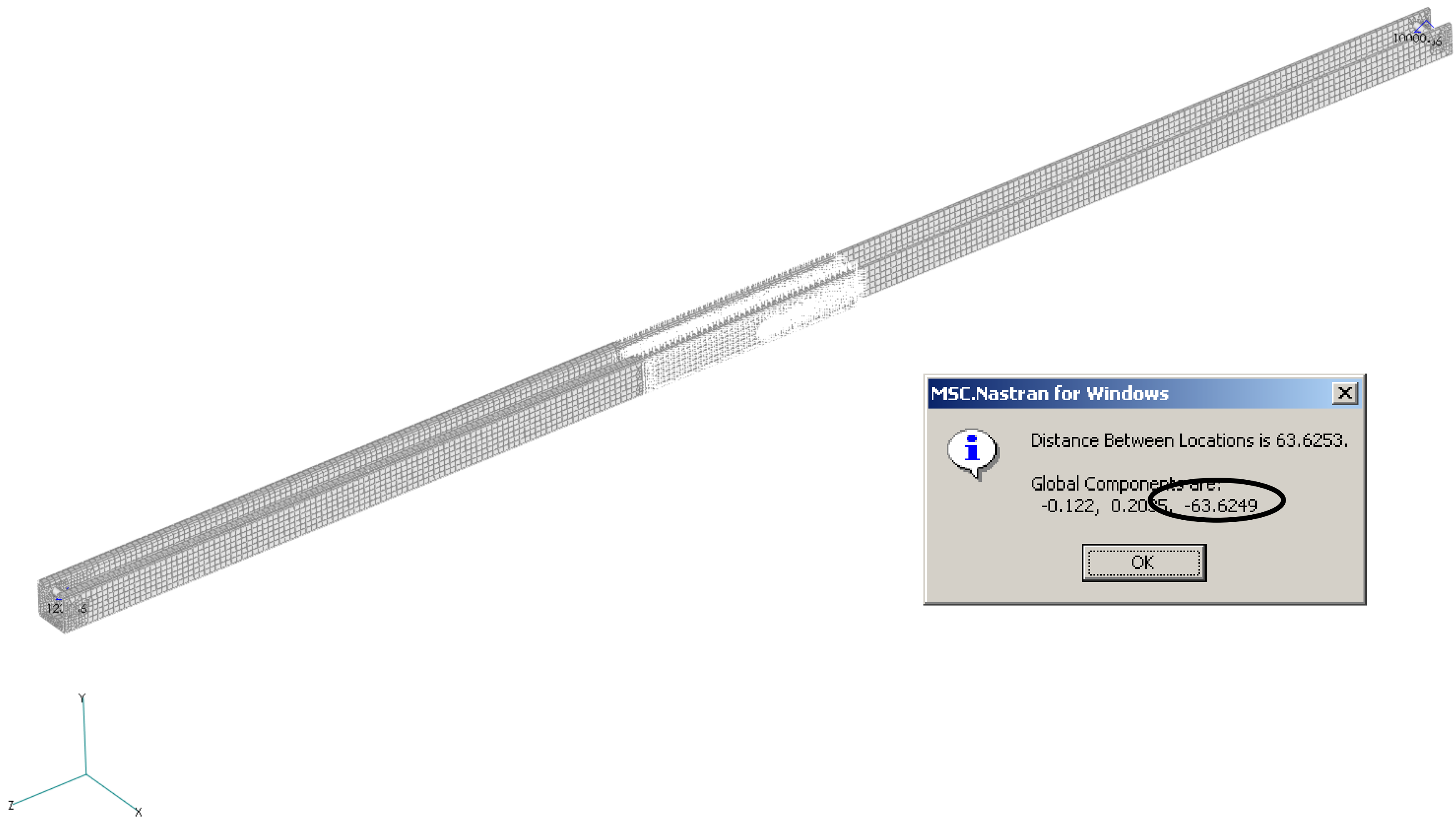
$$Length_{Column} := 98.6 \cdot in$$

$$P_{Cr} := \frac{\left(\pi^2 \cdot Elastic_{Modulus} \cdot I_C\right)}{{Length_{Column}}^2}$$

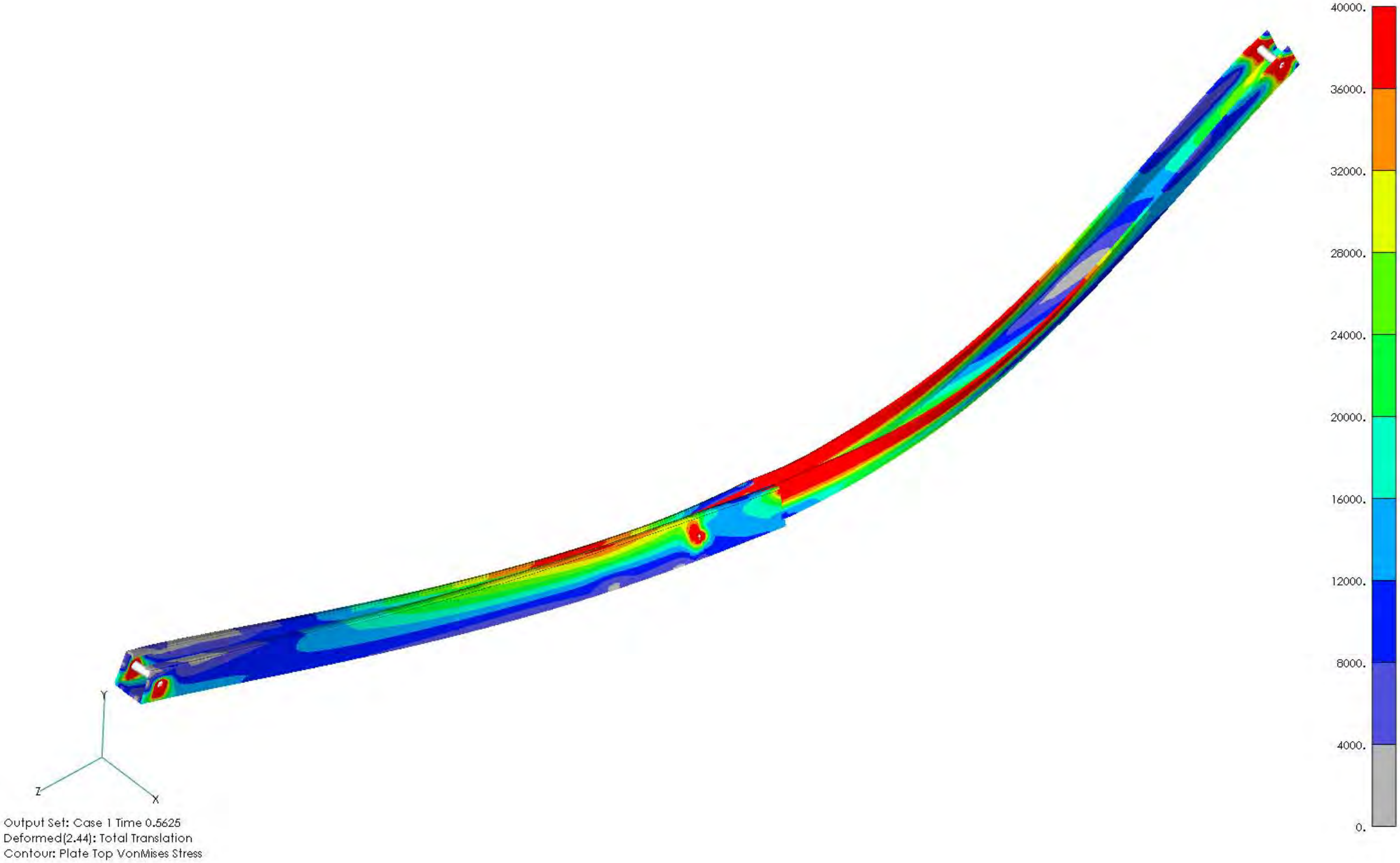
$$P_{Cr} = 2010\,lbf$$

Analytical buckling equation prediction of 2,010 lbf for the 98.6 inch column.

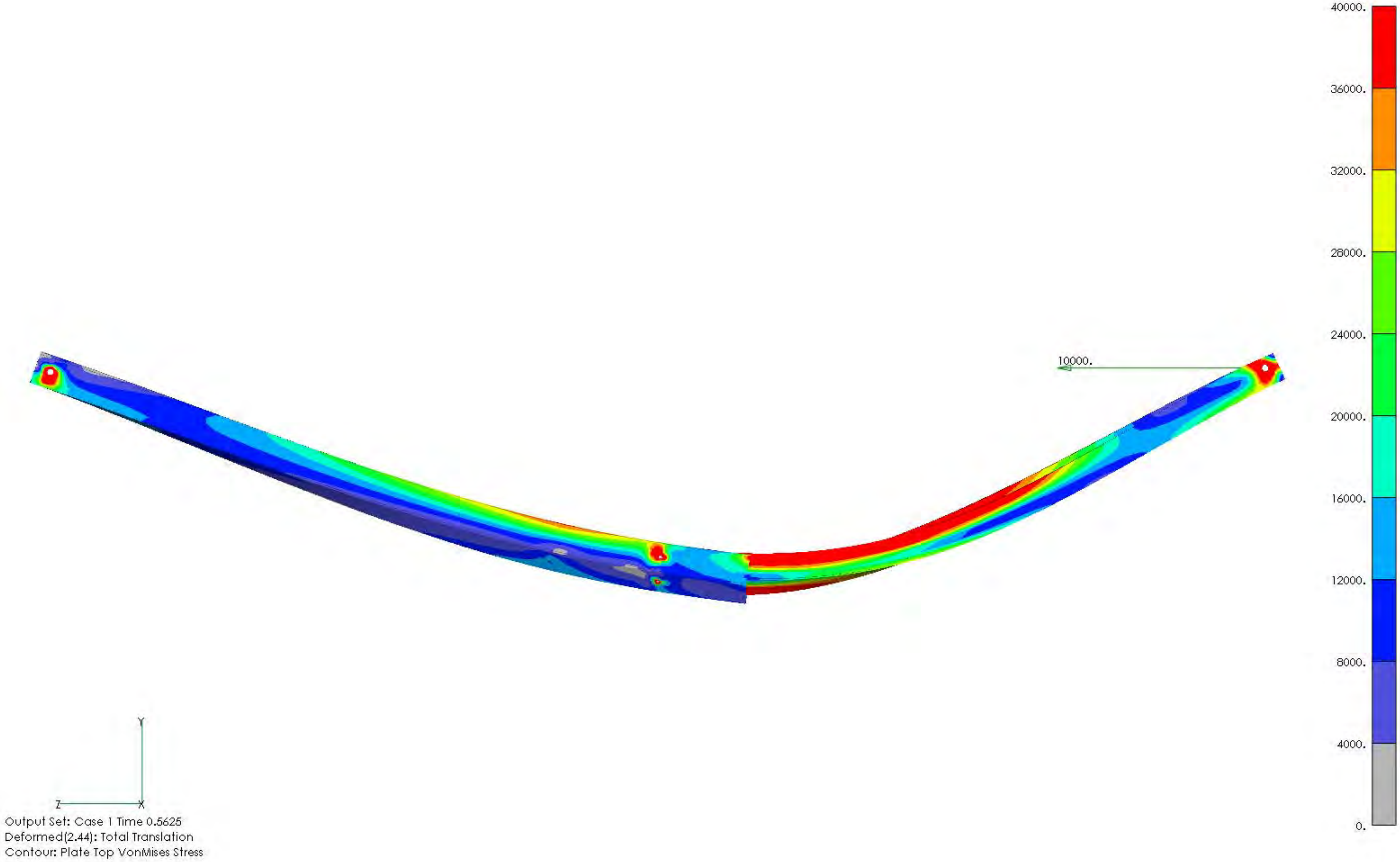
Rear Leg Structure: 63.6 inch Length Buckling Results



The column is 63.6 inches in length from bolt-to-bolt.



The buckling load is 0.562*10,000 lbf = 5,620 lbf.


40000.
36000.
32000.
28000.
24000.
20000.
16000.
12000.
8000.
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0.
10000.
Y
Z
X
Output Set: Case 1 Time 0.5625
Deformed(2.44): Total Translation
Contour: Plate Top VonMises Stress

$$I_C := 0.198 \cdot in^4$$

$$Length_{Column} := 63.6 \cdot in$$

$$P_{Cr} := \frac{\left(\pi^2 \cdot Elastic_{Modulus} \cdot I_C\right)}{Length_{Column}^2}$$

$$P_{Cr} = 4831\,lbf$$

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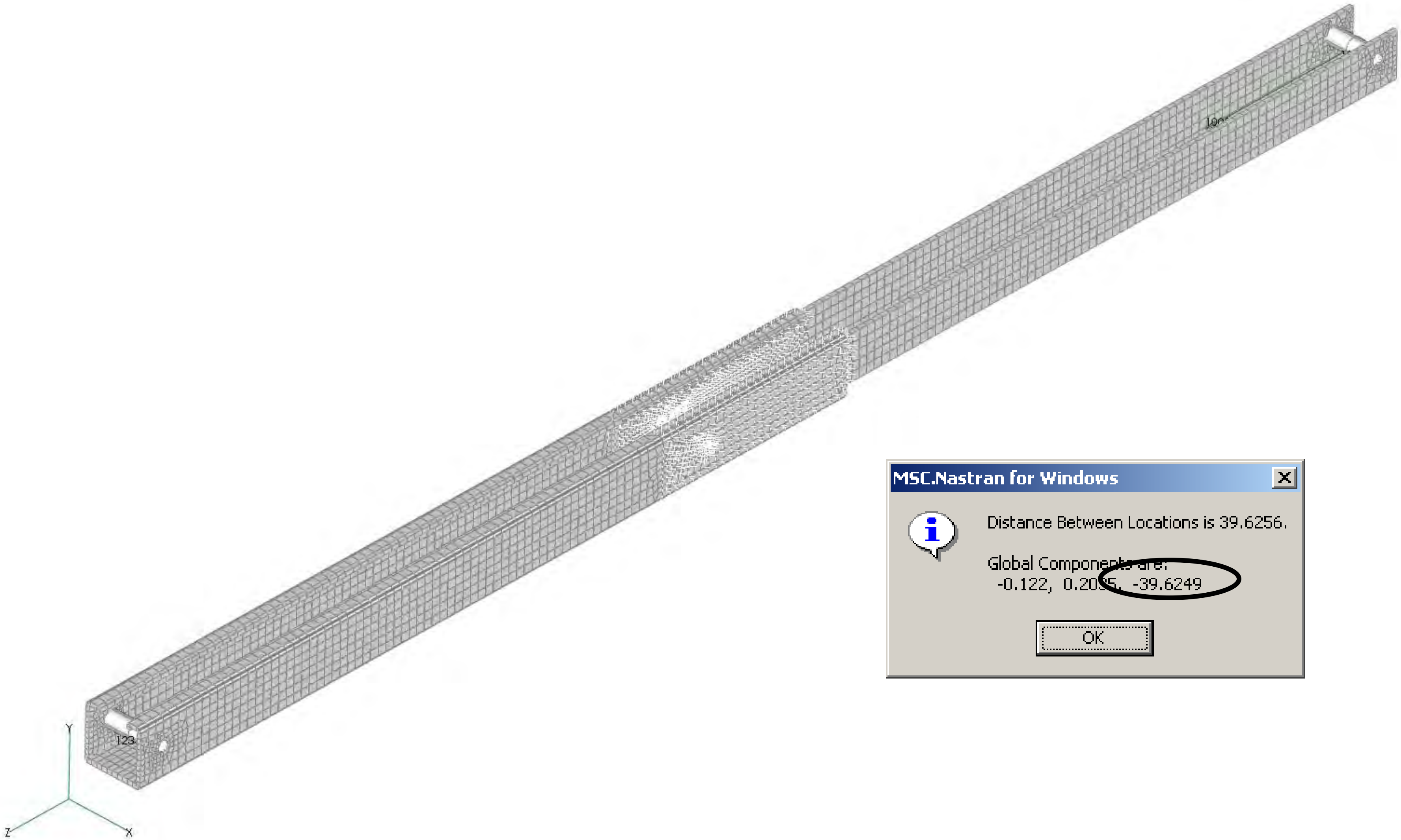
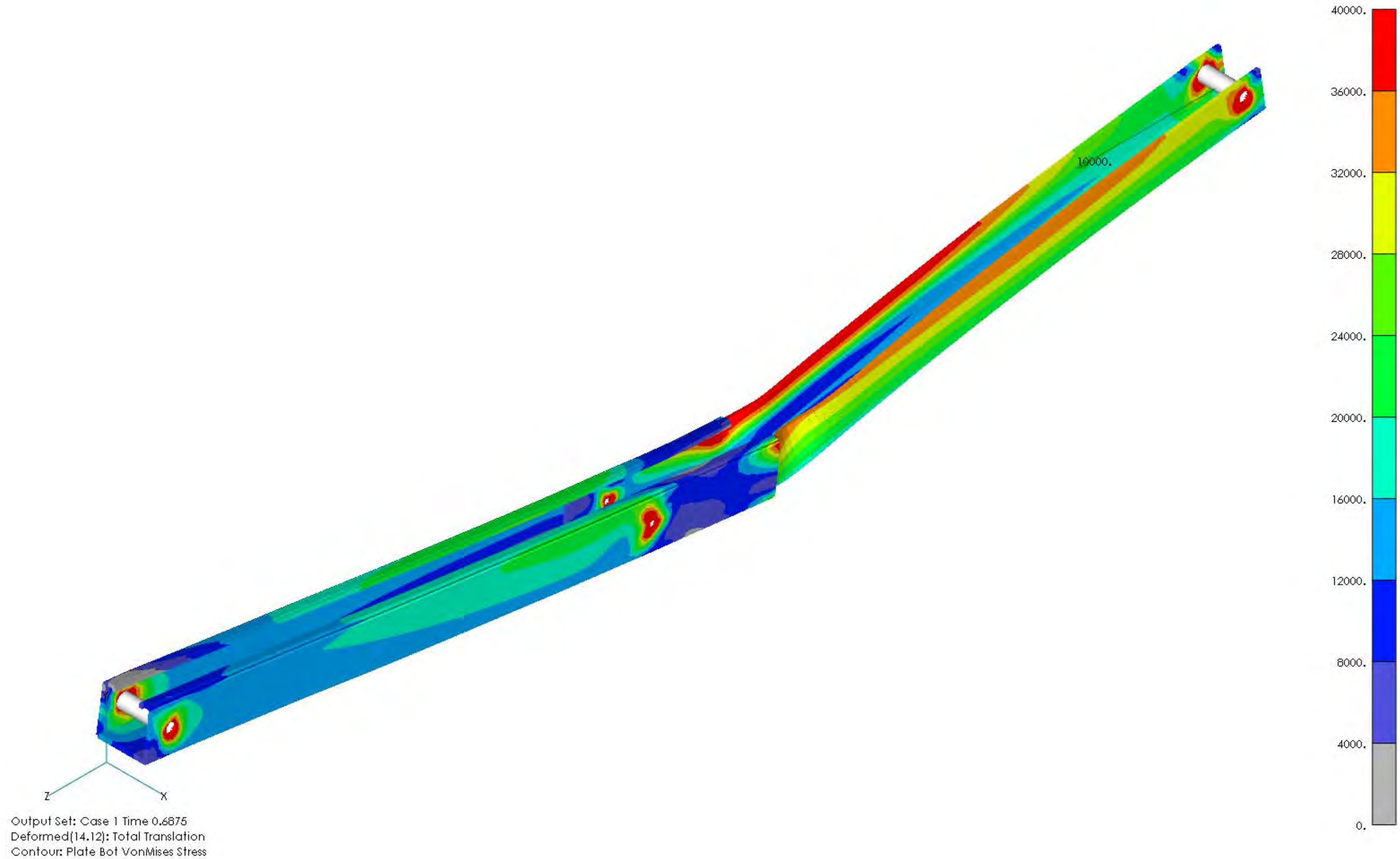
The FEA estimated buckling load is 5,620 lbf as compared to the analytical buckling load of 4,831 lbf. The two are not expected to agree since the FEA model has two different cross-sectional columns (the upper and lower sections) and are overlapped in the middle.

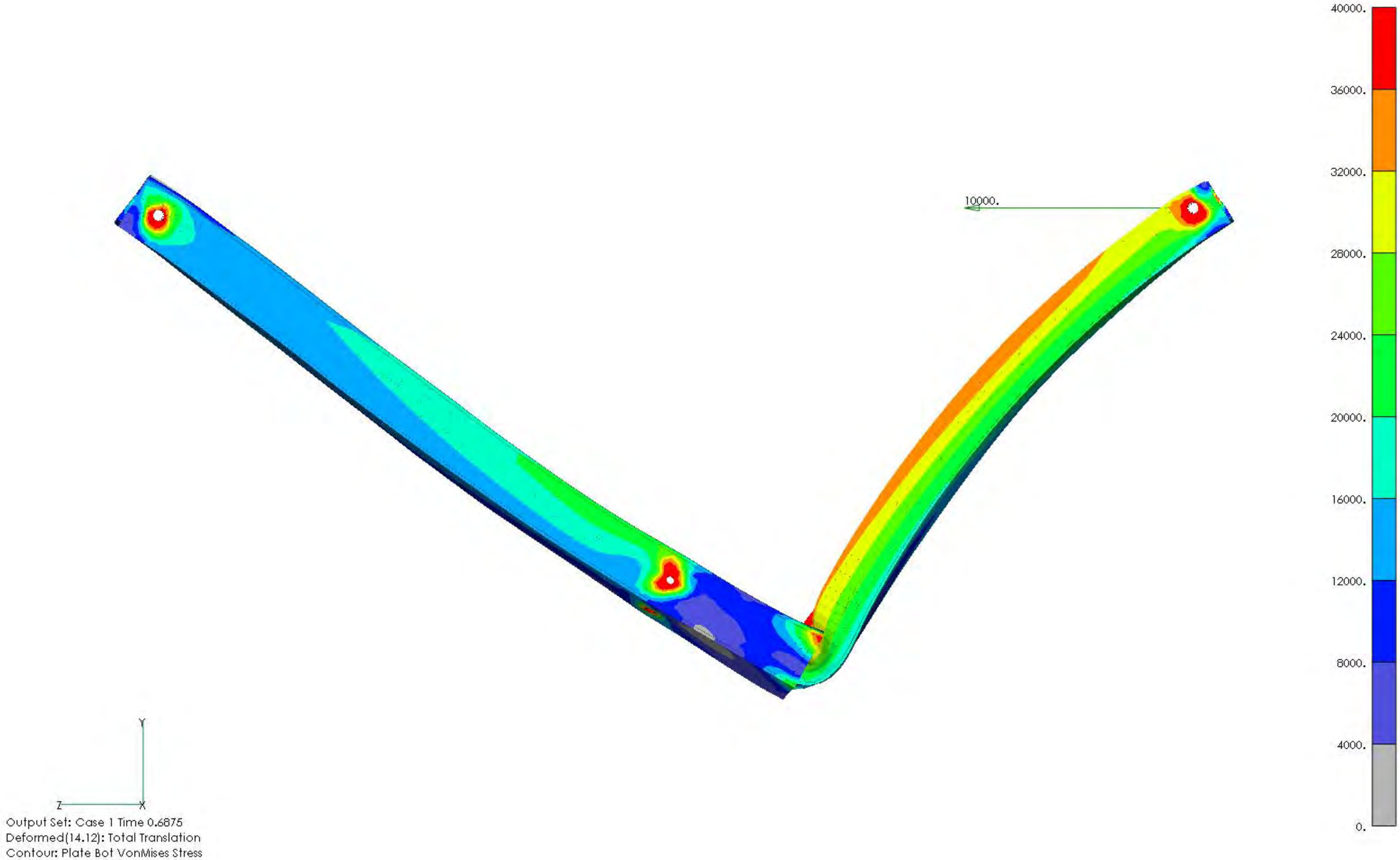
Rear Leg Structure: 39.6 inch Length Buckling Results



The short leg rear column at 39.6 inches.



Flange crippling is clearly shown in the above slide. The column collapses at a buckling load of 0.688*10,000 lbf = 6,880 lbf.


10000.
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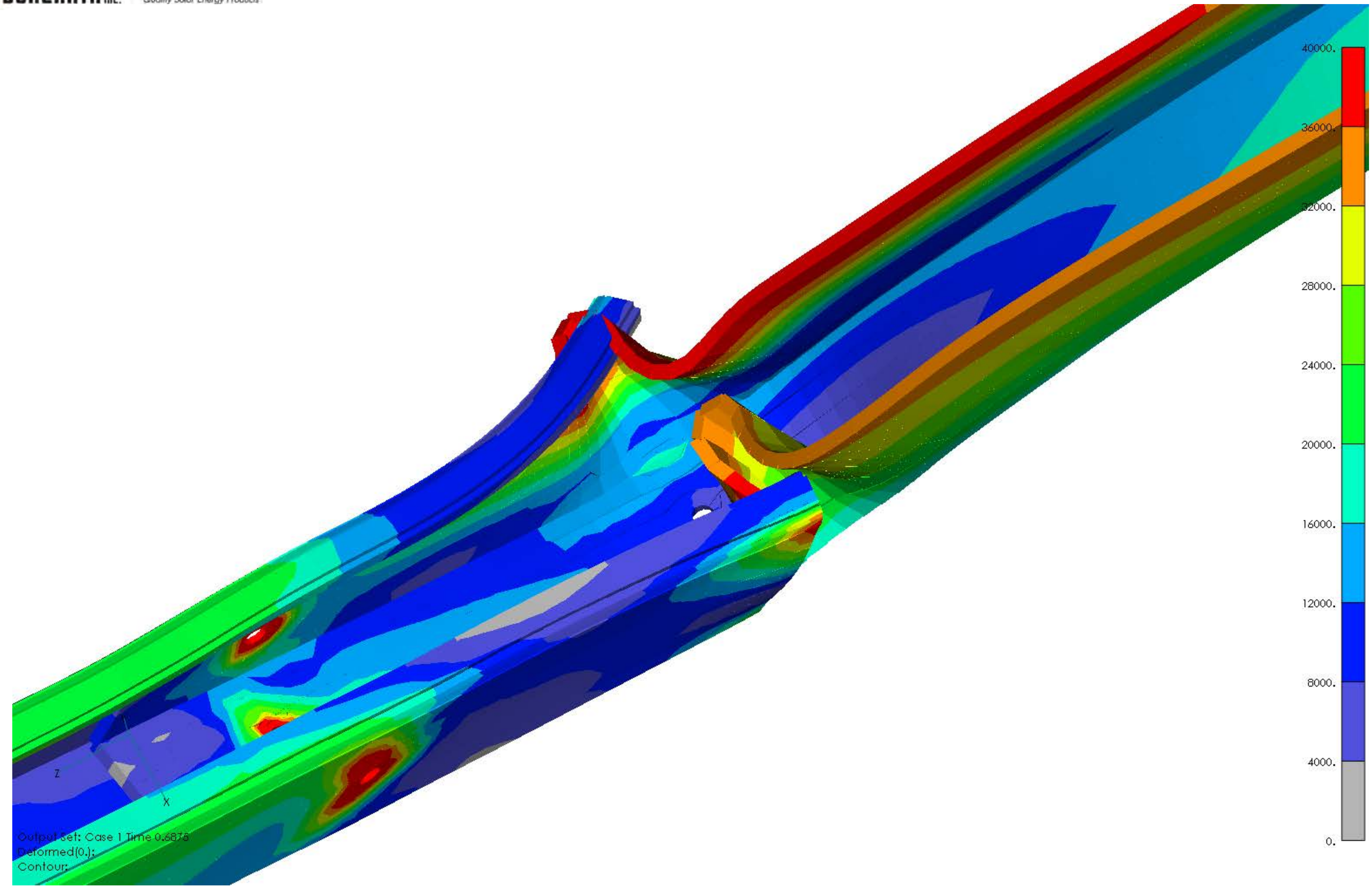
Output Set: Case 1 Time 0.6875
Deformed(14.12): Total Translation
Contour: Plate Bot VonMises Stress


40000.
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Z
X
Output Set: Case 1 Time 0.6875
Deformed(0.):
Contour:

$$I_C := 0.198 \cdot in^4$$

$$Length_{Column} := 36.6 \cdot in$$

$$P_{Cr} := \frac{\left(\pi^2 \cdot Elastic_{Modulus} \cdot I_C\right)}{Length_{Column}^{\;2}}$$

$$P_{Cr} = 14588\, lbf$$

Flange crippling is not covered by the standard eularian buckling formula.

Appendix

Material Property Data for Shear Stress of 300 Series Stainless Steel

Material Property Data for 6063-T6 Aluminum

Tek-Screw Bearing and Shear Load Calculations

Bolted Connections Bearing Load Calculations

Upper Extrusion Load Bearing Calculation

Executing Engineer Certification

ASM MATERIALS

Machined Products

Material	Code	Specifications
Aluminum	A	QQ-A225/3D 2011-T3
Brass	B	ASTM - B - 16 -92, Alloy-UNS-No. C36000[2] Temper - HO2 - half hard QQ-B-626D-ALLOY 360, Temper - half hard
Copper- Tellurium	C	ASTM-B-301-96, Alloy-C14500 Temper-HO2- half hard
Delrin	D	ASTM -D -4181 - 97, Natural, Long term service, temperature 200°F UL - 94 HB, Virgin Grade
Fibre	F	ASTM-D-710-97 UL97HB Maximum Service temperature 230° F
Glass Epoxy	GE	MIL-1-24768/27 -(GEE-F) 25 Feb. 92 G10 UL 94 VE-0
Kel-F	KF	MIL-P-46036, ASTM-D-1430-95 TYPE I Grade I, Class B,C UL 94 VE - 0
*Nylon Virgin Grade	N	LP-410-Natural 6/6, ASTM-D-4066-96A Natural. Service temperature 210°F UL 94HB, Polyamides (Nylon)
Phenolic - Paper	PH	MIL-I-24768/11-92 FBG Service temperature 285°F UL-94 HB
Phenolic - Linen	PHL	MIL-I-24768/13-92 FBE Service temperature 265°F UL-94 HB
A.B.S.	PA	A.B.S. ASTM-D-4673-96-Natural, Service temperature 160°F UL-94 HB
Lexan	L	Polycarbonate (Lexan) ASTM-D-3935-94-PC, 110 B34720. Continuous usage temperature 250°F U -94 V-2
P.V.C.	PP	P.V.C. round only L.P. 1036 Service temperature 140°F UL-94 VO Tolerances: 1/2 Diameter and under + 010, - 000 over 1/2 diameter + .020, - 000
Rulon - Standard Grade	AR	Operating temperature range -400° to 550°F Color - maroon, non-flammable UL -94 V0
+Stainless Steel	SS	ASTM-A581, 582-95b, (non-magnetic) 303 Series, Condition A. For Socket Head Cap Screws ASME/ANSI B18.3-1998 ASTM-F-837
Steel	S	ASTM-A-108-93 (12L14), QQ-S-637
Teflon	T	Virgin Rod - ASTM-D-1710-91A, Type I, Grade I, Class A Continuous service temperature 500°F UL 94 VO, Virgin Grade
ULTEM 1,000 **Polyethermide	UL	ASTM-D-5205-96, PEI-0113 Recommended for high heat applications to 340°F, UL 94 VO
Vespel	VE	MIL-P-46112, service temperature 500°F, UL 94 VO

Stamped Products

Material	Specifications
Aluminum	QQ-A250/1F thru QQ-A250/29A ASTM-B-209-93, AMS 4037
Brass	ASTM-B-36-91 AEL, AMS-4505
Phosphate Bronze	ASTM B-103, AMS-4510
Beryllium Copper	ASTM B-194, AMS-4532
Copper	ASTM-B-152-97A, AMS-4500
Delrin	ASTM-D-4181-97, Natural, Long term service, Temperature 200°F UL-94 HB
Fiber	ASTM-D-710-97 UL 94HB Maximum service temperature 230°F
Glass Melamine-G5	MIL-I-24768/8-92 GSG Maximum recommended continuous operating temperature of 465°F UL 94 VO
Glass Silicone-G7	MIL-I-24768/17-92 GSG Maximum recommended continuous operating temperature of 465°F UL-94 VO
Glass Epoxy-G10	MIL-I-24768/27-(GEE-F) 25 Feb 92 UL 94 VE-O
Kel-F	ASTM-D-1430-95 AMS 3650 UL 94 VE-0
*Nylon	LP-410-Natural 6/6, ASTM-D-4066-96A Natural. Service temperature 210°F UL 94 HB
Phenolic - Paper	MIL-I-24768/11-92 FBG Service temperature 285°F UL-94HB
Phenolic Linen	MIL - I-24768/13 92 FBE Service temperature 265°F UL-94 HB
A.B.S	ASTM-D-4673-96-Natural Service temperature 160°F UL-94 HB
Lexan	ASTM-D-3935-94-PC 110, B34720 continuous usage temp. 250°F UL-94 V-2
Plastic	LP-535-E, ASTM-D-1784-97
Stainless Steel	(17-7PH) ASTM-A693, AMS 5528
Spring Steel	QQ-S-700, ASTM-A-684, AMS5120
Steel	QQ-S-698, ASTM-A-109-98 & A-366-366m-97, AMS 5040
Teflon	ASTM-D-3293, ASTM-D-1710-96, Type I, Grade I, Class A UL 94 VO

Hardness	50-70 SDH	R115	R115	M113	50-70 SDH	73° RC4
Specific Gravity	1.23	1.14	1.16	1.33	2.1-2.3	.930 - .936
Thermal Conductivity, btu/hr/sq. ft/°F/ft	--	.14	--	.17	.15	2.9
Specific Heat, btu/lb/F	--	.4	--	.4	.25	@68°F - 0.99
Resistance to Continuous Heat °F	178	300	400	250	600	-22°F to 180°F
Water Absorption %	--	1.5	1.5	1.5	.006	73°- NIL

* Nylon - UL Rating 94V-2 **Teflon - Non-flammable

Metallic Materials

Typical Approximate Values

	Alum-inum 2011-T3 Federal Spec QQ-A-225/3D	Beryllium Copper Annealed	Beryllium Copper Heat Trtd	Brass (HOH)	Copper
Tensile Strength (psi)	68,000	70,000	180,000	70,000	34,000
Shear Strength (psi)	41,000	--	--	38000	23000
Elongation (%)	20	45	6	30	45
Modules of Elasticity (psi)	10,600,000	19,000,000	19,000,000	15,000,000	17,000,000
Hardness	RB75	RB78	R15N-78-81	RB77	45 Brinell
Specific Gravity	2.77	8.26	8.26	8.46	8.90
Melting Point °F	1180	1600-1800	1600-1800	1660-1715	1949-1981
Electrical conductivity (% of Copper)	30	17	22	26	100
Thermal Conductivity (BTU/hr/ft^2/°F/ft)	70	68	68	70	222
Coef. of Thermal Expansion (in/in°F) (10^6)	12.9	9.3	9.3	10.2	9.3
Specific Heat (BTU/lb/°F)	.23	.10	.10	.09	.09

	Phos. Bronze (Spring Temp.)	Solder (60-40)	Steel	Spring Steel (Heat Trtd)	Stainless Steel (300 Series)
Tensile Strength (psi)	100,000	6,400	65,000	194,000	90,000
Shear Strength (psi)	--	5,700	45,000	--	67,000
Elongation (%)	4	45	30	4	55

Aluminum 6063-T6

Printer friendly version Material sup

Subcategory: 6000 Series Aluminum Alloy; Aluminum Alloy; Metal; Nonferrous Metal

Close Analogs: Eight Other Tempers of This Alloy are in the database.

Key Words: UNS A96063; ISO AlMg0.5Si; Aluminium 6063-T6; AA6063-T6

Component	Wt. %	Component	Wt. %	Component	Wt. %
Al	98.9	Fe	Max 0.35	Si	0.2 - 0.6
Cr	Max 0.1	Mg	0.45 - 0.9	Ti	Max 0.1
Cu	Max 0.1	Mn	Max 0.1	Zn	Max 0.1

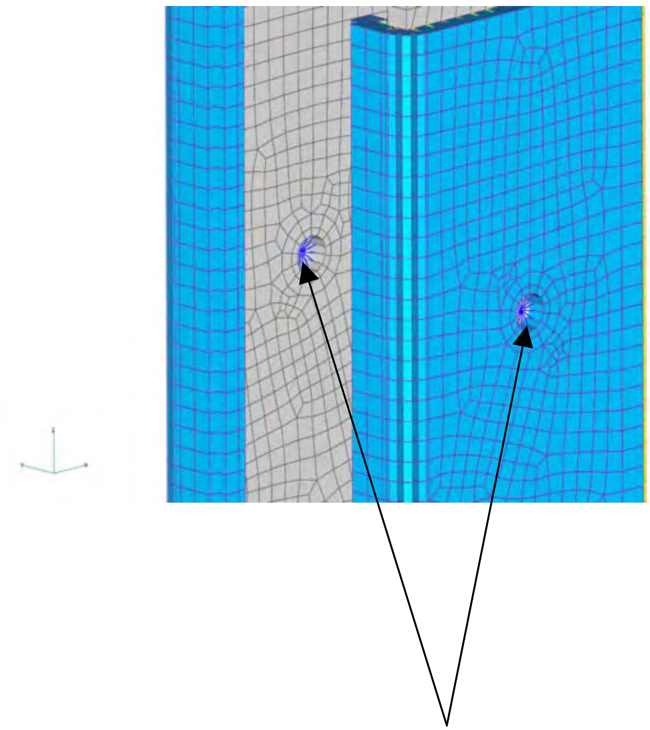
Click here to view available vendors for this material. **We have just added thousands of new supplier listings this mo please check them out!**

Physical Properties	Metric	English	Com
Density	2.7 g/cc	0.0975 lb/in³	
Mechanical Properties			
Hardness, Brinell	73	73	500 kg load with 10 n
Hardness, Knoop	96	96	Converted from Brinell Hardness
Hardness, Vickers	83	83	Converted from Brinell Hardness
Tensile Strength, Ultimate	240 MPa	34800 psi	
Tensile Strength, Yield	215 MPa	31200 psi	
Elongation at Break	12 %	12 %	
Modulus of Elasticity	69 GPa	10000 ksi	Average of Tension and Compression. In Aluminum allo compressive modulus is typically 2% greater than the m
Ultimate Bearing Strength	434 MPa	62900 psi	Edge distance/pin diamete
Bearing Yield Strength	276 MPa	40000 psi	Edge distance/pin diamete
Poisson's Ratio	0.33	0.33	
Fatigue Strength	70 MPa	10200 psi	500,000,000
Machinability	50 %	50 %	0-100 Scale of Aluminum
Shear Modulus	25.8 GPa	3740 ksi	
Shear Strength	150 MPa	21800 psi	

Tek-Screw Bearing and Shear Load Calculations:

The #10 tek-screw bearing area is roughly the diameter of the hole times the thickness of the aluminum extrusion. The hole diameter is 0.19 inch and the thickness of the aluminum extrusion is 0.125 inch. This yields a bearing area of 0.0238 in^2. The compressive bearing stress for 6063-T6 aluminum is 62,900 psi (see material property documentation). ***The bearing load per screw is thus equal to 0.0234*62,900 = 1,494 or 1,500 lbf.***

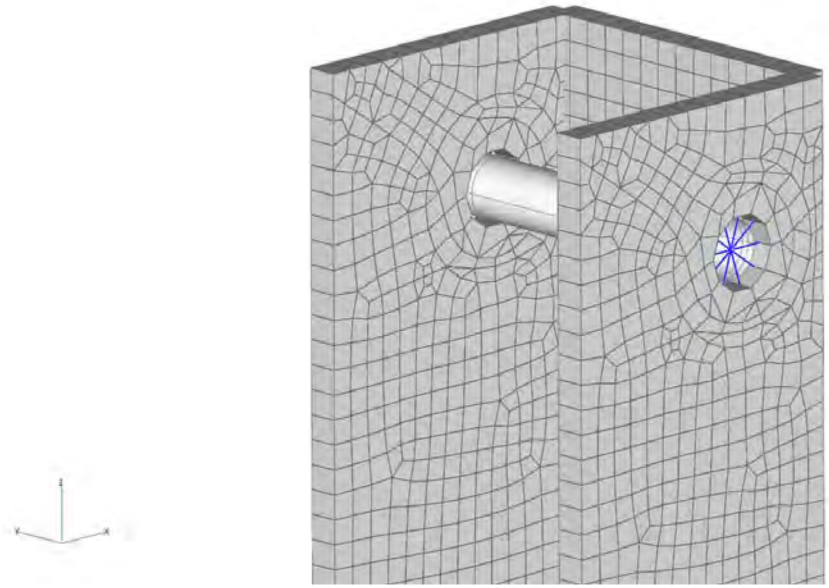
The shear load carrying capacity of each screw is calculated based on the screw's cross sectional area times its shear strength. The #10 tek-screw has a nominal diameter of 0.19 inch and a shear strength of 67,000 psi. ***Based on these numbers, an estimated shear load carrying capacity is 0.0284in^2*67,000psi = 1,899 or 1,900 lbf.***



Tek-screw locations.

Upper Bolted Connection:

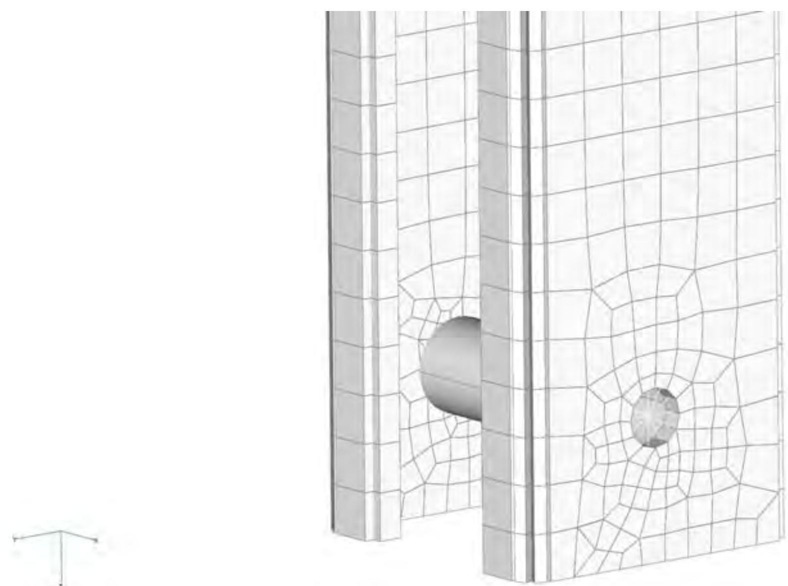
The upper bolted connection is limited by its bearing area onto the aluminum tube having a wall thickness of 0.125 inch. The bearing area is the diameter of the opening (0.3125 inch) times the thickness of the aluminum extrusion (0.125 inch). ***Based on the provided 6063-T6 aluminum ultimate bearing strength of 62,900psi, the bearing load for both sides of the bolt is calculated as – 2*0.3125*0.125*62,900 = 4,914 or 4,900 lbf.***



Lower Bolted Connection:

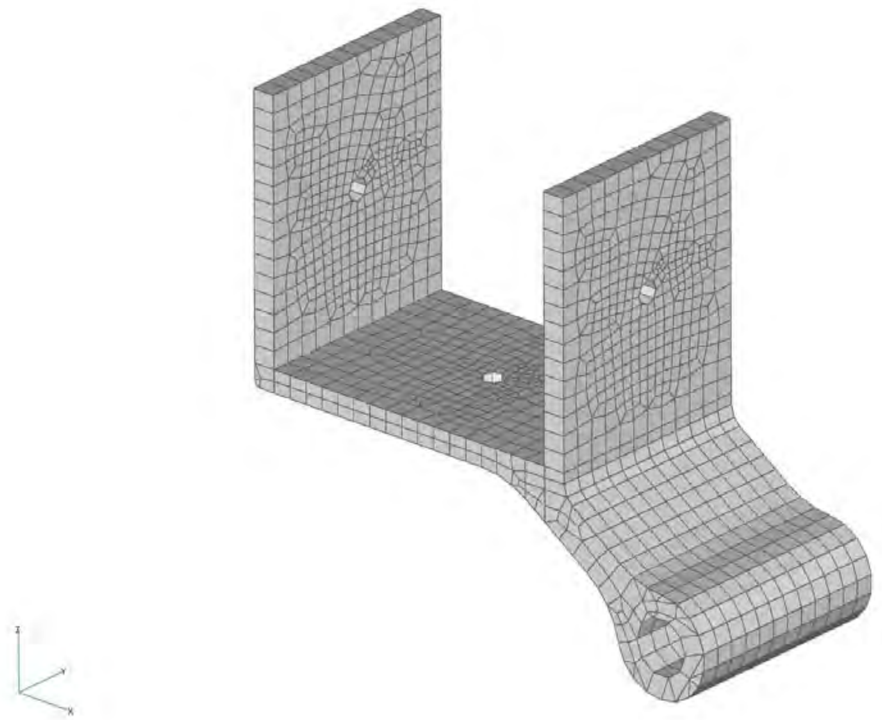
(Applicable only to the Rear Leg Structure)

The lower bolted connection is essentially identical to the uppe connection except for the slightly thinner side-walls at 0.109 inc ***Based on the provided 6063-T6 aluminum ultimate bearing strei of 62,900psi, the bearing load for both sides of the bolt is calcul as – 2*0.3125*0.109*62,900 = 4,285 or 4,300 lbf.***



Upper Aluminum Extrusion Connection:

The alumimun extrusion has a wall thickness of 0.125 inch and is 1.25 inch wide. This gives it a cross-sectional bearing area around the bolt of 0.156 inch. **With an ultimate bearing stress of 62,900 psi, this gives an estimated bearing load of 9,828 or 9,800 lbf.** This value is in far excess of any other structural member load bearing capacity.



All work within this report was done under best industry practices and was executed by George Laird, Ph.D., P.E.