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Aluminium Structure Report

25th January 2020

OVERVIEW

This report will cover the structure of our hybrid rocket. The decisions and analysis of what material was chosen, what configuration, and the pros and cons behind our decisions. This report will be a continuation of the Frame Decision Report filed previously, in which we discussed the difference between an internal and an external frame structure.

Motivation

Much like a house has its foundation, a rocket needs a structural frame. This structural frame will act as the “house” for all components, to adequately incorporate, propulsion, avionics, and recovery. The design of our rocket frame are centered around cost, manufactuability, weight, strength, and availability. These factors will be expressed through analysis seen below.

Methodology

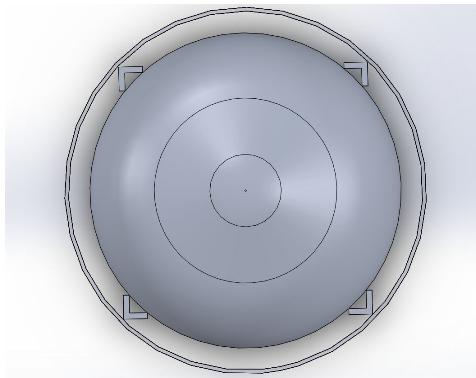
Within each core decision we shall look at the pros and cons behind that decision, proceeding to cost, availability, and weight. Then after FEA and other analysis we shall conclude each component with its manufactuability based off of its design.

Rocket Diameter

The diameter of our rocket is primarily determined by the diameter of the largest component. Within USURPER, the Nitrous Oxide bottle is the determining factor with a diameter of 6.6”. Although Frame V2 and V3 were based off of an inner diameter of 7”, we have selected to expand to 7.5” for V4.

Frame V4 will have an inner diameter of 7.5” for two reasons; the inclusion of aluminium angle support and commercial availability of body tubes at the inner diameter of 7.5” vs 7.0”.

With a 7.0” frame diameter we were left with 0.2” on either side of the combustion chamber for structural support. This simply wasn't enough space to create a structure that could support the thrust of the engine and prevent buckling during flight. After some more research and discussions with Scott Campbell, we expanded the diameter to 7.5” to include four Aluminium angled rods.



Exterior Components

With a 7.5” inner diameter comes the availability of COTS body tubes. Through Apogee Rocket Components and LOC Precision we would be able to purchase Cardboard, Fiberglass, and Poly-propylene Plastic Components.

Apogee Rocket Components offers two body tubes with an inner diameter of 7.5”, a cardboard and fiberglass version.

	Cost	Weight	Length
7.515” LOC Cardboard	$73.27	1726.77 g or 3.81 lbs	60” or 5 ft
7.5” Fiberglass	$282.16	3834 g or 8.45 lbs	48” or 4 ft

Apogee Rocket Components also offers a Nose Cone suitable for an inner diameter of 7.5”.

	Cost	Weight	Nose Length	Shoulder Length
PNC-7.51”	$97.73	876g or 1.93lbs	22 in	5in

These COTS components would only be necessary if we do not collaborate with Durham Boat to create a carbon fiber shell or carbon fiber ogival nose cone.

Drag

Drag = [½] * [Cd (Coefficient of Drag)] * [Density] * [Velocity]^2 * [Reference Area]

Drag	Cd (Coefficient of Drag)	Density of Medium	Velocity	Reference Area
0.898 N	0.05	1.225 kg/m3	257.25 m/s	0.114 m2
0.782 N	0.05	1.225 kg/m3	257.25 m/s	0.993 m2

Due to the increased diameter of our rocket, we will experience a 14.8% increase in Drag.

Skin Friction Drag

Drag = $\int C_f \frac{\rho v^2}{2} dA$

Coefficient of Drag = C_f = $\frac{0.027}{Re_x^{1/7}}$

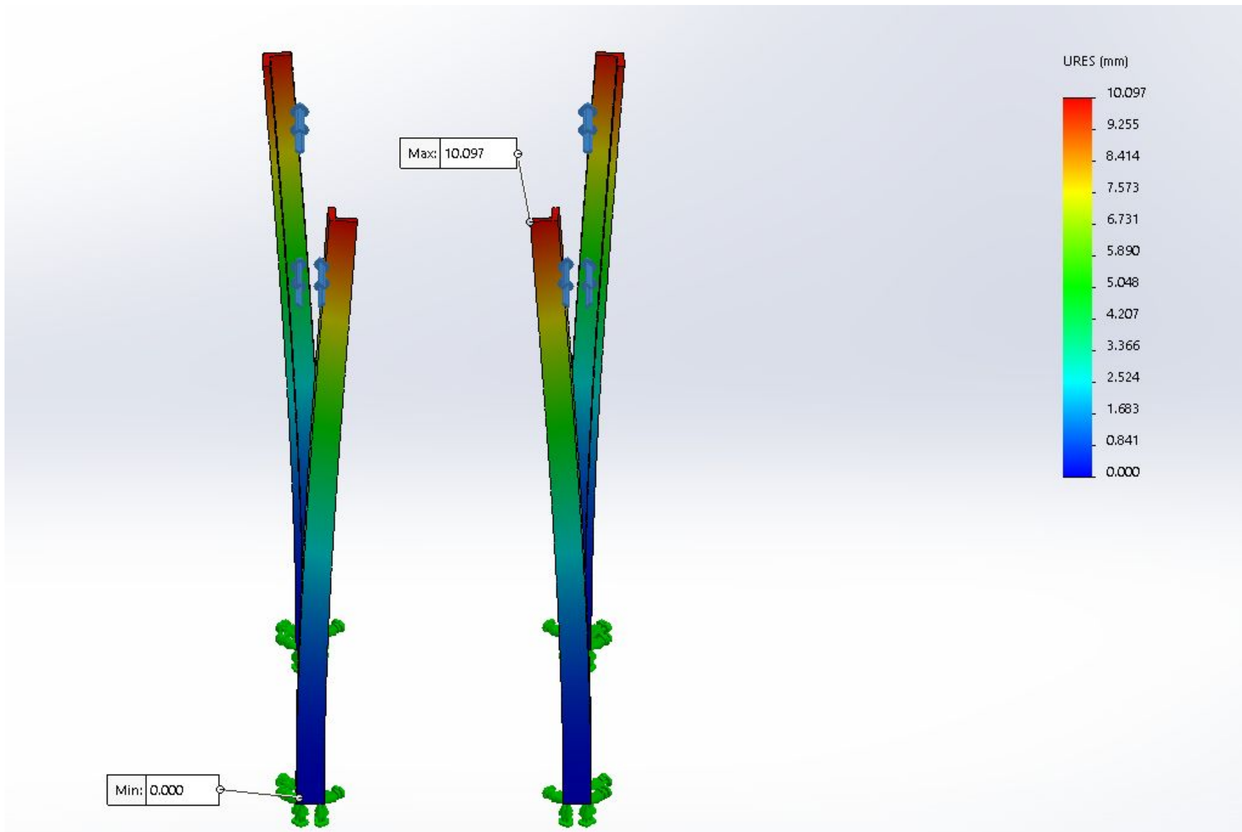
Reynolds Number = $\mathrm{Re} = \frac{\rho u L}{\mu} = \frac{uL}{\nu}$

Drag	Cf (Coefficient of Drag)	Density of Medium	Velocity	Reference Area	Reference Length
231.71 N	0.02238	1.225 kg/m3	257.25 m/s	2.5538 m2	2.1336 m
216.27 N	0.02238	1.225 kg/m3	257.25 m/s	2.3835 m2	2.1336 m

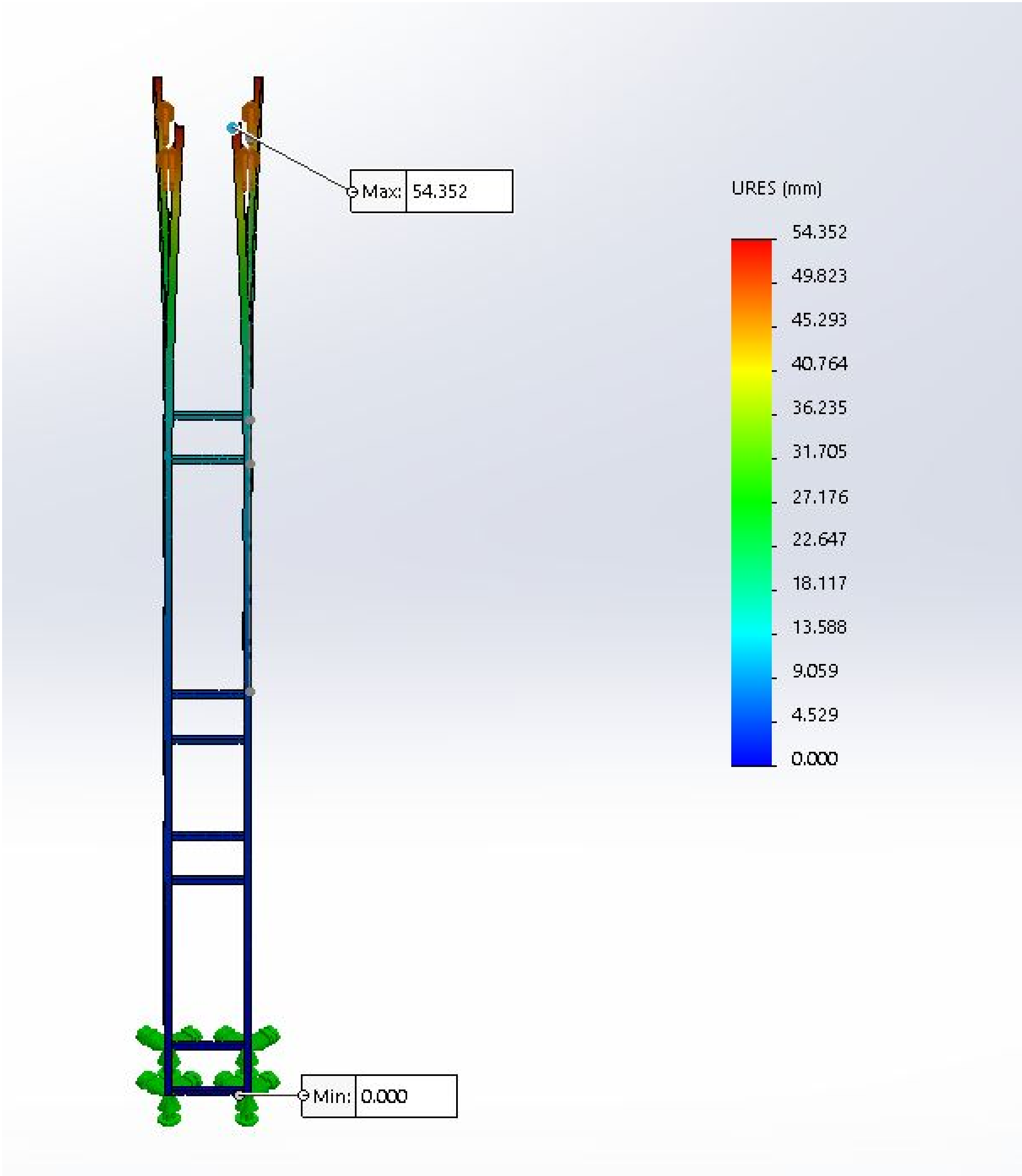
Due to the increased diameter of our rocket, we will experience a 7% increase in Skin Drag.

Support Structure Analysis

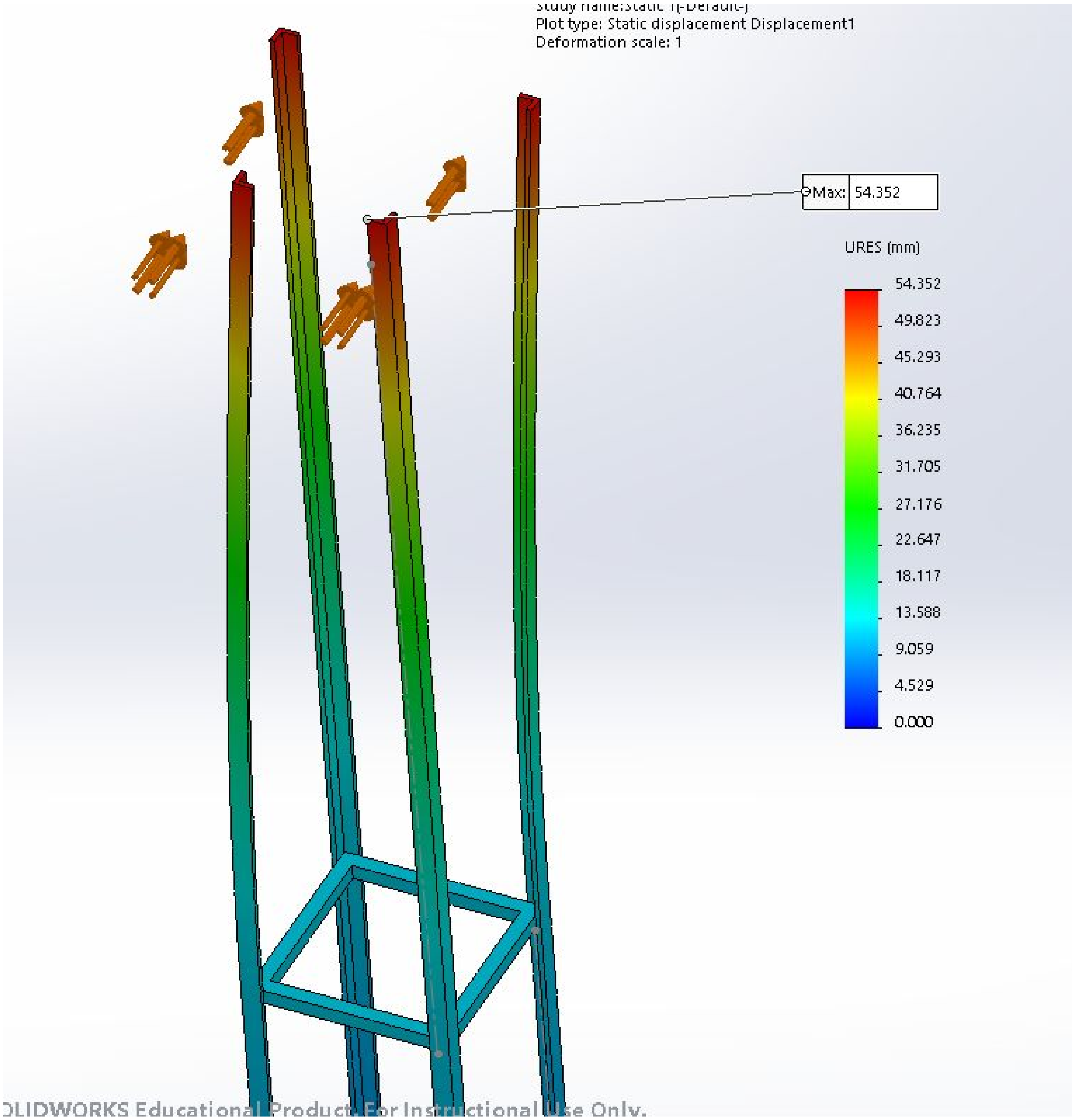
6061 1/8th Aluminium Angle Structure FEA



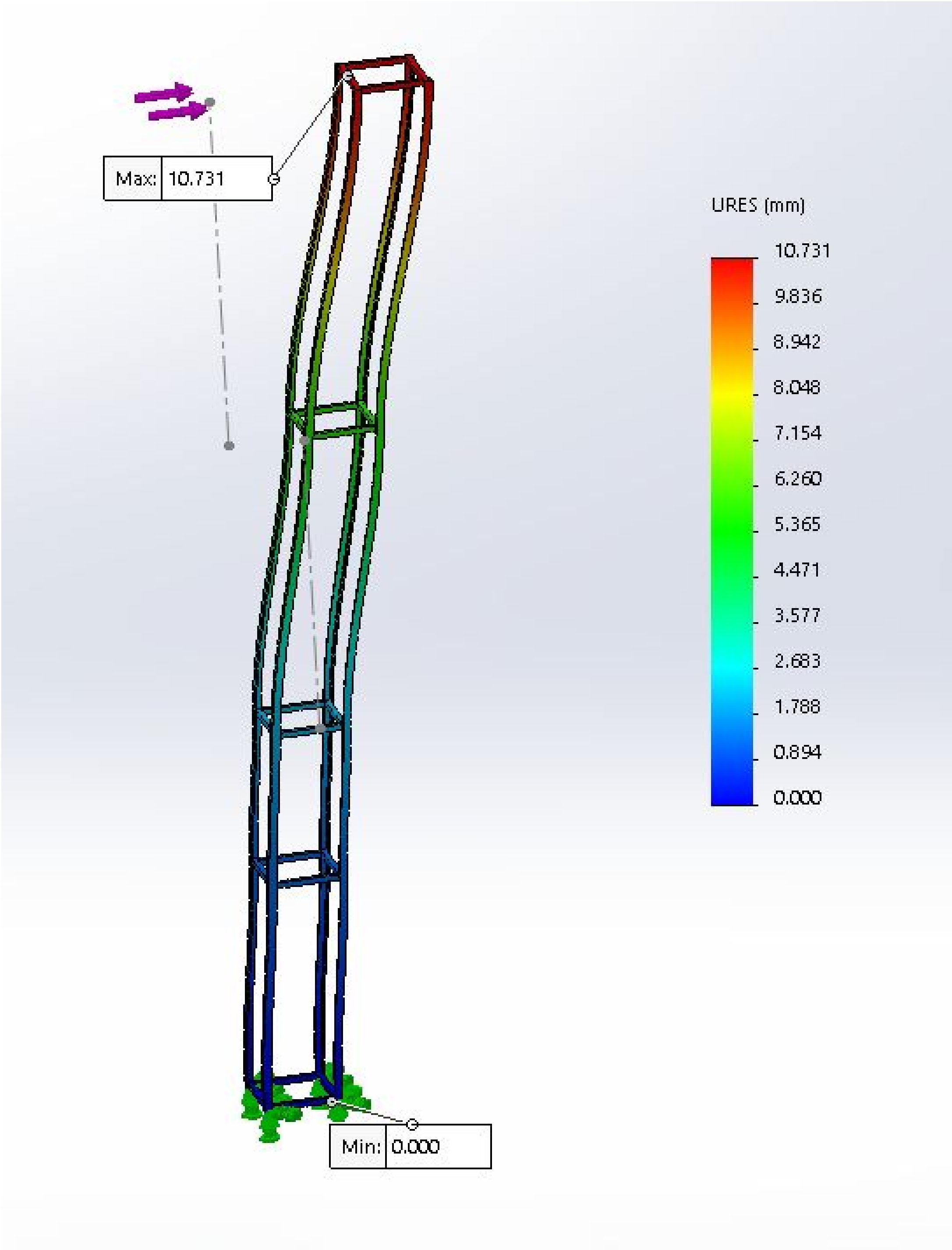
10 lbf applied to top ½ in of one foot rod section.



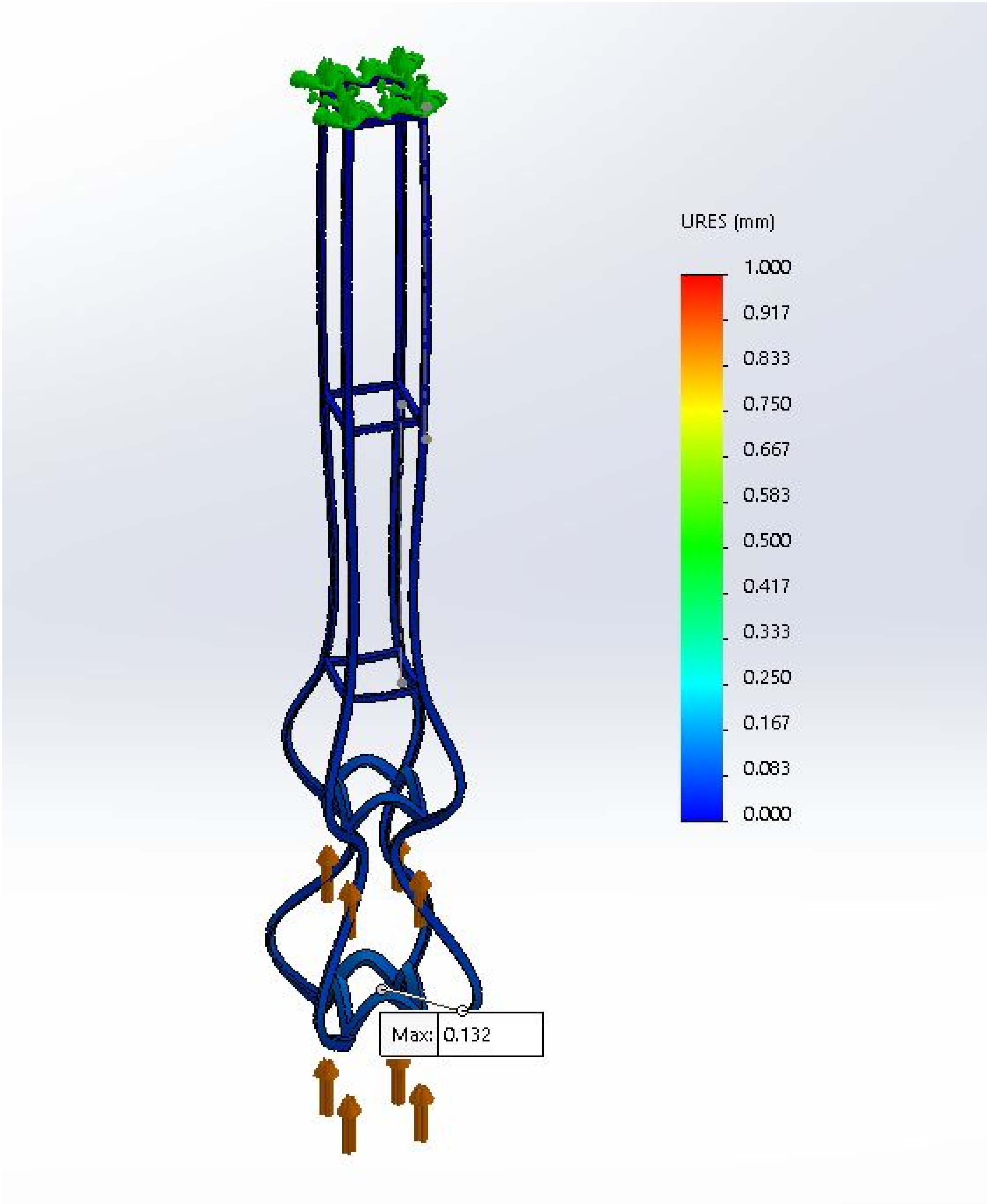
5 lbf applied to top ½ in of full rocket structure



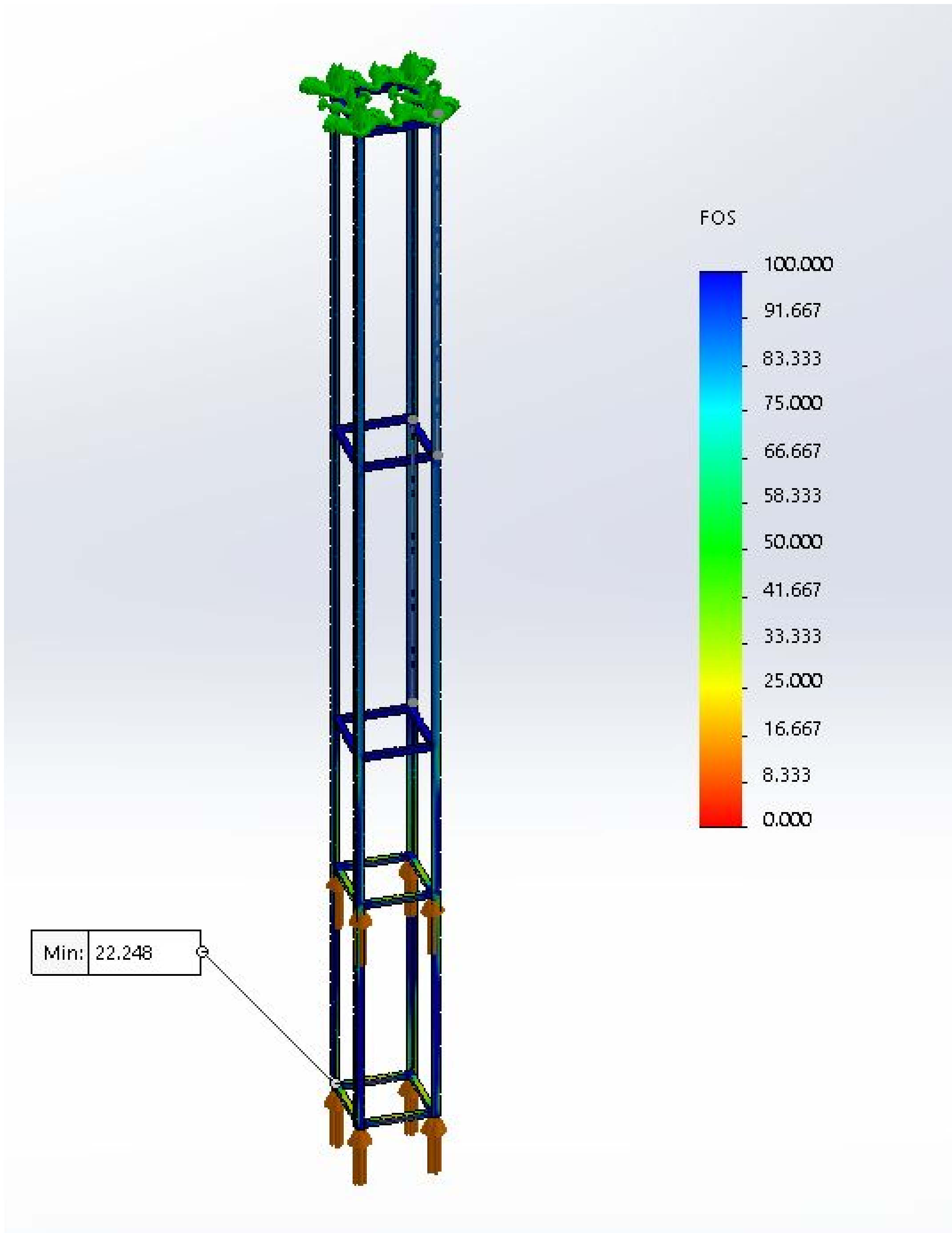
5 lbf applied to top ½ in of full rocket structure



10 lbf applied to top ⅜ th across support rod of full rocket structure

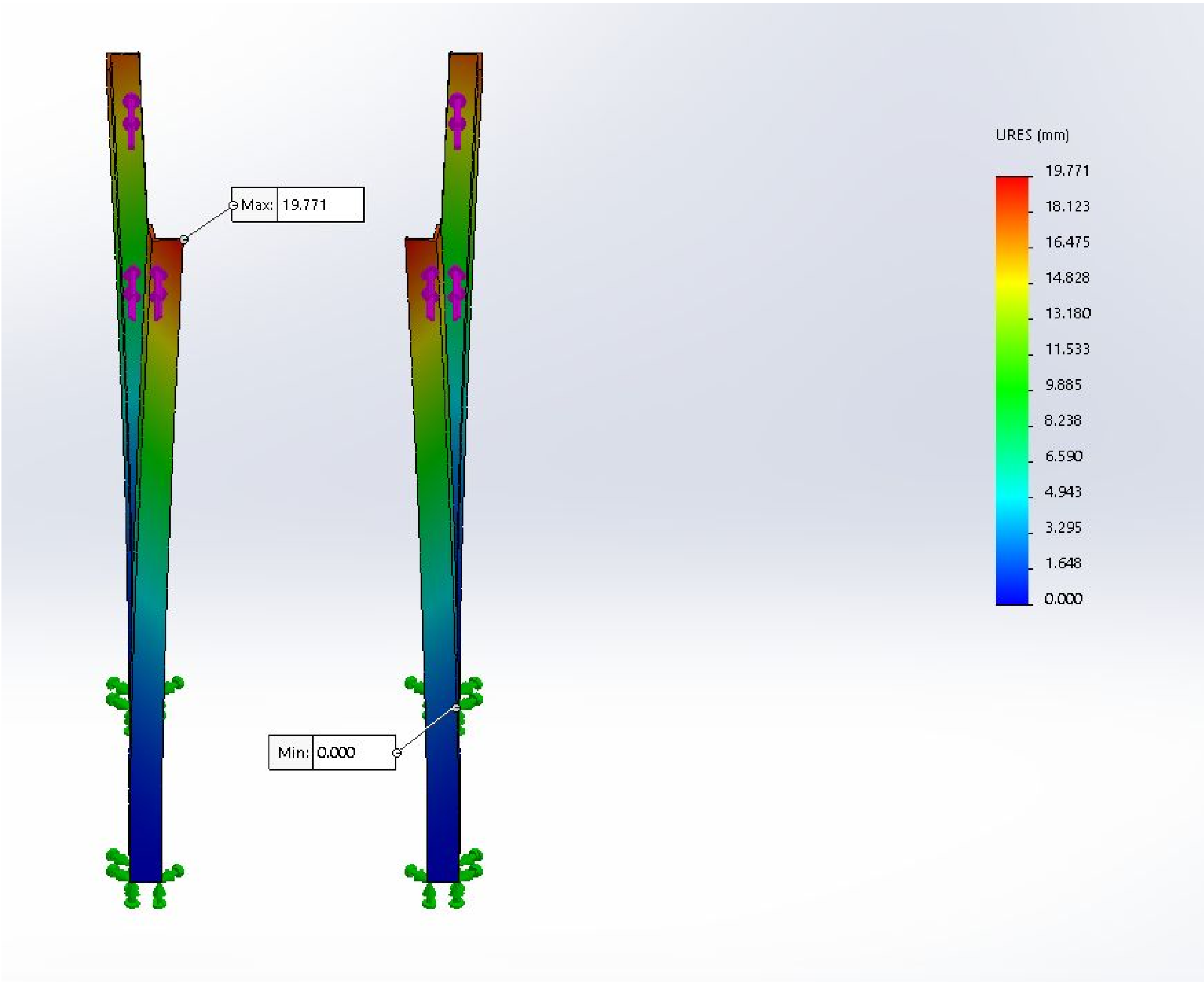


Displacement: 200lbf applied to combustion chamber region of structure with fixed top.

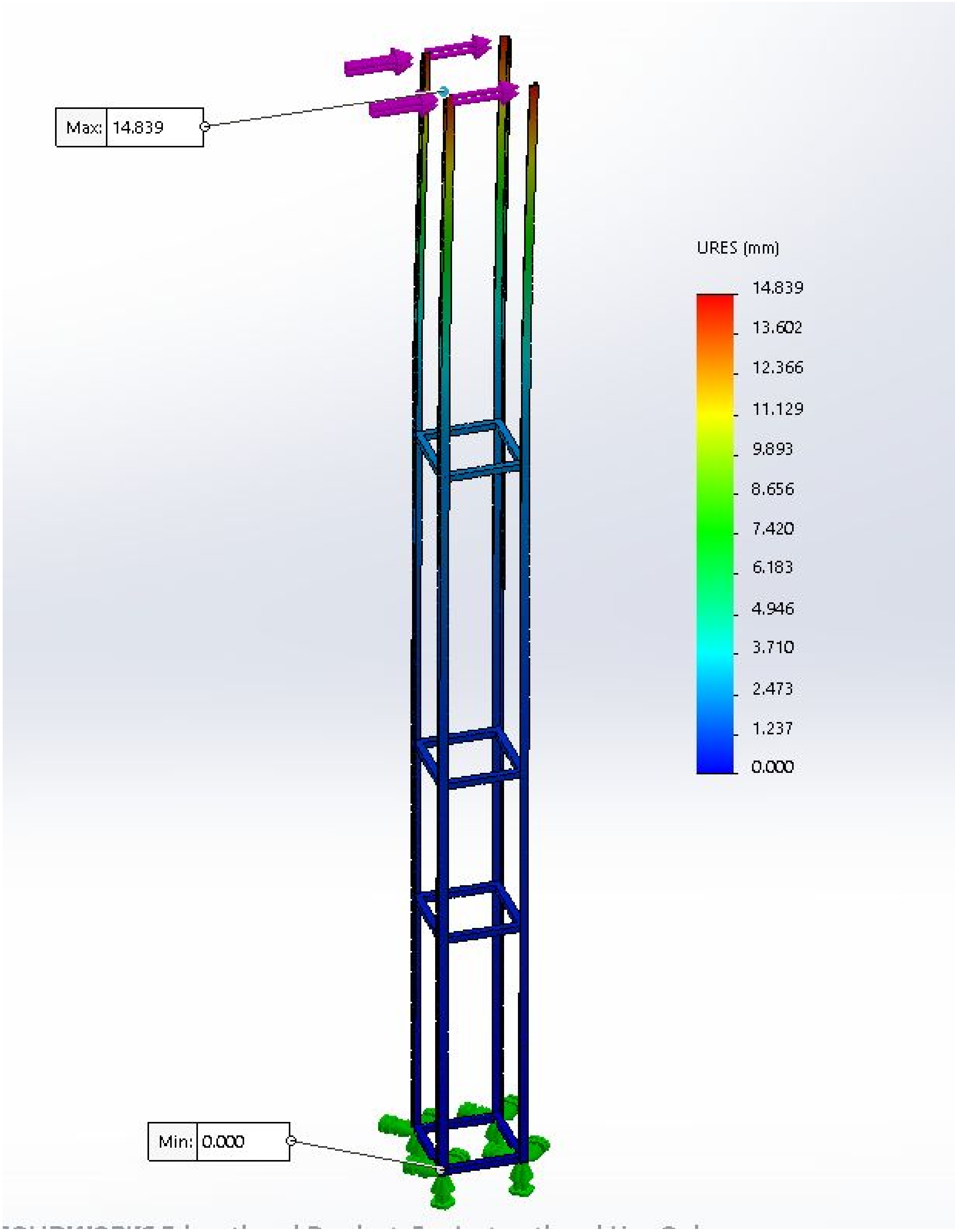


FOS: 200lbf applied to combustion chamber region of structure with fixed top.

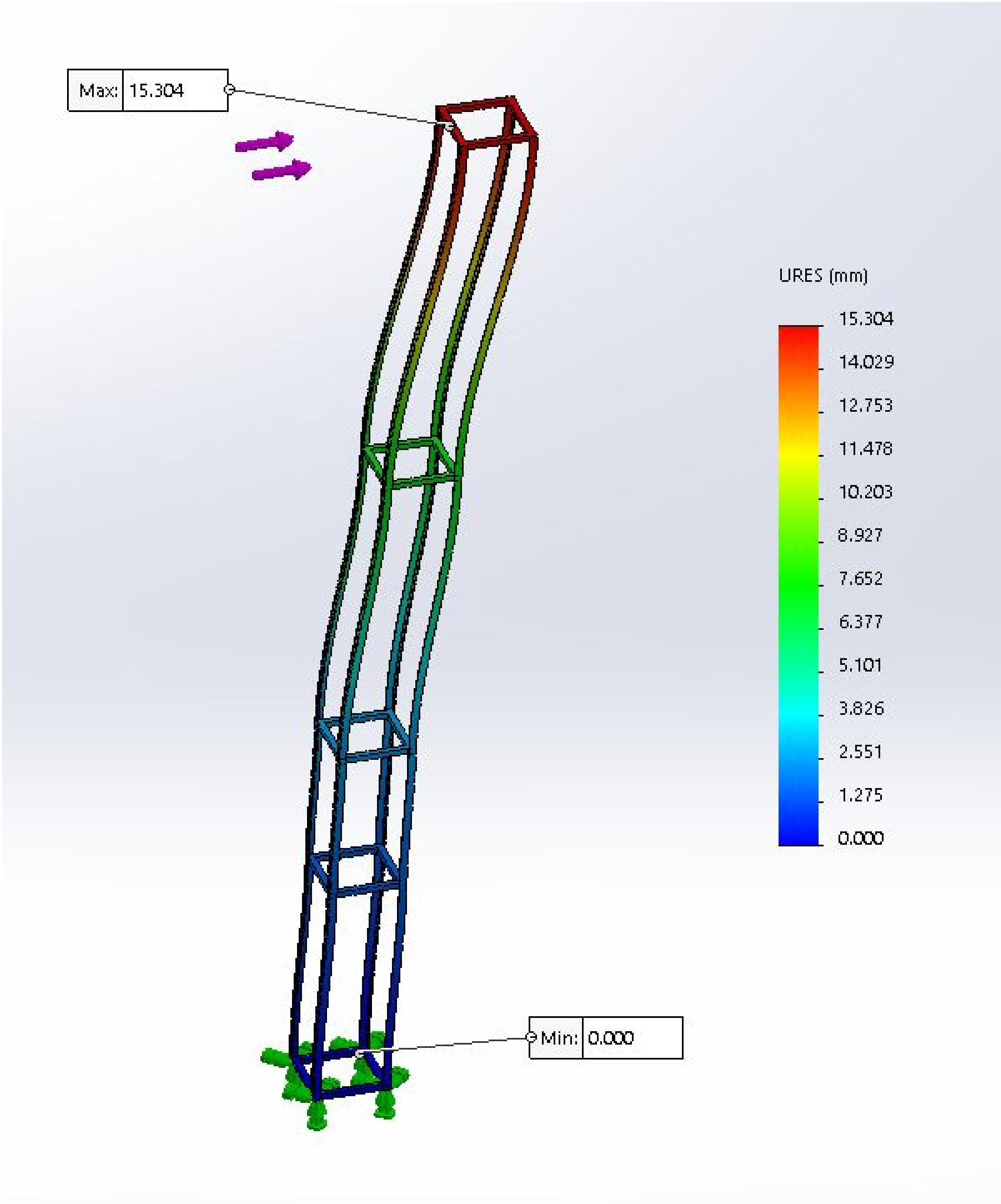
7075 1/16th Aluminium Angle Structure FEA



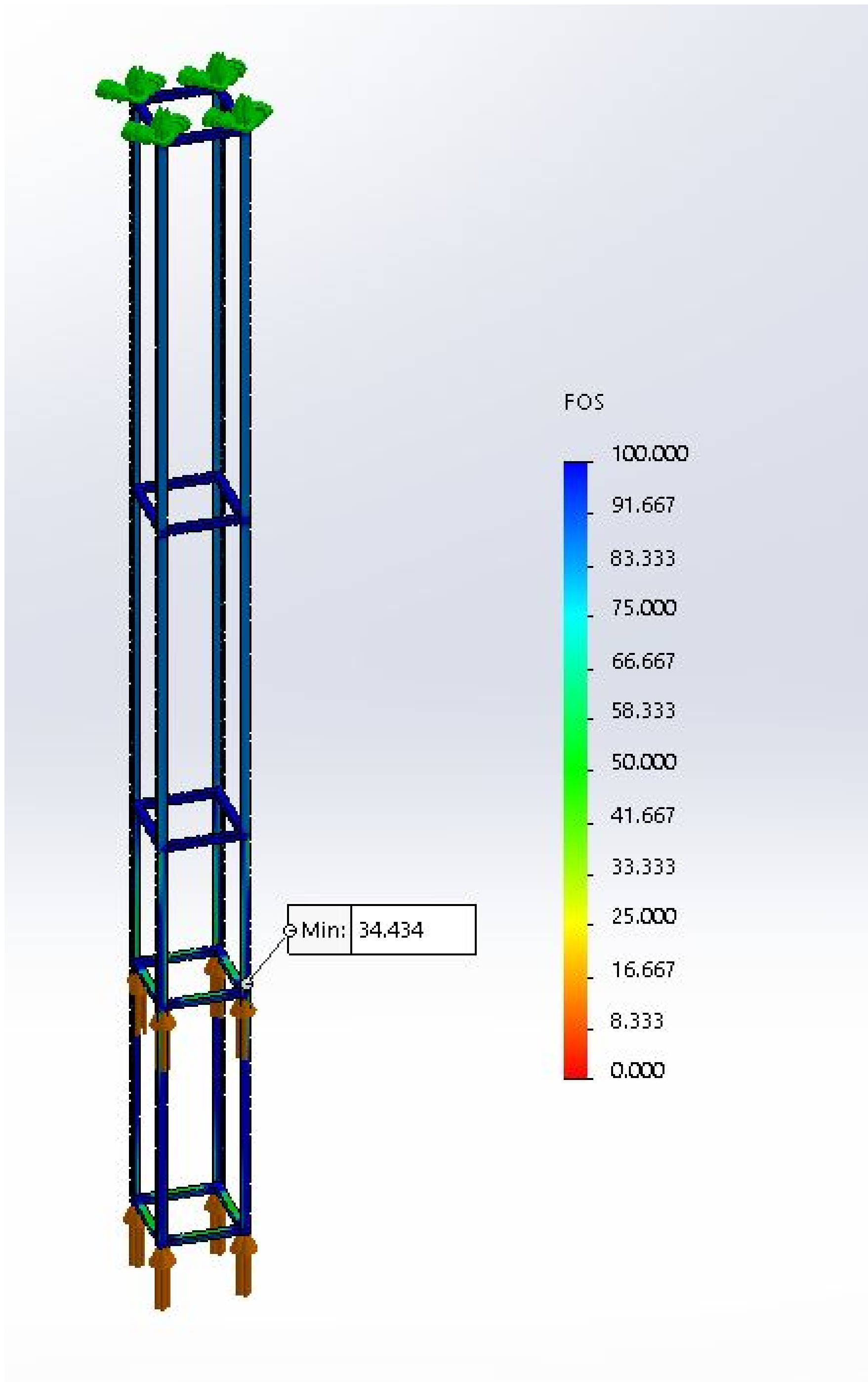
10lbf applied to top ½ in of one foot rod section



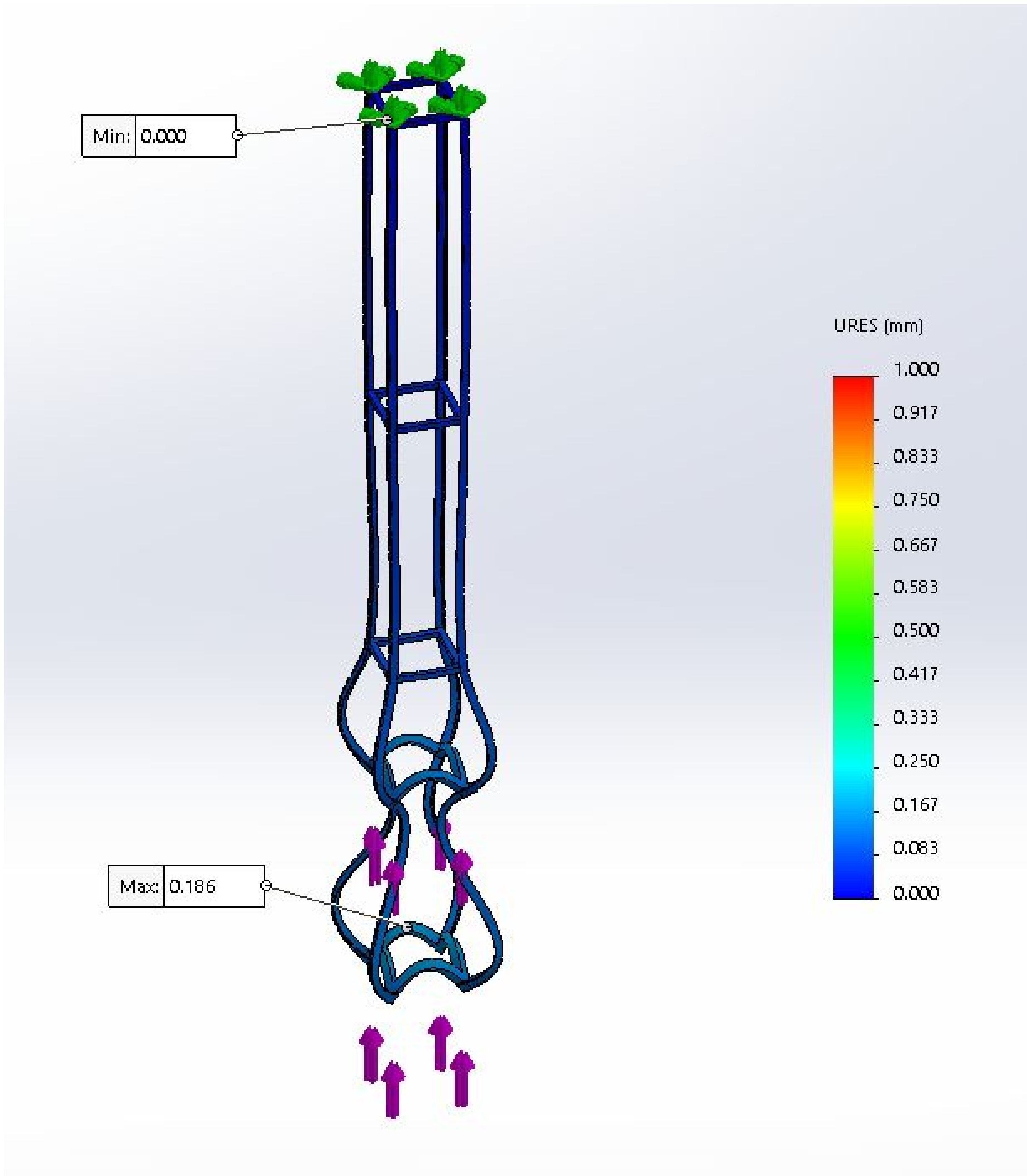
0.75 lbf applied to top ½ in of full rocket structure



10 lbf applied to top ⅜ th across support rod of full rocket structure



FOS: 200lbf applied to combustion chamber region of structure with fixed top.



Displacement: 200lbf applied to combustion chamber region of structure with fixed top.

Analysis

The analysis of the Aluminium support structure is broken into three different tests comparing two viable materials. Aluminium 6061 T6 vs Aluminium 7075 T6.

Basic Mechanical Properties.

	Ultimate Tensile Strength	Yield Strength
Aluminium 6061 T6	42,000 psi	35,000 psi.
Aluminium 7075 T6	74,000 - 78,000 psi	63,000 - 69,000 psi

These mechanical properties are important to keep in mind when looking at the two angled rods presented. Aluminum 6061 T6 rods were presented in 1/8th in thickness vs Aluminum 7075 T6 rods in 1/16th thickness.

Full Support Structure.

	Weight
Aluminium 6061 T6	4.26 lbs
Aluminium 7075 T6	3.21 lbs

Cost of Support Structure (w/o Shipping)

	Cost
Aluminium 6061 T6	$98.21
Aluminium 7075 T6	$242.45

References

1. *7.51in LOC Body Tube: https://www.apogeerockets.com/Building_Supplies/Body_Tubes/High_Power_Tubes/7-51in_LOC_Body_Tube*
2. *7.5in Fiberglass Body Tube: https://www.apogeerockets.com/Building_Supplies/Body_Tubes/Fiberglass_Tubes/7-5in_G12_Fiberglass_Filament_Wound_Tube_48in_Long*
3. *7.5in Blue Tube Body Tube: https://www.balsamachining.com/bt.htm*
4. *PNC-7.51" Nose Cone: https://www.apogeerockets.com/Building_Supplies/Nose_Cones/High_Power_Nose_Cones/PNC-7-51?cpath=&*
5. *Aluminum 7075 T-6 Angle Support Bars: https://www.mcmaster.com/9178t11*
6. *Aluminum 6061 T-6 Angle Support Bars: https://www.metalsdepot.com/aluminum-products/aluminum-angle-6061*
7. *Aluminum 6061 7/16" Cross Support Bars: https://www.mcmaster.com/9872t99*
8. *Aluminum 6061 3/8" Cross Support Bars: https://www.mcmaster.com/9008k78*